LIHI LANI RECREATIONAL COMMUNITY
PAUMALU AND PUPUKEA, Koolaulaoa, 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

Applicant:

Obayashi Hawaii Corporation
Pacific Tower, Suite 2680
1001 Bishop Street
Honolulu, HI 96813

Prepared by:

Group 70 Limited
Architects•Planners•Interior Designers
924 Bethel Street
Honolulu, HI 96813
(808) 523-5866

April 1991
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L. Terrestrial Vertebrates of the Obayashi Project, Pupukea, Oahu, Andrew Berger, Ph.D., January 1988

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P. Noise Impact Assessment Lihi Lani Recreational Community, Oahu, HI, Darby & Associates, January 1991

Q. Air Quality Study for the Proposed Lihi Lani Recreational Community Project, Pupukea, Oahu, Hawaii, Barry D. Neal, January 1991


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T. Economic and Fiscal Impact Assessment for the Proposed Lihi Lani Master-planned Community, Pupukea, Oahu, HI, Peat Marwick and Main Co., December 1990

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 Scout 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 8-8 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.

1. 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 interview and employment in the project. The training program 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
COMMUNITY FACILITIES PACKAGE
NOVEMBER 5, 1990
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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. Waialua Community Assn (Waialua High Scholarship Fund)
11. St. Michael's School (Microscopes)

LEHI LAND BENEFIT VALUATION
NOVEMBER 5, 1990

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Approx. Market Value 1990 ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Child Care</td>
<td>Dedicate one acre to City @ $170,000 per acre.</td>
</tr>
<tr>
<td>D. Community Garden Program</td>
<td>Dedicate one acre to City @ $170,000 per acre.</td>
</tr>
<tr>
<td>E. Education Program</td>
<td>After each residential sale, a $5,000 premium will be put into an escrow account for the program. 120 units @ $5,000/unit.</td>
</tr>
</tbody>
</table>

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
### 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 - $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. $ 1,600,000

### 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

### 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

### II. Prior Community Contributions
#### A. Pa'u Riding Group
1. Aloha Week Parade 1989
   - Costumes, Horse Gear, Leis $ 6,500
2. Kam Day Parade 1990
   - Costumes, Leis, Seastress $ 2,900
3. Aloha Week Parade 1990
   - Costumes, Leis, Seastress $ 3,600

#### 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

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**Total Costs:** $100,625,000
LIHI LANI BENEFIT VALUATION
NOVEMBER 5, 1990
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D. Additional Donations

<table>
<thead>
<tr>
<th>No.</th>
<th>Organization</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>American Youth Soccer Assn</td>
<td>$ 400</td>
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<tr>
<td>2.</td>
<td>Hawaii Junior Golf Assn</td>
<td>$ 1,500</td>
</tr>
<tr>
<td>3.</td>
<td>Kahuku Lokahi Youth Athletic Club</td>
<td>$ 1,500</td>
</tr>
<tr>
<td>4.</td>
<td>Waialua Lion's Club (Waialua High Scholarship Fund)</td>
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</tr>
<tr>
<td>5.</td>
<td>Kahuku High School Scholarship Fund</td>
<td>$ 1,000</td>
</tr>
<tr>
<td>6.</td>
<td>Waialua High School Scholarship Fund</td>
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<td>7.</td>
<td>Girl Scout Council of the Pacific</td>
<td>$ 1,500</td>
</tr>
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<td>8.</td>
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<td>9.</td>
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<td>10.</td>
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<td>$ 500</td>
</tr>
<tr>
<td>11.</td>
<td>St. Michael's School (microscopes)</td>
<td></td>
</tr>
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</table>

**SUB-TOTAL (A-D)**  
$ 32,000

**TOTAL**  
$100,057,000
INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Puakea (TMK: 5-9-05:38 and 5-9-06:1, 1B, 24). The 1.143 acre site is located mauka of Kamehameha Highway and Sunset Beach, surrounded by the COMSAT facility, forest reserve, and the Puakea 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 Puakea 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 Lihli 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 mauna of Kamehameha Highway and northeast of Sunset Beach Elementary School. The remaining area is located on an esplanade 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 Paunalu Stream and Kalanawaiakula Stream respectively. Paunala 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 mauna 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.

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 I, dated February 1984. Wastewater contributions from the proposed facilities within the project are listed below:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Average Wastewater Quantity (gpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clubhouse</td>
<td>10,000</td>
</tr>
<tr>
<td>Tennis Center</td>
<td>2,000</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>1,000</td>
</tr>
<tr>
<td>300 Residences</td>
<td>180,000</td>
</tr>
<tr>
<td>Campground</td>
<td>3,000</td>
</tr>
<tr>
<td>Community Facilities</td>
<td>2,000</td>
</tr>
<tr>
<td>Maintenance Facility</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>199,000</strong></td>
</tr>
</tbody>
</table>

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 moving 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.
The wastewater treatment facility would require about 10 acres of fenced area to accommodate the ponds, basins, 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 ultraviolet 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.

Effluent Characteristics

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
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 assure 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 wastewater 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 exposure 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 contingency, provisions will be included in the design to incorporate odor abatement facilities, should they be needed.

5. **Alarms and telemetering.** Alarms indicating high flow 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, aeration/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/1000 gpd), 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 facing 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, desiccation, elevated temperatures, and exposure to sunlight. Thus, infiltration of these organisms to deep aquifers is not probable.

Conclusion

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.
**WATER SUPPLY REPORT**

**FOR THE**

**PROPOSED LIHI LANI RECREATIONAL COMMUNITY**

PUPUKEA, PAUMALU, KOOLAUH, OAHU, HAWAII

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Prepared by:

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

December 1990
INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Puupuhea (TMK: 5-9-05:38 and 5-9-06:1, 18, 24). The 1,130-acre site is located near the Kamohana 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 non-potable 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 Lih Lani Recreational Community project will result in the development of approximately 598 acres within the 1,143-acre project site. Included in 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 makua of Kamehameha Highway and northeast of Sunset Beach Elementary School. The remaining area is located on an esplanade 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 Paunala Stream and Kaluana'akalak Stream respectively. Paulena 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 kona 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 850-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 Kawailea 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 Kapulu Street (on the Waimea side) and continues along Kamehameha Highway to the Sunset line booster.
located just north of Paula 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:

<table>
<thead>
<tr>
<th>Category</th>
<th>Average Water Demand (gpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clubhouse</td>
<td>20,000</td>
</tr>
<tr>
<td>Tennis Center</td>
<td>3,000</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>2,000</td>
</tr>
<tr>
<td>300 Residential Home Sites</td>
<td>150,000</td>
</tr>
<tr>
<td>Campground</td>
<td>4,000</td>
</tr>
<tr>
<td>Community Facilities</td>
<td>3,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>185,000</strong></td>
</tr>
</tbody>
</table>

Average water demand for residential home sites is based on 500 gpd per home site 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:

<table>
<thead>
<tr>
<th>Type of Use</th>
<th>Flow Rate (gpm)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-residential (clubhouse,</td>
<td>2000</td>
<td>2</td>
</tr>
<tr>
<td>tennis facility, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>1000</td>
<td>1</td>
</tr>
</tbody>
</table>

The water distribution system and the storage reservoirs 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 Pepukea 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 Pepukea Highlands and Sunset Hills communities. The high service zone will be supplied by the Pepukea 892-foot reservoir, and the low service zone will be supplied by the Pepukea 600-foot reservoir.

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

<table>
<thead>
<tr>
<th>Footage</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>170-foot reservoir</td>
<td>242,500 gallons at Pepukea 170-foot reservoir</td>
</tr>
<tr>
<td>600-foot reservoir</td>
<td>242,500 gallons at Pepukea 600-foot reservoir; two 290 gpm capacity at Pepukea booster station no. 1 (one standby capacity)</td>
</tr>
<tr>
<td>892-foot reservoir</td>
<td>242,500 gallons at Pepukea 892-foot reservoir; two 290 gpm capacity at Pepukea booster station no. 2 (one standby capacity)</td>
</tr>
</tbody>
</table>

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 Pepukea 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
PROPOSED POTABLE WATER SYSTEM
CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY
SEE FRAME(S) IMMEDIATELY FOLLOWING
FIGURE 4
PROPOSED NONPOTABLE WATER SYSTEM
Popokes 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 serve 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-low 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 serve the clubhouse and homes in the low service zone on the north end of the site.

Thus, average 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 (161,567 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.

### Nonpotable Water System

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 Pauma, 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 63, 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 evaporation of irrigation water.

<table>
<thead>
<tr>
<th>Service</th>
<th>Homes</th>
<th>GPD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Service</strong></td>
<td>33 Homes</td>
<td>16,500 gpd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16,500 gpd</td>
</tr>
<tr>
<td><strong>High-High Service</strong></td>
<td>Equestrian Center</td>
<td>2,000 gpd</td>
</tr>
<tr>
<td></td>
<td>221 Homes</td>
<td>110,500 gpd</td>
</tr>
<tr>
<td></td>
<td>Campground</td>
<td>4,000 gpd</td>
</tr>
<tr>
<td></td>
<td>Tennis Center</td>
<td>3,000 gpd</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous</td>
<td>3,000 gpd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>122,500 gpd</td>
</tr>
<tr>
<td><strong>High-Low Service</strong></td>
<td>Clubhouse</td>
<td>20,000 gpd</td>
</tr>
<tr>
<td></td>
<td>46 Homes</td>
<td>23,000 gpd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43,000 gpd</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>182,000 gpd</td>
</tr>
</tbody>
</table>
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 served 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-Pauma, 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.
INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Pupukea (TMC-5-9-05:38 and 5-9-06:1, 18, 24). The 1,143-acre site is located near the 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 Lili Lani Recreational Community project will result in the development of approximately 598 acres within the 1,143-acre project site. Included in the proposed development are 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 south 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 Kalanawalekale Stream respectively. Pakulena Stream borders 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 Kahalawai 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 Paoula-Paumalu Ridge. The Paumalu Gulch watershed contains three subwatersheds feeding Ainu Gulch, Paumalu Stream, and Kaleleki 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 560 feet above sea level.
The third watershed, Kalanawalkala Stream watershed, also covers an area of approximately 510 acres. Portions of Sunset Hills and Papakea Highland subdivisions fall within this watershed. The Kalanawalkala Stream watershed converges with the Pakulena Stream watershed approximately 2 miles inland from Kamehameha Highway.

The three watersheds are characterized by steep gullies 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 gullies and is conveyed to existing culverts at Kamehameha Highway. The culvert serving the Paunana Gulch is located approximately 3,200 feet north of the property, with the culverts serving the Pakulena and Kalanawalkala 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 steep areas along Kamehameha Highway between the Paunana 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 gullies 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 usable, 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. Detention/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 control plans will be prepared for construction during the design stage in

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Proposed Land Use (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Golf Course</td>
<td>510</td>
</tr>
<tr>
<td>Residential Other Houses</td>
<td>210</td>
</tr>
<tr>
<td>Horse Pasture</td>
<td>101</td>
</tr>
<tr>
<td>Roadway Other</td>
<td>310</td>
</tr>
<tr>
<td>Open Area</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>1,550</td>
</tr>
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</table>
Market Assessment for the Proposed
Lihi Lani Master-planned Community
Pupukea, Oahu, Hawaii

Prepared for
OBAYASHI HAWAII CORPORATION

January 1991
GOLF COURSE MARKET OVERVIEW, CONTINUED

Hawaii Golf Market Overview
Golf Market Segments
Oahu Golf Course Inventory
Characteristics of Municipal Golf Courses
Characteristics of Daily Fee Courses
Proposed Golf Courses on Oahu
Oahu Private Golf Course Market Review
Inventory and General Characteristics
Membership Fee Structure

TENNIS AND EQUESTRIAN MARKET OVERVIEW

Tennis Facilities Overview
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I - EXECUTIVE SUMMARY

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

BACKGROUND

Ohayashi is planning to develop Lihikai Lani, a recreation-oriented community on about 1,142 acres of land located near Pupukea in the Ko'olaua City Division, Hawaii. The property includes a beach side of Kahala Beach and about 60 minutes by car from Honolulu and Waikiki. The property rises to an elevation of about 250 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 Lihikai Lani and to project its anticipated market performance in terms of:

- Sales absorption or expected demand
- Pricing
- Usage

PROJECT OVERVIEW AND PROPOSED DEVELOPMENT PHASING

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

- 120 country-zoned lots
- 180 affordable homes
- Semi-private Jack Nicklaus-designed 18-hole golf course
- Golf clubhouse and amenities
- Driving range
- Equestrian center
- 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 Lihikai 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 semi-private course at Lihikai 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 cost 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:

<table>
<thead>
<tr>
<th></th>
<th>Average rounds of play</th>
<th>Percent distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local players</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>Members</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>Oahu visitors</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

(1980 dollars)

<table>
<thead>
<tr>
<th></th>
<th>Total fees(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>$75</td>
</tr>
<tr>
<td>1996</td>
<td>75</td>
</tr>
<tr>
<td>1997</td>
<td>80</td>
</tr>
<tr>
<td>1998</td>
<td>85</td>
</tr>
<tr>
<td>1999</td>
<td>85</td>
</tr>
</tbody>
</table>

(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 Lihia 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 Lihia 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 Lihia Lani
- Golf club members
- Residents from the North Shore and Koolauloa communities
- Other Oahu residents and visitors

Recommended Marketing of the Tennis Center

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

- The tennis center could provide an alternative activity center for non-golf-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 10 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-surfacel 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 Lihia 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 Lihai Lani Tennis Center, a proposed tennis membership could be structured, as follows:

**Proposed Lihai Lani Tennis Center**

**Membership and Daily Fee Structure**

(1990 dollars)

<table>
<thead>
<tr>
<th>Type of membership</th>
<th>Initiation Fee</th>
<th>Monthly dues</th>
<th>Guest fees(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf social and tennis club</td>
<td>$6,000</td>
<td>$25 - $100</td>
<td>$10(3)</td>
</tr>
<tr>
<td>Tennis club(4)</td>
<td>5,000</td>
<td>60 - 80</td>
<td>10(3)</td>
</tr>
<tr>
<td>Daily fee play</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hard courts</td>
<td>-</td>
<td>-</td>
<td>8(5)</td>
</tr>
<tr>
<td>Clay courts</td>
<td>-</td>
<td>-</td>
<td>8(5)</td>
</tr>
<tr>
<td>Grass courts</td>
<td>-</td>
<td>-</td>
<td>10(5)</td>
</tr>
</tbody>
</table>

(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 would 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 Lihai 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 Lihai Lani community.

Projected Target Markets

Based on the market overview of equestrian facilities and users, the Lihai Lani Equestrian Ranch could target two segments: the Lihai Lani community and other Oahu residents that wish to stabilize 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 Lihai Lani from other Oahu developments by offering a distinctive 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 Lahi 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 Lahi Lani community and surrounding North Shore and Ko'olau residents. About 70% of the riders are expected to be from these regions.

CABIN MARKET ASSESSMENT

Twelve cabins are planned to be completed in 1993 at Lahi 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 100 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. Oyashii 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:

<table>
<thead>
<tr>
<th>Primary Place of Residence</th>
<th>Full-time</th>
<th>Part-time</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>State of Hawaii</td>
<td>50%</td>
<td>30%</td>
<td>80%</td>
</tr>
<tr>
<td>Other</td>
<td>15%</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td>Total</td>
<td>65%</td>
<td>45%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Proposed Lot Pricing

Initial lot sales prices are estimated to range as follows:

<table>
<thead>
<tr>
<th>Projected Typical Lot Sales Prices</th>
<th>at Initial Marketing</th>
<th>(1990 dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot View Orientation</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Prime Ocean View</td>
<td>$375,000</td>
<td>$425,000</td>
</tr>
<tr>
<td>Distant Ocean/Golf</td>
<td>325,000</td>
<td>375,000</td>
</tr>
<tr>
<td>Golf Course</td>
<td>375,000</td>
<td>425,000</td>
</tr>
<tr>
<td>Other</td>
<td>325,000</td>
<td>375,000</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Projected Lot Sales Absorption</th>
<th>1995 to 1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Lot Sales</td>
<td>60 40 100</td>
</tr>
<tr>
<td>Cumulative Lot Sales</td>
<td>60 90 120</td>
</tr>
</tbody>
</table>

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.
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 Koolau area 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

Ozayashi plans to develop a recreational community on about 1,143 acres of land at Pupukea in the Koolauhan 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
- Semi-private Jack Nicklaus-designed 18-hole golf course
- Golf clubhouse and facilities
- Driving range
- Equestrian ranch
- Tennis center
- Campground
- Hiking and horseback riding trails
- Community parks

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

The golf course, clubhouse, equestrian ranch, campground, and a first increment of about 60 lots and 50 affordable homes are expected to be constructed by 1996. 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 Lihl 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.
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 Koolaua and North Shore regions.

Oahu Resident Population

In 1989, Oahu contained about 76% of Hawaii's resident population, although it comprises only about 5% of the state's land area. During 1989, Oahu was estimated to have a population of 851,600, 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 1.6% per annum rate of growth experienced from 1987 to 1990, to 0.7% per annum through 2000.

Definition of Koolaua and North Shore Regions

The subject site is located near the North Shore edge of the Koolaua region, which is defined as the U.S. Census Divisions 101, 102, and 103. 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 Waialua Bay. A well-developed highway links this area with the adjacent North Shore region. Residential communities bordering the highway include Kaaawa, Punahou, Haiku, and Kaneohe.

The Koolau and Waianae mountain ranges and the area from Waialua Bay to Kena 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, Heeia, and Kahuku. The area is defined as U.S. Census Divisions 99.0, 99.02, and 100.

Koolaua and North Shore Economy

The opening of the Koolaua 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 Koolaua could grow to 3,000 by the time all phases of the resort are completed. Development plans at Koolua include the addition of a 365-room luxury hotel, an additional 18-hole championship golf course and new clubhouse, a 65,000 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 Koolaua Districts could have increased tourism and drive-through visitors in the years ahead as Koolua 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.

Koolaua and North Shore Region Population

The 1980 resident populations of the North Shore and Koolaua regions were 9,800 and 14,200, respectively, as shown in Exhibit II-C. This represented an annual compounded growth rate of 0.0% and 0.0% from 1970 to 1980 for the North Shore and Koolaua regions, respectively.

The 1989 resident populations of the North Shore and Koolaua 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 Koolaua, respectively.
<table>
<thead>
<tr>
<th></th>
<th>Historical:</th>
<th>Estimated(3):</th>
<th>Compounded annual percentage increase:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore(1)</td>
<td>9,200</td>
<td>9,800</td>
<td>11,500</td>
<td>0.6%</td>
</tr>
<tr>
<td>Ko'olau(2)</td>
<td>10,600</td>
<td>14,200</td>
<td>17,200</td>
<td>3.0%</td>
</tr>
<tr>
<td>Total</td>
<td>19,800</td>
<td>24,000</td>
<td>28,700</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

(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 Ko'olau Development Plan areas as of June 1989.


<table>
<thead>
<tr>
<th>Age</th>
<th>Number of Golfers (millions)</th>
<th>Percent of all golfers</th>
<th>Golf participation rate(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 9</td>
<td>2.6</td>
<td>11.0%</td>
<td>11.7</td>
</tr>
<tr>
<td>10 - 19</td>
<td>6.2</td>
<td>26.5%</td>
<td>15.0</td>
</tr>
<tr>
<td>20 - 29</td>
<td>5.5</td>
<td>22.4%</td>
<td>12.9</td>
</tr>
<tr>
<td>30 - 39</td>
<td>3.6</td>
<td>16.2%</td>
<td>12.2</td>
</tr>
<tr>
<td>40 - 49</td>
<td>2.4</td>
<td>10.3%</td>
<td>11.2</td>
</tr>
<tr>
<td>50 - 59</td>
<td>2.4</td>
<td>10.3%</td>
<td>11.2</td>
</tr>
<tr>
<td>60+</td>
<td>1.2</td>
<td>4.4%</td>
<td>10.0</td>
</tr>
<tr>
<td>Total</td>
<td>22.4</td>
<td>100.0%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

(1) Golfers as a percent of total U. S. population.


N/A Not applicable.
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 enhance room, food and beverage revenues. However, current trends suggest golf courses are evolving from spend-saving 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 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.
### Existing Golf Courses on Oahu 1990

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Holes</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort</td>
<td>Makaha Resort and Country Club</td>
<td>18</td>
<td>Makaha Valley</td>
</tr>
<tr>
<td></td>
<td>Kahuku Resort</td>
<td>18</td>
<td>Kahuku</td>
</tr>
<tr>
<td></td>
<td>Ko Olina Resort</td>
<td>18</td>
<td>Ewa</td>
</tr>
<tr>
<td>Private</td>
<td>Waialae Country Club</td>
<td>18</td>
<td>Waialae/Kahala</td>
</tr>
<tr>
<td></td>
<td>Kahuku Country Club</td>
<td>18</td>
<td>Nuuanu</td>
</tr>
<tr>
<td></td>
<td>Mid-Pacific Country Club</td>
<td>18</td>
<td>Lanikai/Kailua</td>
</tr>
<tr>
<td></td>
<td>Honolulu International Country Club</td>
<td>18</td>
<td>Salt Lake</td>
</tr>
<tr>
<td>Municipal</td>
<td>Ala Wai Golf Course</td>
<td>18</td>
<td>Honolulu</td>
</tr>
<tr>
<td></td>
<td>Kahuku Golf Course</td>
<td>9</td>
<td>Kahuku</td>
</tr>
<tr>
<td></td>
<td>Ted Makahana Golf Course</td>
<td>18</td>
<td>Waimanalo/Kalapa</td>
</tr>
<tr>
<td></td>
<td>Pali Golf Course</td>
<td>18</td>
<td>Kaaawa</td>
</tr>
<tr>
<td></td>
<td>West Loch</td>
<td>18</td>
<td>Ewa</td>
</tr>
<tr>
<td>Daily fee</td>
<td>Bay View Golf Center (Par 3)</td>
<td>18</td>
<td>Kaneohe</td>
</tr>
<tr>
<td></td>
<td>Hawaii Country Club</td>
<td>18</td>
<td>Koolau</td>
</tr>
<tr>
<td></td>
<td>Hawaii Kai Championship Golf Course</td>
<td>18</td>
<td>Hawaii Kai</td>
</tr>
<tr>
<td></td>
<td>Hawaii Kai Executive Golf Course (Par 3)</td>
<td>18</td>
<td>Hawaii Kai</td>
</tr>
<tr>
<td></td>
<td>Makaha Valley Country Club</td>
<td>18</td>
<td>Makaha Valley</td>
</tr>
<tr>
<td></td>
<td>Mililani Golf Course</td>
<td>18</td>
<td>Mililani</td>
</tr>
<tr>
<td></td>
<td>Moanalua Golf Course</td>
<td>9</td>
<td>Moanalua</td>
</tr>
<tr>
<td></td>
<td>Olomana Golf Links</td>
<td>9</td>
<td>Olomana</td>
</tr>
<tr>
<td></td>
<td>Pearl City Links</td>
<td>9</td>
<td>Pearl City/Aina</td>
</tr>
<tr>
<td>Military</td>
<td>Barbers Point Golf Course</td>
<td>18</td>
<td>Barbers Point NAS</td>
</tr>
<tr>
<td></td>
<td>Hickam Golf Course</td>
<td>18</td>
<td>Hickam AFB</td>
</tr>
<tr>
<td></td>
<td>Kahuku Country Club</td>
<td>18</td>
<td>Schofield Barracks</td>
</tr>
<tr>
<td></td>
<td>Kaneohe Marine Golf Course</td>
<td>18</td>
<td>Kaneohereas</td>
</tr>
<tr>
<td></td>
<td>Leilehua Golf Course</td>
<td>18</td>
<td>Schofield East Range</td>
</tr>
<tr>
<td></td>
<td>Navy Marine Golf Course</td>
<td>18</td>
<td>Ainaamau</td>
</tr>
<tr>
<td></td>
<td>Fort Shafter Golf Course</td>
<td>9</td>
<td>Fort Shafter</td>
</tr>
<tr>
<td></td>
<td>Hickam (Par 3)</td>
<td>9</td>
<td>Hickam AFB</td>
</tr>
<tr>
<td></td>
<td>Ford Island Golf Course</td>
<td>9</td>
<td>Ford Island NAS</td>
</tr>
</tbody>
</table>

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

**Sources:** Based on published information.

### Fees at Selected Oahu Golf Courses 1990

<table>
<thead>
<tr>
<th>Total green and cart fees</th>
<th>Weekends</th>
<th>Weekdays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort courses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resort guests</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Hawaii residents</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Others</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Kualoa Resort:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resort guests</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Hawaii residents</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>Others</td>
<td>81</td>
<td>90</td>
</tr>
<tr>
<td>Range</td>
<td>26 - 125</td>
<td>41 - 125</td>
</tr>
<tr>
<td>Private club (guest fee):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waialae Country Club</td>
<td>51 - 71</td>
<td>51 - 71</td>
</tr>
<tr>
<td>Kahuku Country Club</td>
<td>29 - 75</td>
<td>28 - 75</td>
</tr>
<tr>
<td>Mid-Pacific Country Club(2)</td>
<td>36 - 150</td>
<td>36 - 150</td>
</tr>
<tr>
<td>Honolulu Country Club</td>
<td>30 - 65</td>
<td>30 - 65</td>
</tr>
<tr>
<td>Range</td>
<td>26 - 150</td>
<td>26 - 75</td>
</tr>
<tr>
<td>Daily fee courses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawaii Country Club</td>
<td>21 - 65</td>
<td>30 - 50</td>
</tr>
<tr>
<td>Hawaii Kai Championship Golf Course</td>
<td>21 - 60</td>
<td>20 - 60</td>
</tr>
<tr>
<td>Hawaii Kai Executive Golf Course (Par 3)</td>
<td>21 - 60</td>
<td>20 - 60</td>
</tr>
<tr>
<td>Matlani Golf Course</td>
<td>29 - 65</td>
<td>28 - 65</td>
</tr>
<tr>
<td>Mililani Golf Course</td>
<td>37 - 50</td>
<td>35 - 60</td>
</tr>
<tr>
<td>Pearl City Links</td>
<td>21 - 65</td>
<td>30 - 70</td>
</tr>
<tr>
<td>Range</td>
<td>21 - 65</td>
<td>30 - 70</td>
</tr>
<tr>
<td>Municipal courses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ala Wai Country Club</td>
<td>19 - 29</td>
<td>23 - 31</td>
</tr>
<tr>
<td>Pali</td>
<td>19 - 29</td>
<td>23 - 31</td>
</tr>
<tr>
<td>Kualoa Country Club</td>
<td>19 - 29</td>
<td>23 - 31</td>
</tr>
<tr>
<td>Kahuku (9 holes)</td>
<td>3 - 4</td>
<td>4 - 4</td>
</tr>
<tr>
<td>Range</td>
<td>3 - 29</td>
<td>4 - 31</td>
</tr>
<tr>
<td>Total range</td>
<td>3 - 150</td>
<td>4 - 125</td>
</tr>
</tbody>
</table>

*(1)* $175 green and cart fee for unaccompanied nonmember.

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

**Source:** Compiled by KPMG Pest 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 owned by individuals, partnerships, or corporations on a "for-profit basis." These facilities are typically:

- 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 municipal courses, with natural viewpoints taken into consideration.
- Similar to municipal courses 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 on Oahu. Of these developments, only six have obtained the permits necessary to begin construction to 1991. These courses are listed in Exhibit III-D. In addition, six planned golf courses, with one currently under construction:

- A second Koolina 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.
- A Lahaina golf course, an 18-hole semiprivate course planned by Asahi Jukken.
- A Kooliea golf course, an 18-hole daily fee course and an 18-hole private course currently under construction.
- A Kooliea golf course, an 18-hole daily fee course planned by Kooliea Land Co.
- A Punahou golf course, 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.
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:

- Wai'alea Country Club in Kailua
- Oahu Country Club in Honolulu
- Mid-Pacific Country Club in Lanalai
- Honolulu Golf Club (HGC), in the Salt Lake area

All of these private clubs are member-owned, except for HGC 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 HGC, 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 overheads:
  - Initiation fees range from $25,000 to $35,000 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 Wai'alea Country Club, $50,000 at Mid-Pacific Country Club, and about $172,000 at HGC. At HGC, all but about $34,000, can be refunded to the nonresident member after 10 years.
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 Kahuku Polo Club 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 61% of the courts have lights for nighttime play and 25 of the facilities have backboards for hitting practice, as shown in Exhibit IV-A. The distribution of the courts by region indicates that:

- The North Shore and Koolau area of Oahu has only six public tennis courts or about 4% of the inventory, two at Sunset Elementary School and four at Kailua Recreational Center.
- Windward Oahu has about 20 courts or about 12% of the overall municipal court inventory.
- Central and West Oahu have 24% and 28% of the public courts on Oahu, respectively.
- Honolulu, with 33 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 Koolau 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

<table>
<thead>
<tr>
<th>Location/Area</th>
<th>Number of Courts</th>
<th>Lighted Courts</th>
<th>Practice Backboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore and Koolau</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunset Beach Park</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Kailua Recreation Center</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>6</strong></td>
<td><strong>6</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Windward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kailua Rec Center</td>
<td>6</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Kaneohe Park</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Manawaui Park</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Waimanalo Park</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>20</strong></td>
<td><strong>12</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Central Oahu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kailua Rec Center</td>
<td>51</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>West Oahu</td>
<td>14</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Honolulu</td>
<td>63</td>
<td>54</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>174</strong></td>
<td><strong>108</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>

Source: City and County of Honolulu, Department of Parks and Recreation, 1990.
Exhibit IV-8

LILI‘I LANI RECREATIONAL COMMUNITY
Selected Ohau Private Tennis Clubs Facility Characteristics

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Maunalei Bay Club</th>
<th>Ohau Club</th>
<th>Kaluau Recquet Club</th>
<th>Walea Iki S Tennis Club</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis courts</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Lighted courts</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Surface</td>
<td>Plexi-pave(1) All-weather</td>
<td>Plexi-pave(1)</td>
<td>Plexi-pave(1)</td>
<td></td>
</tr>
<tr>
<td>Pro shop</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Restaurant</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Snack bar</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Clubhouse</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Locker room</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Weight/exercise room</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tennis instruction</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tennis leagues</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Children's programs</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sauna/Jacuzzi</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Massage</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Other sports</td>
<td>Swimming</td>
<td>Swimming</td>
<td>Aerobics</td>
<td>Fitness</td>
</tr>
<tr>
<td>Other amenities</td>
<td>Valet parking</td>
<td>-</td>
<td>Spectators pavilion</td>
<td>Meeting pavilion</td>
</tr>
<tr>
<td>Tournaments</td>
<td>Various club</td>
<td>Hawaii Grand</td>
<td>Men's Night Doubles</td>
<td>Satellite pro events</td>
</tr>
</tbody>
</table>

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

Source: Compiled by KPMG Pest Marwick based on discussions with managers and tennis professionals at the respective clubs, 1999.

IV-2

- Maunalua Bay Club, with an oceanfront site in Alana Heuna 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.

- Ohau 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.

- Kaluau Recquet 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.

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

General facility characteristics of the private tennis clubs, as shown in Exhibit IV-8, are summarized as follows:

- All have all-weather hard 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 Walea Iki S 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 Ohau clubs also offer weight/exercise rooms, saunas or Jacuzzis, swimming and aerobics or fitness instruction.

- The Kaluau Recquet and Walea Iki S clubs generally have only tennis with no supporting major amenities.

- The Maunalua Bay Club and Walea Iki S 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 windbreakers could help to minimize windy playing conditions.

Private golf clubs on Oahu that include tennis facilities are:

- Walea Country Club, with three Omni-turf synthetic grass courts.

- Mahone Trail Country Club, with four all-weather hard courts.

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

- Plexi-pave is an all-weather hard court surface.
### Exhibit IV-C

**LHIL LANI RECREATIONAL COMMUNITY**

Tennis Facility Characteristics at Private Golf Clubs on Oahu

1990

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Wai'aleae</th>
<th>Honolulu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis courts</td>
<td>Country Club</td>
<td>Country Club</td>
</tr>
<tr>
<td>Surface</td>
<td>Omni-turf(1)</td>
<td>All-weather</td>
</tr>
<tr>
<td>Pro shop</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Yes(2)</td>
<td>Yes(2)</td>
</tr>
<tr>
<td>Clubhouse</td>
<td>Yes(2)</td>
<td>Yes(2)</td>
</tr>
<tr>
<td>Locker room</td>
<td>Yes(2)</td>
<td>Yes(2)</td>
</tr>
<tr>
<td>Weight/exercise room</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tennis instruction</td>
<td>Jacuzzi(2)</td>
<td>Jacuzzi(2)</td>
</tr>
<tr>
<td>Sauna/jacuzzi</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Massage</td>
<td>Golf</td>
<td>Golf</td>
</tr>
<tr>
<td>Other sports</td>
<td>Swimming</td>
<td>Swimming</td>
</tr>
<tr>
<td>Tournaments</td>
<td>Wai'aleae Senior</td>
<td>HCC Junior Open</td>
</tr>
<tr>
<td></td>
<td>Doubles</td>
<td>Championships</td>
</tr>
</tbody>
</table>

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

**Sources:** 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 Wai'aleae 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**

Kahilina Resort plans include a 20-court Nick Nollett 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 1,000 to 3,500 total club membership, most with tennis privileges, at golf-oriented private country clubs on Oahu.

- Kahilina 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 Waialae Country Club, which was developed by the Kahala Hilton, nonmember hotel guest play ranges from 30% 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 10 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 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-4, include:

- The private tennis clubs generally include an initiation fee, monthly dues and nonmember guest fees. The Waialae Country Club has the highest fee schedule with a $2,500 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 Waialae Country Club.

- Waialua Country Club has the most expensive tennis membership initiation fees at $5,000. Monthly dues for the tennis memberships is $125 per month.

- Honolulu Country Club's tennis membership initiation fee is $1,200 for couples and $1,000 for singles. Monthly dues are $125 and $100.

As shown by the review, the Waialae Country Club is the highest priced tennis-oriented club surveyed. The club has attracted 300 members and has temporarily suspended new memberships and started a waiting list.
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 Mauna Lani Bay Club can charge significantly more for new facilities and high levels of service.
- Junior development programs for younger school age children and competitive group clinics for adult players support the social aspect 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 Mauna Lani Bay Clubs where extensive weight training and 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.
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 Koolau field are the best known equestrian club 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 Kualoa and Makaia 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-F, include:

- Circle Z Ranch in Waimanalo, considered the best facility on Oahu, currently has about 100 horses in its stables.
- Kualoa Farms, located in a hilly area of Waimanalo in Kualoa, 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 Koolau and owned by Kualoa Land Co. has about 90 horses in paddocks and pastures.

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Boarding</th>
<th>Training</th>
<th>Rental horses</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crobar Ranch</td>
<td>North Shore</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Turtle Bay Hilton stables</td>
<td>North Shore</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Windward:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-Tri-X Stables</td>
<td>Waimanalo</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Circle Z Ranch</td>
<td>Waimanalo</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Hilltop Ranch</td>
<td>Waimanalo</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Makaia Farms</td>
<td>Kualoa</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Kualoa Ranch</td>
<td>Kualoa</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Other areas:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbers Point Riding Club</td>
<td>Barbers</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Koko Crater Stables</td>
<td>Point</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sheraton Makaia stables</td>
<td>Makaha</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Valley</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Sources: Compiled by KPMG Peat Marwick based on discussions with equestrian facility managers, 1990.
### General characteristics of these facilities, as also shown in Exhibit 14A, include:
- With the exception of horse riding and horse riding facilities, these facilities have between 12 to 40 stalls, with a capacity of 40 to 120 horses. Circle J and Crobar are generally larger in capacity, with visitors lists.
- Stables and equestrian facilities also have more amenities associated with training, exercise and horse riding.
- Facilities are generally more well maintained with visitors lists.
- Grooming, washing and hospital stalls include: 
  - Circle J, Haunani and Crobar include:
  - All facilities have a stable office or residence.

### General characteristics of these facilities, as shown by Exhibit 14A, include:
- Circle J, Haunani and Crobar are considered the best facilities in this type of equestrian facility generally.
- General characteristics of these facilities generally found that most of the facilities have the same number of stalls and amenities.
- Most of the facilities are primarily focused on horse riding, with some horse riding facilities that are primarily focused on training and horse care.

### LIHI LANI RECREATIONAL COMMUNITY

**Selected Oahu Private Equestrian Facility Characteristics**

#### 1990

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Circle J Ranch</th>
<th>Haunani Farms</th>
<th>Crobar Ranch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stables:</td>
<td>60</td>
<td>80</td>
<td>12 (12 x 12, 12 x 12)</td>
</tr>
<tr>
<td>(units)</td>
<td>12 x 16, 30 x 40</td>
<td>12 x 12, 14 x 14</td>
<td>12 x 12, 12 x 12</td>
</tr>
<tr>
<td>Size of stalls (feet)</td>
<td>12 x 16, 30 x 40</td>
<td>12 x 12, 14 x 14</td>
<td>12 x 12, 12 x 12</td>
</tr>
<tr>
<td>Horses stabled (number)</td>
<td>100</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Paddocks (number)</td>
<td>40</td>
<td>N/A</td>
<td>22</td>
</tr>
<tr>
<td>Riding areas</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Full-time employees (number)</td>
<td>7</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Other facilities:</td>
<td>Polo field, Hunt field, Outdoor arena, Outdoor track, Covered arena, Storage area, Grooming, Growing stalls, Jumps, Exercise tracks, Turnout pasture, Hunt field and trails, Grooming stalls, Feed barn, Resident manager's tack room, Jumps, Equipment storage, Hospital stalls, Trailer parking.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

- Haunani Farms are not available.
- Crobar Ranch and Haunani Farms are not available.
- Circle J Ranch is currently owned by the Nokulele Land Co.
- Haunani Farms is currently owned by the Haunani Farm Association.
- Crobar Ranch is currently owned by the Crobar Ranch Association.

---

(1) Only Hospital stalls; horses are kept in the paddocks and pastures.
### Fee Structure

The general fee structure of different equestrian operations, as shown in Exhibit IV-1, 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.

- Hanaumalili Farms charges from $100 to $225 per month for stables and about $160 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 renter or the independent contractor hired by the owner.

- Crobar Ranch charges $100 per month for paddocks and some pastures. Pastures must be paid for by the renter. For 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 type of service offered.

### Success Factors

Key factors to success in equestrian facility operations include:

- 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.

- Hanaumalili 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.
Exhibit IV-1

<table>
<thead>
<tr>
<th>LILE CAIN RECREATIONAL COMMUNITY</th>
<th>Selected Facilities Usage Fees</th>
<th>Costs/Fees</th>
<th>Stable Fees</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle 2 Ranch</td>
<td>$100 to $125 per month for passage $100 per month for passage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable fees</td>
<td>$100 per month for passage $100 per month for passage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable fees include feeding and maintenance of stables. Users must provide feeding.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: FPG Pest Service based on interview with facility managers or other representatives, 1980.
• 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 foreseeable future.

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

• Uplands location in Papukea, 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 Ko'olina courses.
• Extensive project facilities and related recreational amenities.
• Inclusion of a single-family lot development.

Development plans include an 18-hole semi-private 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:

• Ko'olina 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.
• Makaha 9-hole course, an 18-hole semi-private course planned by Ahold Syukian.
• Mokuleia golf courses, including an 18-hole daily fee course and an 18-hole private course planned by Mokuleia Land Co.
• Puna'aua golf courses, three 18-hole daily fee golf course planned by Campbell Estate.

The second Ko'olina 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 would be no emphasis on providing daytime and casual afternoon and sunset activities. In addition to serving users of the golf course, the visitors to the North Shore and Ko'olina 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 40 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-A.

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 185 rounds per day. This range permits comparable rates of play for golfers who are familiar with the courses. Total rounds played at Lihi Lani are expected to increase from about 27,000 in 1999, the first year of operations, to a stabilized rate of about 47,000 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 sub-markets:

• Local recreational players
• Member players
• Visitor golfers
<table>
<thead>
<tr>
<th>Type</th>
<th>Initiation(1)</th>
<th>Monthly fees</th>
<th>Comments(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full membership</td>
<td>$25,000 - 30,000</td>
<td>120 - 160</td>
<td>All privileges(3)</td>
</tr>
<tr>
<td>Limited membership</td>
<td>15,000 - 20,000</td>
<td>100 - 130</td>
<td>Limited golf(4)</td>
</tr>
<tr>
<td>Social</td>
<td>4,000 - 6,000</td>
<td>40 - 60</td>
<td>Use of golf clubhouse facilities, pool and tennis courts.</td>
</tr>
</tbody>
</table>

(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 per/monthly charges at equestrian center.

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

---

**Lihi Lani Recreational Community**

**Projectied Membership Sales Absorption at the Proposed Golf Club**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lihi Lani lot owners</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>Other Oahu residents</td>
<td>60</td>
<td>65</td>
<td>60</td>
<td>55</td>
<td>55</td>
<td>295</td>
</tr>
<tr>
<td>Out-of-state residents</td>
<td>30</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td>20</td>
<td>126</td>
</tr>
<tr>
<td><strong>Annual total</strong></td>
<td>110</td>
<td>125</td>
<td>103</td>
<td>98</td>
<td>75</td>
<td><strong>NA</strong></td>
</tr>
<tr>
<td><strong>Cumulative total</strong></td>
<td>110</td>
<td>238</td>
<td>340</td>
<td>428</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>
LIHI LANI RECREATIONAL COMMUNITY
Projected Rounds of Play at the Proposed Golf Course
1995 to 1999

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily rounds:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmember Oahu residents(1)</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Members</td>
<td>15</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Visitors(1)</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>60</td>
<td>85</td>
<td>125</td>
<td>130</td>
</tr>
<tr>
<td>Average annual rounds</td>
<td>27,400</td>
<td>24,900</td>
<td>22,300</td>
<td>19,700</td>
<td>17,100</td>
</tr>
<tr>
<td>Percentage:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmember Oahu residents(1)</td>
<td>40%</td>
<td>33%</td>
<td>38%</td>
<td>40%</td>
<td>46%</td>
</tr>
<tr>
<td>Members</td>
<td>20%</td>
<td>33%</td>
<td>38%</td>
<td>40%</td>
<td>39%</td>
</tr>
<tr>
<td>Visitors(1)</td>
<td>20%</td>
<td>33%</td>
<td>24%</td>
<td>20%</td>
<td>16%</td>
</tr>
<tr>
<td>Total(2)</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

(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 $30, 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:

<table>
<thead>
<tr>
<th></th>
<th>1995 to 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1990 dollars)</td>
<td></td>
</tr>
<tr>
<td>Total fees(1)</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>$ 75</td>
</tr>
<tr>
<td>1996</td>
<td>75</td>
</tr>
<tr>
<td>1997</td>
<td>80</td>
</tr>
<tr>
<td>1998</td>
<td>85</td>
</tr>
<tr>
<td>1999</td>
<td>85</td>
</tr>
</tbody>
</table>

(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.

TELEPHONE 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 uses of private tennis facilities, the tennis center could be marketed to several different segments, including:

- Lot owners at Lili'i Lani
- Residents from the North Shore and Ko'olau area 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 Ko'olau population, estimated at 22,700 in 1989. This would be the equivalent of about 30 courts serving the existing North Shore population, not including any of the day visitor or part-time resident population, thus making the estimate a fairly conservative one. Factoring in the existing 18 public and 12 resort-oriented courts in the region, 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 Waialae Iki's 8 residential development ratio of one tennis court to 20 lots, an additional demand of two to three courts is expected.

- Demand by tennis-only club members, based on the ULI ratio of 12 players per court, would be subject to the projected number of tennis-only members of the club. Based on an assumed 100 to 250 tennis-only membership, 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 Ko'olau area residents with flexible work schedules, retirees, junior development after-school program and visitors to the community.

The facility could be developed in phases, with between six and eight lighted courts initially. This would allow for facilities to accommodate the developing target market 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 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
- Aerobics and fitness areas
- Jacuzzi, saunas and/or spa
- Snack bar or restaurant area

Recommended Marketing for the Tennis Center

The Lili'i Lani Tennis Center could be marketed as a family-oriented tennis facility:

- The tennis center can provide an alternative activity center for non-golfing 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 ladder for club champions, 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 Ko'olau 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 Lili'i Lani a contributing part of the overall North Shore and Ko'olau 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 Lili'i Lani Tennis Center, tennis membership fees could be structured as follows:
Proposed Liholiho Tennis Center
Membership and Daily Fee Structure
(1990 dollars)

<table>
<thead>
<tr>
<th>Type of membership</th>
<th>Initiation fee</th>
<th>Monthly fees</th>
<th>Guest fees(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis club and golf(s)</td>
<td>$6,000</td>
<td>$75 - $100</td>
<td>$10(3)</td>
</tr>
<tr>
<td>Tennis club(s)</td>
<td>5,000</td>
<td>60 - 80</td>
<td>10(3)</td>
</tr>
<tr>
<td>Hard courts</td>
<td>-</td>
<td>-</td>
<td>8(5)</td>
</tr>
<tr>
<td>Clay courts</td>
<td>-</td>
<td>-</td>
<td>12(5)</td>
</tr>
<tr>
<td>Grass courts</td>
<td>-</td>
<td>-</td>
<td>15(5)</td>
</tr>
</tbody>
</table>

(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 privilege 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 for the Liholiho Equestrian Ranch, recommends the necessary facilities based on the projected target markets, recommended marketing strategies, proposed fee structure and the 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 Liholiho community.

Projected Target Markets

Based on the market overview of equestrian facilities and users, the Liholiho Equestrian Ranch could target two segments, the Liholiho 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 Liholiho Equestrian 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 Liholiho 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 Liliuokalani, proposed stable fees would range between $120 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 Liliuokalani community and surrounding North Shore and Koolau 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 Liliuokalani'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 Liliuokalani. 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 Koolau region residential lot sales

HANAI 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:

- Kahala Ranch
- Maui Olu

This section describes the market and buyer characteristics at the selected lot developments, which may be compared to Liliuokalani 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 166 to 2,700 acres in total and offer a range of lot sizes, prices, infrastructure/amenities and views. The 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-A. 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 lifestyle 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
Table: Summary of the characteristics of selected one-acre and larger lot subdivisions in Hawaii

<table>
<thead>
<tr>
<th>Subdivision and Location</th>
<th>Total lot size</th>
<th>Number of lots</th>
<th>Lot size range</th>
<th>Price range</th>
<th>Infrastructure/amenities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahala Ranch (North Oahu, Island of Oahu)</td>
<td>2,700</td>
<td>222</td>
<td>3.5 - 10</td>
<td>$100,000 - $500,000</td>
<td>Roads, sewage, electricity, underground utilities, water,security and managed gates. Amenities include tennis, golf course.</td>
</tr>
<tr>
<td>Manoa Bluffs (Manoa Valley, Oahu)</td>
<td>380</td>
<td>94</td>
<td>1 - 2.5</td>
<td>$97,000 - $214,000</td>
<td>Roads, underground utilities, water, sewer, security gate.</td>
</tr>
</tbody>
</table>

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

Summary of the characteristics of selected one-acre and larger lot subdivisions in Hawaii

<table>
<thead>
<tr>
<th>Subdivision and Location</th>
<th>Intended uses</th>
<th>Demographic characteristics</th>
<th>Lifestyle characteristics</th>
<th>Main attractions to project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahala Ranch (North Oahu, Island of Oahu)</td>
<td>Primary residence, 50%</td>
<td>Second owner, 40%</td>
<td>Investment, 10%</td>
<td>Good security, value and ocean views, and amenities. Property sales, increased substantially and infrastructure was in place.</td>
</tr>
<tr>
<td>Manoa Bluffs (Manoa Valley, Oahu)</td>
<td>Primary residence, 50%</td>
<td>Second owner, 30%</td>
<td>Investment, 20%</td>
<td>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.</td>
</tr>
</tbody>
</table>

Source: Compiled by KPMG Peat Marwick based on interviews with project managers and sales representatives.
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 16 lots per year at Mauna Lani to an equivalent 100 lots per year at Kohala Ranch, as shown in Exhibit VI-C. Mauna Lani, the only Oahu comparable lot project, was able to sell approximately 43 out of the 50 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.

**Koolauola and North Shore Lot Review**

This section reviews the sales trends in Oahu of residential lots from one to five acres in size and located in the Koolauola and North Shore regions of Oahu. The Pupukea area in Koolauola, where Lili 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 33 in 1987, as shown in Exhibit VI-D. Sales as of November 1990 represent 30 lots in the year. By size, the 0- 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 Koolauola and North Shore regions both showed increasing sales from 1983 to 1988. Recent sales have since declined to 19 lots sold in 1989 and 20 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 1989 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.
LIHI LAKE RECREATIONAL COMMUNITY

Average Sales Prices of Vacant One- to Five-Acre Lots in the Ko'olaupoko and North Shore Regions by Lot Size
1983 to November 1990

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Low</th>
<th>High</th>
<th>Average</th>
<th>Average/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 1.9 acres:</td>
<td></td>
<td></td>
<td>12,500</td>
<td>12,500</td>
</tr>
<tr>
<td>Low</td>
<td>53,000</td>
<td>70,000</td>
<td>65,500</td>
<td>85,000</td>
</tr>
<tr>
<td>High</td>
<td>250,000</td>
<td>250,000</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Average</td>
<td>151,000</td>
<td>151,000</td>
<td>151,000</td>
<td>151,000</td>
</tr>
<tr>
<td>Average/acre</td>
<td>93,000</td>
<td>93,000</td>
<td>93,000</td>
<td>93,000</td>
</tr>
<tr>
<td>2 to 3.9 acres:</td>
<td></td>
<td></td>
<td>95,000</td>
<td>95,000</td>
</tr>
<tr>
<td>Low</td>
<td>194,000</td>
<td>207,000</td>
<td>207,000</td>
<td>207,000</td>
</tr>
<tr>
<td>High</td>
<td>270,000</td>
<td>270,000</td>
<td>270,000</td>
<td>270,000</td>
</tr>
<tr>
<td>Average</td>
<td>256,000</td>
<td>264,000</td>
<td>260,000</td>
<td>258,000</td>
</tr>
<tr>
<td>Average/acre</td>
<td>98,000</td>
<td>104,000</td>
<td>102,000</td>
<td>102,000</td>
</tr>
<tr>
<td>4 to 5 acres:</td>
<td></td>
<td></td>
<td>135,000</td>
<td>135,000</td>
</tr>
<tr>
<td>Low</td>
<td>190,000</td>
<td>200,000</td>
<td>200,000</td>
<td>200,000</td>
</tr>
<tr>
<td>High</td>
<td>255,000</td>
<td>270,000</td>
<td>270,000</td>
<td>270,000</td>
</tr>
<tr>
<td>Average</td>
<td>228,000</td>
<td>255,000</td>
<td>255,000</td>
<td>255,000</td>
</tr>
<tr>
<td>Average/acre</td>
<td>94,000</td>
<td>103,000</td>
<td>103,000</td>
<td>103,000</td>
</tr>
</tbody>
</table>

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

Source: Based on data provided by the TK database.
The next category, 2 to 3.5-acre lots, has achieved high sales prices but lower prices per acre. In 1990, prices ranged from $60,000 to $113,000, averaging $81,000 per acre.

The 4 to 5-acre lots had insufficient sales in 1990 to analyze. The one lot sold for $333,000, or $66,000 per acre, which represented a decline from 1989, but more than twice the per acre price realized in 1987.

Overall, relatively smaller lots showed the strongest price increases with the 1 to 1.9-acre category having the highest average price per acre, at $72,000. It would appear lots sized at four acres or more tend to have less demand 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 by region, as shown in Exhibit VI-1. Kualoa lots had the highest average sales price in 1990 with an average of $195,000. The average price per acre also showed the most rapid price increases from a 1985 low of $16,000 to $227,000 in 1990, representing a 12.65% compound annual rate of increase since 1985.

On the North Shore lot sales averaged $311,000 in 1990, 9% below the average Kualoa 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 $850,000, a decline from 1989 sales but higher compared to previous years.

OTHER REGIONAL DEVELOPMENT PLANS

Kualoa North Shore landowners with significant development plans include Campbell Estate, Castle & Cooke, Hokulea 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 approval. The project consists of 15 acres of committed park land and 28 industrial lots. This development is also held pending resolution by this time.
- Four golf courses were originally planned; however, the necessary land use approvals were denied. Subsequently, an amendment was refiled for three courses.
VI-4

**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.

**Nokulele Land Co.**

Nokulele 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 to 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 have 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-1

**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 Kahana Resort and North Shore and Ko'olina 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-9. 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 Ko'olina 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 Ko'olau and North Shore regions (87% and 97%)
- Oahu lot sales in the Pupukea area and at the Sunset Hills subdivision (95% and 100%)

Western U.S. buyers typically ranged from 6% 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 Lihli Lani, the market for lots in Lihli 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 expected to be encouraged by the developer's plan to market 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:

<table>
<thead>
<tr>
<th>Projected Lihli Lani Lot Buyer Market Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary place of residence</td>
</tr>
<tr>
<td>State of Hawaii</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
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/Ko'olau area of Oahu for residents anticipating retirement.
- The location of the project in the Ko'olau area of Oahu, about 60 minutes away from the state’s largest population and employment centers.
- The emerging visitor economy of the North Shore/Ko'olau 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/Ko'olau 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 sites
  - 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 Ko'olau 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:

<table>
<thead>
<tr>
<th>Lot view orientation</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime ocean view</td>
<td>$375,000-425,000</td>
<td></td>
</tr>
<tr>
<td>Distant ocean/golf</td>
<td>325,000-375,000</td>
<td></td>
</tr>
<tr>
<td>Golf course</td>
<td>275,000-325,000</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>180,000-250,000</td>
<td></td>
</tr>
</tbody>
</table>

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 1990, 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.

---

VII-B

LIHI LANE RECREATIONAL COMMUNITY
Typical Lot Sales Absorption Rates for Selected Comparable Projects
1986 to 1989

<table>
<thead>
<tr>
<th></th>
<th>Average annual absorption per project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oahu and Hawaii Island selected lot subdivisions</td>
<td>70</td>
</tr>
<tr>
<td>Oahu lot sales: (1)</td>
<td>25</td>
</tr>
<tr>
<td>Koalua region North Shore region</td>
<td>18</td>
</tr>
</tbody>
</table>

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

Source: Based upon discussions with project developers or realtors and data from the Multiple Listing Service.
VI-5

# 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/Ko'olau 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, and 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:

<table>
<thead>
<tr>
<th>Year</th>
<th>1995</th>
<th>1996</th>
<th>1997</th>
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<tbody>
<tr>
<td>Annual lot sales</td>
<td>60</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Cumulative lot sales</td>
<td>60</td>
<td>50</td>
<td>120</td>
</tr>
</tbody>
</table>
### Lani Lani Recreational Community
#### Home Purchase and Rental Affordability for Oahu Households
1990

<table>
<thead>
<tr>
<th>Percent of Oahu median household income</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
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<tbody>
<tr>
<td>Household Income:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual(1)</td>
<td>$33,000</td>
<td>$41,200</td>
<td>$49,400</td>
<td>$57,700</td>
</tr>
<tr>
<td>Monthly</td>
<td>2,750</td>
<td>3,420</td>
<td>4,120</td>
<td>4,810</td>
</tr>
<tr>
<td>Home purchase assumptions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum monthly payment(2)</td>
<td>$810</td>
<td>$1,010</td>
<td>$1,240</td>
<td>$1,440</td>
</tr>
<tr>
<td>Less real property tax and insurance</td>
<td>100</td>
<td>125</td>
<td>159</td>
<td>180</td>
</tr>
<tr>
<td>Maximum amount to principal and interest</td>
<td>730</td>
<td>905</td>
<td>1,090</td>
<td>1,260</td>
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<tr>
<td>Maximum mortgage amount(3)</td>
<td>$86,000</td>
<td>$107,000</td>
<td>$129,000</td>
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<tr>
<td>Down payment amount:</td>
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<tr>
<td>At 5% of purchase price</td>
<td>$5,000</td>
<td>$6,000</td>
<td>$7,000</td>
<td>$8,000</td>
</tr>
<tr>
<td>At 10% of purchase price</td>
<td>$10,000</td>
<td>$12,000</td>
<td>$14,000</td>
<td>$17,000</td>
</tr>
<tr>
<td>Home purchase affordability:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum price at 5% down</td>
<td>$91,000</td>
<td>$113,000</td>
<td>$136,000</td>
<td>$157,000</td>
</tr>
<tr>
<td>Maximum price at 10% down</td>
<td>$96,000</td>
<td>$119,000</td>
<td>$143,000</td>
<td>$166,000</td>
</tr>
<tr>
<td>Maximum monthly rent(4)</td>
<td>$870</td>
<td>$1,030</td>
<td>$1,240</td>
<td>$1,440</td>
</tr>
</tbody>
</table>

---

(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.
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<td>2</td>
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</tr>
</tbody>
</table>
SUMMARY AND CONCLUSIONS

This report indicates that agriculture is not a viable option for utilizing Mauna Kea Project lands. Findings are based on one criterion: ecological adaptation, sales potential, economic viability, and intensity of production. Most of the area is ecologically unsuitable for any type of crop production or grazing. Seventy-one percent of the land area, 601 acres, consists of soil types in very low 5CS capability classifications of IVA to VIII. These areas are very badly eroded and consist of steep, rocky gulches. The 170.4 acres of Class II (32.2 acres of 55 Class II) 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 for the project is estimated at 100,000 gallons per acre at an annual per acre cost of $1.22, including both water and development costs. Twenty-five percent of the time, the annual water requirement would amount to and estimated 492,000 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 3,241 gallons per acre per day or 900,000 gallons per day for the approximately 200 acres ecologically suitable 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 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 Mauna Kea Pupukea in relation to alternative production areas, particularly the Neighbor Islands, indicates 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 purposes is that the land is not needed for that purpose. A total of 1,141,615 acres of land on Oahu were scored as Agricultural in 1956 by the State Land Use Commission. Acres in cultivated crops, on the other hand, have steadily declined from 30,100 acres in 1972 to 4,100 acres in 1980. 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.
AGRICULTURAL FEASIBILITY AND NEED FOR OHAYASHI PUPUKA PROJECT LANDS

INTRODUCTION

This report investigates the agricultural feasibility of the Ohayashi Pupukea Project lands and the probable effect 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 Ohayashi Pupukea Project lands for crop production and/or grazing is based on the following criteria:

1. Ecological Suitability, including soil type, configuration, accessibility, rainfall, availability of supplemental irrigation water, temperature, wind, light intensity and insect and disease problems, if applicable.

2. Sales Potential 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 rezoning 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 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 Ohayashi Pupukea Project are shown in Figure 1. A total of 356.2 acres of Prime Agricultural Land is distributed in 8 parcels throughout the project. Likewise, scattered throughout the project are 19 parcels constituting 337.9 acres of Other Agricultural Land. A total of 72.4 acres of land, consisting primarily of steep, rocky, eroded gullies, 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 (SCS) and the University of Hawaii Land Study Bureau (UHLS) 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 1 to XII, with 1 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:

Kelleman Series

This series consists of steep to extremely steep well drained soils on alluvial fans and colluvial slopes on the sides of gullies. The only soil in this series is Kelleman Silty Clay, 30 to 50 Percent Slopes (HUCD). There are 80.6 acres of this soil type in the project area, stretching from the toe to the base of the slopes boundary along the South border. This unit is given a very low capability classification of VII 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.
Kama Series

This series contains 49.3 acres in the north-south section of the project above the rocky cliffs. The area includes parcels of three subseries: Kpd, 17.6 acres; Kpa, 17.4 acres; and Kpa, 19.3 acres. The series consists of well-drained soils on uplands, which are gently sloping to very steep. The topsoil is very dark red to dark brownish-black subangular blocky silty clay about 12 inches in depth. The subsoil is dark reddish-brown to dark grayish-brown subangular blocky silty clay about 33 inches thick. The subsoil is a subangular blocky structure about 33 inches thick. This series is not recommended for truck crops or orchards, but could be used for grazing.

Kama Silty Clay, 2 to 6 Percent Slopes, Kpa (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 I, with moderate limitations for crop production because of the slight erosion hazard. This soil is good for sugar beets, truck crops, and orchards, but the small size of the parcel makes it infeasible for sugar beet production.

Kama Silty Clay, 6 to 12 Percent Slopes, Kpa (17.4 Acres)

This subseries is the same as Kpa, except that runoff is slow and the erosion hazard is slight to moderate. The SCS capability classification is I, with slight limitations for commercial crop production.

Kama Silty Clay, 12 to 20 Percent Slopes, Kpa (19.3 Acres)

This subseries is similar to Kama soils of lower slopes, except that runoff is medium and the erosion hazard is moderate. Workability is somewhat difficult because of the slope. This soil is downgraded to a capability classification of IV because of the erosion problem. The soil is marginal for crop production because of the erosion problems and is not suitable for use in the project area. It can be used for grazing, but this use is also limited because of the erosion problem.

Hama Series

There are several scattered parcels of the Hama Series in the north-south section of the project above the ridges, amounting to a total of 14.7 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 porous pisolitic 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 pisolitic sheet.

**Hanauma Silty Clay, 3 to 9 Percent Slopes, NPS (4.1 Acres)**

For this subseries, runoff is slow, the erosion hazard is slight and depth to the pisolite sheet is 20 to 50 inches. The capability classification is IIa, 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. Commercial crop production is limited, however, because this unit consists of small noncontiguous parcels of 2.8, 13.0 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.

**Hanauma Silty Clay, 8 to 15 Percent Slopes, NPS (4.3 Acres)**

This is the same as Hanauma silty clays of lesser slopes, except that runoff and the erosion hazard are increased to moderate. The soil is classified as IIb 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.

**Hanauma Silty Clay, 15 to 25 Percent Slopes, NPS (7.7 Acres)**

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

**Hanauma Silty Clay, 25 to 40 Percent Slopes, NPS (37.3 Acres)**

This subseries has rapid runoff and an erosion hazard of moderate to severe. The SCS capability classification is IVa. It cannot be used for crop production and grazing is marginal. It consists of two isolated parcels of 30.4 and 7.1 acres.

**Paiana Series**

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

**Paiana Silty Clay, 3 to 12 Percent Slopes, NPS (43.6 acres)**

This parcel consists of a narrow strip paralleling the South-Waimea border of the project and bounded by steep gulleys. 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 1.7 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. Variability is slightly difficult because of the slope. The SCS land capability classification is IIIb. 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 inaccessible parcel. These restrictions would also seriously limit use of the parcel for truck crops or orchards.

**Fomalua Series**

This series consists of well-drained silty clay soils on uplands. It is the predominant series in the project, encompassing 575.1 acres, including Fomalua baldlands. 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.

**Fomalua Silty Clay, 3 to 8 Percent Slopes, NPS (46.7 Acres)**

This is the best soil of the Fomalua series. Runoff is slow to medium, the erosion hazard is slight and workability is easy. The capability classification is IIa, 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 gulleys.
Punualu Silty Clay, 8 to 15 Percent Slopes, PeC (13.7 acres)

This soil is the same as PeC, except that the erosion hazard is slight to moderate and workability is slightly difficult. The capability classification is 1Ve, 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 acreage, but the use of this small isolated parcel is not feasible for that purpose. This soil is also fairly well adapted to truck crops production, but the small size of the parcel would limit its use for that purpose.

Punualu Silty Clay, 15 to 25 Percent Slopes, PeD (135.5 acres)

This soil is the same as PeC, except that runoff is increased to serious and the erosion hazard is moderate. The capability classification is 1Ve, irrigated or nonirrigated, reflecting very severe limitation for crop production because of the steep slopes and erosion problem.

Punualu Silty Clay, 25 to 40 Percent Slopes, PeK (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 soil is downgraded to 1Ve and is not usable for cultivated crop production or recommended for pasture.

Punualu Bedland Complex, 50 to 70 Percent Slopes, PeE (324.7 acres)

These soils, which constitute about 29 percent of the entire project area, predominate in the waiku section of the project where they consist of steep hilly canyons that surround plateaus of somewhat better lands. Most of the soils have been removed from the bedlands by wind and water erosion. About 55 percent of the area includes rocky land, stony steep land, rock outcrop and rockland. This land has the lowest capability classification of 2Ve and is not adaptable to any type of crop production. Some of the steep areas are marginal for grazing, but the erosion problem makes grazing impractical.

Rock Land, PeK (115.2 acres)

A narrow strip of rock land forms steep cliffs surrounding the plateaus and canyons in the west and northern sections of the project. Exposed rock covers most of the surface and the remainder is very rocky and very plastic clay. The SCS capability classification is 2Ve because of the steep, rocky conditions. This land cannot feasibly be used for any type of crop production or grazing.

Vehawa Series

These soil types in the Vehawa series covering 89.9 acres are located in west-makai section of the property. These consist of 82.0 acres of VeB, 5.7 acres of VeC and 2.2 acres of VD2.

The Vehawa series consists of well drained soils in upland areas. The soils developed from residuum and old alluvium derived from basaltic 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 subsoil is weathered basaltic igneous rock. The topsoil is medium acid and the subsoil is medium 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:

Vehawa Silty Clay, 3 to 8 Percent Slopes, VeB (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 DSC capability classification of 1Ve because of the need for erosion protection under tilling. This subseries is good for sugar cane, pineapple, truck crops, orchards and grazing. Truck crops and orchards are presently grown on the same soil type adjoining developed areas of Pupukea. Withstanding 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 unsuitable for crop production and limited accessibility.

Vehawa Silty Clay, 8 to 15 Percent Slopes, VeC (5.7 acres)

This subseries is similar to VeB, 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 2Ve, irrigated or nonirrigated. This small parcel of 5.7 acres is marginal for crop production but could be used for that purpose in conjunction with the 44-acre parcel of VeB which it adjoins, subject to the same extraneous limitation of VeB.

Vehawa Silty Clay, 15 to 25 Percent Slopes, Eroded, VD2 (2.2 acres)

This subseries is similar to the better Vehawa 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 classified as 1%V, 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.

Valaisan Series

This series, which includes 11 acres in the central-moak area of the project, consists of moderately well drained soils on alluvial fans. The soils developed from alluvium weathered from basalt igneous rock. The topsoil is dark reddish-brown silty clay with a subangular block structure about 26 inches thick. The subsoil is dark reddish-brown, mottled silt 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.

Valaisan Silty Clay, 0 to 3 Percent Slopes, UGA (4.4 Acres)

This subsite is the same as described above. Runoff is slow and the erosion hazard is no more than slight. This site is the only one in the project area with a capability classification of 2, with essentially no physical limitations affecting its use for crop production and grazing. The soil is good for hay, anfract, 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. Frustration to salt water plus the salt laden winds make this unit unsuitable for orchard crops. The fact that it is a small, isolated parcel would also restrict its use for agriculture.

Valaisan Silty Clay, 5 to 8 Percent Slopes, UGA (4.6 Acres)

This soil in the same as UGA, except for the somewhat steeper slopes, for which it is slightly downgraded to a capability classification of 1%. The same limitations to crop production apply because of its proximity to the ocean and to salt laden winds.

LAND STUDY BUREAU CLASSIFICATIONS (195)

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, sugarcane, 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 1 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 1,125.5 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-moak corner of the project. This unit has an overall crop 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.

B112
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-moak 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.

B113
This soil type encompasses 14.2 acres in the project, consisting of a long narrow plateau of 9.3 acres near the North central border and another plateau of 4.9 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 guchas.
This unit consists of an isolated high plateau of 259 acres bounded by steep canyons in the North-Mauna section of the project. The overall crop productivity rating is C if nonirrigated and B if irrigated. Selected crop productivity ratings if nonirrigated are a 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, e for pines 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.

Unit C20 totals 34.6 acres, including a long narrow plateau of 31.4 acres surrounded by canyons paralleling the South-Mauna border and a small plateau of 3.2 acres bordering a steep canyon in the North-Mauna 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 area is isolated high plateau, they are submarginal for agricultural production.

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-Mauna areas of the project. As with most of the plateau, these parcels adjoin or are surrounded by steep rocky gulleys. Without irrigation the overall crop productivity rating is C and selected crop ratings are c for pineapple and b for all other crops. The inavailability 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.

This section encompasses 156.0 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-Mauna areas of the project. Most areas of the plateaus are bounded by steep, rocky gulleys. These units are given an overall crop productivity rating of C, irrigated or nonirrigated. Selected crop productivity ratings if nonirrigated are a 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.

D122

The 12.5 acres in this soil type are divided into two isolated
parcels of 9.0 and 3.5 acres in the southwest corner 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 c for forage. These
two parcels are contiguous to a 53.3 acre parcel of D111 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
erating 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.

D20

This soil type consists of a very narrow elongated 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 c for sugarcane and d for all other crops. With
irrigation, the overall rating is D and the selected ratings are
b for pineapple and c 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.

D28

This soil type is located on a small 6.7 acre parcel in the corner 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 unirrigated and a if irrigated. The
soil is steep and has poor machine tillability. It is not
adequate to any type of cultivated crop production.

D91

This soil type is located on an irregularly shaped, narrow
plateau of 27.9 acres in the North-west 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 waka 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.

D23

This 8.5-acre parcel is located above the waka cliff in the
South-west corner of the project. The overall crop
productivity rating is D if nonirrigated and C if irrigated.
Selected crop productivity ratings 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 potential for the parcel. The parcel is, therefore, not
recommended for cultivated crop production, but is ecologically
adaptable to grazing.

D43

This unit consists of 17.1 acres in the small section of the
property that extends wakas 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
Northeast shore.

-17-
This unit consists of 35.0 acres, including two separate parcels of 23.3 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 selected parcels consist of the sides of steep gulches. No crop production is ecologically feasible in this area. Grazing is suboptimal and not recommended because of the erosion problem.

This unit of 10.5 acres is located in the lower part of the steep kulak cliff 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.

This unit encompasses 50 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.

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 a long, narrow area through the center of the project from the Makai border to the makai 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.

This soil type consists of a long, narrow rocky slope of 12.6 acres in the South-Makai section of the project. The overall rating is E and selected crop productivity ratings are D for grazing 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 176.6 acres or 15.6 percent of the total land area of 1,129.5 acres have crop capability classifications of 1 (0.4 acres) and 11 (170.6 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 157.2 acres or 13.9 percent of the land area if nonirrigated are considered marginal for crop production. Some of these lands are upgraded when irrigated, thus the land in Class III decreases slightly to 147.9 acres or 13.1 percent if irrigated. A total of 600.9 acres or 53.3 percent of the project area is ecologically infeasible for crop production if nonirrigated. When irrigated, this decreases to 776.2 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 1 and 11. With irrigation, however, the land area classified as A and B by LSB increases to 231.3 acres as compared to 181.4 acres in SCS classes 1 and 11. 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, 70.4 acres or 62.2 percent of the land area is rated E and considered infeasible for crop production as compared to 600.9 acres or 53.3 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 (1 to 8). Thus, whereas LSB class A soils 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 soils fall into the SCS class IV category, which is considered infeasible for cultivated crop production. Field 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, Obhayashi Corporation Pupukea Project, ESCA Classifications

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acreage</th>
<th>Capability Classification</th>
<th>Nonirrigated</th>
<th>Irrigated</th>
</tr>
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<tr>
<td>K10G</td>
<td>80.6</td>
<td>VIIa</td>
<td>VIIa</td>
<td>VIIa</td>
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<tr>
<td>KanC</td>
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<td>IIVa</td>
<td>IIVa</td>
<td>IIVa</td>
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<tr>
<td>KanE</td>
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<td>VIII</td>
<td>VIII</td>
<td>VIIIa</td>
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<tr>
<td>KIG</td>
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<td>VII</td>
<td>VII</td>
<td>VIIa</td>
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<tr>
<td>KpB</td>
<td>6.3</td>
<td>IIIE</td>
<td>IIIE</td>
<td>IIIE</td>
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<tr>
<td>KpC</td>
<td>12.4</td>
<td>IIIE</td>
<td>IIIE</td>
<td>IIIEa</td>
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<tr>
<td>KpD</td>
<td>19.8</td>
<td>IVe</td>
<td>IVe</td>
<td>IVe</td>
</tr>
<tr>
<td>KpG</td>
<td>61.3</td>
<td>IIE</td>
<td>IIE</td>
<td>IIE</td>
</tr>
<tr>
<td>KpD</td>
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<td>KpE</td>
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<td>VII</td>
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<td>VaC</td>
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<td>VWB</td>
<td>4.6</td>
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**Total** 1,129.5 1,129.5 1,129.5

<table>
<thead>
<tr>
<th>Class</th>
<th>Acreage</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I &amp; II</td>
<td>176.4 (15.1%)</td>
<td>187.4 (16.4%)</td>
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<tr>
<td>Class III</td>
<td>332.2 (30.1%)</td>
<td>349.9 (30.7%)</td>
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<tr>
<td>Class IV-VII</td>
<td>800.9 (73.9%)</td>
<td>849.2 (74.9%)</td>
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</tbody>
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**Note:** Classified only for nonirrigated. Thus irrigated is given the same classification.

---

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

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acreage</th>
<th>Capability Classification</th>
<th>Nonirrigated</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
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<td>R21</td>
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<td>E108</td>
<td>12.6</td>
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</tbody>
</table>

**Total** 1,129.5 1,129.5 1,129.5

<table>
<thead>
<tr>
<th>Class</th>
<th>Acreage</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A &amp; B</td>
<td>162.2 (14.4%)</td>
<td>261.7 (22.8%)</td>
</tr>
<tr>
<td>Class C</td>
<td>740.9 (66.4%)</td>
<td>759.9 (66.5%)</td>
</tr>
<tr>
<td>Class D &amp; E</td>
<td>230.6 (20.7%)</td>
<td>239.9 (20.7%)</td>
</tr>
</tbody>
</table>

**Note:** Classified only for nonirrigated. Thus irrigated is given the same classification.
Another severely limiting factor is that the limited land area in SGN classes I and II (SGN classes A and B) consists of small, noncontiguous plateaus surrounded by steep, badly eroded gullies. This prevents economy 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 gullies severely limits the types of crops that might be grown.

Sugar cane requires economies of scale, which are crucial to mechanization and advanced technology in order to even approach economic viability under current and foreseeable prices. Even under plantation agriculture, sugar production on Oahu is reported to be uneconomic. Four hundred of 500 small sugar cane farms on the Ewa Coast, some as large as 700 acres, have gone out of business during the past 10 years. Thus sugar cane 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 efficient management. This crop cannot viably be grown on the small isolated plateaus of the project area.

Fruits, such as mangos, citrus, lychees and avocados are grown in the developed areas along the Pupukea Road and would be adaptable to the project area if an economy is concerned. However, mangos are better adapted to a drier climate, such as Waihe'e 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 a few, is moving from Oahu to the outside islands, particularly Maui, where production is growing on cultivated land is much cheaper than on Oahu.

Several varieties of fruit crops could be grown in the project area with respect to ecological adaptation, providing that low cost, potable water is available at affordable rates. Among these are coconuts, ginger, plumeria, orchids, and pitomintas. The small size of parcels of better type soils would be a less serious problem for fruit culture 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 nature 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, bitters 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 were incurred for labor and management. 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 840-00 (Pupukea Farm), which is located near the project at an elevation of 670 feet, best approximates the area elevation of the better soil types. Rainfall was recorded by AWA at this station during 13 years of the period from 1932 to 1946. Median annual rainfall during the 13 recorded years was 31.7 inches (Table 3). During 75 percent of the time, annual rainfall did not exceed 46.7 inches and was less than 40.9 inches 25 percent of the time. The annual maximum was 73.5 inches and the annual minimum was 46.6 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 Okahayashi Project

<table>
<thead>
<tr>
<th>MONTH AND ANNUAL RAINFALL SUMMARY, 1974</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
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<td>------</td>
</tr>
<tr>
<td>SUM</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>SUM</td>
</tr>
</tbody>
</table>

Vegetables and tree fruits, which are ecologically adaptable to the better soil types, require delivery of 4,500 gallons and effective use of 3,921 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, totaling 7.0 acre-inches for the 8-month period.

Analysis based on long-term median rainfall underestimates 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 any one year. Based on the 25 percent of the time factor, annual rainfall amounts to 33.2 inches as compared with an annual requirement of 36.8 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 acre of arable land in the Okahayashi project area are presented in Table 4. The median annual cost would amount to $1,273.00 over a long-term amortization period, but 25 percent of the time the cost would amount to $1,290.00 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 amortized among all 200 acres of scattered plateaus rather than among the entire 1,100.5 acres in the project. Application of this excessive cost of water to available budget analyses for truck crops and tree fruits would render the enterprise 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 areas of Pukue. This is only 25 percent of required market delivery. The other 75 percent would have to come from additional wells to serve

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

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Table 4. Compositions of Water Costs For Truck Crop Production, Ohaysahri Pupukea Project

<table>
<thead>
<tr>
<th>Item</th>
<th>Total Cost</th>
<th>Amortization Period (years)</th>
<th>Annual Cost (Amortized)</th>
<th>Annual Cost Per Acre/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wells, Pumps, Trans. to Reservoir</td>
<td>$1,600,000</td>
<td>20</td>
<td>$80,000</td>
<td>$400.00</td>
</tr>
<tr>
<td>Reservoir</td>
<td>$500,000</td>
<td></td>
<td>$25,000</td>
<td>$25.00</td>
</tr>
<tr>
<td>Transmission to Plateau</td>
<td>$2,000,000</td>
<td>20</td>
<td>$50,000</td>
<td>$50.00</td>
</tr>
<tr>
<td>Farm Irrigation System</td>
<td>$300,000</td>
<td>10</td>
<td>$30,000</td>
<td>$30.00</td>
</tr>
<tr>
<td>Sub Total</td>
<td>$3,400,000</td>
<td></td>
<td>$185,000</td>
<td>$1,175.00</td>
</tr>
<tr>
<td>Water (25% of time requirements)</td>
<td>655,140 gallons @ $2.25 per 1,000 gallons</td>
<td>$173.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (median requirements)</td>
<td>190,076 gallons @ $4.25 per 1,000 gallons</td>
<td>$47.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median Annual Cost Per Acre</td>
<td>25% of time</td>
<td>$1,232.52</td>
<td>$1,232.52</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>$1,240.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Based on 200 acres of arable land.

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 3.0 milligrams per liter or 1,180 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 870 feet 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 local storms. Wind damage is reported to be somewhat less severe in Pupukea than in more exposed areas on Oahu, such as Kailua, Kualoa 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 POTENTIAL**

Sales potentials in this analysis are relevant only for those crops which are ecologically adaptable to ESC class II (SGC class E) soils and to some class III soils that are interplanted with class II soils. The acreage in class I soils is negligible. An estimated 200 acres of the 1,175.5 acres in the project area could be utilized for diversified crop production, considering ecological restrictions, 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 fruits. 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 890.00 (Pupukea Farm)

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Daily Maximum (°F)</th>
<th>Mean Daily Minimum (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>75.3</td>
<td>62.7</td>
</tr>
<tr>
<td>February</td>
<td>75.3</td>
<td>63.1</td>
</tr>
<tr>
<td>March</td>
<td>74.8</td>
<td>62.0</td>
</tr>
<tr>
<td>April</td>
<td>77.3</td>
<td>58.4</td>
</tr>
<tr>
<td>May</td>
<td>79.5</td>
<td>65.7</td>
</tr>
<tr>
<td>June</td>
<td>81.0</td>
<td>68.0</td>
</tr>
<tr>
<td>July</td>
<td>82.0</td>
<td>69.3</td>
</tr>
<tr>
<td>August</td>
<td>81.2</td>
<td>69.6</td>
</tr>
<tr>
<td>September</td>
<td>82.3</td>
<td>69.0</td>
</tr>
<tr>
<td>October</td>
<td>80.3</td>
<td>68.5</td>
</tr>
<tr>
<td>November</td>
<td>77.6</td>
<td>66.8</td>
</tr>
<tr>
<td>December</td>
<td>75.2</td>
<td>64.7</td>
</tr>
</tbody>
</table>

**Annual** 79.8 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 value use 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 gullies. Grazing cattle and horses in the area has been a nonbusiness type operation, with inadequate consideration for an economic return to the land or to profit maximization. LSR estimated that lands with a productivity rating of 8 (comparable to SOC II) provide average live beef cattle gains of 60 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 average required to displace imports. Sales potentials for Pupukea for the above crops plus paways 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 Waimanalo. 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 for sweet potatoes, onions, and fruit crops which might be grown in the project area are shown in Table 6. The total of 791 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 Obayashi 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 Obayashi Pupukea Project are discussed in the following analyses.

The area devoted to snap bean production on Oahu declined from 60 acres in 1977 to 50 acres in 1980, with a proportionate decrease in marketing. 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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Market Supply</th>
<th>Yield Per Acre</th>
<th>Acreage Required To Displace Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1,000 pounds)</td>
<td>(pounds)</td>
<td>(acres)</td>
</tr>
<tr>
<td>Beans, Snap</td>
<td>580</td>
<td>330</td>
<td>12,000</td>
</tr>
<tr>
<td>Corn, Sweet</td>
<td>1,040</td>
<td>767</td>
<td>8,000</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>3,720</td>
<td>2,624</td>
<td>20,000</td>
</tr>
<tr>
<td>Eggplant</td>
<td>1,300</td>
<td>196</td>
<td>30,000</td>
</tr>
<tr>
<td>Peppers, Green</td>
<td>2,050</td>
<td>1,392</td>
<td>20,000</td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>2,000</td>
<td>676</td>
<td>30,000</td>
</tr>
<tr>
<td>Watermelons</td>
<td>14,300</td>
<td>831</td>
<td>25,000</td>
</tr>
<tr>
<td>Bananas</td>
<td>9,700</td>
<td>10,887</td>
<td>30,000</td>
</tr>
<tr>
<td>Avocados</td>
<td>1,300</td>
<td>576</td>
<td>8,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>793</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Oahu is the major producer of sweet corn in Hawaii, but acreage declined from 365 acres in 1977 to 220 acres in 1986. Marketings during the same period declined from 1,345,000 pounds to 885,000 pounds. At the same time, imports increased from 617,000 pounds 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 Ohau Pupukea were competitive in relation to existing sweet corn production areas on Oahu, such as Waimalu, 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 460 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 4,200,000 pounds in 1977 to 2,720,000 pounds in 1986. During the same period, imports increased from 1,027,000 pounds to 2,024,000 pounds, indicating an 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 Kauai, 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 1,000,000 pounds in 1977 to 2,050,000 pounds in 1986. During the same period imports increased from 1,173,000 pounds in 1977 to 2,020,000 pounds in 1986, but decreased to 1,220,000 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 1,150,000 pounds in 1977 to 2,409,000 pounds in 1986. Imports did not change substantially during that period, amounting to 655,000 pounds in 1977 and 676,000 pounds in 1986. The date 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 trends, Oahu production might be expected to decline further.

Watermelon acreage in Hawaii approximately tripled during the 10-year period, from 218 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 2,072,000 pounds in 1977 to 14,300,000 pounds in 1986. During the same period, inshippments decreased from 3,561,000 pounds in 1977 to 831,000 pounds in 1986 and Hawaii became almost self-sufficient in watermelon production. Only an estimated 3% of the increase in Hawaii was due to the increase in inshippment. Watermelon has advantages over Papayas in soils, climate and production costs. Thus, any further expansion in watermelon acreage is likely to take place on Oahu.

Harvested banana acreage in Hawaii increased from 550 acres in 1977 to 960 acres in 1986. Most of the increase in banana acreage occurred in the Puna district on Hawaii. Maui County harvested acreage increased from 315 acres in 1977 to 370 acres in 1986. During the same period, Oahu harvested acreage increased from 445 acres to 425 acres. Most Maui County acreage consists of high yielding Williams bananas and the majority of Oahu production consists of low yielding, but higher priced, Braeburn (apple) bananas. Hawaii banana production increased from 3,600,000 pounds in 1977 to 9,700,000 pounds in 1986. During the same period, inshippments increased from 9,000,000 pounds to 10,800,000 pounds. Thus, whereas Hawaii production has been increasing, local producers have not been successful in displaced imports, which would require a very substantial additional 365 acres. There is good indication that Hawaii banana production will continue to expand, but expansion is likely to take place in Maui and Kauai Counties and not on Oahu. Furthermore, the Papaya 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 1977 to 145 acres in 1977 to 340 acres in 1977 and 330 acres in 1986. Most of the increase was in Kona, where labor and land costs are less than on Oahu and natural rainfall is sufficient to meet 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. Inshippments also increased, from 210,000 pounds in 1977 to 325,000 pounds in 1986. Since a segment of the population prefers the small California avocados and because of the need for inshippments for seasonal adjustments, further displacement of imports is not likely. Unless restrictions on shipments to the U.S. mainland because of proscribed 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.

Papayas are 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 2,105 acres in 1977 to 2,355 acres in 1986. In spite of the slight increase in acreage, utilized production decreased from 63,561,000 pounds in 1977 to 61,000,000 pounds in 1986. Most of the production is in Maui County where farmers depend primarily on natural rainfall, land is available to permit planting for root rot control and labor costs are lower than on Oahu. Oahu acreage is very small and growth has been insignificant. There were 45 acres in 1977 and 46 acres in 1986. It is quite evident that the Papaya 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 Oh bayashii Papaya 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 1971 to 47,100 acres in 1981 and 40,700 acres in 1986 (63). The very small decline of 4,400 acres in crop production between 1981 and 1986 exceeds that which has been converted to use 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 2,446 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 to diversified crop production with respect to ecology, but high land prices, market limitations and difficulties in obtaining agricultural subsidies permits from the City and County of Honolulu have prevented its use for agriculture.

The 128 classified 53,039 acres of land on Oahu outside urban areas as good agricultural land in 1972, of which 79,583 acres were given crop productivity ratings of A and 33,450 acres were rated as B. In addition, 17,637 acres were classified as C, which is marginal for cultivated crop production. This compares to a total of only 49,700 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 land by 12,339 acres. With Class C land included, the availability of cultivatable land based on the 1972 data exceeds the 1986 acres in cultivated crop production by 50,178 acres. However, some of excess good agricultural land has been converted to other uses and is no longer available for agriculture.
Land used urban by the State Land Use Commission increased by 9,797 acres from 1972 to 1985 (79,700 acres to 87,497 acres). During the same period land used Agricultural decreased by 2,556 acres (148,000 acres to 145,444 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 used from agricultural to urban consisted of A and B soils. On this basis, A and B lands available for agriculture would have decreased from 32,038 acres to 19,813 acres from 1972 to 1985. This would decrease the amount by which A and B land acres exceed acreage in cultivated crops in 1985 from 11,325 acres to 9,123 acres. On the same basis, the excess of A, B and C lands outside of urban areas would have decreased from 33,176 acres to 24,950 acres for 1985.

The SCU classified 67,342 acres of good agricultural land in 1972, with 23,356 acres rated as I and 43,786 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 SCU and LS8 land productivity ratings are fairly comparable, a smaller excess of 9,115 acres of good agricultural 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 1985. These lands are, with some exceptions, restricted to agricultural use and are separate from lands used as Urban or Conservation. The land area used as Agricultural is far in excess of the 40,700 acres in cultivated crop production in 1985, the 53,029 acres classified as A and B by LS8 (adjusted to 49,813 acres for 1985) and the 67,342 acres classified as I and II by SCU.

The large acreage used 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 agricultural 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, sugarcane and truck crops are moving to the outside islands. Oahu sugar plantations continue to convert less productive sugarcane acres to other crops. Substantial areas of former pineapples continue to lose their productivity. Thus the supply of unused prime agricultural land on Oahu continues to decrease as the agricultural need for it decreases.

Occupied 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 SCU Class I (LS8 Class A) soil types. There are only 6,4 acres of Class I soils, 176.4 acres of Class II soils if irrigated, and 182.4 acres of Class II soils, if irrigated, out of a total of 1,129.5 acres in the project area. Most of the land, 900.9 acres, consists of Class IV to VIII soils and is unsuitable for any type of cultivated crop production or grazing. Project lands have the further disadvantage of consisting of small parcels, 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 Papio project lands unsuitable for any economic use.
SELECTED REFERENCES


11. Soil Conservation Service, Soil Survey of Islands of Kauai, Oahu, Molokai, and Lanai - State of Hawaii, USDA Soil Conservation Service in cooperation with the University of Hawaii Agriculture Experimental Station, August, 1972, 328 pp. plus maps.

GROUNDWATER CONDITIONS
PUPUKEA-PAUMALU, OAHU

John F. Mink
June 6, 1970

The proposed golf course and ancillary development are located in the Pupukea-Paumalu region in the northern sector of Oahu between Malaekahana Bay and Kualoa. 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 Kalunawai 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 protrusion 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 Kalunawai 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 Kalunawai -- 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. 1791) places Pupukea-Paumalu in the North Sector of Oahu in the Kawaiola Aquifer System and identifies the Aquifer Type as unconfined, basal in lavas of the Koolau volcanic series. The Aquifer Code is 30403111. The Kawaiola Aquifer System extends from the Anahulu River near Haleiwa to the Koolau rift zone at Waialua. 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 dikes of aquifers of the rift zone at Waialae 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 Paauilo valley just outside the property boundary. Well 3902-01 lies 6500 feet inland where the head was measured as 2.6 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 of aquifer hydraulic conductivity provides an estimate of groundwater flow in the distance between Ma'ili and Waimanalo. The common range of values for hydraulic conductivity of the Koolau formation is 1000 to 2500 ft/day. The equation for groundwater flow in a basal lens at steady state is:

\[ q = 4 \pi h^2 k / 2x \]

in which \( q \) (ft²/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 flow, yet nevertheless a low estimate of 3 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 Ma'ili 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 Investments) 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):
<table>
<thead>
<tr>
<th>Item</th>
<th>3902-02</th>
<th>3902-03</th>
<th>4002-04</th>
<th>4002-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original owner</td>
<td>Finance Factors</td>
<td>Capital Inv.</td>
<td>County</td>
<td>County</td>
</tr>
<tr>
<td>Date drilling</td>
<td>1946</td>
<td>1956</td>
<td>1945</td>
<td>1949</td>
</tr>
<tr>
<td>Diameter (in.)</td>
<td>12</td>
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<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Elevation (ft.)</td>
<td>499</td>
<td>511</td>
<td>66</td>
<td>70</td>
</tr>
<tr>
<td>Depth BSL (ft.)</td>
<td>-55</td>
<td>-49</td>
<td>-59</td>
<td>-70</td>
</tr>
<tr>
<td>Head (ft.)</td>
<td>2.0</td>
<td>2.7</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Chloride (mg/l)</td>
<td>143-378</td>
<td>43-110</td>
<td>42-122</td>
<td>42-122</td>
</tr>
<tr>
<td>Pump rate (gpm)</td>
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<td>140</td>
<td>55</td>
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<tr>
<td>Distance coast(ft.)</td>
<td>5500</td>
<td>7200</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Status</td>
<td>Unused, abandoned</td>
<td>Abandoned RHS</td>
<td>RHS</td>
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</tbody>
</table>

Mualua wells. On the Mualua side of the sector, water from Mualua 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 overlain 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 application of fertilizers and water will control the passage of nitrate, the chief fertilizer component, to a few mg/l. Prohibition of the use of undesirable 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.
Assessment of Potential Impacts
Irrigation of Lihl Lani Golf Course
Pupukea-Paumaui, Oahu

John F. Nance
December 31, 1990

Introduction

The Lihl 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 Paumaui 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 usage 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-Paualu is part of the Kawaiola Aquifer System. In the vicinity of Lihii 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 Chyben-Herzberg ratio of 40 feet of fresh water below sea level for every foot above. The thickness of the fresh water zone 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 Paualu Stream and Kalunawialala 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-Paualu, 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-Paualu portion of the Kawaiiho Aquifer System has not been exploited for domestic water supply except at a BWS station consisting of two wells (4002-04 and 4002-05) located on the west bank of Paualu 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 Waialua from an aquifer that is not connected to the basal lens south of Paualu. 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 borings, one a pumpable well (3902-01) and the other a test hole (3902-02), were drilled in Kaunawaki and Pukulena Valleys, respectively, more than twenty years ago. The test hole could not be located during field work, but the well may still be usable. The wells are plotted on an accompanying map.

As part of the Lihui 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 pumping 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 100 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 Mailoa 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 basal 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:

\[ y = \frac{Q}{2kbi} \]

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 (0.63 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 Kailua Valley to Paunani 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 Lihikai 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 (gpd), for a total of 440,000 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 7.4 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.

References
Two wells were drilled in Punalu'u 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.

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<thead>
<tr>
<th>Item</th>
<th>Well 1</th>
<th>Well 2</th>
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<tbody>
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</tr>
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<td>Ground Elev. (ft)</td>
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<td>465.5</td>
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<tr>
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</tr>
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<td>Casing Dia. (in)</td>
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<td>12</td>
</tr>
<tr>
<td>Blank Casing Length (ft)</td>
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<tr>
<td>Depth to Static Water (ft)</td>
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<td>500</td>
</tr>
<tr>
<td>Pump Set Depth (ft)</td>
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<tr>
<td>Airline Set Depth (ft)</td>
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<td>Maximum Test Chloride (mg/l)</td>
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<td>336</td>
</tr>
<tr>
<td>Test Date</td>
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<td>8/21-24/89</td>
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<tr>
<td>Test Time (hrs)</td>
<td>52</td>
<td>76</td>
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<tr>
<td>Recovery</td>
<td>Inst.</td>
<td>Inst.</td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Time(hrs)</th>
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<th>Dr(fft)</th>
<th>Time(hrs)</th>
<th>Rate(gpm)</th>
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<td>3 - 4</td>
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<td>0</td>
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<td>5 - 52</td>
<td>500</td>
<td>2.3</td>
<td>5 - 76</td>
<td>500</td>
<td>0.46</td>
</tr>
</tbody>
</table>

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.
**LABORATORY ANALYSIS REPORT**

TO: Engineering Concepts

ATTN: Ken Ishizaki

SAMPLES OF: Well water

RECEIPT DATE: 11/8/88

LOG NO.: 3091-3097

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**DATE:** FEB 1988

**PUPUKEA GOLF COURSE**

WELL NO. 1, 2

**WELL LOCATION MAP**
### Laboratory Analysis Report

**TO:** Engineering Concepts

**SAMPLES:** Well water

**RECEIPT DATE:** 8/22/89

**ANALYSIS DATE:** 9/23/89

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</tr>
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<td></td>
</tr>
</tbody>
</table>

**Analysis Date:**

**UNIT:** 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, 203
  - Sample #6: 8/24/89, 12 noon, 336

---

**TO:** Roscoe Moss Company

**SAMPLES:** Well water (Papakea)

**RECEIPT DATE:** 8/22/89, 8/24/89

**ANALYSIS DATE:** 9/12 mn

**MEASUREMENT:** Chloride

**UNIT:** mg/L

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Date</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample #1</td>
<td>8/21/89</td>
<td>274</td>
</tr>
<tr>
<td>Sample #2</td>
<td>8/21/89, 12 noon</td>
<td>271</td>
</tr>
<tr>
<td>Sample #3</td>
<td>8/22/89</td>
<td>279</td>
</tr>
<tr>
<td>Sample #4</td>
<td>8/23/89, 12:00 midnight</td>
<td>308</td>
</tr>
<tr>
<td>Sample #5</td>
<td>8/23/89, 6 pm</td>
<td>203</td>
</tr>
<tr>
<td>Sample #6</td>
<td>8/24/89, 12 noon</td>
<td>336</td>
</tr>
</tbody>
</table>

**Remarks:**
December 23, 1990

Mr. Norman Quon
Suite 1000 Palani 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,

[Signature]
ENVIRONMENTAL ASPECTS OF STORM WATER RUNOFF

Lihl Lani Recreational Community
Pupukea, Oahu, Hawaii

December, 1990

by

Gordon L. Dusan, Ph.D.,
Environmental Consultant

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INTRODUCTION

The proposed Lili Lani Recreational Community Project, located at Papukea in the Koolau Valley 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 Kaneohe Bay. This area will provide the location of the main access road to the proposed development. With the exception of the 1100 ft wide portion the remainder of the property comprises the bluff above the Sunset Beach area and cannot be seen from Kaneohe 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 800 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 designated 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
TABLE 1
Proposed Land Uses,
Lihi Lani Recreational Community,
Pupukea, Oahu, Hawaii

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf course</td>
<td>90</td>
</tr>
<tr>
<td>Golf Course Maintenance Area</td>
<td>5</td>
</tr>
<tr>
<td>Clubhouse</td>
<td>6</td>
</tr>
<tr>
<td>Driving Range</td>
<td>10</td>
</tr>
<tr>
<td>Tennis Center</td>
<td>12</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>19</td>
</tr>
<tr>
<td>Horse Pasture</td>
<td>78</td>
</tr>
<tr>
<td>Campground</td>
<td>15</td>
</tr>
<tr>
<td>Community Facilities</td>
<td>10</td>
</tr>
<tr>
<td>Subdivision (120 lots)</td>
<td>161</td>
</tr>
<tr>
<td>Affordable Housing</td>
<td>28</td>
</tr>
<tr>
<td>Roadways</td>
<td>44</td>
</tr>
<tr>
<td>Sewage Treatment Plant</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>492</strong></td>
</tr>
</tbody>
</table>

a) Based on the December 10, 1990 Master Plan Map by Group 70, for Obayashi Hawaii Corporation, Pupukea, Koolau 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

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 Lihle 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.

In essence, all the work consisted of estimating the alterations in volume and quality of surface water runoff from the proposed project. In practical terms, 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 require the determination of reasonable rainfall-runoff coefficients for varying magnitude and duration storms, and for different land management, vegetation, soil, and soil moisture conditions, at a given but 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 Dungan, 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, Kekaha, Paauilo, Kauaiwa, and Waialua; two are Class C, Helmano and Hanama; and one, Kahului, 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 25%, 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 bereaved 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 (Ciaccio 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 include 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 is 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, Fujitani (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>
<thead>
<tr>
<th></th>
<th>Residential C</th>
<th>Commercial C</th>
<th>Industrial C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids</td>
<td>411</td>
<td>246</td>
<td>246</td>
</tr>
<tr>
<td>Suspended Solids</td>
<td>192</td>
<td>142</td>
<td>40</td>
</tr>
<tr>
<td>COD</td>
<td>142</td>
<td>209</td>
<td>45</td>
</tr>
<tr>
<td>BOD</td>
<td>10</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>7.1</td>
<td>5.7</td>
<td>6.7</td>
</tr>
<tr>
<td>NO3-N</td>
<td>0.311</td>
<td>0.045</td>
<td>1.1</td>
</tr>
<tr>
<td>TNH</td>
<td>0.381</td>
<td>0.272</td>
<td>2.70</td>
</tr>
<tr>
<td>Total P</td>
<td>0.57</td>
<td>0.53</td>
<td>2.17</td>
</tr>
<tr>
<td>Ortho P</td>
<td>0.57</td>
<td>0.19</td>
<td>1.57</td>
</tr>
<tr>
<td>Grease</td>
<td>2.8</td>
<td>1919</td>
<td>2.2</td>
</tr>
<tr>
<td>Lead</td>
<td>0.497</td>
<td>0.987</td>
<td>1.657</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.013</td>
<td>0.021</td>
<td>0.013</td>
</tr>
<tr>
<td>Zn</td>
<td>0.512</td>
<td>0.792</td>
<td>0.729</td>
</tr>
<tr>
<td>Copper</td>
<td>0.036</td>
<td>0.036</td>
<td>0.021</td>
</tr>
<tr>
<td>Iron</td>
<td>0.377</td>
<td>0.299</td>
<td>0.049</td>
</tr>
<tr>
<td>Total coliform</td>
<td>8.3,000</td>
<td>31,500</td>
<td>11,500</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>1,965</td>
<td>463</td>
<td>580</td>
</tr>
<tr>
<td>Fecal strep</td>
<td>6,293</td>
<td>7,900</td>
<td>7,350</td>
</tr>
</tbody>
</table>

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 Kuhoolani Stream.
c Storm water samples collected at Beretania Street between Haunakea and River Streets.
d Storm water samples collected near Iwilei and Pacific Streets.

Ammomia 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 (1999) 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 Libi 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...
assumed for storm water runoff that didn't account for potential percolation from storm water runoff generated from developed areas and flushing 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 assuring 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 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 becomes 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 runways 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 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 interseason 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, 1961) and secondary (U.S. Environmental Protection Agency, 1979) drinking water standards, respectively. Inasmuch as essentially all new automobiles have switched over to unleaded gasoline 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 Lili 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 (1999) 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 (1996) 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 intercession 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 used in general are used 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 limiting 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.
REFERENCES


January 15, 1991

MEMORANDUM

TO: Jeffrey H. Overton
    Group 70
    924 Bethal Street
    Honolulu, Hawaii 96813

FROM: Gordon L. Dugan, Ph.D.
    Environmental Consultant
    704 Anapo Street
    Honolulu, Hawaii 96825

SUBJECT: Mitigation effects on storm water runoff quality and quantity for Lili Lani Recreational Community

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 undoubtedly significantly decrease the output of the constituent load that I originally determined for the project under unrestricted (no mitigative measures) storm water runoff conditions.

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 mazes, 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 wet side of the property, fronting Kaseheheha Highway, will also decrease storm water runoff volume and associated constituent loads.
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 Lihia Land Golf Course consists of 18 holes and attendant facilities near the 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 Alisols 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 0.3 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 careful control of 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 Punalu‘u 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 at least 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 Greens Irrigation and Drainage" (Terrell, 1980).

- 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 fertilization, 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 BDN, 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 6002-05 pump from the Kawaiola 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 Lihl 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 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 Lihl 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 Kaluaniwai Stream and on the northeast by Paumalu Stream, approximately. The northeast and south portions of the property are divided by Pakulela Stream. The proposed golf course is located on the upland area between Pakulela and Paumalu Streams (see Appendix Figure 1). The mauka end of the golf course is dissected by Kauteliki Stream, which is a tributary to Paumalu Stream. None of these streams is perennial. The golf course would likely provide runoff to Kauteliki, Paumalu, and Pakulela Streams during periods of high rainfall, and runoff would reach the ocean through Paumalu and Pakulela 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 Orthic Tropohumults) and Kauai silty clay (Aeric Rhodoxids). 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

<table>
<thead>
<tr>
<th>Map symbol</th>
<th>Series &amp; slope</th>
<th>Classification</th>
<th>Approximate % of total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>MpB</td>
<td>Manana silty clay 3-8%</td>
<td>Orthoxic Tropohumult</td>
<td>10</td>
</tr>
<tr>
<td>MpC</td>
<td>Manana silty clay 8-15%</td>
<td>Orthoxic Tropohumult</td>
<td>17</td>
</tr>
<tr>
<td>MpD</td>
<td>Manana silty clay 15-25%</td>
<td>Orthoxic Tropohumult</td>
<td>5</td>
</tr>
<tr>
<td>MpE</td>
<td>Manana silty clay 25-40%</td>
<td>Orthoxic Tropohumult</td>
<td>5</td>
</tr>
<tr>
<td>KpB</td>
<td>Kemoa silty clay 2-6%</td>
<td>Oste Rhodustalfs</td>
<td>5</td>
</tr>
<tr>
<td>KpC</td>
<td>Kemoa silty clay 6-12%</td>
<td>Oste Rhodustalfs</td>
<td>5</td>
</tr>
<tr>
<td>KpD</td>
<td>Kemoa silty clay 12-20%</td>
<td>Oste Rhodustalfs</td>
<td>5</td>
</tr>
<tr>
<td>PEB</td>
<td>Paumaui silty clay 3-8%</td>
<td>Orthoxic Tropohumult</td>
<td>8</td>
</tr>
<tr>
<td>PEC</td>
<td>Paumaui silty clay 8-15%</td>
<td>Orthoxic Tropohumult</td>
<td>8</td>
</tr>
<tr>
<td>PDE</td>
<td>Paumaui silty clay 15-25%</td>
<td>Orthoxic Tropohumult</td>
<td>12</td>
</tr>
<tr>
<td>PZ</td>
<td>Paumaui-Badland complex</td>
<td>10-20%</td>
<td>20</td>
</tr>
</tbody>
</table>

2. Climate and Hydrology

Mean annual rainfall for the Lihi Lani area is approximately 50 to 60 inches (Giambellucci, 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 (Staite 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 8-3).

Figure 1. Mean monthly rainfall and mean monthly pan evaporation for the Lihi Lani area (Ekern and Chang, 1985; Giambellucci et al., 1986).

Figure 2. Rainfall minus pan evaporation for the Lihi Lani area (Ekern and Chang, 1985; Giambellucci 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 Kawaiola System of the used for drinking water, is irreparable 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 turfgrass 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 used 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 (NH₄) likewise moves little in soils. Nitrogen applied in the ammonium form, however, is rapidly converted to the nitrate form (NO₃) 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 isobutylideneara (IBD), ureaformaldehyde (UF), and sulfur-coated soluble fertilizers. A study by Brown et al. (1962) 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 IBD and 1.5% as UF leached.

Fertilizer use rates for the different golf course areas are shown in Table 2.

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 estimate 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 (Harley 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 Lahi Lani golf course.

<table>
<thead>
<tr>
<th>Turfgrass area</th>
<th>Area (acres)</th>
<th>Chemisal</th>
<th>No. appli. per year</th>
<th>Rate (al./acre)</th>
<th>Annual total (al.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Herbicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Greens</td>
<td>4</td>
<td>MSMA</td>
<td>6 times/year</td>
<td>2 lbs. al./acre</td>
<td>48 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>benzamide</td>
<td>2 times/year</td>
<td>12 lbs al./acre</td>
<td>96 lbs al.</td>
</tr>
<tr>
<td>B. Tees</td>
<td>4</td>
<td>MSMA</td>
<td>6 times/year</td>
<td>2 lbs. al./acre</td>
<td>48 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Timent®</td>
<td>3 times/year</td>
<td>1 gal./acre</td>
<td>12 gal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>benzamide</td>
<td>2 times/year</td>
<td>12 lbs al./acre</td>
<td>96 lbs al.</td>
</tr>
<tr>
<td>C. Fairways</td>
<td>46</td>
<td>MSMA</td>
<td>6 times/year</td>
<td>2 lbs. al./acre</td>
<td>552 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Timent®</td>
<td>3 times/year</td>
<td>1 gal./acre</td>
<td>17 gal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>metribuzin</td>
<td>2 times/year</td>
<td>0.75 lbs al./acre</td>
<td>69 lbs al.</td>
</tr>
<tr>
<td>D. Roughs</td>
<td>36</td>
<td>MSMA</td>
<td>2 times/year</td>
<td>2 lbs. al./acre</td>
<td>144 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>metribuzin</td>
<td>1 time/year</td>
<td>0.5 lbs al./acre</td>
<td>18 lbs al.</td>
</tr>
<tr>
<td>II. Insecticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Greens</td>
<td>4</td>
<td>chlorpyrifos</td>
<td>As needed</td>
<td>1 lb. al./acre</td>
<td>24 lbs. al.</td>
</tr>
<tr>
<td>B. Tees</td>
<td>4</td>
<td>chlorpyrifos</td>
<td>As needed</td>
<td>1 lb. al./acre</td>
<td>24 lbs. al.</td>
</tr>
<tr>
<td>C. Fairways</td>
<td>Spot treatments</td>
<td>chlorpyrifos</td>
<td>As needed</td>
<td>1 lb. al./acre</td>
<td>50 lbs. al.</td>
</tr>
<tr>
<td>III. Fungicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Greens</td>
<td>4</td>
<td>metalaxyl</td>
<td>As needed</td>
<td>1.3 lbs al./acre</td>
<td>33 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chlorothalonil</td>
<td>As needed</td>
<td>8 lbs al./acre</td>
<td>96 lbs al.</td>
</tr>
<tr>
<td>B. Tees</td>
<td>4</td>
<td>metalaxyl</td>
<td>As needed</td>
<td>1.3 lbs al./acre</td>
<td>33 lbs. al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chlorothalonil</td>
<td>As needed</td>
<td>8 lbs al./acre</td>
<td>96 lbs al.</td>
</tr>
<tr>
<td>C. Fairways</td>
<td>Spot treatments</td>
<td>chlorothalonil</td>
<td>As needed</td>
<td>8 lbs al./acre</td>
<td>150 lbs al.</td>
</tr>
</tbody>
</table>

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 Lahi Lani site from pan evaporation (Ehren and Chang, 1955) and rainfall (Glambellku 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 Lahi 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 47% 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 (for 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 Lahi 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 Mitabayashi (1989) was from golf courses in areas ranging from very arid (the Kona Coast, Kohi) to relatively wet (Papenaolis). 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 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 rootzone 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 (Rau et al., 1980) is presently being evaluated (Khan and Liang, 1989; Leaque 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 X 10^{-6} for simazine (lowest contamination potential) to 7.1 X 10^{-3} for trichlorfon (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 X 10^{-3}, 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 herbicides Trimeb. 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.1

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metribuzin</td>
<td>3.5 X 10^5</td>
</tr>
<tr>
<td>Meoprop</td>
<td>1.3 X 10^5</td>
</tr>
<tr>
<td>Dicamba</td>
<td>7.1 X 10^3</td>
</tr>
<tr>
<td>Simazine</td>
<td>2.1 X 10^6</td>
</tr>
<tr>
<td>Trichlorfon</td>
<td>7.1 X 10^3</td>
</tr>
</tbody>
</table>

1Based on the following conditions: soil organic carbon content = 1.5%; soil bulk density = 1.2 g/cm^3; soil water content = 25% 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 evapotranspiration 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 replaced 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 primarily to Paumaui 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. Paumaui Stream is a major drainage way to which thousands of acres of watershed in the Ko'olau Mountains contribute runoff. This suggests that chemicals in runoff from a golf course would be highly diluted in Paumaui 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.

11
V. LITERATURE CITED


APPENDICES
Appendix Table 9-1. Properties of pesticides used on turf in Hawaii.

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Mode of Action</th>
<th>Toxicity to Fish</th>
<th>Seed Toxicity</th>
<th>Animal Toxicity</th>
<th>Human Toxicity</th>
<th>Environmental Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Herbicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Soil contact</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Parathion</td>
<td>Systemic</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Porgonate</td>
<td>Systemic</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>B. Insecticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Contact</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Contact</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Systemic</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>R. Fungicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trityl</td>
<td>Systemic</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>A. Herbicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Systemic</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Parathion</td>
<td>Systemic</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Porgonate</td>
<td>Systemic</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>


Appendix Table B-2. Toxicity classes of pesticides.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Warning Statements</th>
<th>Oral LD50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Highly Toxic</td>
<td>Poison, Skull &amp; Cranium</td>
<td>1-50</td>
</tr>
<tr>
<td>2</td>
<td>Moderately Toxic</td>
<td>Danger</td>
<td>51-500</td>
</tr>
<tr>
<td>3</td>
<td>Low Toxicity</td>
<td>Warning</td>
<td>501-5,000</td>
</tr>
<tr>
<td>4</td>
<td>Very Low Toxicity</td>
<td>Caution</td>
<td>&gt;5,000</td>
</tr>
</tbody>
</table>

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 infecting 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, 1986; Tashiro, 1988) 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 breakdown, 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 LD50 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 chloroxuronil (VP=1.3 x 10^-5 atm at 25°C) and chlorpyrifos (VP=2.4 x 10^-8 atm at 25°C). In comparison, DBF, which is known to be volatile, has a vapor pressure of 1.2 x 10^-3 atm at 21°C, i.e. at least 100 times the vapor pressure of chloroxuronil 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.
Table D-1. Droplet size range for a typical flat-fan nozzle at 20 and 40 psi (from Hofman et al., 1986).

<table>
<thead>
<tr>
<th>Droplet size range (microns)</th>
<th>Percent of spray volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 psi</td>
</tr>
<tr>
<td>0-21</td>
<td>0.1</td>
</tr>
<tr>
<td>21-63</td>
<td>3.0</td>
</tr>
<tr>
<td>63-105</td>
<td>10.7</td>
</tr>
<tr>
<td>105-147</td>
<td>16.2</td>
</tr>
<tr>
<td>147-210</td>
<td>36.7</td>
</tr>
<tr>
<td>210-294</td>
<td>27.5</td>
</tr>
<tr>
<td>&gt;294</td>
<td>5.8</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>Nozzle ht. (in.)</th>
<th>Pressure (psi)</th>
<th>Wind speed (mph)</th>
<th>Percent deposited</th>
<th>Distance to drop 4 ft.</th>
<th>Distance to drop 8 ft. to 1% of volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>40</td>
<td>3.5</td>
<td>3.1</td>
<td>0.6</td>
<td>7.0</td>
</tr>
<tr>
<td>27</td>
<td>40</td>
<td>5.5</td>
<td>5.9</td>
<td>1.5</td>
<td>13.0</td>
</tr>
<tr>
<td>18</td>
<td>30</td>
<td>5.3</td>
<td>9.3</td>
<td>2.2</td>
<td>14.0</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
<td>9.9</td>
<td>10.3</td>
<td>3.1</td>
<td>15.5</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
<td>9.9</td>
<td>9.1</td>
<td>3.6</td>
<td>17.0</td>
</tr>
</tbody>
</table>

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...
Mr. Jeffrey H. Overton  
Group 70, Ltd.  
914 Bethel St.  
Honolulu, HI 96813  

January 18, 1991

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. Exner. 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
INTEGRATED PEST MANAGEMENT (IPM) PROGRAM FOR LIHI LANI GOLF COURSE

Prepared by:
Oliver V. Heidemann, Ph. D.
Roy K. Nishimura, 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 and 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 830 plants per square foot. A single grass plant may have almost 400 miles of roots. With such an extensive root system it is not surprising that grasses can 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 washed into our drinking water supplies, but rather move into the trash 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 times 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 curbing 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, vandalism and age can 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. Grasses are an excellent CO$_2$ and oxygen converter, and 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 huge 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 perfluorohexane. Grasses are quickly renewed and their beneficial effects on the environment are immediate. In addition to their absorption of CO$_2$ and other gases 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°F warmer than bare soil, illustrating the tremendous cooling capacity of transpiration of moisture from the soil to the atmosphere (Anon., 1990).
Integried Pest Management

Integrated Pest Management (IPM) is now, for entomologists and plant pathologists alike, the new philosophy of pest control. Following World War II, the widespread use of the new synthetic organic pesticides took much of the uncertainty out of pest control and brought considerable benefits in the field. The effectiveness of these new pesticides and the economic benefits derived from their use has resulted in an almost complete reliance on preventative application of chemical pesticides to control agricultural pests. Today it is apparent that the "calender spray schedule" is no longer acceptable. The tendency has been to apply pesticides irrespective of the need. Most everyone is aware of the undesirable side effects from the common 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 the amount of pesticide needed to manage pests.

Today IPM utilizes the broad interdisciplinary approach that employs a unified systematic effort to control pests using integrated management practice and pest control technologies to solve the problem. An IPM program requires the collaborative efforts of plant pathologists, weed scientists, entomologists, ecologists, economists, agriculturists, horticulturists, turfgrass management specialists, and other specialists. To assure 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, acceptable, 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 human health. IPM is a decision making process that determines 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 basic data is time consuming and expensive. In Hawaii, most of our pests are from foreign areas (Australasian and Oriental regions) where basic biological and ecological information is lacking.

Although an on-going formal unified Turfgrass IPM Program in Hawaii has not yet 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 movement 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, pest 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 proved to be one. An organism may be a pest in 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 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 to cause significant damage to turfgrass, but are not threatening. These insects or specific areas. Their interactions are often due to disruptions in natural control, climate, or specific areas. Migrants do not cause any significant damage or loss to turfgrass under 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 economic 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 never use regular turfgrass management techniques. 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 a fixed sampling unit at a predesigned upper or lower threshold level. Random sampling, most commonly used in IPM, requires good field coverage. It measures the number of insects or damage per unit within consideration of the total number of insects per acre, Action levels for many of the pests in turfgrass have been 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 can 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 and control 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 mechanism 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 as different stages of turf 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 growing 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 in year, 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 chemical use. Pesticides will be applied only when necessary. Timing of applications is based upon data obtained through monitoring systems. Action levels, environmental factors and experience. IPM will reduce the use of chemicals by reducing the development of pest 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 specialisation of all disciplines to work together as a team to understand the 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 during the year 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 parasitoids 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 improves the management technique will be applied only when needed.
2. PESTICIDE MANAGEMENT:

Timing of a management pest control technique is based on 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. Incomplete 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 "insurance money," and are generally effective in controlling the pest. However, with experience and knowledge of IPM, they realize the fallacy of relying only 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 personnel are aware of IPM procedures.

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 will be applied to maintain turfgrasses in a vigorous condition. Turfgrass fertilization programs should be designed to supply the required essential nutrients at an optimum level. Turfgrass irrigation scheduling will be based on need rather than calendar 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 Lihikai高尔夫球场 is 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 Lihikai Golf Club 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 PEITES OF TURF

A brief description of the difference between insects 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 insect and mite 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 population, action levels (economic threshold) for initiating management techniques (if known), biological control agents, cultural control techniques, and chemical control methods.

There are 10 invertebratearthropods that may become a problem in turfgrass in the Lihikai district area. Common and scientific names and classification of seriousness of the pests are given below.

Key Pest:

- Grass webworm (GWV) (Moth): Herpetogramma bicolorata (Walker)
- Grass cutworm (BCV) (Moth): Agrotis ipsilon (Hubner)

Occasional Pests:

- Bermuda grass mite (BGM) (Mite): Eriophyes bermudana (Sayde)
- Hunting billbug (HBB) (Snout beetle): Sphenophorus venaticus verrucatus (Chinen)
- Lawn armyworm (LAW) (Moth): Spodoptera mauritia (Boisd.)
- Rhodesgrass mealybug (RGM) (Mealybug): Aonias grandis (Maskell)
- Southern chinch bug (SCB) (Chinch bug): Blissus insularis Barber

Potential Pests:

- Bagworm (BW) (Moth): Bradyspermum griseum detritus
- Black cutworm (BCV) (Moth): Agrotis ipsilon (Hubner)
Bermudagrass scale (BGS) (scale): Odonaspis rathae Koisisky

Fiery Skipper (FS) (Moth): Hylephila phyleus (Drury)

MANAGEMENT OF DISEASES AND NEMATODES:

Environmental and cultural practices not only affect insects and mite pests, but are important in the development of disease and nematode pests of turfgrasses. For a disease to develop, 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 Lii 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 differentiating these from turfgrass diseases are presented.

The major and potential diseases of bermudagrass which might be a problem in the Lii 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.
Fusarium blight: Fusarium spp.
Leaf rust: Puccinia spp.

Potential Pests:
Bacterial stripe: Xanthomonas spp.
Drechslera leaf spot: Drechslera spp.

Nematodes:
Criconemoides spp.
Helicotylenchus spp.
Meloidogyne spp.
Pratylenchus spp.

Trichodorus spp.

*Drechslera 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 i.e., grasses, sedges and broadleaves are identified and discussed in relation to the management and location of the Lii 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
Hilagrass: Paspalum conjugatum
Smutgrass: Sporobolus poiretii

Occasional Pests:

Annual bluegrass: Poa annua
Dallisgrass: Paspalum dilatatum
Lovegrass: Eragrostis spp.
Stargrass: Chloris dividendata
Swollen fingergrass: Chloris barbata
Vastygrass: Paspalum urvillei

Potential Pests:

Sandbur: Cenchrus ciliaris

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Sedges:

Key Pests:
- Green kyllinga: Kyllinga mansceeta
- Purple nutsedge: Cypretas rotundas

Occasional Pests:
- White kyllinga: Kyllinga brevifolius

Broadleaves:

Occasional Pests:
- Alternanthera: Alternanthera repens
- Asiatic pennywort: Centella asiatica
- Buttonweed: Barssiera laevis
- Creeping indigo: Indigofera endechaphylla
- Dandelion: Taraxacum officinale
- Drymarias: Drymarias cordata
- Garden spurge: Euphorbia hirta
- Kalmi clover: Desmodium canum
- Marsh pennywort: Hydrocotyle sibthorpioides
- Prostrate spurge: Euphorbia prostrata
- Purslane: Portulaca oleracea
- Sensitive plant: Mimosa pudica
- Synechella: Synechella nodiflora
- Yellow wood sorrel: Osaalas corculus

Potential Pest:
- Pink wood sorrel: Osaalas mariana

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 dependence 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 roots 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 onto water-logged lawns, the trapped pollutants are washed into our drinking water aquifers, but rather move into the soil and surface soil areas where they are immediately acted upon by billions of soil microorganisms that are present in these areas. Healthy turfgrass absorbs rainwater six times more effectively than a wheat field and four times 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 (CO₂) levels in the earth’s atmosphere. Planting of trees has been suggested as a method of counteracting the increased CO₂ level. While intentions of planting more trees in the world, 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 a much faster and more lasting positive effect on the environment. Grass is an excellent CO₂ and oxygen converter, a turfgrass area only 50 by 50 feet produces enough oxygen to meet the needs of a family of four. The same size turfgrass area would absorb large quantities of CO₂. In addition, turfgrasses also absorb and render harmless other air-polluting gases poisonous to humans, such as ozone, hydrogen fluoride and peroxycetyl nitrate. Grasses are quickly recovered and their beneficial effects on the environment are immediate. In addition to their absorption of CO₂ and other gases and production of oxygen, grasses are very effective in cooling the surroundings. It has been estimated that from 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 tons 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 in June on a summer day of greens, irrigated turfgrass is approximately 40°F cooler that bare soil. Surface temperatures of unirrigated, brown, dormant turf was approximately 25°F 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 enter much damaging levels which make it necessary to institute pest control. Controlling turfgrass pests usually involves applying a chemical pesticide (in this report the term pesticide is used generically and often to a material applied to control a pest; herbicides, insecticides, miticides, algaecide, 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 regulated. 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 susceptible to pollution, 19 monitoring wells were installed in gradients in green, tee, 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 detected in 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 1933 and so 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 considerable 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 the use of pesticides in our ecosystem. IPM is an effective program that

DOES NOT ELIMINATE PESTICIDES

but will reduce reliance on chemicals and the amount of pesticide needed to manage pests.

Today IPM utilizes the broad interdisciplinary approach that employs a unified systems approach utilizing 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.

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 minimize pest populations below levels that cause economic damage or unacceptable aesthetic or functional injury to turfgrasses 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. An IPM system is organized and integrated into a single unit after the basic information on the methods are known. Development of base line data is time consuming and expensive. In 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 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 levels, and environmentally acceptable control 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:

1. IPM IS A CONTAINMENT STRATEGY, NOT AN ERADICATION PROGRAM

   Continuous presence of a harmful species in the ecosystem is natural. Low levels of a beneficial effect as basis for beneficial organisms (parasites and predators) will attack them.

2. IPM maximizes natural control factors (physical and biological) by reducing 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 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

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 PEST SPECIES AND BENEFICIAL ORGANISMS:

   Positive, accurate identification of organisms in the management unit is necessary to secure biological, ecological, distribution, biological control, and pest resistance, etc. 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 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 are additive.

   Pests (weeds, insects, nematodes, rootworms, 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 turfgrasses at certain times or in specific areas. Their flush-up is often due to populations 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 populations may emerge and become serious.

   Migrant pests are highly mobile, non-resident, that may migrate in and infest turfgrasses for short periods of time, often causing severe economic 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

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 the pest population density related to the number of insects or their damage per unit of turfgrass area. Sequential sampling, not widely used in IPM, is required if continuous 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 insects per acre. Action levels for many of the pests of turfgrass in Hawaii have been developed. As techniques for sampling and monitoring pest populations become more accurate, reliable, and more expensive, it becomes necessary to develop practical sampling techniques for each pest and each monitoring situation. Time requirements and economic factors make it necessary to develop practical sampling techniques for each pest and each monitoring situation involved. An understanding of turfgrass growth and development and related pest interactions is essential in pest management. 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 stimulate future population trends.

4. ACTION LEVELS ECONOMIC THRESHOLD:

Most IPM specialists consider the term Action Level and Economic Threshold to be synonymous. Action levels are 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 muck than in the sandy for pests and less for pests that are 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. In Hawaii, when turfgrasses pests populations rapidly increase or in 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 on data obtained through the monitoring system. Action level, environmental and economic factors will be used in pesticides 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 economics, sociologists, nutritionists, etc. Complexity of the agroecosystem requires the specialists all disciplines to work together as a team to understand 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, combined with 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 control 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 enable the management technique to be applied only when needed.

2. PESTICIDE MANAGEMENT:

Timing of a management control technique is based on the data obtained through observation and monitoring the management site. Pesticide management should pursue the usefulness of the chemical.

3. ECONOMICAL TURFGRASS PROTECTION:

Application of pesticides will only be used when necessary. Utilizing the Action or Threshold Level concepts 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 the "calendar schedule" waman 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 pests are expensive, simply to apply as "paid insurance" and is generally effective in controlling the pest. Timing of IPM 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 (Pooae or Gramineae) is relatively large, containing over 600 genera and 5,000 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 Festucoidae, Pooidae, and the Pooidaeae. The members of the Festucoidae and Pooidaeae are adapted to cooler environments and have been referred to as cool season grasses. The members of the Pooidaeae and Pooidae 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 60-72°F. Growth and development is severely restricted at soil temperatures above 80°F. Warm season grasses, on the other hand, grow best at approximately 80°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 bentgrasses (Agrostis spp.) are the most important warm season grasses used on golf courses, although zoysiagrasses (Zosia 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) (Tee and Snow, 1976; Ehleringer, 1976). In Hawaii, the turf was found that warm season grasses predominated 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 (4695 feet) is approximately 9°C (48°F) and the mean minimum temperature for the warmest month of approximately 24°C (75°F) (Rundel, 1980). A similar study along an altitudinal gradient in Kenya (Tietz, 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 24°C (75°F) and the mean minimum temperature was 8°C (46°F), very close to the 24°C 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°C to 18°C (59-64°F) reported from temperate regions (Tee and Snow, 1976; Ehleringer, 1976). 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 1630 meters (5342 feet) elevation in Hawaii is less than 5°C (approximately 9°F) (Pierce, 1966).

Since the elevation at the site of the proposed Lih Bank 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 A. C. transvaalensis) and therefore has been used in southern areas of the mainland U.S., its use on the Lih Bank golf course would require very frequent applications of pesticides (particularly fungicides) because of its higher susceptibility to fungal diseases. Our discussions will therefore be restricted to various cultivars of bermudagrass only.

Plant Structure

Grass plants are composed of a complex arrangement of leaves, stems, and roots that arise from seed and various vegetative propogules. These parts are interrelated in that the roots function to anchor and support the plant 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. Many studies have 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 evolved 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 growing point located atop an elongated stem called a crown near the surface of the soil. The capacity to sustain a dynamic and complex turfgrass community depends greatly on a thorough knowledge of how turfgrass 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 grasses or at the nodes of lateral stems (tillers) and/or rhizomes) which come in contact with the soil. The root system of 10 to 12 feet under known conditions. The major portion of the root system of putting greens conditions the major portion of the root system is in the upper 18 inches of the soil. Under

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 growing under conditions of adequate soil moisture and nutrients availability. Numerous environmental and cultural factors may 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 6.5 to 7.5 is optimum.

3. Soil oxygen levels. Soil composition 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. Shocks 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 important 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 unsaturated 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 by which to keep the surf of many cultivars of bermudagrasses, as they do not produce seeds. 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 plants use the term leaf when they are referring to the 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 blade, gives plants the unique ability to carry out this process. It also gives turfgrasses the dark green color which makes 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 growth 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 82-90°F. Air temperatures below 70°F result in reduced growth and may result in a semi-dormant state if prolonged.


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 of golf turf, especially for tees and greens, are such that turf must be mown very frequently and at a low mowing height. Mowing greatly reduces the leaf surface available for food manufacturing. Bermudagrasses are maintained under panning-green conditions of daily mowing at a height of 0.16 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 as lawns below 1,000 meters (3,300 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. transversa (Burr-Davey) are well adapted to very close frequent mowing required for golf putts and greens. Bermudagrasses are intolerant of shade and require relatively frequent applications of fertilizer.

Roughs

The Lihue Kauai golf course will be designed using the "target pate" concept in which only the fairways, teeing areas, greens and immediate surroundings are maintained. The roughs are largely undisturbed and will consist mainly of the natural vegetation of the area. The primary roughs, or the roughs immediately surrounding the cooking area, 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), Subara (C. dactylon (L.) Pers), Tifway (Tifton 419) (C. dactylon x C. transversa (Burr-Davey), Tifway II (C. dactylon x C. transversa (Burr-Davey), and Tifgreen (Tifton 32B) (C. dactylon x C. transversa (Burr-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 Subara and the three hybrid bermudagrasses. Subara 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. Subara is a relatively new cultivar and has not been used in 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. transversa (Burr-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 green 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 Lihue Kauai golf course. Tifgreen has proven to be more wear resistant and less susceptible to certain diseases. Tifgreen is perhaps the most desirable cultivar for use on the Lihue Kauai site.

Etablissement

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 seed-soil contact and rapid establishment of a deep healthy root system. The soil should have adequate water permeability and good drainage (both surface and internal) to prevent waterlogging or ponding in areas after wet periods. There should be no subsoil deficiencies or minerals. All large rocks should be removed to the invasion of fairy rings fungi which are discussed in the section on turfgrass diseases.

The soil should contain sufficient organic matter to provide nutrients and moisture retention properties and to retard the movement of pest control chemicals to groundwater. The existing soil 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.

Trees 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 trees 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 are the Lili Lani area would be bentgrass, emeraldgrass or rye grass (Poa virginalis spp.), Idaho Koa (Lolium leecephalum), Bromo brome (Bromus virginicus), etc. Translated 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 plants which might reinvade the graded areas. roundup (chlorothionate) will provide adequate control of root 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 tee 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 relative small areas in greens and tees combined consider only approximately 8 to 6 sheets. 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 rhizomes in rows, sodding (planting pieces of sod over the entire area), spraying (planting pieces of sod solid over the entire area), or transplanting (planting plugs of turf and soil at spaced intervals). All of these methods provide a rapid method of vegetative propagation for fairways. The recommended method of vegetative propagation is sodding, as it requires less planting material than other methods and there are no sprigging machines available which greatly facilitate the operation. For tees and greens the recommended method of vegetative propagation is sodding, as it provides rapid establishment of a more uniform surface than other methods.

If fairways and primary mounds are seeded, the highest quality seed attainable should be used. (Seed quality refers to purity, and seed germination. The seed should be free of infection of weeds and all types of bermudagrass. Common bermudagrass lots are often under competition with extremely coarse, undesirable types of grass bermudagrass. Beware of small percentages of weed seed or weeds which has 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. As recommended seeding rates for bermudagrass, this would result in 3 to 5 potential weeds per square feet. Hulled for bermudagrass seed (seed with the husks removed) should be used. Minimum seed purity should be 98%. Minimum germination should be 95%. Seeding rate for hulled seed is 30 to 65 feet.

For sprigging bermudagrasses, only seed containing no foreign grasses should be used. Seed fields should be inspected prior to accepting sprigs to be sure there is no contamination. Approximately 200 to 300 bushels of sprigs are required (an average yard of sprigs will produce approximately 1 bushel of sprigs). Since there are few sod farms in Hawaii, and perhaps some which can supply the large amount of sprigs needed for spraying the fairways of a golf course, arrangements should be made in advance for growing the sod. It 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 is the best method for spraying seeded bermudagrasses. This equipment turns 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 containing 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 tamps the soil around the sprigs in the rows. For fairways, can be tamped at the same time and in the same manner as fairways.

Greens should be planted after the fairways and areas surrounding the greens have been established. The resite soil should always be fumigated with methyl bromide plus chloropicrin. Fumigation should be done after fairways 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 and greens with a broad leafed weed. This sometimes results in a slowing of greens and replanting the desired manner of a cultivar different from that used for fairways. Trees should be planted at the same time as greens and in the same location. Trees are usually 8 to 12 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 as it will reduce evaporation from the soil 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 constructed 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. Frequency (2 to 3 times/day), light irrigation 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 time is small. Water should not puddle or runoff. It is not also 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 fairways and rough plantings should start when the seedlings have reached approximately 2 inches height and have established sufficient cover to prevent raking 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 4 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 midnight. 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 rolling with a flexible steel drag. Greens and tees should be dry enough when topdressing is applied to prevent razing by equipment.

MAINTENANCE OF ESTABLISHED TURF

Roughs

Mowing

The roughs of the Lihue 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 roughs will be the same cultivar used in the fairways. Bermudagrass primary roughs should be mowed as approximately 1.5 inches. Higher mowing heights may be desired for tournament play, or on other special occasions. Because the thick, dense growth habit, bermudagrass roughs mowed at heights above 1.5 inches are excessively peaky. 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 metribuzin 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 dependence on chemical weed controls. Good establishment and maintenance practices will reduce the dependence upon herbicides to control weeds. The action level for weed control in roughs will be lowest at that of any area of the golf course.

Insect control

Insecticide applications may sometimes be necessary in the primary rough 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 (turfing, aeration, 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.

Lining may be necessary to adjust soil reaction periodically (usually no more often than once 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 Lihue Lani site.

Fairways

Mowing

Bermudagrass fairways should be mowed 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 every 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. Dial or improperly aligned mowers will tear the turf and provide ideal entry points for disease organisms. A vest grinder and backlapping 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. Ripping and tearing of the leaf blades are the result of opening mowers at excessive speeds. Mower turns should be made at a reduced speed and should be wide enough to avoid braking 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 resowed on 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 aeration exchange capability, amount of rainfall and 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 cooler, cloudy weather. 4-1-2 ratios are applied. The rate and frequency of application will depend largely on the apparent need and the source of nitrogen in the fertilizer. Fertilizers in which the nitrogen is in a slow-release form (ammonium nitrate, 28% N, or sulfate 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. Soluble N forms are also desirable from the standpoint of maintaining a steady growth of turf because large amounts of available N are not present soon after fertilization. Local, sustained growth of turfgrass resulting from excessive nitrogen stimulation is also more susceptible to drought stress, weed stress, and attack by disease organisms. Alternate ways of providing a steady rate of N fertilization is by applying a small amount of N with each irrigation through the irrigation system (irrigation), however irrigation application is not uniformly distributed, especially under the windy conditions which exist in the L.H. Rael site. Fertilization is not recommended at this location. Light, frequent applications of soluble N sources, but this will increase the frequency of fertilizer applications and increase maintenance costs. This increased cost of more frequent fertilization application with soluble N sources may be offset by the greater cost of lower-frequency 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, recuperative 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 every 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 turf maintenance. Proper water management is very important in all aspects of turf growth and quality. Hawaii. Over watering is one of the most common problems encountered on golf courses in states where there is a drier environment. Excessive water promotes moisture stress and reduces the soil oxygen necessary for root growth and development. Excessive water also increases the potential for pest damage, and results in soft succulent growth which is susceptible to disease and environmental stresses. Under watering results in reduced growth and vigor of turf grasses and, if the grass is under moisture stress too long, death of the plants. It is therefore extremely important that irrigation management be practiced.

Evapotranspiration of turf is the water transpired by the plants plus that evaporated from the soil, thus the sum evapotranspiration. Water use by dense vigorous turfgrass stands which fully cover the soil is essentially all evapotranspiration. Grasses transpire large amounts of water. Most of the water is used for regulating the temperature of the plant, since evapotranspiration of grasses can be 70% to 50% less water than cool season grasses. Research has shown very little difference in water use between different grasses in the same season. Evapotranspiration programming should be done to replace the water actually used by the plant. There is a critical period during which the turf is most susceptible to leaching. In some cases there is insufficient rainfall to leach the plant, which may be necessary to prevent nutrient leaching. This is sometimes referred to as “leaching fraction”.

Several methods may be used to determine the amount of water used. These may be divided into the amount of water used by the turf for a given amount of time and replacing the water holding capacity of the soil and the rate at which water is being used by the turf. For practical purposes, the depth of rooting of turfgrass under irrigation conditions can be considered to be 1 foot deep. 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. A general rule of thumb is that soil may hold as much as 0.5 inches of water per foot of depth. Sandy soils may hold as little as 0.3 inches of water per foot of depth. Clay 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 the soil is dry. General recommendation is 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 1.3 inches of available moisture per foot of depth, 0.75 inches of water should be applied when water (10 to 15% in addition to that actually used) is usually applied to account for equipment efficiency and for equipment cover.

Once the available water holding capacity of the soil has been determined, the next step is to determine the rate of water application. 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 Evaporation Pan. A standardized pan (6 feet in diameter) which is set up according to certain specifications and the amount of water evaporating daily is measured. Water in the pan will be automatically accounted for as negative evaporation. Pan evaporation is a satisfactory measure of weather elements and can be used to estimate the amount of water used by plants in response to these weather elements. Research at several locations has shown that grasses use water by transpiration, including bermudagrass cultivars, using only 45% to 50% of the pan evaporation. Thus 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 reading the pan every day. Records are available which record the amount used of this still
requires looking at the record. Modern irrigation systems have electronic weather sensing elements which sense the weather conditions (usual 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 estimate obtained by pan evaporation or from electronic weather stations. 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 of 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 aeration, 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 or special mowers in which the blade operates in a vertical plane to thin the turf and remove some of the dead organic material) alleviates this with core aeration is the most effective method of correcting a thatch problem once it is present. Thatch control 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, reduced root system due to oxygen deficiency in the rootzone, a shallow-rooted, unimpressive turf, a striped appearance in turfgrass density and increased susceptibility to environmental stress and diseases.

Soil compaction can be improved 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 aeration or slicing equipment. The frequency of these operations will depend upon turf use patterns, and environmental factors discussed previously. Core aeration 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 aeration.

**Greens**

**Mowing**

The demand for high quality, uniform, smooth putting surfaces requires extremely close and frequent mowing. This places severe stress on the turfgrass. Roasting, deep, carbohydrate reserves, wear resistance, ability to recover from injury, resistance to disease, 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 16 to 22 inch mowing width and the riding triple (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 require less maintenance than mowing greens. Riding mowers, on the other hand, are faster. One to 2 riding greens mowers can cut the 18 greens of a golf course in 2 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.

 Bermgrass putting greens in Hawaii should be mown at 0.19 to 0.25 inches (1/8 to 1/4 inch). Although some golf courses in Hawaii now mow greens as low as 0.125 inch (1/8 inch), this practice places great stress on the turf and is not recommended as a long-term practice. Generally, the higher cutting height is preferable in terms of vigor of the height must be carefully considered by the individual superintendent and depends largely on the desires of management. From the viewpoint of turfgrass, the higher cutting height will reduce the susceptibility of putting green 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 Liholiho 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 (the tendency for the grass to grow in one direction). This 9:00 to 10:30 and finally 1:30 to 3:00. The cycle can be reversed once the four directions are completed (6 to 12, 9 to 3, 10 to 4:30, and 9:30 to 1:30). The exact directions may be limited by turning areas, especially when riding triple greens mowers are used. Turfgrass wear and damage is usually a problem around the perimeter of greens mowed
with a riding triple mower. This results from the standard practice of making a final mowing pass around the perimeter of the greens 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 green 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. 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 uses 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 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.) which the nitrogen is immediately available. Other nitrogen carriers are water insoluble for very slowly solubilized and then released from the carrier. Several sources are utilized in the complex compound before it is available to the plants (slow-release or controlled-release urea). Soluble nitrogen sources have the advantage of providing a rapid initial turf response, however, the nitrogen is soon used by the turf and leached from the rooting zone and the response is short-lived. Soluble N sources in carrier such as ureaformaldehyde (UF), and sulfur-coated urea (SCU) carriers are used by the turf and leached from the rooting zone and the response is short-lived. Sulfur-coated urea is a slow-release product which should be used at a rate of 2 to 3 ounces per 100 sq. ft. at biweekly to monthly intervals are needed on warm season soils. Sulfate of iron is an iron molecule attached to an organic compound 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 (55%), or by use of acid forming fertilizers (sulfate, urea, urea-coated urea, etc.). The pH may be raised by application of lime. The amount and rate of application of each can only be determined by soil analysis by an experienced laboratory technician. Golf greens constructed with sand have a high pH (7.5 to 8.5) which is impossible to adjust. Materials, such as sulfur, applied to the greens would react with the soil to raise the pH. The greens constructed with sand have a high pH (7.5 to 8.5) which is impossible to adjust. Materials, such as sulfur, applied to the greens would react with the soil to raise the pH. The greens constructed with sand have a high pH (7.5 to 8.5) which is impossible to adjust. Materials, such as sulfur, applied to the greens would react with the soil to raise the pH. The greens constructed with sand have a high pH (7.5 to 8.5) which is impossible to adjust.Materials, such as sulfur, applied to the greens would react with the soil to raise the pH. The greens constructed with sand have a high pH (7.5 to 8.5) which is impossible to adjust. Materials, such as sulfur, applied to the greens would react with the soil to raise the pH.

If the greens are constructed of 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 greens 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
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 will draw water. The fact that golf greens are constructed of mixtures 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. Mowing 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 gophers 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.

Spraying (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. Spraying functions primarily to increase the relative humidity of the immediate area surrounding the turf leaf and also reducing the transpiration rate of the turf. Most modern irrigation systems have a spray cycle built into the sprinklers around the greens. Alternately, spraying 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. Times of 0.25 to 0.5 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 mowing over the 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 overstimulation 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 materials 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 struck 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 mowed at 0.3 to 0.5 inches. The mowing frequency will depend upon the growth rate of the grass. In practice the grass if they are not excessively heavy. Tees are usually mowed with a single mower with six to eight blades per reel. The mower blades should be kept sharp and well adjusted. Before moving tees, the area should be inspected and shoe spikes and wooden tees should be removed, as they may damage tee blades or bedknives of mowers.

Fertilization

Sufficient N fertilization must be maintained to provide rapid recovery from divot injury. Phosphorus fertilization is also important to impart wear resistance to the turf. Fertilization with a 4-1-2 (400 lb. of N/1000 sq. ft.) 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 application can best be determined by submitting a soil sample to a competent soils laboratory.
Irrigation

Tests are made relatively closely and frequently and may be conducted similarly to putting greens, therefore irrigation of tests is similar to that discussed for greens. The water distribution method, utilizing pan evaporation data should be used as a guide for scheduling irrigation. Amount and frequency of irrigation of individual tests will need to be adjusted for micro environment conditions.

Divot Injury

Because of the nature of the type of play on golf tests, divots are taken which cause thinning of the green and may lead to weed invasion. Divot injury is best controlled by regular moving of the tee markers. The outline is defined as the area between the tee markers and the club missing behind them. Divot injury can best be controlled by frequent moving of the tee markers. The markers should be changed every day. On small tests 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, top dressing 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 tests is the same as previously discussed for greens.

Compressing correction

Tests may become compacted from vehicular or foot traffic. Compacting and top dressing as described for greens are best cultural controls of compression. Coring should be done at least 3 times a year on tests.

MANAGEMENT OF TURFGRASS PESTS IN HAWAII

Hawaii has fewer pests of turfgrasses than the mainland United States. Experience on various crops from the main island 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 use and use of pesticides are continually changing. Pesticides mentioned in the various sections of this Manual were registered in Hawaii for applications 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 existed 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 they may be more seasonal variation in population size.

A turfgrass manager should familiarize himself with the basic biological and ecological knowledge of the insect and mite to lead to weed invasion. 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 move the environment, antennae (1 pair that contains sensory hair, cuticles, 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 have one or two pairs of wings. The abdomen is the terminal end of the insect body and the last segment contains structures for reproduction, ovipositing in the female and embryos in the male. Insects possess structures for the five senses common with man, sight, smell, taste, hearing. Adult moths and butterflies do not damage turfgrasses while adult billbugs, chinch bugs and mealy bugs feed on turfgrasses.

Aphids are relatives of insects but differ greatly. They have only one body region that is see through. 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 stages or a series of stages, in which the exuviae (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 moults 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. Nymphs are developed externally during the early instars (stages) and nymphs generally live in the same habitat and feed on the same food as adults. Chinch bugs, mites, grasshoppers, cockroaches, slugs, snails, 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 (pill bugs or snout beetles) or different than the adult. Larvae do not have compound eyes. Wing development is internal. Larvae molt and pass through several instars, increasing in size and color changing in color. The larve is the the primary target of a pest management program. After the last larval instar, the insect pupates. 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 chitin cuticle, 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 restructured into adult tissues. Pupae develop externally. The pupal stage is difficult to kill with pesticides as 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 heights, improper selection of turfgrass cultivars, 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 tufts, dying or dead patches, chewed or frayed leaf blades, and the presence of webbing or frass (fungal pellets) in the grass. The presence of large numbers of black spots 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 turfgrasses.

In IPM we encourage the use of all pest control tactics in an integrated unified program. Pesticides are not eliminated 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 turfgrasses is done by feeding of adults 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 and mites lack jaws from the plant. Some pests feed only in the pupal stage. 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 area and immediate remedial action. Insects and mite damage may be recognized by defoliation, yellowing, twisted or withered tips, abnormal elongation of the internodes, stunting, browning and bleaching of leaves or death 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 tracheate beetle or pill bug (Order: Coleoptera). One is a meatbug (Order: Homoptera). Early workers have erroneously called the meatbugs scale insects (Order: Rhodogramma scale). One is a scale insect (Homoptera). One new pest of St. Augustine grass which has only recently (August 1990) been reported in the state is a chinch bug Order: Nymphaeidae. One species of mite (Order: Acari) is a pest of bermudagrass. Each of these will be covered separately.

**MOths AND BUTTERFLIES**

Order: Lepidoptera

**KEY PESTS:**

**GRASS WEBWORM (GWW).** Herpestogramma lacustrisalis (Walker) (Family: Pyralidae) is the most serious pest of turfgrasses in Hawaii. It was first reported in 1957 feeding on St. Augustine. Feasofa. The old name is Chaetopterus ex Chois., (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 (tragged blades), green fecal pellets, and the conspicuous amounts of webbing on the surface leading to holes in the thatch. Feeding occurs at night. During the day larvae may be found near the base of the grass and congregate by the root system. Larvae are usually white-green when feeding and brownish when sated. 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 a serious pest of St. Augustine grass, Cynodon dactylon and Zoysia. (Davis, 1969) reported feeding on 13 other grasses in Hawaii (Table 1), including all the important bermudagrasses. Host preference studies by Munloch and Tashiro (1976) with St. Augustine grass, common bermudagrass, C. dactylon (L.) PPA; Tifgrass bermudagrass, C. dactylon C. transatlanticus Turf-Davey; Tifway bermudagrass, C. dactylon C. transatlanticus Turf-Davey; FB-127 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. Reinstad and Hasty (1983) reported on resistance of several bermudagrass selections to the tropical sod webworm, Herpestogramma phaeoparaisa 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 Chang (1955); Davis (1969); Tashiro (1976, 1977, 1979) and Mardlen (1979).

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 spots scattered about the wings. Wings span 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. Predominant period varied from 3 to 6 days.

Egg: Production averaged 249 per female with a maximum of 557. Malting and oviposition occurs at night. Adult longevity averaged 13.1 and 13.2 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 Heteropogon apiculatus in Hawaii.

<table>
<thead>
<tr>
<th>Host common name</th>
<th>Host scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow-leaved cypress</td>
<td>Acrocnis affinis Chase</td>
</tr>
<tr>
<td>California cypress</td>
<td>Breckia matsch (Forsk)</td>
</tr>
<tr>
<td>St. Augustinegrass</td>
<td>Chloris dierensiana R. Br.</td>
</tr>
<tr>
<td>Hairy cypress</td>
<td>Cypridod sp. Rich</td>
</tr>
<tr>
<td>Pacific cypress</td>
<td>Diploaura adunculata H. K. B.</td>
</tr>
<tr>
<td>Cenizo</td>
<td>Distichia demosthen Stenl</td>
</tr>
<tr>
<td>Torpedograss</td>
<td>Eriocaulon diosmiforme (Munro)</td>
</tr>
<tr>
<td>Fewgrass</td>
<td>Eremochloa epipoda (Munro)</td>
</tr>
<tr>
<td>Hakea</td>
<td>Hakea racemosa L. R. Garrod</td>
</tr>
<tr>
<td>Panicum</td>
<td>Panicum repens L.</td>
</tr>
<tr>
<td>Paspalum</td>
<td>Paspalum conjugatum Berg.</td>
</tr>
<tr>
<td>Sea grass</td>
<td>Paspalum vaginatum Sw.</td>
</tr>
<tr>
<td>Kikuyugrass</td>
<td>Pennisetum clandestinum Hochst.</td>
</tr>
<tr>
<td>Rain grass</td>
<td>Spinibrasica africana (Poir)</td>
</tr>
<tr>
<td>St. Augustinegrass</td>
<td>Steenbergenia secrundianu (Vahl) Kantu</td>
</tr>
</tbody>
</table>

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 12 in. in height.

Larvae: 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 ingestion of plant material. All other instars have brown head capsules. Larger larvae have 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 rosy hue 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 conspicuous hair (halos). First instar larvae are about 0.14 inch long and the mature larva (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 leave only inactive 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 loose material 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 in 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. T. L. Ross (1976) estimated that the optimum temperature for development of the GWW was slightly above 33°C (87.4°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 pyrithione 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, 1961; Niemczyk, 1981). Flower pots 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. Natural feeding larvae cause to the surface to feed and remain, since the board excluded lights (Mitchell and Moodie, 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.

Yablon et al. (1983) made comparisons of the boards, sprinkling can and submergence of an area with water alone and water containing either pyrithione or a detergent. For submergence tests, three metal rings (each 8 in. in diameter and 2 in. in high) were compared to a rectangular metal frame 8 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 area. Four liters of water were applied to the frame, allowed to stand for 10 minutes with continuous stirring of the water coming to the surface. Number of larvae surfacing was compared with larval counts under the boards. Researchers indicated more than one gallon of liquid irritant per treated area may be needed to completely smother the turf.

Liquid irritants tested were water alone, water with 0.003% (v/v) pyrithione and water with 0.25% (v/v) liquid detergent. The detergent used was a mixture of anionic and nonionic surfactants plus ethyl alcohol (Jeyes, Proctor 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 effective as pyrithione and 23% 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 recover the turf before 10 min. period is up. It is recommended that a metal frame, circular in shape (6 in. high and 20 in. in diameter), be used as a sampling frame. Four liters of water containing either 0.003% pyrithione 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 armyworms (LAW), flyer skipper (FS), and black cutworm (BCW) larvae responded
to liquid irritants in the same manner as the GWV. 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 where some species require that a decision must be made whether to control 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 still dependent upon available moisture, temperature and vigor of turfgrass. Pests in Hawaii are active throughout the year, but become inactive if temperature goes below 61°F. Threshold levels for more valuable greens and tees will be lower than for fairways 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 consultative (insecticide) must be applied (Mitchell and Munck, 1974). Grass webworm larval counts of 5 per 2 sq. ft. indicates that more frequent observations were needed to determine the impact. An average of 10 GWV larvae per 2 sq. ft. is considered the action level at which a pest management consultative must be considered. These action levels are a beginning and can be flexibly tuned with experience.

Bowen (1980) in California recommended control measures be initiated if pest populations exceed 5 cutworms, 10 skipper larvae, 15 sod webworms, or 9 billbug larvae per square yard of turfgrass.

BIOLGICAL CONTROL: A number of parasites and predators attack various stages of the GWV in Hawaii. Several of these beneficial organisms are naturally introduced for other lepidopterous pests, others arrived accidentally. Pathogenic organisms attacking the GWV have not been reported to date in Hawaii.

Egg parasites: Davis (1960) reported an accidentally introduced wasp, Trichogramma sp., parasitizing up to 96% of the GWV eggs from sea level to 2,000 feet (600 meters) elevation. An average of two parasites emerged from each GWV egg. The parasite was mis-identified as T. semifumatum.

Larval parasites: Three parasitic wasps and one fly have been recorded attacking GWV larvae (Table 2). Adult tachinid flies, Eucartolilia armigera, have been observed, in a wide range of field conditions, to be an effective parasite. The lecithnomiidae wasp, Cremastus flavo-oralis, also ranked high in parasite emergence.

A single Chalcid wasp was reported parasitizing the GWV pupa. Data on the impact of the larval and pupal parasites is meager.

Both larvae and vegetation pests have been recorded feeding on GWV larvae. The high-bred ant, Phakola megacephala (F.) (Family Formicidae) was the most common insect. Avian predators included the cattle egret, Burhinus ibis L.; the mynah bird, Acridotheres cristatellus L.; the Hawaiian roller, Pseudocolax hoactli (Latham); and the Pacific golden plover, Pluvialis dominica fulva (Gmelin). Head capsules of the GWV have been found in the dung of the giant toad, Bufo marinus (L). The impact of these predators on GWV populations is not known.

Table 2. Grass webworm larval and pupal parasites.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Order</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larval Parasites:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cremastus flavo-oralis</td>
<td>Hymenoptera</td>
<td>Ichneumonidae</td>
</tr>
<tr>
<td>Crematita (= rana)</td>
<td>Hymenoptera</td>
<td>Ichneumonidae</td>
</tr>
<tr>
<td>Hesperia longirostris</td>
<td>Hymenoptera</td>
<td>Ichneumonidae</td>
</tr>
<tr>
<td>Eucartolilia armigera (Cox)</td>
<td>Diptera</td>
<td>Tachinidae</td>
</tr>
<tr>
<td>Pupal Parasites:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pristomyia sp.</td>
<td>Hymenoptera</td>
<td>Chalcidae</td>
</tr>
</tbody>
</table>

Biocontroll 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 GWV population.

CULTURAL CONTROLS:

Some of the cultures of bermudagrass have shown differences in feeding injury by GWV larvae (Munson and Tashiro, 1976, Tashiro, 1976 and Reiner and Breyer, 1982). Future genetic selection of bermudagrass may show resistance to GWV feeding. Good management practices, fertilization, irrigation, aeration, etc., which produces healthy turfgrasses, allows the turf a better chance of recovery from GWV damage. Mowing as 1.5 inches and reduced use of chlorine fertilizers has been recommended in Florida (Short, 1990). Short recommended using water insoluble (slow release) N and controlling thatch.

CHEMICAL CONTROLS:

Insecticidal control is the first line of defense when there is a sudden widespread increase of defoliation by GWV 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 2). 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 turfgrasses 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, disodium and organic phosphate insecticides, CANNOT BE USED ON GOLF COURSES AND SOIL FARM. But may be used by homeowners on their lawns. The federal and state regulations change frequently and one must follow the directions on the 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 Department 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, nonpharmaceutical, have a low toxicity 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 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 representatives. 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.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Trade name(s)</th>
<th>Use*</th>
<th>Classification**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bifenthrin</td>
<td>Javelin, Th坦克cid</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Ivalophos</td>
<td>Tucum</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>Sylvest</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Organic Phosphates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acephate</td>
<td>Orthene, Trefl, Tree and Ornamental spray</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Durban 50W</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Ethion</td>
<td>Ethion 8 EC</td>
<td>L A R</td>
<td></td>
</tr>
<tr>
<td>Isotachtos</td>
<td>Olan 2</td>
<td>L</td>
<td>G</td>
</tr>
<tr>
<td>Metamol</td>
<td>Lannate</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Trichlorfon</td>
<td>Dylox 80</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Synthetic Pyrethroids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flumethrin</td>
<td>Mustang Aquaflow</td>
<td>L A G</td>
<td></td>
</tr>
</tbody>
</table>

*Use: L = Insecticide, A = Acaricide, N = Nematicide
**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 armyworms in Florida are acephate, benzocarb, Bifenthrin, Tefluthrin, ethion, methomyl, and trichlorfon (Short 1990, Keilin 1976, 1983a). These materials have not been tested against lepomopterus pests in Hawaii.

For the GWW and other lolympoless larvae, chlorpyrifos (Durban) 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. Treatment should be applied in the evening or late afternoon and not watered in. Repeat the treatment if necessary. Chlorpyrifos is normally tightly applied over 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 winter it is the most important pest of turfgrass in Hawaii and in order to reduce its impact, a wide variety of pesticides and predators. Information on the biology and ecology of the LAW have been published by Tanada and Beardsley (1958), Marzden (1979a) and Tashio (1976).

DAMAGE: The larval stage or caterpillar damages the turfgrass by feeding on the blade, stems and leaf. Young larvae may feed on the blades during daylight hours and the grass shows a silvering at the tips. Watch for these signs of feeding damage. As the larva increase in size they feed on the blades and stems in the path and greener portions of the crowns leaving only the tough old runners. Damage areas have 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 damaged area spreads out from around the bases of buildings or trees and shrubs where eggs have been deposited. Older larva feed at night and hide in the grass during the day.

HOST RANGE: In Hawaii LAW damage was most severe on 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 edeals (Fimbristylis tenuis Roemer and Schultes), two weeks old sugarcane seedlings and several grass species (Table 4). In the Orient the insect sometimes causes injury to rice. Survival of LAW larvae on these hosts ranged from 72 to 100 percent in various experiments.

DESCRIPTION OF THE LIFE STAGES: Descriptions of the life stages and the biology of the LAW have been published by Francis (1930), Marzden (1979a, Tanada and Beardsley (1958) and Tashio (1976).

Adult. Moths are nocturnal and commonly attracted to lights. Adults are common grey-brown with a wingspan of 1 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 half-colored orbicular spot and the dark brown-shaped spot. The female is slightly larger (1.4-1.6 inch wingspan) than the male and this area is dull grey-brown and not much different from adjacent areas of the forewing. The dark brown-shaped spot is well defined. The hind wings of both sexes...
Table 4. Host Range of Spodoptera mauritia in Hawaii

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda grass</td>
<td>Cydonia spp.</td>
</tr>
<tr>
<td>McCoy grass</td>
<td>Cyperus gracile R. Br.</td>
</tr>
<tr>
<td>Kylings</td>
<td>Cyperus kyllingii Endl.</td>
</tr>
<tr>
<td>Neagras</td>
<td>Cyperus remondii L.</td>
</tr>
<tr>
<td>Hawaii’s Crabgrass</td>
<td>Digitaria albonodea 11.B.K.</td>
</tr>
<tr>
<td>Wiregrass</td>
<td>Erianthus indica (L.), Gaertn.</td>
</tr>
<tr>
<td>Dalligrass</td>
<td>Paspalum dilatatum Poir.</td>
</tr>
<tr>
<td>Napagrass</td>
<td>Pennisetum purpureum Schumach.</td>
</tr>
<tr>
<td>Brittle Foxtail</td>
<td>Setaria verticillata (L.)</td>
</tr>
<tr>
<td>Buffalo grass St. Augustine Grass</td>
<td>Stenotaphrum secundatum (Walt.)</td>
</tr>
<tr>
<td>Sedge grass</td>
<td>Zoysia matrella (L.) Meun.</td>
</tr>
</tbody>
</table>

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 sugarcane water, adults live for 9-14 days.

Egg. Females usually deposit their eggs on the foliage of shrubs and small trees. Females rarely deposit their eggs on grass. Wooden and concrete structures, especially near outdoor lights, allow them to feed on the window from which light emanates, were used as oviposition sites.

Egg. 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 nearly flat and as development progresses into gray or brown tint prior to hatching. Eggs are circular, flattened and sculptured with fine lines. Eggs hatch within 3-5 days.

Larval Caterpillars of the L.A.W 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 5th to 7th 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 35 days.

Pupa. Pupa occurs in a loosely formed silken cocoon containing dry, 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 L.A.W populations are the same as described for the GW. 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 L.A.W have been low probably due to the impact of predators, parasites and pathogens organism. A general level of 5 L.A.W larve 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.

BIOLICAL CONTROL: In Hawaii a number of natural enemies have made an impact on populations of L.A.W. Several of these beneficial organisms were introduced for other lepidopterous pests and others arrived accidentally with the host.

Microorganisms: A polyhedrosis virus attacking L.A.W was reported by Bianchi (1937). The virus has been observed in both young (second to fourth instar) and older larval. The viral infection was most likely introduced by the insect. Tanaka and Beardsley (1955) and Tanaka (1956) described the virus as Barrella virulenta sp. The virus could infect all larval stages but was more pathogenic to the younger than older larve.

A microsporidian, Nesetema spp., was found in L.A.W eggs. The microsporidian was highly infectious but its impact on L.A.W populations has not been determined. A fungus and bacterial disease of L.A.W has been reported in Australia (Smith 1933) and Sri Lanka (Husain 1920). Neither of these two microorganisms has been reported in Hawaii. Some of the microorganisms may show promise in microbial control of the L.A.W.

Egg Parasites: Two species of parasitic wasps, (Telenomus novail Ashmead [Family: Scelionidae] and Trichogramma nicoletti Riley [Family: Trichogrammatidae]) attack L.A.W. eggs. Parasitism of eggs ranges from 20 to 60 per cent. The heavy coating of hair and several layers of eggs appear to hinder the egg parasites.

Egg Larval Parasite: The braconid wasp, Chelonus tanas (Cresson) was observed ovipositing in L.A.W eggs. The parasitoid was introduced into Hawaii from Texas to control Lepidoptera exigua (Walk.) (Bianchi 1949). The wasp larva emerges from fifth or sixth instar L.A.W 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: L.A.W caterpillars attacked by braconid wasps are killed usually before they are full grown. One of the most important parasites of L.A.W larvae is Apanteles marginovarsi (Cresson.) It was reared from early instar L.A.W larvae. The cocoon, usually found on a grass blade. The life cycle of A. marginovarsi is completed in 12-18 days.

Three species of ichneumon flies, Choresiaella maculata (Biol.) Acanthoscelis chlorophaea (Westwood) and Euplectrus antiques (Coq.) have been found parasitizing L.A.W 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 no 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 cicadellid (ladybird) beetles, Coreus chalybeus (Boisdu.) larvae and adults, and only adults of Cryptocritus monosceletus Mulsant and Symbus rupelii Plücker 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 road, Bubo marinus (L.), and the Indian mynah bird, Acridotheres tristis (L.). The road 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, doves, 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 lawns and walkways. Move grass properly. Avoid the build-up 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 biocrustal, Brevicarpia sternbergi var. sternbergi 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 sprayed with granular formulations should be watered down following application. Equipment treated with preferred and repeated applications may be necessary.

POSSIBLE PEST:

FIERY SKIPPER (FS) Hyphela phylea (Dauray) (Family: Hesperiidae)

The skipper butterfly 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 ericaceous flight pattern of the adults.

DAMAGE: Larvae are seldom seen and the first evidence of damage is 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 Bermuda grasses (Cynodon spp.), bermudagrasses (Agrostis spp.), crab grasses (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 Ixora, hibiscus, plumeria, 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 underside of the wings.

Egg. Hemispherical eggs are deposited singly on the upper surface of the grass blades. Freshly deposited eggs are nearly white and as development continues change to powdery blue, then greenish blue within 1-2 days. Just prior to hatching the eggs 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 tightly 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 lawn insects. The head is strongly constricted to 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 hairs for all five instars. Later instars the body becomes yellowish-brown to grey-brown with a faint median longitudinal stripe. FS larvae are approximately 1.0 inch in length. Just prior to pupation the body becomes rigidity straight (prepupa). First instar larva reach the edges of the blade and later instars consume the whole leaf. Third to fifth instar larvae spit large quantities of waste liquid. Larval development at 81-84°F is completed in about 15.5 days.

Pupa. Pupa. Pupation 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 lie 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. Pupa 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 feld bermudagrass. When reared at 81-84°F it took only 21 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 reasons for such low populations but believe it must be due to environmental conditions and the impact of predators or parasites. 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.
BIOLICAL CONTROL: Information on natural enemies of FS is lacking for Hawaii. In California a braconid wasp, Apanteles sp., and an ichneumonid wasp, Aphidius spp., attack the larvae and pupae, respectively.

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 CONTROLS: Insecticide treatments may not be needed if the FS populations continue to remain low. The insecticides suggested for GW 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 insecticide down into the thatch and grass at the surface of the soil. Apply the pesticides to the evening or late afternoon. Repeat treatments may be necessary.

POSSIBLE 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 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 geasy 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 larva hide in the thatch, ground litter or burrow into the soil.

HOST RANGE: In Hawaii it 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 Sunsurf Bermuda grass, Cynodon dactylon and Spiderman experimental grass at Waimea. 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, . In California it feeds on daisies and white clover.


Adult: Moths are dark grey to black or brown. Antennae of the male is pectinate and filiform for the female. In the forewing is a black unifoem 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 radicles rise 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 24 days.

Larva: Like other lepidopterous pests, BPM programs are directed against the worm stage. The larvae are nearly a uniform dark greyish-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 larva feed on the grass blades and later leaves enclosed 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 segment 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 GW. Liquid emuliants or flooding the area force the larva 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 predators and parasites and environmental conditions. Because of the low populations action levels for BCW have not been established. As a starting point an artificial control measure may be necessary if the larval population reaches 5 per square yard.

BIOLICAL 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 larva and pupa. Information on vertebrate predators is lacking. The mynah and other birds, the giant spadefoot probably consume BCW larva 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 GW and LAW are also effective for the BCW. Products containing diazinon thiosulfate, carbaryl, chlorpyrifos or trichlorfon are suggested for BCW application. Refer to the label instructions on proper application, dosage rates, and precautions.

The biological control strategy for BCW is still under development.

POSSIBLE PEST:
BAGWORM (BW): Spodoptera frugiperda (J. E. Smith)

The bagworm was found in Kauai, 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
Table 5. Invertebrate parasites and predators of BCW in Hawaii

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Scientific Name</th>
</tr>
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<tbody>
<tr>
<td>Diprera</td>
<td>Tachinidae</td>
<td>Archyris cirrata Curtiss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choristopodina monolepis (Bishop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eucladus armiger (Cox)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chloroboris zoeae Cresson</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>Braconidae</td>
<td>Methotria hypophanae Viereck</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Epiperbius phytophagus Howard</td>
</tr>
<tr>
<td></td>
<td>Ichneumonidae</td>
<td>Hypoestus chrysophanus (Viereck)</td>
</tr>
<tr>
<td>Predator</td>
<td>Carabidae</td>
<td>Calosoma blagojewi (Gertsch)</td>
</tr>
</tbody>
</table>

**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 bermsudagrass, buffalo grass (Buchloe dactyloides), fescue (Festuca spp.), and bluegrass (Poa spp.).

**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 males, wingless, legless, lacking eyes, antennae, and mouthparts. The females remain in the silken case made while it was a larva. The male, probably with a pheromone, 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 0.2 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 from 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 Control:** Brushing the silken cases from buildings may provide a measure of control.

**Chemical Control:** With the present population pressures, control with chemicals has not been researched. The insecticides suggested for GWB should be effective against bagworm larva.

**Beetles**

**Order: Coleoptera**

**Occasional Pest:**

**Hunting Billbug (HBB): Sphenophorus venetus venetus Chopard (Family: Coccinellidae)**

This scavenger beetle was first reported in Hawaii in 1960 infesting sugarcane. 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 turfs 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 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 pastures 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 2250-2750 feet elevation on the island of Hawaii were damaged by the billbug and were also damaging sugarcane and corn seedlings. Literature reports St. Augustinegrass, zoysia grass, crabgrass, signal grass, bermudagrass, Bahia grass, Kikuyugrass, and Paspalum have been affected. In Hawaii, zoysia grass, bermudagrass, and bahiagrass 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 fly up and may remain 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 bolling billbug in Hawaii.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermudagrass</td>
<td>Cynodon sp.</td>
</tr>
<tr>
<td>Maunaloa (Common Bermuda)</td>
<td>Cynodon dactylon (L.) Pers.</td>
</tr>
<tr>
<td>Yellow nutsedge</td>
<td>Cyperus esculentus (L.) Sw.</td>
</tr>
<tr>
<td>Kikuyugrass</td>
<td>Pennisetum clandestinum Hochs. ex Chiov.</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Saccharum officinarum L.</td>
</tr>
<tr>
<td>Corn</td>
<td>Zea mays L.</td>
</tr>
<tr>
<td>Manila grass</td>
<td>Zoysia matrella (L.) Murr.</td>
</tr>
<tr>
<td>Japanese lawngrass</td>
<td>Zoysia japonica Steud.</td>
</tr>
</tbody>
</table>

Biollogies and descriptions of the HBB have been published by Wooduff (1966), Masden (1979), Tadino (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 0.5 inches in length. Upon hatching, the young grubs hollow out the stem and fill the space with frass. As the larva grows in size, the stem can no longer contain 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 3-5 weeks.

Pupa: Pupation takes place in an earthen cell in the soil. Development to adult stage takes 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 latter instars that are outside the stems. The use of liquid insecticides forces a few adults to the surface but the largest grubs do not respond like the GWB, WBG and BCW larvae. If adults 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, Beauveria bassiana (Bals. ex Vuille.). This disease attacks many insect species if conditions are optimum. A biocontrol parasite, Brachymeria sp. sp. nephropous钼es, was released in 1968 (Chong, 1968). A myrmicid egg parasite, Pseudosimix columnaris (Galun) had multiple releases in 1939, 1963, and 1967 (Blanchette, 1968). Neither one has been recovered to confirm establishment. Scars of the giant trail, Buge morio, have contained large numbers of HBB adults (Habeck, 1964). Some HBB were alive in the fecal droppings. The most feeds at night on HBB, GWB, WBG, LAW, and BCW.

CHEMICAL CONTROL: Interspecific competition is suggested because the HBB is free of effective parasites or predators. For effective control, the chemical must reach the larva which are located in or below the thatch or under the surface of the soil. Most researches suggest preemergence irrigation of the area to soak the thatch layer and the upper surface of the soil. The wounding of the area will allow better penetration of the herbicides to the depth of the roots and the area where adult and larval HBB exist. Post treatment irrigation is recommended when granular, isopropanol, petroleum or chlordane have been suggested for HBB control in Florida (Shan, 1953). 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:

RHODES GRASS MEALYBUG (RGM): Antonina grandis (Maskell) Family: Pseudococcidae

The Rhodes grass mealybug has been misnamed Rhodes grass scale. The insect has been in Hawaii since 1910 and occasionally develops troublesome infestations on turf grasses. It is found on all islands.

DAMAGE: Rhodes grass mealybug damage to grasses is difficult to see because the insects are small and located on 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. Direct activity in the grass or being stung while walking barefoot in the grass are often the first signs of a mealybug population. Closer examination of the mealybugs will reveal small, reddish, globular insects enroiled in white, felt-like waxy RGM cause the infested grass to become whitish and weak in appearance. The bases of the infested plants, including roots, 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, eugenia grass, eugenia grass (Eugenia polystachya (H. B. K.) Hitch.), sorrel paragrass (Panicum sorreideum Crail.), Paspalum spp., rhodosgras (Chloris gayana (Kunth)) and pineapple moss (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 globular, dark purplish, reddish-brown, scalelike body about 0.125 inch diameter, suckling 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. Crawlers and adults 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 scalelike 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 honeydew and ants feeding on the honeydew there is most likely an infestation developing. Further close inspection of the infested grass is suggested.

ACTION LEVELS: We do not have an action level for RGMB. People are being sung, by bees feeding on the honeydew, as they walk across the turf a pest management tactic is suggested.

BIOLICAL CONTROLS: In Hawaii one encyrid parasite, Anagrus antoninae, has been observed attacking RGMB. The parasite has effectively controlled RGMB populations in some situations. Failures have probably been due to parasite mortality 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 aids in preventing damage. Do not spread grass clippings from an infested area to uninsected areas.

CHEMICAL CONTROL: Insecticidal control has not been very effective because of the sticky secretions protecting the mealybug. In Florida methamidophos in combination with methyl parathion has been recommended for control. In Hawaii the insecticides suggested for GWM control have also prevented population increases of RGMB. Timing of the insecticide applications is important to control the crawler stages.

SCALE INSECTS
Order: Hemiptera Superorder: Homoptera

The pest of turfgrass is an armored scale. They are generally small, flat disc or plate-like organisms without legs and antennae. They live under a scale (armor) formed of wax secrections of the insect and grass or skin of insects. The scales vary in size, shape and color. Scale insects also produce honeydew.

POTENTIAL PEST:

BERMUDA GRASS SCALE (BGS). Odontaspis rufae Kochikey [Family: Diaspididae]

This insect was first discovered in Hawaii in 1910 (Zimmerman 1948). It is also called Rush’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 vigor and growth of turf. Heavily infected turfgrass takes on a brown, dry appearance and new growth is retarded. The scale does well in shade and heavily shaded 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 rejected on the root.

Egg: Eggs are deposited by females under their oyster-shaped scale.

Nymph or Crawler: 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, lose their legs, insert their piercing sucking mouthparts into the grass, start to feed and become sessile. In moist clay they lose 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 warrant an action level.

BIOLICAL CONTROLS: As with the mealybug only a single encyrid wasp, Dactylopus papillaris, 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 uninsected areas.

CHEMICAL CONTROLS: Infestations in Hawaii have not required pesticide applications. The insecticides suggested for GWM control should also be effective for control of this pest. Timing of the application is important so that the crawlers that are already in contact with the insecticide. The waxy covering protects the scale from the spray so the treatment may be incorpoated 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 a recent arrival in Hawaii. It was first 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, called stylets, into the plant tissues and feed on the phloem fluid. Injury is most severe on young, tender shoots and on the tips of leaves. Infected leaves turn brown and dry, and the affected area may become spotted or discolored. Severely damaged areas may be killed or list the turf, causing it to lose its green color and become yellowish or brownish. Infected areas may be difficult to mow and may require additional watering.

HOST RANGE: Its major hosts are St. Augustinegrass, Stenotaphrum secundatum. Other grasses in close proximity to St. Augustinegrass that have been slightly damaged by SCB are zoysia grass, centipede grass, bahiagrass, and bermudagrass. Some selections of St. Augustinegrass are resistant to SCB.

DESCRIPTION OF THE LIFE STAGES: Adult. Adults are 0.2 inch long, black with yellow 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 margins. Legs are reddish to reddish yellow. Fully winged (macropods) and short-winged (brachyptera) adults may be found in the population.

Egg. Eggs are deposited in the leaf sheaths and in the ground or roots. The eggs are nearly cylindrical, are 3.5 to 5.0 times longer than broad, and are whitish when freshly deposited. As development progresses the color changes to yellow and a deep red prior to hatching. Egg development takes 7 to 10 days.

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 irrigation liquids will force the adults and nymphs to the surface to be counted. Ten minutes of continuous counting is advised.

ACTION LEVELS: Adult levels exceeding 25 per square foot have been associated with significant damage to the turf. A recommended treatment threshold is 25 SCB per square foot for St. Augustinegrass and 10 SCB per square foot for more hardy cultivars such as Zoysia.

BIOLOGICAL CONTROLS: The infestation is so recent in Hawaii, no information is available on beneficial organisms here. In brotactical, Neomuraena obscura, and a number of parasites and predators have been recorded elsewhere (Takahashi 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 Busby and Coy (1988), Busby and Caner (1987), and Busby (1990), discuss the vulnerability of St. Augustinegrass and the genetics of resistance. Floristam and accretions PA 101 and PA 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 chinch bug 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 low foot swath surrounding it is suggested. Refer to the label for directions on dosage rate, application methods, precautions, etc. Insecticides containing chlorpyrifos, diazinon, and metabolites of these 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 topsoil. In some areas phosphine resistant populations of chinch bugs are present in Hawaii. Resistant cultivars is the best control for SCB.

BERMUDAGRASS MITE
Order: Acarina

OCCASIONAL PEST:

BERMUDAGRASS MITE (BGM). Eriophyes cydonioides Sayed [Family: Eriophyidae]

This eriophyid mite, also called the bermudagrass stent mite, was first detected in Hawaii in 1966. It has spread to all islands. It can be a serious pest of bermudagrass 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 thinning and curling of the leaves, and a spotting or blotching of the leaves. Severe winter damage may occur. In severe cases the area looks chlorotic without interstages. Walking over the area the turf feels lumpy. With heavy infestations the grass turns brown and dies. Adults and immature eriophyes suck plant juices.

HOST RANGE: At the naming 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: Adults. Adults of the mite are extremely small and may be difficult to see with a 10X hand lens magnifier. They are white to yellow in color and have four legs near the head end. They are found feeding near the leaf sheath or sucking plant sap.

Eggs: Eggs are spherical, transparent to opaque white and deposited singly or in clusters.
groups behind the leaf sheaths.

Nymphs: Nymphs resemble the adults in being microscopic in size, about two-thirds the size of the adults, larger than broad with two pairs of legs at the head end. The nymphs may be observed behind the leaf sheath looking 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 3-10 days.

MONITORING METHODS: Look for tufted or roseted 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.

BIOTICAL CONTROLS: Information on parasites and predators of BGM in Hawaii is still limited. Two predacious mites, Neolaelaps andrei (Baker and Hoffman) [Family: Cunulidae] and Stenotarsonemus grumpe (Marchal) [Family: Tarsonemidae] have been reported reducing BGM populations in Florida and Arizona, respectively (Butler 1965, Johnson 1973).

CULTURAL CONTROLS: Several cultivars, Midiron, Tifdwarf, Tifgreen 328, Tifway 419 exhibited degrees of resistance to BGM (Reinert 1982, 1983). 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-microbe, fluoresced has been recommended in Florida. Reinert and Cromby (1981), Reinert (1983) and Butler (1983) 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 in 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>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Comments on disease potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOTIC DISEASES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthracnose</td>
<td>Colletotrichum spp.</td>
<td>Minor - weak pathogen, limited reports in 1982</td>
</tr>
<tr>
<td>Bacterial leaf blight</td>
<td>Xanthomonas spp.</td>
<td>Major - can be serious</td>
</tr>
<tr>
<td>Brown spot</td>
<td>Botrytis allii</td>
<td>Minor - weak pathogen in cool areas above 2000 ft</td>
</tr>
<tr>
<td>Dethelia leaf spot</td>
<td>Dethelia gigantea</td>
<td>Minor - weak pathogen, can be serious in turf under stress</td>
</tr>
<tr>
<td>Fusarium blight</td>
<td>Fusarium spp.</td>
<td>Minor - weak pathogen, can be serious in turf under stress</td>
</tr>
<tr>
<td>Grease spot</td>
<td>Pythium spp.</td>
<td>Major - serious in wet, warm weather, serious in wet cool weather</td>
</tr>
<tr>
<td>Melting out</td>
<td>Bipolaris cynodontis</td>
<td>Major - can be serious at times</td>
</tr>
<tr>
<td>Nematode decline</td>
<td>Several genera and species</td>
<td>Minor - problem in turf under chronic moisture stress</td>
</tr>
<tr>
<td>Rust</td>
<td>Puccinia spp.</td>
<td>Minor - aesthetically unpleasant, a problem in poorly drained areas</td>
</tr>
<tr>
<td>BIOTIC DISORDERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algal scum</td>
<td>Algae, green</td>
<td>Minor - aesthetically unpleasant, a problem in poorly drained areas</td>
</tr>
<tr>
<td>Black scurf</td>
<td>Bacteria, anaerobic</td>
<td>Minor - problem in poorly drained soils</td>
</tr>
<tr>
<td>Fairy ring</td>
<td>Basidiomycetes</td>
<td>Minor - aesthetically unpleasant, a problem in some areas</td>
</tr>
<tr>
<td>Fusarium scurf</td>
<td>Various</td>
<td>Minor - several insects are serious periodically</td>
</tr>
<tr>
<td>Sclerotinia scurf</td>
<td>Phytophthora</td>
<td>Minor - aesthetically unpleasant, of local importance only</td>
</tr>
</tbody>
</table>

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
2. Disease or disorder associated with turf generally thinning out in small
   to large areas ............................................................................. 10
3. Disease associated with turf in spots or patches ................................ 3
4. Thinning out usually sharply demarcated from healthy turf, punkish insects found
   in white, powdery masses inside leaf sheaths ............................................ 4
5. Surface covered with a blackish-green scum ................................... 5
6. Subsurface color is heavily bunched and has a black straw, smelling of hydrogen
   sulfide (rotten egg smell) ................................................................. 7
7. Thinned area with chlorotic rings .................................................. 8
8. Thinned area without chlorotic rings .............................................. 9
9. Disease occurring in warmer areas below 2,000 ft. elevation .......... Melting Out
10. Disease occurring in cooler areas above 2,000 ft. elevation ............... Brethren
11. Causal agent usually infects younger leaves .................................. 11
12. Causal agent usually infects older leaves ....................................... 14
13. Infection of young leaves produces a blight .................................... 12
14. Bacterial leaf blight ...................................................................... 13
15. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
   under very humid conditions ......................................................... 15
16. Grease spot .................................................................................. 16
17. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
18. In humid weather an colored mycelium may be seen cell to cell across the surface
   of dead grass .................................................................................. 18
19. Small black spores become elongate and develop an irregular
20. Bacterial ring ................................................................................ 20
21. Smaller chief spores become elongate and develop an irregular
22. Yellowish spores become elongate and develop an irregular
23. Smaller chief spores become elongate and develop an irregular
24. Causal agent of disease ................................................................ 24
25. Disease occurring in warmer areas below 2,000 ft. elevation ........ Melting Out
26. Disease occurring in cooler areas above 2,000 ft. elevation ............... Brethren
27. Causal agent usually infects younger leaves ............................... 27
28. Causal agent usually infects older leaves ................................. 28
29. Infection of young leaves produces a blight ........................................ 29
30. Bacterial leaf blight ........................................................................ 30
31. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
32. Grease spot .................................................................................. 32
33. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
34. In humid weather an colored mycelium may be seen cell to cell across the surface
35. Small black spores become elongate and develop an irregular
36. Bacterial leaf blight ........................................................................ 36
37. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
38. Grease spot .................................................................................. 38
39. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
40. In humid weather an colored mycelium may be seen cell to cell across the surface
41. Small black spores become elongate and develop an irregular
42. Bacterial leaf blight ........................................................................ 42
43. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
44. Grease spot .................................................................................. 44
45. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
46. In humid weather an colored mycelium may be seen cell to cell across the surface
47. Small black spores become elongate and develop an irregular
48. Bacterial leaf blight ........................................................................ 48
49. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
50. Grease spot .................................................................................. 50
51. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
52. In humid weather an colored mycelium may be seen cell to cell across the surface
53. Small black spores become elongate and develop an irregular
54. Bacterial leaf blight ........................................................................ 54
55. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
56. Grease spot .................................................................................. 56
57. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
58. In humid weather an colored mycelium may be seen cell to cell across the surface
59. Small black spores become elongate and develop an irregular
60. Bacterial leaf blight ........................................................................ 60
61. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
62. Grease spot .................................................................................. 62
63. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
64. In humid weather an colored mycelium may be seen cell to cell across the surface
65. Small black spores become elongate and develop an irregular
66. Bacterial leaf blight ........................................................................ 66
67. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
68. Grease spot .................................................................................. 68
69. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
70. In humid weather an colored mycelium may be seen cell to cell across the surface
71. Small black spores become elongate and develop an irregular
72. Bacterial leaf blight ........................................................................ 72
73. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
74. Grease spot .................................................................................. 74
75. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
76. In humid weather an colored mycelium may be seen cell to cell across the surface
77. Small black spores become elongate and develop an irregular
78. Bacterial leaf blight ........................................................................ 78
79. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
80. Grease spot .................................................................................. 80
81. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
82. In humid weather an colored mycelium may be seen cell to cell across the surface
83. Small black spores become elongate and develop an irregular
84. Bacterial leaf blight ........................................................................ 84
85. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
86. Grease spot .................................................................................. 86
87. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
88. In humid weather an colored mycelium may be seen cell to cell across the surface
89. Small black spores become elongate and develop an irregular
90. Bacterial leaf blight ........................................................................ 90
91. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
92. Grease spot .................................................................................. 92
93. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
94. In humid weather an colored mycelium may be seen cell to cell across the surface
95. Small black spores become elongate and develop an irregular
96. Bacterial leaf blight ........................................................................ 96
97. Smaller leaf blight spots are formed in turf which produce abundant white mycelium
98. Grease spot .................................................................................. 98
99. Leaves in small spot or patches seem to wither or collapse and turn tan to brown.
100. In humid weather an colored mycelium may be seen cell to cell across the surface
101. Small black spores become elongate and develop an irregular
102. Bacterial leaf blight ......................................................................

Table 3. Bermudagrass damage in Hawaii evaluated for probable causal agents and
based on percentage of occurrence during various seasons of the year spanning a
twelve year span.

<table>
<thead>
<tr>
<th>Season</th>
<th>Bupa</th>
<th>Peng</th>
<th>Grease</th>
<th>Mel</th>
<th>Suta</th>
<th>UnSp</th>
<th>Other</th>
<th>Phys</th>
<th>Suta</th>
<th>Grease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr.</td>
<td>6</td>
<td>5</td>
<td>13</td>
<td>26</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>4</td>
<td>153</td>
<td></td>
</tr>
<tr>
<td>May-Sept.</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>17</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Oct-Dec.</td>
<td>5</td>
<td>3</td>
<td>9</td>
<td>18</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>11</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>13</td>
<td>4</td>
<td>27</td>
<td>61</td>
<td>14</td>
<td>15</td>
<td>11</td>
<td>60</td>
<td>101</td>
</tr>
</tbody>
</table>

* = Three seasons based on environmental factors
** = Major diseases of bermudagrass turf; Bupa = Brown patch (Rhizoctonia spp.)
Peng = Grease spot (Pythium spp.) Mel = Melting out (Helmithosporium = Bipolaris & Exserohilum spp.) Suta = Suta = Subtotal of percentage of disease related problems
*** = Other causal agents of damage; UnSp = Undetermined causes, unable to find causal agents; Phys = Physiological, associated with chemical or cultural problems; Suta = Subtotal of percentages of "other causes" related problems; Grre = 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 each of these 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 dedicated to carrying out the principles of IPM.

For the past 10 years, bermudagrasses (common and its hybrids) (Cynodon dactylon) 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, the golf course manager can have disease problems peculiar to his golf course. Each island in Hawaii the environment varies along sites on each island also be on 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 pathogens. Living causal agents capable of infecting are grouped as biotic and are also called pathogenes 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 physical agents 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
imbrination 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
Nonfetitious Diseases and Disorders
ABIOTIC AGENTS
Environmental Agents

These 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 assume the impact that each environmental factor 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 of damage occurs. Low temperatures cause warm season turf such as bermudagrass to go dormant. Prolonged low temperatures can reduce the growth of cold season turf causing evaporation cooling. High temperatures, related to solar radiation, speeds up the objects which can provide the heat and moisture given off by evaporation of the leaves or from soil or water in a period of time. Excessive heat and evaporation deplete the soil of moisture and can increase accumulation of toxic gases around the roots because of the 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 mechanical damage, footpasting occurs when the grass is dry and it is more prone to moisture loss than to rebind after being stepped on. In such cases the turf is under moisture stress and should be irrigated, 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 aeration and irrigation.

Excessive water results in plant damage through root growth. Subsoilation (lack of oxygen necessary for root respiration) along with build up of toxic gases can cause root growth. 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 is impaired. Management and renovation of these areas must be addressed as to the practicality of methods and alternatives for corrective measures. Adequate remedial treatment includes careful consideration of 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 soil 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 stems, rhizomes, and roots require a much longer time to decay. Thatch can be kept under control with periodic venting and aerification. Thatch can be built up whenever dressing is used instead of venting and aerifying, or when using too much top dressing after aerification. Thick layers of thatch interfere with penetration of air, water, sulfur from the soil is limited. Further, escape of harmful gases such as hydrogen cyanide, sulfur dioxide, and other gases accumulate in thatch, causing the soil to become less productive and new roots cannot penetrate the layer unless it is vented. This results in the turf more vulnerable during high die off. Dense thatch can cause the turf to be hyphodermic.

Landscape plants

Landscape plants and trees, which have shallow root systems, compete with turf for water and nutrients. These plantings of trees and shrubs near trees and green shade cut off oxygen and compete 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 and shredding of leaf blades. Injured leaf tips will die in a few days and show a brown color on the turf surface. Dull rotary mower blades resemble the injury with dull reel mowers. During wet weather, the turf is predisposed to

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 marrined at a very low mowing height, such as putting greens and tees must be mowed frequently to prevent removing too much of the frequently enough that no more than one-third of the leaf is removed at one time. Scalped 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, and basins 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 paint 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 treated with an absorbent material such as activated charcoal will reduce damage. The fume 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 the plant fluid. Excessive salt can accumulate from constant usage of brackish water, if rainfall is insufficient to leach the excess salts from the soil. If no water is applied, or during the dead grass period. 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 crop. Scrupulous care in the application of herbicides to be applied to a specific 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 test 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 number of applications or to 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 agents, along with the plants and 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, 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 for one reason or another is a candidate for algal to flourish. Algae feed on organic breakdown products of turf on the soil surface. Algae produce a thick layer of glistening black scum on the soil surface. When 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-summer will not have an algal problem if kept that way through the winter months. Turf fertilization 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 which can cause injury to turf and can lead to excessive amounts of algae. If the concentration of algae is high, the algae should be avoided. Algae should be given to firmly manage the disease by reducing the concentration of algae in the water. If the concentration of algae is high, the concentration of algae in the water should be reduced by applying additional water to the area. As the concentration of algae is reduced, the algae will be killed or before making applications of algicides. A combination of mazonocid and cupric oxide may be used in severe cases.
Black Layer

Black layer is a below-ground phenomenon consisting of the occurrence of a stratum (or strata) of black in appearance. This condition has been referred to by some as "black layer" and by others "black plaque".

Symptoms: First indication of black layer may be a thinning 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 stratum 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 elsewhere 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 as 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 fertilization procedures. If greens have a heavy thatch problem, manure for control of thatch 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 assure 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 in the saprophytic stage. The causal agents involved belong to a class of fungi whose fruiting structures are either mushrooms or puffballs (Basidiomycetes). These fungi derive their nutrition from decaying organic matter such as thatch and buried wood, e.g., lumber, urea 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 the turf 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 normal. In others, a ring of lush green grass will grow on the outer ring 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 areas 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 fairy 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 mycelia. 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 mark 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 infected area, then fertilizing and watering with a liquid 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 main area down to six inches below where the white mycelial threads of the fungus can be seen and in a zone extending about 18 inches beyond the outer green ring and filling the hole with new, unaffected soil and sod. In some cases, deeply aerifying the area and fungigating 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 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 yellowish, slimy growth emerges from the soil and grows up on any erect surfaces in its vicinity whether they are 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 Myxomycota. 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 3 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 reoccurrence.

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 colder temperatures (50 to 60°F) which occur during the winter months, or at higher elevations, growth of bermudagrass is retarded and goes into a dormancy period. This puts the plant under stress. For the most part the pathogens are 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, Ficing 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 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 to form spores 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, 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**

<table>
<thead>
<tr>
<th>Environmental and cultural factors</th>
<th>BPA</th>
<th>FeC</th>
<th>GSp</th>
<th>M or</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Low (50-70°F)</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>b. Moderate (70-85°F)</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>c. High (85-95°F)</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>2. Moisture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Humidity, air, high</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>b. Prolonged leaf wetness</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>c. Excessive soil moisture</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>d. Low soil moisture</td>
<td>+</td>
<td>+++</td>
<td>0</td>
<td>+++</td>
</tr>
<tr>
<td>3. Sunlight, low</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>4. Nitrogen fertility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Excessive</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>b. Low</td>
<td>+</td>
<td>++</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>5. Thatch, excessive</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>6. Poor maintenance</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>7. Nematodes (plant stress)</td>
<td>+++</td>
<td>++</td>
<td>0</td>
<td>+++</td>
</tr>
<tr>
<td>8. Insects (plant stress)</td>
<td>0</td>
<td>+++</td>
<td>0</td>
<td>+++</td>
</tr>
</tbody>
</table>

* Diseases: BA = Brown patch (Rhizoctonia solani) FeC = Ficing out (Fusarium spp) GSp = Grease spot (Pythium spp) M or = Melting out (Bipolaris cynodontis)

**Role of each factor:**

(0 = 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 remove during extended dry periods. Prolonged leaf wetness is encouraged by lack of air movement and/or shade. Freely cut leaves are more 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 grasses 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 anaerobiosis.

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 in greatest need, e.g., in grass, 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 grass its green color. The 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 these 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, Melting out, Grease spot or Melting out. Further, excessive amounts of fertilizer will burn the plant tissue and cause other damage such as burning 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 rhizomes. 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 compaction of the soil. Compaction of the soil results in a reduction of free 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 suppressive 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 Rhododendron mealybug resemble effects of Melting out or Melting out. However, advance of the weakening-out margins 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 weed pathogens.

Weeds:

Weeds compete with turf for water and nutrients. Certain weeds are more aggressive, therefore can render turfgrasses more susceptible to attack by weed pathogens.

BIOTIC CAUSAL AGENTS OF MAJOR INFECTIOUS DISEASES IN HAWAII

BROWN PATCH (Rhizoctonia blight)

The causal agent of brown patch disease is a fairly common occurrence fungal pathogen. Its disease association with bermuda turfgrasses in Hawaii has often been seen 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 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 cobwebly fungal growth, and is visible only in early morning while grass is moist. Blighted areas soon turn a light brown color. Changes in predispersing conditions or effective fungicidal control will allow new growth to be formed. Persistent attacks by the fungus can 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 need to stain young fungi to determine whether they are the cells of the fungus biologically or endophytes. The fungus is able to survive in soil by formation of small hardened masses of mycelium, 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 temperatures above 80°F. Outbreaks of disease occur during hot, humid weather, although some Rhizoctonia spp. are able to infect in cooler temperatures. 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 pathogens may be carried from green to green or course on self-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 tillage drainage to its maximum. Sprays with an appropriate fungicide when disease occurrence exceeds the threshold level.

FADING OUT (Curvularia blight)

Although the causal agent of fading out is not considered to be a strong pathogen, it has the potential to cause damage under conditions of cultural or environmental stress or when turf grass 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 coalesce to form larger areas. Turfgrass may take on an ochreous or light green, moldy appearance. A closer inspection of the leaves will show a tip burn or yellowing on the basal leaves or the flag leaf. Infected leaves will turn tan and later grayish brown. Usually, the leaves, where only 3-4 green leaves remain on a green of Tifdwarf bermudagrass in fading out visible.

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, or in the axil 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. Blowing 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 chaff 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 damage should be employed. Reduce morning shade as much as possible. Manage chaff control program through spring, summer and early fall. Fungicides are available for leaf protection and reduction of spore production in the upper chaff 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 fungicides, 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 on the sides of a quarter can appear on the grass, which later turn tan or brown. New grass in areas of the slope. Soggy patterns of spots can also occur when moving or boiling water. The name grass spot was given because the water-soaked leaves in the spot which, cottony webbing (fungus mycelium) or the yellow and brown. Leaf sheaths become severely affected earlier because the sheath of water is held by surface tension between a leaf and an adjacent leaf sheath. Leaf blight occurs when a spot enlarges or turns into more spots on the leaf. The disease is extensive over a small area of turf, the disease is referred to as a blight, and a band outside the dark band which is chlorotic. Melting out may develop slowly or initially on the leaf tip, the disease conditions turn unfavorable for continued disease development, a static period occurs. Upon the onset of ideal conditions for disease reactivation, the disease outbreak will seem at though it occurred overnight. 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 autumn to spring, depending on weather. Air temperatures in the column of the colony and the water are barely warm, and a fine film for disease development in the leaf. High humidity is not necessary for disease outbreaks. This species is considered sensitive to light and air. Management: Essential for the same conditions that favor Fading out caused by Curvularia spp. are similar and favoring Melting out. However, Bipolaris is considered temperature sensitive and the plant can develop. Sensitivity to temperature and humidity is not necessary for disease development. Management procedures for Fading out should also be considered for controlling Melting out.

BIOTIC CAUSAL AGENTS OF MINOR INFECTIOUS DISEASES IN HAWAII

ANTHRACNOSIS

Anthracnose is a name given to diseases in which the spores are produced in specialized structures (acervuli) which appear as tiny black dots in the dead tissue. The fungus is found worldwide and commonly invades watering plant tissue.

Symptoms: During cool, wet periods, pointed lesions, which are initially water-soaked, are formed. These spots become brown and serve as points of invasion. Water-soaked lesions, which can cause turf for disease incidence. Anthracnose is a dark, reddish brown margin borders the necrotic area of the spot. When the leaf sheaths are severely affected earlier because the sheath of water is held by surface tension between a leaf and an adjacent leaf sheath. Leaf blights occur when a spot enlarges or turns into more spots on the leaf. The disease is extensive over a small area of turf, the disease is referred to as a blight, and a band outside the dark band which is chlorotic. Melting out may develop slowly or initially on the leaf tip, the disease conditions turn unfavorable for continued disease development, a static period occurs. Upon the onset of ideal conditions for disease reactivation, the disease outbreak will seem at though it occurred overnight. In severe disease outbreaks, crowns and roots of the plant become infected, turn brown and rot.

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Symptoms: During cool, wet periods, pointed lesions, which are initially water-soaked, are formed. These spots become brown and serve as points of invasion. Water-soaked lesions, which can cause turf for disease incidence. Anthracnose is a dark, reddish brown margin borders the necrotic area of the spot. When the leaf sheaths are severely affected earlier because the sheath of water is held by surface tension between a leaf and an adjacent leaf sheath. Leaf blights occur when a spot enlarges or turns into more spots on the leaf. The disease is extensive over a small area of turf, the disease is referred to as a blight, and a band outside the dark band which is chlorotic. Melting out may develop slowly or initially on the leaf tip, the disease conditions turn unfavorable for continued disease development, a static period occurs. Upon the onset of ideal conditions for disease reactivation, the disease outbreak will seem at though it occurred overnight. 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 autumn to spring, depending on weather. Air temperatures in the column of the colony and the water are barely warm, and a fine film for disease development in the leaf. High humidity is not necessary for disease outbreaks. This species is considered sensitive to light and air. Management: Essential for the same conditions that favor Fading out caused by Curvularia spp. are similar and favoring Melting out. However, Bipolaris is considered temperature sensitive and the plant can develop. Sensitivity to temperature and humidity is not necessary for disease development. Management procedures for Fading out should also be considered for controlling Melting out.
Causal agent: Colletotrichum graminicola attacks a wide range of grass species. It is reported that C. graminicola has pathogenic races in other graminicoleous 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. Sprout of the fungus are abundant in bunch 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 in 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 transulence 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, stroma (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 60-90°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 bacteriological chemical control recommended. Particular attention is directed to exclusion and keeping up 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 to the Fusarium causal agent in a weak pathogen, but contributing 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. (Fusarium are ubiquitous fungi).

Epidemiology: See Anthracne.

Management: See Anthracnose. Fungicides are recommended during the recovery phase. Denitum 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 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 Liliuokalani 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 merge the whole leaf. As the lesions enlarge rapidly, concentric bands of tan and dark brown appear, this gives rise to the symptom type, zone eye spot. Severely affected turf thins out as the leaves become necrotic.

Causal agent: Drechslera gignadae

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 50-81°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 Melting out and Melting out. Fungicitol control should be applied during peak infective times in late fall and winter to protect the leaves from early 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 sporeless mycelium, exposing tiny reddish-brown spots which may be seen with a hand lens. In cereals, rusts can be very destructive. Familiar are rusts 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 matured 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 dislodged 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, wider and turn brown.

Causal agent: Puccinia cynodontis and P. graminis graminea. Another genus of rust is reported to infect Cydonia in China. Generally rust fungi are host-specific. P. cynodontis infects only Cydonia, but P. graminis graminea attacks both Agropyron and Cydonia. The rust fungus is an obligate parasite, which means that it needs a living host on which to reproduce. All other fungi which infect bermudagrass in Hawaii are able to survive asexually, which enhances their longevity 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 rust infection, unlike other pathogens, rust fungi can produce new spores in moderate humidity. As in many other benomyl-resistant fungal species, 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 infections.

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 unwary. Symptoms appearing directly on the roots are of little help in field diagnosis. Indirect symptoms of growth decline, shining-out of the grass that does not respond to improved cultural practices 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 glistening infiltration 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 fibrous root system such as that of grasses.
Stubby root nematodes: a reduced root system with 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 salivary containing enzymes, then suck back the partially digested cellular contents into their esophagus. Nematodes can be grouped based on their feeding habits, i.e., endoparasitic (feeding from the outside of the root or to the death of a few cells), and endoparasitic (perforating the root before commence 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 or be completed in the egg. The life cycle is delayed until the proper conditions are met. The first stage larvae develop into the egg. It molts and the second stage hatches out of the egg case. The nematode becomes mobile 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/parasitic.
Lesion nematodes: Pratylenchus spp., endoparasitic/parasitic.
Spiral nematodes: Helicotylenchus spp., endoparasitic/migratory.
Stubby root nematodes: Trichodorus spp., endoparasitic/parasitic.
Ring nematodes: Criconema spp., endoparasitic/parasitic.

Epidemiology: Although plant parasitic nematodes are mobile, if left undisturbed in turf they may move only a few inches in a year's time. Movements of nematodes of greater distances usually requires outside assistance such as, surface run-off water or in soil-carryed on equipment, shoes or forking. Nematodes are usually most active in the temperature range of 68-80°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 noticeable on the turf.

Management: Cultural practices which favor good turf grass 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 longimerus, the ailing nematode, is widespread there and has not as yet been reported in Hawaii.

If chemical control is recommended, there are two fungistat types, to be used prior to planting turf (preplant) and systemic 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 Tifgrass and TifGreen putting greens. Mottled spots occur most frequently during the winter months.

Symptoms: Areas of turf of various sizes on greens thin out beginning 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 without symptoms similar to those of overfertilization. In some cases the spots appear as if reseeded with only chlorotic rings to outline the affected area.

Causal Agent: The causal agent for the mottled spot condition remains unknown. Numerous isolates yield certain Fungi, Actinomycetes, Pseudomonas, Bipolaris, and Acremonium. The frequency of any one genus was insufficient for a tentative indication. No pathogenicity tests were conducted with the isolates.

Epidemiology: Mottled spot occurs most frequently during the onset of cool weather. Turf under low fertilizer 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 conjecture 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 the species level is inadequate to prove pathogenicity. Incubation of a pure culture of an organism, commonly associated with a disease, on a healthy host must be made. Insufficiently crushed, 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 achieved with the use of a 10X hand lens and learning to look for signs of the disease for tilable spaces. In finding a grayish-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 common blight symptoms caused by Pythium spp. He should be able to identify these actions conducted by a specialist for verification. Identification kits for the fungi and other materials that are available but not 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 concomitance of the predisposing cultural and environmental factors present to determine the urgency of a sufficient disease that control measures must be undertaken, at least for the site where symptoms are observed. The superintendent must then decide whether to implement a management practice. Presence of visible disease symptoms usually signify that control measures must be undertaken, at least for the site where symptoms are observed. The superintendent must then make a decision whether to implement a management practice. Presence of visible disease symptoms usually signify that control measures must be undertaken, at least for the site where symptoms are observed. The superintendent must then make a decision whether to implement a management practice.

BIOLICAL, 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 biontomy, or other broad spectrum pesticides, where must be taken in the period immediately 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 suppressed 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 time 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 effectively 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 sanitation practices, often considered one of the most important factors, which may be 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 sanitation practices, and disease control is most frequently a management system which involves two or more types of control measures. For example, good sanitation practices, such as removing diseased tissue, are often used in combination with chemical and biological controls.

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. Insurance and destruction of infected or infected plant material.
2. Disinfection of plant material, seed, and potting soil.
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. Vegetative propagated grasses passing by this rigorous test are used to start 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 the seed, amount of weed seed, amount of moldy seed, 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. Certification does not imply freedom from diseases or pathogens. If seed, true or some disease, in low percentage, may also be made. Nurseries are inspected to ensure that indeed, the seed industry in Hawaii is so small that it is not efficient to have a non-sterile nursery for which no seed are available, should either establish their own sod or use reputable sod nurseries to grow a predetermined amount of sod to be delivered at a single rate available in Hawaii in limited quantity. If a developer waits until just before planning time to find sod, the supply will likely be insufficient to plant the entire golf course.

AVOIDANCE:

Avoidance tactics in managing turf diseases makes use of techniques which are directed to the following areas:  

1. Site selection -- 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 the high fungal and nematode population.
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 golf soil moisture balance.
7. Fertilization -- soil should be tested periodically for nutrients and soil reaction (pH). Proper balance of nutrients promotes plant vigor.

8. Soil composition -- most seed can function properly, excessive vehicle and foot traffic cause severe compaction. Heavy soils should be avoided.
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 are exposed to the environment. They are especially effective in spreading diseases. Outdoor nurseries should be in a section of a disease-free area. Grass clippings should be disposed of in places where they will not be a problem. Nursery waste areas should be removed from all areas of the golf course, 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 resistance to the bermudagrass diseases present in Hawaii.

CHEMICAL IPM OF TURF DISEASES

The prudent use of chemicals in the management of turfgrass diseases helps the golf course manager offset unpredictable changes in the environment which may lead to a sudden increase in soil moisture, favorable conditions for infection development, or ERIHICATION

Eradication is an ideal that is seldom, if ever, achieved. An attempt at eradication which is incomplete is eradication 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 a large goal, is unrealistic. The eradication of a disease involves limiting the methods available for use and the cost of implementation, and the removal and subsequent exclusion from re-infecting. 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 pathogen, such as the fungus spore, lands in a lesion or injury, the chemical is then applied and is then applied and moved into the plant. The mode of action of the fungicide used on turf is a fungicide. It is necessary to use the fungicide in place on the leaf before the fungal spore arrives. One of the more commonly used fungicides for control of turf in Hawaii disease management is to whether assign the fungicide’s level of toxicity, its’re and the herbicide 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 a 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 bermudagrass than on Tifgreen in the fallways.

Table 10. Turfgrass disease pesticides registered in Hawaii, their site of action, type of action and general classification.

<table>
<thead>
<tr>
<th>Common or chemical name</th>
<th>Site of action</th>
<th>Type of action</th>
<th>General classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>azoxystrobin</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>benomyl</td>
<td>sys</td>
<td>pro &amp; cur</td>
<td>gen</td>
</tr>
<tr>
<td>chlorothalonil</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>cupric oxydiazine</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>etoxazole</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>iprodione</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>mancozeb</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>metalaxyl</td>
<td>con</td>
<td>pro</td>
<td>gen</td>
</tr>
<tr>
<td>thidiazuron</td>
<td>sys</td>
<td>pro</td>
<td>gen</td>
</tr>
</tbody>
</table>

* = 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.

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Dusting or fogging</th>
<th>Diseases reported in Hawaii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaprop</td>
<td></td>
<td>Anthracnose</td>
</tr>
<tr>
<td>Benomyl</td>
<td></td>
<td>Bacterial leaf blight, Brown spot,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curvularia leaf spot, Foliar blight,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physarum blight, Rust</td>
</tr>
</tbody>
</table>

# = 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 select one or two pesticides. Check periodically with the manufacturer’s representative as a pesticide may not be active.


FACTORS INFLUENCING THE EFFECTIVENESS OF FUNGICIDES

Several factors influence the effectiveness of pesticides when used as contact sprays. Some of these factors are:

Timing: Protection of the plant must be taken 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 is essential to control disease. Spray applications must be made in such a manner as to ensure that the fungicide is applied to all parts of the leaf. Sprays should be applied on a regular basis to prevent disease development. Sprays of the active ingredient should be used on an area as large as possible to ensure that all parts of the plant are covered.

Preparation: A fungicide must be placed on the leaf surface in a manner that allows it to enter the plant. The active ingredient should be applied to the leaf surface and should be thoroughly mixed with the water to which it will be applied. The mixture should be applied to all parts of the plant, especially the tips and edges of the leaves.

Stability: A fungicide must be stable in the environment. It should not degrade rapidly in the air or on the leaf surface. Stability is important to ensure that the fungicide remains active for an extended period of time. Stability is also important to ensure that the fungicide is not leached from the plant or washed off by rain or irrigation water.

phytotoxicity: A fungicide must not injure the plant. Phytotoxicity is the ability of a fungicide to injure the plant. Phytotoxicity is important to ensure that the fungicide is not harmful to the plant. Phytotoxicity is also important to ensure that the fungicide is not harmful to other plants in the area. Phytotoxicity is important to ensure that the fungicide is not harmful to other plants in the area. Phytotoxicity is important to ensure that the fungicide is not harmful to other plants in the area.
spray mix, some combinations may be either phytotoxic or rendered ineffective when mixed. Compatiblity charts are available, which indicate the mixing of 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 plants. 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 it is important to wash the foliage off the leaves. Cocks 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 pathogenic organisms at some stage in their life cycle. Such agents are sometimes highly desirable but they do have their drawbacks. Because the pathogen is exposed to the pesticide during a longer span of time, sometimes at a sublethal dose-rate, there is an opportunity 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 Metarhizium, is 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 turfgrasses are those that can grow and reproduce themselves in management conditions specific to turfgrass. The factors affecting weed growth are temperature, humidity, precipitation, sunlight and wind, resulting in the soil being disturbed once the seed is sown. Thus, hundreds of weeks in Hawaii only become serious turfgrass pests when turfgrass is reasonably well-maintained. Those species likely to be present at the proposed golf course site are well-adapted to Hawaii's climate (temperature, humidity, precipitation, sunlight and wind, and other factors). The specific weeds will be described in this report.

Many weeds that were abundant at the proposed golf course site such as side (Crispinus spinosa), and various vetches (Vicia sativa, Vicia faba, Vicia fava) 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 so as to provide a source of food for parasites or predators that attack them. At these low populations, 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, the weeds that have been proven to have a large quantity of seeds or vegetative propagules which enable them to reproduce themselves. Thus, if one wants to keep weeds at a threshold level for a weed in turf, one could control weeds before they produce reproduction (i.e., propagules, spores, seeds) or 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. Broadleaves 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 stem, 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 genera, genera, 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 can be used to identify weeds in Hawaii. The best one available is "The Handbook of Hawaiian Weeds", by Fitchwood, Winer and Hirano (Hawaii Ed., 1985). 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:

Goutweed, Elyronium indica. Annual or perennial. Perennial daisy blooming at ground level (50 feet or less). Present on greens, tees, fairways and roughs. Can grow...
up to 2 feet high. Tufted growth with branching at the base. Leaves blade-shaped, flowering head with 2 to 6 fingerlike branches. Invasive on turf areas and roadsides. Leaves have a distinctive appearance. Propagates by seed. Its tufted growth habit creates an unacceptable appearance in turfgrass in Hawaii, and there are good management tools to control it.

Henry's crabgrass, Digitaria sanguinalis, is perennial. Present in fairways and roughs, rarely on greens. Leaves blue-green. Creeping habit, not standing in a dense mass from a few inches to a few feet in diameter. It can completely crowd out 2 to 4-inch-compressed branches. Propagates by seed and creeping stems. Once established, it is only controlled by chemicals. Propagates by seed and creeping stems. Once established, it is only controlled by chemicals. Fortunately, selective chemicals can be used to achieve this. However, selective applications are usually necessary.

Hilgass, Paspalum conjugatum, is perennial. Present in fairways and roughs. Leaves light green under nitrogen deficiency condition to dark green with high nitrogen. Creeping habit, in various directions; can form a mat. Flowering head with mostly two slender branches 2 to 4 inches long. Conditions that favor its growth. Leaves well in full sun and shady conditions, but tend to be more prevalent in areas with a high rainfall and poorly drained soil. It is often controlled by selective chemicals, but repeated applications are needed.

Smug grass, Sporobolus pectinifolius or raceless grass, Sporobolus airoides, is similar. Both species are perennial, and in appearance, will be described together. Present in fairways and roughs. First growth in small clumps. Flowering head can be up to about 15 inches long with the branches closely compressed in the main axis. Propagates by seed. These weeds are important because they are already abundant in the growing areas at the proposed golf course site. Once established, these weeds 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, narrow leaf blading. Creeping habit, 2 to 4 inches long. Conditions that favor its growth. Leaves well in full sun and shady conditions, but tend to be more prevalent in areas with a high rainfall and poorly drained soil. It is often controlled by selective chemicals, but repeated applications are needed.

Dallis grass, Paspalum dilatatum, perennial. Present in fairways and roughs. Leaves somewhat broad (1/4 to 1/2 inch wide), dark green. Creeping growth, can be 2 to 4 inches long. Conditions that favor its growth. Leaves well in full sun and shady conditions, but tend to be more prevalent in areas with a high rainfall and poorly drained soil. It can be controlled by selective chemicals, but repeated applications are necessary.

Lovergrass, Erhagrostis spp. Annual. Present in fairways and roughs. Leaves spreading, tufted growth. Flower heads with numerous delicate branches about 1 to 2 inches long. Propagates by seed. This weed has become quite common in the last few years. It appears to tolerate the selective herbicides.

Stargrass, Chloris diversiseta, perennial. Present in fairways and roughs. Creeping habit, branches freely and form a mat. Leaves bluish green. Flowering stem 4 to 7 branches resembling a star, sometimes mistaken for common couchgrass, but with bristles on seeds. Propagates by seed and creeping stems. 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 thrives in a well-drained environment.

Swellen fingergrass, Chloris barbata, annual. Present in fairways and roughs. Leaves generally erect, tufted growth. Flowering heads with purple, fingerlike branches 1 to 2 inches long. Persist in dry areas. Propagates by seeds. This weed tends to be a problem in poorly maintained turf.

Vesey 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. This weed is not a common problem of turfgrass, but once established, it is a serious problem because of its spiny burs.

Sedges:

Key Pests:

Green kyllinga, Kyllinga monosperma, perennial. Present in fairways and roughs, sometimes on tees, rarely on greens. Leaves resemble purple nutgrass. Each new purple nutgrass, there is no seed structure at its base. Flowering head is green in appearance which some greens. Once on greens, hand-weeding may be necessary.

Purple nutgrass, Cyperus rotundus, perennial. Present in fairways and roughs, sometimes on tees, rarely on greens. Leaves upright, spreading later. All leaves arise from a horizontal stem creeping at or slightly below the soil surface. Unlike the bulbinifera, it has no seed structure at its base. Flowering head is a spindly clump of 1 to 3 inches long of the flowering stalk. Propagates by seed. This weed is not a common problem of turfgrass, but once established, it is a serious problem because of its spiny burs.
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 breviflorus*. Perennial. Present in fairways and roughs, sometimes on tees, rarely on greens. Visually 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.

**Broadleafes:**

**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.

Astilbe pennycow. *Genista asiatica*. Annual or perennial. Present on fairways and roughs. Creeping habit. Leaves round to heart-shaped arising from creeping stems. Larger than marsh pennycow with leaves 34 to 2 inches in diameter. Flowers are greenish on a long slender spike. Propagates by seed. A similar species with narrow leaves, *Genista silvatica* or bushy *Plantago lanceolata*, tends to be less prevalent in Hawaii.

**Broad-leafed 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, *Plantago lanceolata* or bushy *Plantago lanceolata*, tends to be less prevalent in Hawaii.

**Buttonweed. Borreria laetia*. 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 anacampsis*. 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 purple. Propagates by seed. Early control is suggested, once a dense mat forms, the humed grass 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 foliage. Propagates by seed and crown. Controlled by selective herbicides.

**Drymarnia. Drymarnia cordata*. Annual or perennial. Present on fairways and roughs. Prostrate and creeping habit. Leaves small (about 1/2 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.


**Kailii clover. Desmodium caesium. Annual or perennial. Present on fairways and roughs. 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 indicum*. Kailii clover and related species were abundant in the plateau areas of the proposed golf course.

**Marsh pennycow. 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 arise from creeping stems. There appears to be several ecotypes exhibiting different degrees of hairiness on the leaf surface. Persist under mild to dry soil conditions. Propagates by seed and creeping stems. Marsh pennycow can be controlled by selective herbicides, but some ecotypes are reportedly tolerant to these herbicides.


**Purple loosestrife. *Lythrum salicaria*. Annual or perennial. Present on fairways and roughs. Freely branching, spreading, prostrate stems, reddish or dull green appearance. Small single flower formed along the stem. Propagates by seed or by stem pieces. A grow cut stem can root when moisture is provided, even if the cut stem was previously left in the sun for 6 weeks.

**Sensible plant. *Mimosa pudica*. Annual or perennial. Present on fairways and roughs. Creeping habit, stems thorny, leaves will close with touch at night. Flower heads pink to purple, round appearance. Propagates by seed. Early control is suggested because of its thorny stems.

**Syndrelle. Syndrelle adiantifolia. Present on fairways and roughs. Generally upright, but becoming prostrate with mowing. Opposite ovate leaves, often hairy and with 3 distinct veins. Flower buds small, yellow. Propagates by seed. A similar smaller-stemmed species, *Syndrelle thyrsiflora*, is also prevalent in turf. These species tend to be present in poorly maintained turfgrasses.

**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 which generally originates from the creeping stem. Flowers yellow, forming an oblong fruit capsule about 1/2 inch long. The fruited capsule explodes at maturity, sending seeds a few feet away. Propagates by seed and creeping stems. Leaves are easily differentiated by selective herbicides used for grass and weed control, but regrowth occurs.
Potential Pest:

Pink wood sorrel, Ozalis maritana. Perennial. Present on fairways and roughs. Tufed appearance because all leaves arise from underground bulbous portions. 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 WEEF SPECIES:

The level of weed invasion that would trigger an action is dependent on many factors, such as the management system. Most weeds with a tufted growth habit and/or has the ability to form a dense mat (fibers' grass, Halo grass, Kylinger) may be counted per unit area of the course, the number of times it occurs per week site. More complex methods to characterize distribution are also used. For the purpose of this report, the level would consist of 15% of the area (measured by holding both arms perpendicular to the ground by 200 feet long (measured by dropping both arms per foot) for a unit area of 1,000 square feet.

NONPECTIFICAL CONTROLS:

A vigorous surf cover is the best preventive control method for weeds in turf. A dense turf grass is one that stands well, and provides good germination by reducing light and other factors. If any seed is present in the soil, the primary source of reproduction is the soil surface. In turfgrass culture, the soil is disturbed once the seedbed is prepared. Weed seeds are typically present in high quantities at any site. However, once the seedbed is disturbed, the seeds will germinate. It is important to remove the seed before it becomes established, but after it has reached the stage of seedling. To achieve this, the soil should be tilled deeply to a depth of 6 inches. 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 herein (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 and propagate reserved suggested as an alternative course of action. However, the action level suggested would result in a more effective golf course setting.

Weed species have been monitored by various means. Typically, density is measured by counts of weeds per unit area. For example, clover, cheatgrass, fescue, or blacktop, nettles, or clover, and other factors. In general, the action level for weeds in a golf course setting is a function of the number of weeds present in the fairway, and finally to the greens. On a fine, fairway, and greens, clover is the most important. For example, clover is less competitive than other grasses, and the action level for the former species may be lower than the latter species, if the basis for the action level is the interference of the lawn turf. If visual appearance is a factor, all weed species may have similar action levels.

Unlike many nuts, there is a distinct advantage to reduce weed pests to near zero populations. The advantage test with the reduction of the reproductive ability of the weed species. Each mature weed species has the ability to produce thousands of seeds once mature, or underground propagules (seed, seedings, seeds, or bulbs). Once produced, they serve as the means by which new weeds may be produced. Typically, the potential for any weed is limited by the number of seeds present. But there are many exceptions, such as purslane, sensitive plant, and probably kainui clover, creeping thistle, etc. Small amounts of seeds can sometimes persist much longer than the turf grass. If weeds can be removed before they become mature, the future primary source of reproduction is disrupted.

In turfgrass culture, the soil is disturbed once the seedbed is prepared. Weed seeds are typically present in high quantities at any site. However, once the seedbed is disturbed, the seeds will germinate. It is important to remove the seed before it becomes established, but after it has reached the stage of seedling. To achieve this, the soil should be tilled deeply to a depth of 6 inches. The level of weed management during the first few years, but a reduction in labor requirement during subsequent years.
Table 12. Suggested action level for weeds in different golf course areas in Hawaii.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>greens</th>
<th>tees</th>
<th>fairways</th>
<th>roughs</th>
<th>Number of weeds per 1,800 sq. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Goosegrass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>St Augustine</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Annual bluegrass</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Swedish fingergrass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Ryegrass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Daily grass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Valsy grass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Henna crabgrass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
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<tr>
<td>Hilo grass</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Sedges:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purple nuttage</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>100</td>
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<tr>
<td>Green kyllinga</td>
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<td>10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>White kyllinga</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Broadleaves:</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td>Marsh pennyworn</td>
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<td>20</td>
<td>100</td>
<td></td>
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<tr>
<td>Asilic pennyworn</td>
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<td>100</td>
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</tr>
<tr>
<td>Premise spurge</td>
<td>1</td>
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<td>100</td>
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<tr>
<td>Tijuel sparge</td>
<td>1</td>
<td>5</td>
<td>20</td>
<td>100</td>
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</tr>
<tr>
<td>Yellow wood sorrel</td>
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<td>100</td>
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<td>Pink wood sorrel</td>
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</tr>
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<td>Dymaria</td>
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<tr>
<td>Kalam clover</td>
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<tr>
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<tr>
<td>Sensible plant</td>
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<tr>
<td>Blood leaved plantain</td>
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<td>10</td>
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</tr>
<tr>
<td>Spondrella</td>
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<td>10</td>
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<td></td>
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<tr>
<td>Distillation</td>
<td>1</td>
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<td>Aluminum</td>
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<td>100</td>
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<tr>
<td>Purslane</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Burroweed</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

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 agrochemical 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 agrochemical 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 tank 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 individuals. 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:

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.
<table>
<thead>
<tr>
<th>Common name</th>
<th>Trade names</th>
<th>Restricted use herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSMA</td>
<td>Weed Hoc 108</td>
<td>no</td>
</tr>
<tr>
<td>CAMA</td>
<td>Super Dal-E-Rad/Clear</td>
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<tr>
<td>Mefluidone</td>
<td>DuPont Lexone DF Herbicide</td>
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<td>Imazaquin</td>
<td>Image Herbicide 1.5 LC</td>
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<td>Pronamide</td>
<td>Kerb 50-W in Water Soluble Pouches</td>
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<tr>
<td>Simazene</td>
<td>Princep 80W</td>
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<tr>
<td>Glyphosate</td>
<td>Roundup</td>
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<tr>
<td>Dicamba</td>
<td>Banvel Herbicide</td>
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<tr>
<td>2,4-D</td>
<td>Rhone-Poulenc Formula 40 Herbicide</td>
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</tr>
<tr>
<td>2,4-D mixture</td>
<td>SUPER TRIMEC BROADLEAF HERBICIDE</td>
<td>yes (1 qt.)</td>
</tr>
<tr>
<td>(+dicamba)</td>
<td>TRIMEC SOUTHERN BROADLEAF HERBICIDE</td>
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<tr>
<td>+mecoprop +dichloprop</td>
<td>TRIMEC CLASSIC BROADLEAF HERBICIDE</td>
<td>yes (&gt;1 qt.)</td>
</tr>
<tr>
<td>+TRIMEC BROADLEAF HERBICIDE</td>
<td>yes (&gt;1 qt.)</td>
<td></td>
</tr>
</tbody>
</table>

Suggested corrective chemical control action for selected species on grasses and tees:

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Greens</th>
<th>Suggested chemical for control</th>
<th>Tees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goosegrass</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
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<tr>
<td>Annual bluegrass</td>
<td>MSMA, CAMA</td>
<td>Propanil, MSMA</td>
<td></td>
</tr>
<tr>
<td>Henysa crassgrasses</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
<td></td>
</tr>
<tr>
<td>Purple nutedge</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
<td></td>
</tr>
<tr>
<td>Green clover</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
<td></td>
</tr>
<tr>
<td>White clover</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
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</tr>
<tr>
<td>Marsh pennwyen</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
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<tr>
<td>Yellow wood soil</td>
<td>MSMA, CAMA</td>
<td>MSMA, CAMA</td>
<td></td>
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<td>Pink wood soil</td>
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<td>MSMA, CAMA</td>
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<td>Dyerclaw</td>
<td>2,4-D Mixtures</td>
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<tr>
<td>Creeping zinnia</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Sedge-like plant</td>
<td>Simazine, Mefluidone</td>
<td>Simazine, Mefluidone</td>
<td></td>
</tr>
<tr>
<td>Broad-leaved plant</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Synodela</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Delamia</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Littlenose</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
<tr>
<td>Buttonweed</td>
<td>2,4-D Mixtures</td>
<td>2,4-D Mixtures</td>
<td></td>
</tr>
</tbody>
</table>

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. Mass noxious weed: 2,4-D Mixtures > MSMA > Dicamba > Mefluidone > Simazine > Pronamide
2. Leaching potential: Dicamba > 2,4-D Mixtures > Mefluidone > 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-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 areas, conditions of applications, etc. Because the label may change from time to time, it is imperative that labels 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, 1-800-222-1222; their telephone number is 941-441.

Some pesticides available for use in turfgrass on the mainland may not be available in Hawaii because it may not be registered for use 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 for Hawaii. The Department of Agriculture also regulates pesticide use in Hawaii. TCAA is only periodically 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 by Hothon, 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 Department of Health becomes involved when there are special health risks, such as pesticides in water.

In other cases, a pesticide may be found to be effective on certain turf pests, 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 effectiveness must be presented with concurrence obtained for its registration by the manufacturer.

SAFE AND EFFECTIVE USE OF PESTICIDES

One of the basic tenants 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 term ending in "icide" (from the Latin word to kill) are classes of pesticides. In legal terms it is classified as an "economic pest" 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

<table>
<thead>
<tr>
<th>Pesticide class</th>
<th>Pests to be controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acaricide</td>
<td>mites, ticks</td>
</tr>
<tr>
<td>Algaecide</td>
<td>algae</td>
</tr>
<tr>
<td>Bactericide</td>
<td>bacteria</td>
</tr>
<tr>
<td>Fungicide</td>
<td>fungi</td>
</tr>
<tr>
<td>Herbicide</td>
<td>weeds</td>
</tr>
<tr>
<td>Insecticide</td>
<td>insects</td>
</tr>
<tr>
<td>Miticide</td>
<td>slugs</td>
</tr>
<tr>
<td>Mothicide</td>
<td>pupae, slugs</td>
</tr>
<tr>
<td>Nematocide</td>
<td>nematodes</td>
</tr>
<tr>
<td>Oxadiazonide</td>
<td>snails, slugs</td>
</tr>
<tr>
<td>Rodenticide</td>
<td>destroy insect and rate eggs</td>
</tr>
<tr>
<td></td>
<td>rodents (moles, rats)</td>
</tr>
</tbody>
</table>

Chemicals classified as pesticides not bearing the "icide" suffix:

- Atrazine
- Methylcarbamate
- Insecticide
- Desiccant
- Growth Regulator
- Phemerocine
- Insecticide
- Repelent
- Repelent
- O Bayard, 1989

Federal Environmental Protection Agency (EPA) and State (Hawaii Department of Agriculture (DOA), Hawaii Pesticide Lavel) regulations require all pesticides to be classified according to label directions by anyone. If RESTRICTED USE - These can be purchased and applied only under the direct supervision of a certified applicator. Hawaii list of restricted pesticides will include the federal list and any additional state 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 the training and preparation of personnel wishing to take the examination for certification. For more information send in the "Chemicals in 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 dust, spray particles, mist 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 LD50 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.

<table>
<thead>
<tr>
<th>Category</th>
<th>Signal word required on label</th>
<th>Acute LD50 (mg/kg)</th>
<th>Oral</th>
<th>Dermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Highly Toxic)</td>
<td>Danger, Poison &amp; Caution</td>
<td>0.5-0.50</td>
<td>0-200</td>
<td></td>
</tr>
<tr>
<td>II (Moderately Toxic)</td>
<td>Warning</td>
<td>5-50</td>
<td>20-200</td>
<td></td>
</tr>
<tr>
<td>III (Slightly Toxic)</td>
<td>Caution</td>
<td>50-500</td>
<td>20-2000</td>
<td></td>
</tr>
<tr>
<td>IV (Relatively Non-Toxic)</td>
<td>Caution</td>
<td>&gt;5000</td>
<td>&gt;20000</td>
<td></td>
</tr>
</tbody>
</table>

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, LD50, 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 LD50 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). Maximal toxicity levels for insectsicides registered for use on turf in Hawaii are presented in Table 15.

PRECAUTIONS:

The most important documentary 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 conditions, instructions, precautions, safety and use suggestions. The label for a pesticide is a product. LABELS ARE IMPORTANT, IF FOLLOWED PRECISELY, WILL PREVENT PROBLEMS FROM USE OF THE PESTICIDE. Read the label every time the pesticide is used. Labels can be amended at any time.

Safe use of pesticides has four main concerns: personal safety, safe handling, (transport and storage), and safe disposal. The 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 producer or the Cooperative Extension Service. Use the prescribed protective clothing (recommended respirator, protective clothing, etc.). Protective clothing is important when using and handling pesticides.

Keep a written record of the date, time of day, weather conditions, name of the pest to be controlled, exact name and formula of the pesticide used, area to be treated, equipment used, names of individuals supervising and making the application, safety information, the greater the value in analyzing the situation if control is not obtained or if complaints of noise occur. Follow label specifications 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 phytotoxicity to 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 
est control on golf courses.*

<table>
<thead>
<tr>
<th>Common name of Pesticide</th>
<th>Representative Trade names**</th>
<th>LD50 (mg/kg)†</th>
<th>Acute oral</th>
<th>Acute dermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetanilid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dicarbamid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fluvalinate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lindane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>malathion</td>
<td></td>
<td></td>
<td></td>
<td>1,300</td>
</tr>
<tr>
<td>parathion</td>
<td></td>
<td></td>
<td>1,300</td>
<td></td>
</tr>
<tr>
<td>toxaphene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For more information on the toxicity levels of these pesticides, refer to the EPA's Pesticide Data Query (PDQ) database available at [https://www.epa.gov/pesticides/pesticide-data-query](https://www.epa.gov/pesticides/pesticide-data-query).

** Trade names selected for this table are 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.

† LD50 is the dose (milligrams of toxic substance/kg of body weight) that kills 50% of the test animals. (LD50) values are from Agrochemical Handbook, 1987 ed., Royal Society of Chemistry, Info. Services, Nottingham, England.

| The text animals were rats. |

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 control of a 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 directions on pressure, types of nozzles, speed of power equipment, etc. Never smoke, eat, drink, chew while applying pesticides. Do not spray in a manner that may cause injury to others. Avoid applying pesticides to plants that will be eaten by livestock. Apply pesticides with the wind at your back. Follow label recommendations about maximum wind speed 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 unfavorable. Do not feed pesticide-treated turf clippings to animals.

Transportation of partial or partially filled pesticide containers should not be transported in a passenger car or in a truck loaded with foodstuffs, clothing, feed, etc. Never transport a leaking 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 stored should be on an impervious material, such as concrete and faced 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 for the use of water to contain water, and metal containers. Rinse water should be poured into the spray tank and not down a drain to contain water used in the environment. Puncture or break containers so that they cannot be reused. Store empty containers in a secure area until they can be disposed of 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 primarily to applicators of the pesticide in the case of golf courses where there is 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, surface water or create a hazard to wildlife exposed to pesticides. 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 (Hawaii Star Bulletin, Aug. 13, 1987) 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 waters, does not necessarily constitute a health hazard as defined by the U.S. Environmental Protection Agency (EPA). EPA has set "Lifetime Health Advisory Levels" (LHALs) (concentrations in drinking water) for many chemicals. EPA estimates these levels from available human and experimental animal data. LHALs are considered tentative and are updated as new information becomes available. LHALs vary widely. Generally chemicals with high oral toxicity have lower LHAL values. Because chemicals are highly toxic does not necessarily indicate that they will create hazards to 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. 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 in 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 relatively 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 Lihl Ueh golf course to which pesticides might be applied totals only 50 acres (4 acres of greens, 46 acres of fairways and 36 acres of maintained rough). The total chemical application to acres 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 surface 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, 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 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-lives 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 Lihl Ueh site the warm soil temperatures and favorable soil moisture and oxygen status which will be provided by surfgrass 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 tendency 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 sediments in runoff. A pesticide which is highly sorbed to soil particles may move in the sediment if heavy rainfall creates erosion. The likelihood of this occurring 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.†

<table>
<thead>
<tr>
<th>Pesticide common name</th>
<th>Representative trade name</th>
<th>Solubility in water (ppm)</th>
<th>Half-life in soil (days)</th>
<th>Soil Sorption Index (Koc)</th>
<th>Surface loss potential</th>
<th>Leaching loss potential</th>
<th>Toxicity to fish &amp; wildlife</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetamiprid</td>
<td>Omena Surf, Tree and Ornamental spray</td>
<td>650,000</td>
<td>3</td>
<td>100</td>
<td>small</td>
<td>small</td>
<td>-</td>
</tr>
<tr>
<td>carbaryl</td>
<td>Sevin 80</td>
<td>40</td>
<td>7</td>
<td>229</td>
<td>medium</td>
<td>small</td>
<td>moderate</td>
</tr>
<tr>
<td>chlorothalonin</td>
<td>Sylo 60</td>
<td>154,000</td>
<td>27</td>
<td>7</td>
<td>small</td>
<td>large</td>
<td>moderately</td>
</tr>
<tr>
<td>clorpyrifos</td>
<td>Durban 50W</td>
<td>0.005</td>
<td>50 E*</td>
<td>1,000,000 E*</td>
<td>large</td>
<td>small</td>
<td>-</td>
</tr>
<tr>
<td>dicofol</td>
<td>Turan</td>
<td>40</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>isofluprel</td>
<td>Ortho 2</td>
<td>24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>mecoprop</td>
<td>Lanate</td>
<td>57,000</td>
<td>8</td>
<td>28 E*</td>
<td>small</td>
<td>medium</td>
<td>-</td>
</tr>
<tr>
<td>benomyl</td>
<td>Tersan 911</td>
<td>2</td>
<td>100</td>
<td>2,100</td>
<td>small</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>chlorfluazone</td>
<td>Duxall 2787</td>
<td>0.6</td>
<td>20</td>
<td>1,280</td>
<td>large</td>
<td>small</td>
<td>low (bird)</td>
</tr>
<tr>
<td>monocrotox</td>
<td>Dithane M-45</td>
<td>0.5</td>
<td>35</td>
<td>1,000 G**</td>
<td>large</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>azinphos</td>
<td>Dyneox 4</td>
<td>10 G+</td>
<td>1</td>
<td>3,000</td>
<td>small</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>iprodione</td>
<td>Chlоро 26091</td>
<td>13</td>
<td>20 G**</td>
<td>500 E*</td>
<td>large</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>etalidox</td>
<td>Tercane 33</td>
<td>50</td>
<td>20 G**</td>
<td>10,000 E*</td>
<td>large</td>
<td>small</td>
<td>-</td>
</tr>
<tr>
<td>cupric hydroxide</td>
<td>Blue Shield</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>malathion</td>
<td>Subside 2E</td>
<td>7,100</td>
<td>7</td>
<td>16</td>
<td>small</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>methidrin</td>
<td>Bayclon 25</td>
<td>260</td>
<td>21</td>
<td>273</td>
<td>medium</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>pyrazolate</td>
<td>Kerb 50W</td>
<td>15</td>
<td>30</td>
<td>990</td>
<td>small</td>
<td>small</td>
<td>low (fish)</td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup</td>
<td>1,000,000</td>
<td>30</td>
<td>10,000 E*</td>
<td>large</td>
<td>small</td>
<td>low (bird)</td>
</tr>
<tr>
<td>simazine</td>
<td>Princep 40W</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>imazapicin</td>
<td>Derris 40X</td>
<td>3.5</td>
<td>75</td>
<td>138</td>
<td>medium</td>
<td>large</td>
<td>low</td>
</tr>
<tr>
<td>metribuzin</td>
<td>Lexan DP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>dinofos</td>
<td>Barvel</td>
<td>800,000</td>
<td>14</td>
<td>2</td>
<td>small</td>
<td>large</td>
<td>low</td>
</tr>
</tbody>
</table>

Continued on next page

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Table, continued:

<table>
<thead>
<tr>
<th>Pesticide common name</th>
<th>Trade name</th>
<th>Solubility in water (ppm)</th>
<th>Half-life in soil (days)</th>
<th>Soil Sorption Index (Koc)</th>
<th>Surface loss potential</th>
<th>Leaching loss potential</th>
<th>Toxicity to fish &amp; wildlife</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSMA</td>
<td>Derris MSMA, Weed Hoe, Crop Spray MSMA, Dal-E-Rad 120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2,4-D (amine)</td>
<td>Dimec 40G Weed Killer, Weed 64</td>
<td>1,000,000</td>
<td>100</td>
<td>10,000 E*</td>
<td>large</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>2,4-D (amine)</td>
<td>Crop Amine, Weedone 530</td>
<td>300,000</td>
<td>10</td>
<td>109</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
</tr>
</tbody>
</table>

** E = Estimated value, probable error is 2X to 3X for half-life, 2X to 5X for solubility and Koc (Wasmuth, 1988).
†† G = Guess value, probable error is 5X for Half-life, 1 to 2 orders of magnitude for solubility and Koc (Wasmuth, 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 preparer 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, Wart (1980), Tahir (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 condition 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 equipment include solutions, emulsifiable concentrates, soluble powders, wettable powders, flowable powders and dispersible 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 wastewater when cleaning tanks.

The capacity of tanks must be known in order to add the correct amounts 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 emulsifiable 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 run 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 performance. 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 deliver up to 600 psi pressure and deliver up to 25 gpm. Diaphragm pumps are excellent 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 susceptible to wear. Rollers for the roller pump are replaceable, thus pumps are also used. Rollers for the roller pump are replaceable.

Sprayers:

These types of sprayers are commonly used on agricultural sprayers. Sprayer 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 sprayer. Coarse basket strainers should be used in the tank filter 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 coarser than the diameter of the suction line. A second line strainer (usually 50 mesh) should always be used on the pressure side of the pump to protect the nozzle. 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, boom and nozzles are used to distribute the spray. Select hoses and boom 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.

Nozzle strainers must be air tight, noncollapsible, relatively short, and as large as the pump intake. If it is difficult to maintain pump 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 minimum 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. Drill 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 are not the best. Worn nozzles distort the spray pattern and result in improper application 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 negligible compared to the cost of pesticides. Spraying 50 acres of farmland 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 removed 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 pattern. Depending on the nozzle type, the pattern may be overcasted 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 "antisidip" nozzles may require an increase in pressure. "Low pressure" (LP) flat-fan nozzles are available. This type of nozzle develops distribution and spray pattern at pressures from 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 each other, overlapping spray from 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 bellow tube (usually PVC or other plastic material) fitted with a herbicide solution and a series of short ropes or a wanut 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 added to the herbicide solution to reduce dripping. These applicators may be either manual or small hand operated units. They are most effective for controlling weeds which have a slower growth habit than the turf. Control of weeds is possible to 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 of 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. Gravity 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 pulled 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 applicator consists 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 spread 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, DDN, chemical manufacturer's representative or other sources on methods of application.

Spray monitors:

Perhaps the simplest and most foolproof 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 microcomputer 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 (Nordick, 1982).

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 following 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.

<table>
<thead>
<tr>
<th>Nozzle spacing (inches)</th>
<th>Calibration distance (feet)</th>
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<td>40</td>
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</tr>
<tr>
<td>10</td>
<td>408</td>
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</table>

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 distance 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 consistently 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 formula 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 = 
Swath width (feet) X linear distance in test run
43,560 (number of sq. ft. in an acre)

B. Application rate (pounds/acre) = Pounds used in test run
Area (acres) in test run
APPENDIX A

SELECTED PESTICIDE LABELS

1. FUNGICIDES
2. HERBICIDES
3. INSECTICIDES

(AVAILABLE UPON REQUEST)
SELECTED REFERENCES

TURFGRASS MANAGEMENT:
Cohen, Stuart Z., Susan Nickerson, Robert Masey, Ashley Dupay, Jr. and Joseph A. Serafia. 1990. A ground water monitoring study for pesticides and nitrates associated with golf courses on Cape Cod. GWWR 79: 160-172.

ENTOMOLOGY:


PLANT PATHOLOGY:


WEED SCIENCE:


BIOGRAFICAL SKETCH

Oliver V. Hultman

Oliver V. Hultman 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. Hultman'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 conducts these efforts in his retirement. He serves as an Advisor to the Board of Directors, Hawaii Turfgrass Association and assists them with the conduct of their educational programs. He has served as a consultant to turfgrass growers on numerous occasions.

BIOGRAFICAL SKETCH

Charles L. Murdoch

Charles L. Murdoch was born in Ashland, Arkansas, in 1932. He completed his B.S. in Agriculture (1953) and M.S. (1955) in Agronomy at the University of Arkansas and Ph. D. (1966) in Agronomy at the University of Illinois. In 1968 he joined the Agronomy Department, University of Arkansas as a Research Associate in Agronomy and position he held until 1970 when he joined the University of Hawaii at Manoa in 1970 as Assistant Professor of Horticulture and Turfgrass Specialist. In 1974 he was made Associate Professor and Associate Specialist, and in 1979, he was named Professor of Horticulture and Turfgrass Specialist, position he currently holds. He has also served as Chairman of the Horticulture Graduate Faculty from 1986 to 1990. 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 addition, he has taught courses in Principles of Horticulture and Turfgrass Management; he has served as major advisor of numerous M.S. and Ph.D. 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 recalled 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 AFB) and Guam (Anderson AFB).
BIOPGRAPHICAL 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 Assistante 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 and research fellow, Department of Vegetable Crops, Cornell University (1976-77); Senior Research Horticulturist, University of Hawaii (1980-81 and 1982-83); Vice President, Agricultural Loan Administration, Bank of Hawaii (1988-84); Acting Assistant Dean for Academic Affairs and 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, cattage, coffee, guava, macadamia, papaya, coconut, and soybean. He has conducted research on the biology of the development of new herbicide technology and its integration into 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.

BIOPGRAPHICAL 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. (1953) degrees in Entomology from Iowa State University. Upon completion of his MS degree he came to the University of Hawaii at Manoa as an Instructor and Asst. Entomologist. He advanced through the ranks to full professor and retired as Professor Emeritus in 1985. During his many years service with UH-M he taught General Entomology and conducted research and published papers and research on tropical economic entomology, specializing in termites, insects, and mites and insect 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 (15 years), 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 für Technische Zusammenarbeit (GTA) and the Consortium for International Crop Protection (CICP). He is also an advisor to the Board of Directors of the Hawaii Termiticide Association.
GLOSSARY OF TURFGRASS TERMS

ahletic -- Non-living substance, as one time may have been living.

application -- A mechanical process used to facilitate soil air/water relationships of the turf without degrading the integrity of the soil.

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.

ascervulus -- 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.

biostatic -- Living substances.

bight -- 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 dicotyledonous group (andelion, 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 killed 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.

collopling -- Leaves, stems and stolons cut off by mowing.

collar -- Area between the putting area and the apron.

colored -- Dye used to color turf.

colonging -- 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 winter. A member of the subfamily Pooidae.

coring -- Method of application 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.

dicouleleuse disease (daffodil) -- Botanical taxonomic group in which dicouleleous plants are placed. Having two couleles (seeding leaves). Leaves are generally broader than long. Leaf veins are reticulated rather than parallel.

disease -- Any damage to 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.

disinfectionization -- 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 intermittent.

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.

dust -- Suspension of one liquid in another, as distinguished from a solution where two panticles 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.

epidemology -- 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.

fertilizer — 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.

fumar burner — 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 filaments (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 stems.

graminicolous — Members of the grass family, Graminaceae.

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 incorporated.

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.

tapping, 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.

moss — See thatch.

monocotyledonae — Botanical group in which monocotyledons (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.

nonaesthetic — 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.

osmotic — 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 winters.

panicle — Many branched flower head with flowers at the end of each branch. Common in grass 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.

polling -- 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.

gerush -- Part of the golf course which borders the tee, fairway and greens. Usually mowed at a higher level and maintained less intensively than either 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 mycelium 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 fertilization in which a blade cuts through the turf intermittently, perpendicular to the surface.

sod -- Piece, 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.

sporangiate -- Process by which a fungus produces spores.

spot spraying -- Application of a pesticide to small areas. Constrained 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.

subsidization -- 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.

spraying -- 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 generally 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.

vertical cutting -- 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 Bambusoideae. 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 soil compaction 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
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 forms 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 to cleaning and rinsing.

Mixing and agitation of spray solutions is essential to assure 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 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

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Figure 1: Components of a typical spray system. [From Robert G. Conley and Wesley E. Yantis, 1974, Proceedings of the California Gold Coast Superintendents Institute, pp. 31-41.]
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.

Sprayers 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 with 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 nozzle in use; this will prevent excessive accumulation of the spray droplets. Pressures of 25 to 40 pounds per square inch (psi) are adequate for most materials and most 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 avoid 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 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 function of breaking up the spray stream into properly sized droplets for 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, ceramic, 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 spray is being used in a systematic schedule of nozzle tip replacement, maintenance is critical to correct spray pattern, 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 cause inadequate materials that might clog the nozzles and large abrasive materials that might clog the nozzles. As mentioned previously, nozzle screens should be 50 to 100 mesh, with 20 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 nozzle, 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 as 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 pests. 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 principles 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 spraying 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**

<table>
<thead>
<tr>
<th>Nozzle tip number</th>
<th>Spray pressure 20 psi</th>
<th>Spray pressure 40 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>8002</td>
<td>71°</td>
<td>62°</td>
</tr>
<tr>
<td>8008</td>
<td>72°</td>
<td>63°</td>
</tr>
<tr>
<td>9506</td>
<td>90°</td>
<td>93°</td>
</tr>
<tr>
<td>9506</td>
<td>94°</td>
<td>65°</td>
</tr>
</tbody>
</table>


Table 2. Spray delivery rate of flat-fan spray tips at 20, 30, and 40 psi

<table>
<thead>
<tr>
<th>Nozzle tip</th>
<th>Spray pressure 20 psi</th>
<th>Spray pressure 30 psi</th>
<th>Spray pressure 40 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>nozzle delivery rate (gal/min)</td>
<td>nozzle delivery rate (gal/min)</td>
<td>nozzle delivery rate (gal/min)</td>
</tr>
<tr>
<td>8005</td>
<td>0.35</td>
<td>0.43</td>
<td>0.50</td>
</tr>
<tr>
<td>8006</td>
<td>0.56</td>
<td>0.69</td>
<td>0.80</td>
</tr>
<tr>
<td>9506</td>
<td>0.42</td>
<td>0.52</td>
<td>0.60</td>
</tr>
<tr>
<td>6506</td>
<td>0.42</td>
<td>0.52</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Figure 1. Effect of boom height on spray pattern. Distance are 30° angle flat-fan type spaced 18 inches apart on the boom.

**Figure 2.** Effect of boom height on spray pattern. Distance are 30° 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 80 miles per hour = 48 feet in one second, 80 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 formula:

1. Acres covered in one hour by one nozzle = (GS + S20° + NS)/43,560

Where:
- GS = ground speed in mph
- S20° = feet in one mile
- NS = nozzle spacing in feet

2. Spray rate 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 8006 nozzles spaced 18 inches (1.5 feet) apart, at 40 psi, the spray rate is:

1. (3 mph + 520° + 1.5 ft)/43,560 = 0.55 gal/acre

2. (0.4 GPM × 60)/0.55 gal/acre = 43.6 gal/acre

Table 3 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 (granular 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:

\[ W_s = \frac{R × V}{GPA} \]

Where:
- \( W_s \) = 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

(\( W_s \) 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 3100/40 = 0.55 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 150 gal of spray solution to apply at the rate of 2 pounds formulated material per acre, the spray rate is 40 gallons per
### Table 3. Relationship between nozzle spacing, nozzle spray angle, and nozzle height

<table>
<thead>
<tr>
<th>Nozzle spacing (inches)</th>
<th>Nozzle spray angle</th>
<th>60°</th>
<th>80°</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>13</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>13</td>
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<td>18</td>
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<td>20</td>
<td>21</td>
<td>16</td>
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<tr>
<td>24</td>
<td>25</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>


### Table 4. Speed required to travel 80 linear feet in different lengths of time

<table>
<thead>
<tr>
<th>Time elapsed (seconds)</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>24</td>
<td>2.5</td>
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<tr>
<td>20</td>
<td>3.0</td>
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<td>17</td>
<td>3.5</td>
</tr>
<tr>
<td>15</td>
<td>4.0</td>
</tr>
<tr>
<td>12</td>
<td>5.0</td>
</tr>
</tbody>
</table>

### Table 5. Relationship between ground speed, nozzle discharge rate, and spray rate in gallons per acre for nozzles spaced 10 inches (1.5 feet) apart

<table>
<thead>
<tr>
<th>Nozzle discharge (gal/min)</th>
<th>Ground speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spray rate (gal/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
</tr>
<tr>
<td>0.3</td>
</tr>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>0.6</td>
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<td>0.7</td>
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<tr>
<td>0.8</td>
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</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.6</td>
</tr>
</tbody>
</table>

For other nozzle spacings, spray rate * 10 = correct spray rate.
Table 6. Amount of dry formulation pesticide to use per gallon of spray solution when spraying at different rates

<table>
<thead>
<tr>
<th>Desired rate (lb formulation/acre)</th>
<th>Spray rate (gal/acre)</th>
<th>40</th>
<th>60</th>
<th>60</th>
<th>70</th>
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<tr>
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<td>1.0</td>
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<td>0.7</td>
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</tr>
<tr>
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<td>1.6</td>
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<td>1.1</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
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<td>2.0</td>
<td>1.6</td>
<td>1.3</td>
<td>1.1</td>
<td></td>
</tr>
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<tr>
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<td>4.0</td>
<td>3.2</td>
<td>2.7</td>
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</tbody>
</table>

For example, if you wish to mix 75 gallons of spray solution at 40 ppm to be sprayed at 32 ounces per acre, the desired rate is 32/32 = 1.0 lb formulation per acre, and the spray rate is 75 gallons per acre, then 1.0 lb formulation/acre = 150 gallons of spray solution = 120 fluid ounces or 2.0 gallons per gallon of spray solution = 120 fluid ounces of pesticide per gallon. Volume of spray = gpa

For example, if you wish to mix 150 gallons of spray solution to apply at the rate of 3 pt formulation material per acre, and the spray rate is 0.05 gallons per acre, then 150 gallons of spray solution = 1.0 fluid ounces per gallon of spray solution = 100 fluid ounces (or 1 gallon, 1 quart, and 5 fluid ounces).

Conversion Factors for Mixing Pesticides

- **Liquid measure:**
  - 1 teaspoon = 1/3 fluid ounce
  - 2 teaspoons = 1 fluid ounce
  - 16 tablespoons = 1 pint
  - 2 cups = 1/2 pint
  - 1 gallon = 8 fluid ounces
  - 1 gallon = 8 pints

- **Linear distance:**
  - 1 mile = 5280 feet

- **Area:**
  - 1 acre = 43,560 square feet

- **Speed:**
  - 1 mph = 5280 feet/minute
  - 60 mph = 88 feet/second

Table 7. Amount of liquid formulation pesticide to use per gallon of spray solution when spraying at different rates

<table>
<thead>
<tr>
<th>Desired rate (fl oz formulation/gal spray solution)</th>
<th>Spray rate (gal/acre)</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 (1 pt)</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>32 (2 pt)</td>
<td>0.8</td>
<td>0.6</td>
<td>0.8</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>48 (3 pt)</td>
<td>1.2</td>
<td>1.0</td>
<td>1.1</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>64 (4 pt)</td>
<td>1.6</td>
<td>1.3</td>
<td>1.3</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>80 (5 pt)</td>
<td>2.0</td>
<td>1.6</td>
<td>1.6</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>96 (6 pt)</td>
<td>2.4</td>
<td>1.9</td>
<td>1.9</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>128 (8 pt)</td>
<td>3.2</td>
<td>2.6</td>
<td>2.4</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

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 32/32 = 1.0 lb formulation/acre = 150 gallons of spray solution = 120 fluid ounces of formulation per gallon of mixure. To calculate the amount of liquid formulation to add to the spray tank, use the following formula:

\[ V = \frac{R}{GPA} \]

Where:
- \( V \) = fluid ounces of material for spray tank
- \( R \) = desired rate in fluid ounces of pesticide per acre
- \( GPA \) = spray rate in gallons/acre

For example, if you wish to mix 150 gallons of spray solution to apply at the rate of 3 pt formulation material per acre, and the spray rate is 0.05 gallons per acre, then 150 gallons of spray solution = 1.0 fluid ounces per gallon of spray solution = 120 fluid ounces (or 1 gallon, 1 quart, and 5 fluid ounces).
THE AUTHOR

C. L. Murdoch is a professor of horticulture, College of Tropical Agriculture and Human Resources, University of Hawaii.

ACKNOWLEDGMENT

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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
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 nozzle and to reduce wear on the pump. All materials poured into the tank should be screened with a screen (10 to 20 mesh) before 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 fine mesh screen the pump and the solid core. For broadcast pesticide application, the flat-fin 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 and vibration, and cost. Consult your sprayer equipment supplier for specifications of various nozzle types.

The Pressure Gauge
A pressure gauge is essential to control the pressure at which the nozzle is being applied. Calibration methods covered later in this publication depend on the operator's knowledge of the spray pressure. The pressure gauge should be set at one-half the maximum possible in the boom to prevent rupture of the nozzle. 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 match the liquid from several nozzles (or even each nozzle) 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 the spray solution. The by-pass line should not be considered sufficient for agitation of wettability powders, however. If the spray tank does not have mechanical agitation, it should have a separate line with fine holes in it from the pressure side of the tank (before the pressure regulator valve), extending into the tank to provide movement of the liquid.

Spray Nozzles
Spray nozzles are the most important part of the spray gun. 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. These 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.

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 be added to the spray tank is essential for proper use of pesticides. Too little pesticide will fail to control the pest, too much 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 principles of information are needed. The following discussion of the principles of sprayer calibration and the formulas, tables, and figures presented 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 8001 nozzle produces a spray pattern of 60 psi and delivers 0.2 gallons per minute.

Table 1 and 2 illustrate the effect of spray pressure 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>
<thead>
<tr>
<th>Nozzle tip number</th>
<th>Spray pressure</th>
<th>Spray angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 psi</td>
<td>40 psi</td>
</tr>
<tr>
<td>8005</td>
<td>70°</td>
<td>60°</td>
</tr>
<tr>
<td>8008</td>
<td>70°</td>
<td>60°</td>
</tr>
<tr>
<td>9506</td>
<td>60°</td>
<td>50°</td>
</tr>
<tr>
<td>6506</td>
<td>55°</td>
<td>65°</td>
</tr>
</tbody>
</table>

Table 1. Spray angle of flat-fan spray tips at 20 and 40 psi.
Table 2. Spray delivery rate of flat-fan spray tips at 20, 30, and 40 psi

<table>
<thead>
<tr>
<th>Nozzle tip number</th>
<th>Spray pressure (psi)</th>
<th>Nozzle delivery rate (gal/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 psi</td>
<td>30 psi</td>
</tr>
<tr>
<td>8005</td>
<td>0.35</td>
<td>0.43</td>
</tr>
<tr>
<td>9008</td>
<td>0.56</td>
<td>0.69</td>
</tr>
<tr>
<td>9506</td>
<td>0.42</td>
<td>0.52</td>
</tr>
<tr>
<td>6506</td>
<td>0.42</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Neelz stroke. 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 gate 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, 88 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.

Determine 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

For example, you wish to mix 100 gallons of sprayer 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 5 explains how much powder to use per gallon of solution when spraying at different rates. For example, if you wish to mix 50 gallons of sprayer solution to apply at the rate of 2 pounds formulated material per acre, and the sprayer rate is 40 gallons per acre.
Table 3. Relationship between nozzle spacing, nozzle spray angle, and nozzle height

<table>
<thead>
<tr>
<th>Nozzle spacing (inches)</th>
<th>60°</th>
<th>80°</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>


Table 4. Speed required to travel 80 linear feet in different lengths of time

<table>
<thead>
<tr>
<th>Time elapsed (seconds)</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>24</td>
<td>2.5</td>
</tr>
<tr>
<td>20</td>
<td>3.0</td>
</tr>
<tr>
<td>17</td>
<td>3.5</td>
</tr>
<tr>
<td>15</td>
<td>4.0</td>
</tr>
<tr>
<td>12</td>
<td>5.0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nozzle discharge (gal/min)</th>
<th>Ground speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spray rate (gal/acre)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>33.0 26.4 22.0 18.9 16.5 14.7 13.2</td>
</tr>
<tr>
<td>0.3</td>
<td>49.5 39.6 33.0 28.3 24.0 22.0 19.8</td>
</tr>
<tr>
<td>0.4</td>
<td>66.0 57.8 44.0 37.7 33.0 29.3 26.4</td>
</tr>
<tr>
<td>0.5</td>
<td>82.5 66.0 55.0 47.1 41.1 36.7 33.0</td>
</tr>
<tr>
<td>0.6</td>
<td>99.0 79.2 66.0 55.6 49.5 44.0 39.6</td>
</tr>
<tr>
<td>0.7</td>
<td>115.5 92.4 77.0 65.0 57.0 51.3 46.2</td>
</tr>
<tr>
<td>0.8</td>
<td>132.0 105.6 80.0 67.4 60.0 53.4 46.2</td>
</tr>
<tr>
<td>0.9</td>
<td>148.5 118.8 90.0 74.9 66.0 59.4</td>
</tr>
<tr>
<td>1.0</td>
<td>165.0 132.0 110.0 94.3 82.5 73.3 66.0</td>
</tr>
<tr>
<td>1.1</td>
<td>181.5 145.2 121.0 102.7 90.0 80.7 72.6</td>
</tr>
<tr>
<td>1.2</td>
<td>198.0 159.4 132.0 113.1 99.0 88.0 79.2</td>
</tr>
<tr>
<td>1.3</td>
<td>214.5 171.6 143.0 122.6 107.3 95.3 85.8</td>
</tr>
<tr>
<td>1.4</td>
<td>231.0 184.8 154.0 132.0 115.5 102.7 92.4</td>
</tr>
<tr>
<td>1.5</td>
<td>247.5 198.0 165.0 141.4 123.0 110.0 99.0</td>
</tr>
<tr>
<td>1.6</td>
<td>264.0 211.1 176.0 150.9 132.0 117.3 105.6</td>
</tr>
</tbody>
</table>

a For other nozzle spacings, spray rate x 18 = correct spray rate, nozzle spacing.
Table 6. Amount of dry formulation pesticide to use per gallon of spray solution when spraying at different rates

<table>
<thead>
<tr>
<th>Desired rate (lb formulation/acre)</th>
<th>Spray rate (gal/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>2.4</td>
</tr>
<tr>
<td>7</td>
<td>2.8</td>
</tr>
<tr>
<td>8</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>3.6</td>
</tr>
<tr>
<td>10</td>
<td>4.0</td>
</tr>
</tbody>
</table>

For example, if you wish to mix 75 gallons of a spray mixture to be sprayed at 32 ounces per acre, and the pesticide is a liquid formulation, and the spray rate is 50 gallons per acre, then 32/75 gallons/50 gallons per acre = 0.32 ounces (or 3 pint) 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 = 6, 500 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

<table>
<thead>
<tr>
<th>Desired rate (fl or formulation/gal spray solution)</th>
<th>Spray rate (gal/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 (1 pt)</td>
<td>0.4</td>
</tr>
<tr>
<td>32 (1 pt)</td>
<td>0.8</td>
</tr>
<tr>
<td>48 (3 pt)</td>
<td>1.2</td>
</tr>
<tr>
<td>64 (4 pt)</td>
<td>1.6</td>
</tr>
<tr>
<td>80 (5 pt)</td>
<td>2.0</td>
</tr>
<tr>
<td>96 (6 pt)</td>
<td>2.4</td>
</tr>
<tr>
<td>120 (7 pt)</td>
<td>2.8</td>
</tr>
<tr>
<td>128 (8 pt)</td>
<td>3.2</td>
</tr>
</tbody>
</table>

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
1 acre = 43,560 square feet
1 mile = 5280 feet
1 mph = 88 feet/minute
10 mph = 88 feet/second

1 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:

\[ FL = \left( \frac{V \times R}{GPA} \right) \]

Where:
- \( FL \) = fluid ounces of material for spray tank
- \( V \) = volume of spray in gallons
- \( R \) = desired rate in fluid ounces of pesticide per acre
- \( GPA \) = spray rate in gal/acre
In the project site, located on the north shore of Oahu in the Koolau District, consists of two large plateaus separated by a large gully and bordered on either side by large gulches. The elevational range is approximately 20 feet near Kaukoheka Bay to nearly 850 feet in the uplands behind the plateau region. The vegetation of the region has been characterized by Higginson and Bonkou (1941) as Xerophytic Shrub (Zone A) along the coast, Mixed Open Forest and Shrub in mesic portions of the uplands (Zone B, Low Phase) and Shrubs and Cloud Forest in wet portions of the uplands (Zone B, Low Phase). The natural vegetation in the Xerophytic Shrub Zone consists of Lantana (Lantana camara), koa-basole (Hymenaea courbaril), lii (Ananas comosus), cactus (Opuntia megacanthos), and 'i'llil (Ficus sellowii). Above this in the Mixed Open Forest and Shrub Zone, koa-basole and lii are still dominant but koa (Acacia koa) and various grasses become increasingly important. In mesic areas of the uplands (Zone B, Low Phase) koa becomes the dominant shrub. Species characteristic of this zone include sensitive plant (Mimosa pudica var. sensitiva), Mili grass (Paspalum conjugatum), seregrass (P. subulatum) and haukekgrea (Pogonopogon hirticulus). According to their surveys, pasturing in the rangeland areas and in the low phases of zones C and D.

Aerial photographs taken in 1960 reveal that eighteen years ago pasture dominated much of the project site. These were recutected on the plateaus but also could be found along the gully slopes. Shrubs, probably Christmas berry (Hibiscus forsteri) and strawberry guava (Psidium cattleianum) or guava (Psidium guajava), were generally confined to the gully floors and trees which are easily identified as ironwood (Casuarina equisetifolia) was found along the top of the cliffs on the mala'ek edge of the plateau and in the upper elevations. Large groves of ironwood formed a broad band across the center of the eastern plateau.

**INTRODUCTION**

**METHODS**

In December 1967, walk-through and 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 (12/67) 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. globulus, E. sp.), grasslands, herblands, and weedy bushlands. 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 vegetation class 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**

The most prevalent vegetation type in the site is the Casuarina Forest which is dominated by ironwood trees 20 to 30 feet tall. Typically the trees provide 100% canopy cover; the shrubs and herb layers are almost non-existent due to the deep shade and the thick accumulation of litter (i.e., the "lecake"). Shrub-basole (Raphidophyllum subcoccum) and the native hebe (Cassidina ferndiannum) are among the very few species to be found in this shady situation.
In several areas, strawberry guava forms a dense secondary canopy. Individually and groves of swamp mahogany (Eucalyptus robusta) too small to warrant mapping are scattered throughout the Cauanira Forest.

Erosional scars and other exposed sites are found in this community type. In these areas such common woody species as sensitive plant, three-flowered beggarweed (Eucalyptus trifida), Spanish clover (G. rumonia), Jamaica vervain (StachysTeenana), tallow grass (Dierichia squar) and Stylidium fruticosum 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 Cauanira 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, bushy, is common throughout the forest. 'Akia (Wittia aspera) and 'akia (Strypholos novaezelandiae) were recorded as "occasional" throughout this community type and 'Ilim (Cynodon echinatus) and 'kalua (Valeria americana) were also "occasional" but only in sunny sites. More than 22 others were recorded as "uncommon" or "rare".

**Eucalyptus Forest (EF)*

Several large groves of swamp mahogany, a smaller grove of an unidentified species (Eucalyptus sp.) and a single extensive grove of ironwood (E. camaldulensis) are found in the project site. Typically this forest consists of planted eucalyptus trees 60 to 100 feet tall with a canopy cover of 75-100%. In some areas the sparse understory consists of occasional houston's curse (Cithara spira), Lantana, Chinese cherry, hibiscus-hibiscus and the native 'akia; in other areas strawberry guava or Christmas berry form a dense understory 10 to 15 feet tall. Small oak (Quercus robur) and ironwood are widely scattered throughout the forest. Several native species are also associated with the Eucalyptus Forest but with the exception of hibiscus and others they were all considered "rare".

**Valeria herbland (VH)**

A characteristic portion of the plateau area presently being utilized as pasture consists of Valeria herbland dominated by the Indigenous 'halaus. Typically, 'halaus provide 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 woody herbaceous species as sensitive plant, tallow grass, an unidentified _Decalepis_, perennial forseti (Decalepis semidec). pattiee pea (Gaussia postermeriditana) and _Stilidium_.

Small groves and individuals of ironwood, strawberry guava, guava, Christmas berry, will oak and Java plum (Eugenia candicans) are also found in this community. In addition to the ubiquitous 'halaus the only other native species recorded in this community was 'ilet. Unconscious in its absence is the native "ilia" which is commonly found in similar habitats elsewhere.

Intensively grazed areas are characterized by a larger grass component consisting largely of golden beargrass (_Chrysocephalum scoparium_), West Indian dropseed (_Cyperus scoparius_) and Milo grass. Three-flowered beggarweed is also common in such areas.

**Grassland (G)**

Grassland communities are found on the plateaux often adjacent to the Valeria herbland communities and on the upper slopes of gulches. These are characterized by brownrigg (Elytrochloa viridiflora) or tallow grass, with emergent individuals of small groves of ironwood, strawberry guava, Java plum and ironwood in low (Brachysod sp.) Common in the Grasslands are such herbaceous species as Jamaica vervain, pattiee pea, Spanish clover, and Asiatic pomegranate (_Punica granatum_). The native weed fern (_Hydropila malata_) is also common. Several other native species including pala's (_Gonostegia chrysanthemum_).
alahe'a (Cassia longifolia), 'aloha, 'lumbee, 'gila and 'aloha are also found but in small numbers. Most of the Gramineae 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 kakea'a (Digitaria ischaemum), paraginos (Brachiaria mutica), personal forseti and golden broomchips.

Whether they are being actively grazed today or not, the Grassland community on the plateaus together with the Callitris forest are remnants of former pasture lands. They are being invaded by strawberry guava and ironwood and even have been reduced in size by more than 50%. On the other hand, Grassland communities on the Kula 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 Schima Brush community below.

**Pipturus ciliatus.** (PCA)

This community type is found on the floor and lower slopes of the plateaus, 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 kakea'a. Dominance of these two aggressive species is so complete that they often form nearly pure stands. The upper canopy tree component consists largely of ladurb (Combretum obcordatum), ironwood, ma'ama and hinau red gum.

Numerous species are associated with this community type but only 10 or so are common and on the middle slopes in what might be considered a transitional zone with the Cauamarina Forest, and also on somewhat exposed sites on the gulch floor these species are found in significant numbers. On additional species and on the middle slopes such common native species as 'aloha, 'aloha

Ovisanthus collina, sato, po'opoe, cauaua (Lavina po'te'gawae), 'aloha (Heteromeles arbutifolia), pali'a, 'gila, and 'aloha 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 floor are occupied by common woody species such as lama'elua, Astilbe pensyseus, partridge pea, Spindal clover, sensitive plant, hinau grass, and aegrotum (Aegrotum compactum).

**Schima Brush.** (SS)

The middle and lower reaches of the major gulches, the lower slopes of the seaward cliffs and east of the small ravines are dominated by Schima Brush. This vegetation type is characterized by dense stands of Christmas berry 10 to 20 feet tall with occasional emergent Farnhamia kaa, 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 the irionwood is dominant in the understory.

The Schima 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, lama'elua and kakea'a become common. Associated with these moist sites are also partridge pea, personal forseti, Astilbe pensyseus and hinau. Where it extends up the ravine slopes the plants become shrubbed and more widely spaced. Numerous other species are found in these upper slope habitats, most notably Astragalus, partridge pea, broomedge and melastomates (Melastoma malabathricum). Species diversity is rather low in this vegetation type due in part to the varied ecological habitats within it occupies but most of the species are found in low numbers.

**Pipturus ciliatus.** (PCA)

This community type is only found in the moist, upper half of the gulch which constitutes the south boundary of the project site. The Cauamarina Forest which
dominates the slopes in this region extends down to the gulch floor. Consequently, the Pseudalpinia Salix Association is confined to the very floor of the gulch. This community type is characterized by dense stands of strawberry guava 13 to 25 feet tall with occasional emergent ironwood, silk oak and row apple (Ficus montana). 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, Jamaican vervain, hilo grass, Anistia pennisetum and cash lepiot (Lepia petiolata).

It appears that portions of the gulch were cultivated in the past. Several very large mango (Manilkara hubcepta), avocado (Persea americana) and breadfruit (Artocarpus altilis) trees are found in the upper reaches of the gulch. Coffee (Coffee arabica) has become naturalized in one section and several banana plants (Musa spp. uniplanta) 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 (1901)

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 graminea and Mammillaria urvel. Also included are small heterogeneous communities with no expression of species dominance. These communities contain numerous weedy species such as 'ahinaha, Anistia pennisetum, guava, koate'a cutanea, malacang, kowai, moro jo, kiheia, stylosanthes, and buttressed Anisotome (Anisotome hypogala). It is the smallest of all the community types found in the project site.

Maunohi Forestland (19)

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-cupped kiona (Pipturus mollis) forest line Kamehameha Highway. Included are several heterogeneous community of weedy species such as guinea grass (Eleusine indica), bellows (Cassia leptophylla), broom bells (Hapalocarpus bulbosus), grass, sensitive plant and partridge pea, also an intensively grazed pasture consisting of short-cropped grasses such as kipuapua'a and hilo grass, a thicket of rose-bush, a weedy pasture of guinea grass, Jamaican vervain, Indian pluchea (Pluchea indica), pluchea (P. minuta) and kio (Anemone spongiosa), and a small forest of casse rubber (Hevea brasiliensis). Savannah (Panicum capillare) is common throughout this vegetation type.

Nalulu Rarapu and Rarapu 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 Pseudalpinia Salix Gulch Association, small numbers of 'okalea, terepi, ulu, palu'a, and pluchea grow in close proximity to each other but these patches 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. 'Okalea and palu'a 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. 'Okalea and palu'a, also widespread throughout the project site, are generally restricted to shady, exposed sites especially on the upper slopes.

Several undesirable species (Pipturus mollis, Gomphocarpus physocarpus) are found on steep, sunny slopes, and six nene (Cassiope canorus) individuals were observed. Although
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 fertilized runoff which will stimulate new 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 those trees and thus insure their survival. Here active management of this unique resource may include monitoring for flowers and fruits and propagation experiments with a view toward 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.

Potential problems and mitigating measures

A portion of the field survey was conducted during a heavy rain during which a considerable amount of runoff was observed on the existing, eroded areas. This resulted in heavy ciff-side streams in many of the gullies and consequent 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 disturbed, steps should be taken to alleviate runoff and soil erosion.
LITERATURE CITED


SPECS Checklist

Plant families are arranged alphabetically in three groups - Pteridophyta, Gymnospermae and Angiospermae. The Angiospermae are subdivided into Monocotyledoneae and Dicotyledoneae. Genera and species are arranged alphabetically within each family. Taxonomy of the Pteridophyta follows that of Wagner's unpublished list and common names for the taxa are those which are commonly accepted. Taxonomy, common names and the status of the Gymnospermae and Angiospermae generally follow that of St. John (1972).

EXPLANATION OF SYMBOLS

Species Status:

1. = Native to the Hawaiian Islands, i.e. occurring naturally nowhere else in the world.
2. = Indigenous, i.e. native to the Hawaiian Islands but also occurring naturally elsewhere.
3. = Exotic (alien), i.e. plants introduced after the Western discovery of the Islands.
4. = Polynesian Introduction, plants introduced before the Western discovery of the Islands.
5. = Native, exotic or indigenous (the Pteridophyta only)
6. = Federal register status; official listing by U.S. Fish & Wildlife Service (if applicable)
7. = State protected status listing by Fedders & Herbst (1975) (if applicable)
## Check List of Plants

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**Vegetation Types:**
- LF: Coniferae Forest
- LST: Logalupus Forest
- GN: Gutteria Benfleum
- FGCA: Palmae-Glinia Glih Association
- SG: Selonia Stands
- SGA: Palmae Glih Association
- IGA: Illus Glih Association
- LWA: Lusloun 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.
- D: Occasional, generally distributed throughout a given area in small numbers.
- E: Uncommon, observed unusually but more than 10 times in a given area.
- R: Rare, observed 2-10 times in a given area.
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Phase I: Paumalu - Kealeiki 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 Kaneohe 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, Kealeiki Stream; to the south are Kaluauaika‘i Stream and Pakulena Stream.

Field studies to search for wetlands along the Paumalu and Kealeiki streams were conducted 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 Paumolu Stream consists of Christmas berry scrub (Schinus terebinthifolius), 10 to 20 ft. tall, with emergent Java plum trees (Eugenia sumun). Scattered trees and shrubs of Fornesian koa (Acacia confusa) and guava (Psidium guajava) are occasional along the streamside. Along the upper one-half of Paumolu Stream, Java plum and Fornesian 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 moist 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 such as grasses (Paspalum scutatum), basket grass (Pennisetum hirtellum), downy wood fern (Christella pseudopitys), and Java’s (Microseris scapotricia). Seedlings of Java plum are numerous. Barren, red clay hard-pans, rounded boulders, and piles of debris (branches and leaves) typify the streamside on this portion of the property. Also during heavy rains, the streamside are periodically swept clean of vegetation.

Along most of Kuleleiki Stream, the vegetation is a dense tangle of Christmas berry scrub. On its upper reaches, stands of strawberry guava (Psidium cattleyanum), 10 to 20 ft. tall, with an understory of Easter’s curse (Clidemia hirta) become the dominant components. Again ground cover along the streamside is sparse with bare soil, rocks, and litter characteristic.

**DISCUSSION**

The vegetation is typical of most lower elevation, disturbed stream areas in the Hawaiian Islands. Both Paumolu and Kuleleiki streams are dominated with Christmas berry, along with scattered plant of Java plum and guava, along most of their length. The upper portion of Kuleleiki 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 conditions 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 Paumolu and Kuleleiki 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.

**References**


Terrestrial Vertebrates of the Ohheyahi Project, Pupukea, Oahu

By Andrew J. Berger

This study was prepared on instructions received from Ralph Fortmore of Group 70, Honolulu, Hawaii. For our initial site visit, I met Mr. Fortmore 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 equisitifolia). Other introduced tree species are Christmas berry (Schinus terebinthifolius), 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.

1. Amphibians

   1. Giant Neotropical Toad (Bufo marinus). This toad was first introduced to the Hawaiian Islands 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 Nanos Valley (Oliver and Shaw, 1953:77). The toads were very successful, and “in a little over two years more than 100,000 descendants of the original stock were distributed through Dr. Pemberton’s activities throughout the islands.” Buncaker and Brees (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 1857” (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, 1933). By 1967, Hunsaker and Bresee 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 flushed 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 (*Leptodactylus jamabilis*), fox gecko (*Hemidactylus arnoldi*), and the metallic skink (*Lygosoma metallicum*). All are foreign to the islands, all are insect eaters, and all adapt well to both urban and rural areas (McKeown, 1976). 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 Papouka region.

A. Order Ciconiiformes

1. Family Ardeidae, herons and egrets

   1. Cattle Egret (*Bubulcus 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" (Bresee, 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 Hawai’i Audubon Society (Fyle, 1987); 306 egrets were reported in the Waipio valley 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 "precludes the intestine, produces undesirable toxins, and hinders breeding." Havahb Gojraz (1979) reported infection by bird malaria, Haemoproteus, and Leucocytozoon in birds at the Honolulu Zoo. Kishimoto and Baker (1969) reported finding the fungus Cryptosporus neoformans in 12 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; Bull (1965:458) 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 (Bryant, 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  

3. Barn Owl (Tyto alba leucotis). 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 (Tonich, 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, Ryd and Telfer (1980) reported that Barn Owls had killed more than 100 seabirds and their chicks on Kauai and Kaua'i Island.

No study of the spread of the Barn Owl from the Kaaula 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 Waianae 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 Ha-wai 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” (Cram, 1933). This babbler is found in both the Ko'olau 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 are often 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. jaccus) 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 Hanu imported Shamas in 1940 and released them in Nuuanu Valley “and at some houses in the 2400 block on Hakiki 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 Majiro, and Majiro 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 (*Opile ariharae*). This warbler, which is native to Japan and Formosa, was first released on Oahu in 1929 (Caum, 1933). The Japanese name is Ugusa. 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 Munia

11. Common Indian Myna (*Acridotheres cristatella*). 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 plagues of army worms that were 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 in abundance 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 (*Psittacus*, 1966:79; 1973:81-82). A number of species have established wild populations in the Kailua region and undoubtedly will spread from there.

12. Nutmeg Mannikin or Ricebird (*Lonchura punctulata*). 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 "eats 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 Zealand (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 1858) 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.


15. Red-crested Cardinal (Paroaria coronata). Although this species traditionally 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.

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 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 are "House Finch" caused a 50 to 50 percent loss in the sorghum fields at Kiluaea 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 Puakea region.  

17. Gallinaceous Birds (Order Galliformes, Family Phasianidae, Family Phasianidae). 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 Puakea area. These birds include the following: Red Jungle Fowl (Gallus gallus), Snaihoe Pheasant (Lophura swinhoii), Ring-necked Pheasant (Phasianus colchicus), Silver Pheasant (Lophura n. nycthemera), Chukar Partridge (Alectoris chukar), and the Common Quincefowl (Husmid melanocephala).  

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  
1. Black-crowned Night Heron (Nycticorax n. nycticorax).  
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 domy young of seabirds and probably the domy young of the endangered Hawaiian waterbirds. They also relish prawns and the State Land Board gave producers a 120-day permit to destroy black-crowned herons which have been causing economic havoc at Oahu's Kauhu 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.
Seabirds

1. White-tailed Tropicbird (*Phaethon lepturus dorotheae*)

This is the only one of the seabirds that needs to be mentioned because it does nest on the cliffs that bound Waima Valley. There appears to be no nesting habitat for this tropicbird in the Pupukea project area, however.

II. Migratory Species.

The most conspicuous of these is the Lesser Golden Plover (*Pluvialis dominica japonica*), 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.

II. Endemic Birds

These are birds that are restricted to the Hawaiian Islands; they are unique to the islands. At least 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 Waima Valley: Kokoa or Hawaiian Duck (*Alopochen moxillipes*), Hawaiian Gallinule or Aloa 'Ula (*Gallinula chloropus sandvicensis*), and Hawaii Coot or Aloa Ke'oke'o (*Fulica americana ahl*). There is, however, no suitable habitat for these waterbirds in the project area.

Pueo or Hawaiian Owl (*Aego chionops sandvicensis*).

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 et al. (1966) 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 Maui area and one bird along Palohua Road on December 22, 1986 (Breuer, 1987).

I did not see any Pueo during my field studies. However, one bird was found dead in Waima Valley several years ago.

The Mammals

I. Endemic Mammals

The only endemic land mammal in the Hawaiian Islands is the Hawaiian bat (*Lasiurus cinereus semotus*), a subspecies of the North American hoary bat. The Hawaiian bat occurs primarily on the islands of Kauai and Hawaii (Tomich, 1969);
Kramer, 1972; 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 surmicaudatus), 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 traps 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 Waihee Valley and probably occur in the upper stretches of the Papuakea 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.

I. Bryme (1907) 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 (1972) 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 Papuakea 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 *Alternanthera*. The Red-vented Bulbul and the Japanese White-eye cause considerable damage to ornamental flowers and to fruit crops (Kuffer, et al., 1976). The Barn Owl is known to eat birds and their young on Kauai and Kaua'i, 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, developments, 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 Papukea project area. In fact, if ponds are constructed in the golf courses, the heron might well adapt to them for feeding and nesting.

5. The Lesser Golden Plover now occupies the nonforested portion of the Papukea 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, Fukulena, and Kalunawaikaala, located in the Pupukea Paumalu area of Oahu's North Shore.

Introduction

A preliminary survey of four streams: Paumalu, Kaleleiki, Fukulena, 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 Fukulena 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 28 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 Pauwulu 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 Pauwulu Stream, Aiu Gulch and Kaleikehi Stream consisted primarily of mud with small pools of water. Kaleikehi Stream was completely dry from below Site J to where it joins Pauwulu Stream (and is nearly impassable due to thick vegetation).

The lower portion of Pakulea 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. Kalunaikaa 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 Pauwulu Stream and one (Site Q) on its tributary, Aiu Gulch. Goblets 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 Kaleikehi Stream, also a tributary to Pauwulu Stream. On Pakulea Stream five sampling sites were chosen. No samples were taken on Kalunaikaa Stream as there was insufficient water.

**Site D, Aiu Gulch.** This site is as far upstream as we were able to survey on Aiu 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, Pauwulu 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, Pauwulu 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, Pauwulu Stream.** Riparian cover at Site M was 75%. The substrate consisted mostly of mud with rocks, boulders, and roots interspersed. The width of the stream channel in this area was 2.7m and the water was 30cm deep. Amphipods and the introduced
Site P, Kaleoleih Stream. Site F is the uppermost point surveyed on Kaleoleih Stream. Riparian cover was 50% 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, Kaleoleih 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, Kaleoleih 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 J and Site J, Kaleoleih Stream. Below the jeep trail which crosses Kaleoleih Stream, flow is minimal. Water was primarily small isolated pools surrounded by mud. The introduced riparian Cyprinidae, *Gobiomorpha* 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 40 cm deep. Water flowed out of the pool and downstream in a trickle (30 cm wide, 2 cm deep). Organisms collected at this site included the introduced riparian Cyniidae Geotromus pyrurus, an endemic Valiidae (Microvelia vagans), an endemic Dytiscidae (Rhantus pacificus), the introduced mayfly Caenodes nigropunctatus, flatworms, and thalid 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 90 cm and depth was 10 cm. 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 Haleleiki Stream) included isopods, amphipods, caddis (Geotromus pyrurus), thalid 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. Kaluakoi 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 Suzuoto generously assisted in species identification.

Figure 1. Area covered during survey (indicated by bold). Dashed line is property boundary.
Figure 4. Location of post larval gobies. (Dashed line is property boundary.)

REFERENCES


Terrestrial Vertebrates of the Ohboyachi Project, Papuakua, 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 myself 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 Cocos ironwood (Cocos nucifera).

Other introduced tree species are Christmas tree (Schinus terebinthifolius), 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 Islands in 1932 when Dr. C. E. Pemberton brought 18 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 Hanaa Valley (Oliver and Shaw, 1953:77). The toads were very successful, and “in a little over two years more than 100,000 descendants of the original stock were distributed through Dr. Pemberton's activities throughout the islands.” Bannister and Brees (1967) wrote that Bufo marinus was the “commonest species of amphibians 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 species 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 1869” (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 (Pareas brasiliena). "This small,
secretive snake was apparently introduced from the Philippines
in the dirt surrounding plants that were brought in for land-
scaping 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 Bresee 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 flushed 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
(Acanthodactylus lepidus), fox gecko (Herpetotherium francisi),
and the metallic skink (Corucinae metallica). 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 Pukuea region.
A. Order Gruiformes

a. Family Ardeidae, herons and egrets

1. Cattle Egret (Bubulcus 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" (Bresee, 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
(Talbot et al., 1986); 986 egrets were reported on the Honolulu
Christmas count of the Hawaii Audubon Society (Pyle, 1987);
986 egrets were reported in the Waipio sector alone during the
same period (Bresee, 1959). 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 "reduces the intestine, produces undesirable toxins, and hinders breeding." Wavab Gojratii (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 (1965:468) 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 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 Papukoa 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 Kahoa. This dove is very common throughout the project area and the Papukoa 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 domestic*). The first Barn Owls were imported from California and released on Hawaii Island during April 1958. Barn Owls were released at Kaua‘i, 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 Kaua‘i during October 1959 (Yonich, 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, Eyre and Teller (1980) reported that Barn Owls had killed more than 100 seabirds and their chicks on Kauai and Kaena Rock.

No study of the spread of the Barn Owl from the Hanula 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 Ko'olau Mountains east of Oahu, and they undoubtedly occur in the project area.

D. Order Passeriformes

1. Family Microstomidae, babblers

6. Melodious Laughing-thrush (Garrulax canorus) Long called the Chinese Thrush or Hua-nai 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" (Coom, 1933). This babbler is found in both the Ko'olau and the Na'alehu 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 jocosus). 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 (1982); the status of the Red-whiskered Bulbul (P. jocosus) 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 Nu'uanu Heights road" (Horsham, 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 (Casu, 1933). Later importations were made by the Hui Manu and by individuals. The Japanese name is Mejro, and Mejro clubs held singing competitions with these birds. The White-eye has been a remarkably successful introduction and this species 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., Kauai, 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 (Casu, 1933). The Japanese name is Uguie. Berger (1975) 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" (Casu, 1933). The Myna is still common to abundant 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 Papahana region.

6. Family Pipridae, 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 (*Lepido*, 1966:19; 1975:81-82). A number of species have established wild populations in the Koolau region and undoubtedly will spread from there.

12. Hutton’s Munia or Ricebird (*Lonchura oryzivora*). Also called the Spotted Munia, this Asian species was released in Hawaii by Dr. William Hillebrand about 1865 (Casu, 1933). Casu 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 Manakin is another abundant species on all of the islands, and is widespread in the Papakea 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 Zealand (where the species had previously been brought from England). Cauer (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 Papakea region.

b. Family Fringillidae, Cardinals and New-world Sparrows.

14. Red-crested Cardinal (*Cardinalis coronatus*). Although this species traditionally 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 (Cauer, 1933). The species is common in 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 Papakea region.

15. Cardinal (*Cardinalis cardinalis*). This species has been given a number of vernacular names; for example, Virginia Cardinal, Kentucky Cardinal, Kentucky Redbird. Its native range is in 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 (Cauer, 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 Papakea 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" (Cauer, 1933). The House Finch is now an abundant species on all of the islands, in both rural and urban areas, and probably in 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 \( \text{House Finch} \) 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 such 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), Snowdrift Pheasant (Lophura spinosa), Ring-necked Pheasant (Phasianus colchicus), Silver Pheasant (Lophura n. agrippina), Chukar Partridge (Alectoris chukar), and the Common Guineafowl (Numida meleagris).

11. 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 Ciconiformes

a. Family Ardeidae, Herons and Egrets

1. Black-crowned Night Heron (Nycticorax n. boulbou). 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 prawns a “120-day permit to destroy black-crowned herons which have been causing economic havoc at Oahu’s Kauka prawn farm as well as other aquaculture forms 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.
Seabirds

1. White-tailed Tropicbird (*Phaethon lepturus saraeae*)
   This is the only one of the seabirds that needs to be mentioned because it does nest on the cliffs that bound Waima'a Valley. There appears to be no nesting habitat for this tropicbird in the Pu'upehe project area, however.

Migratory Species

The most conspicuous of these is the Lesser Golden Plover (*Pluvialis dominica fulva*), 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, and 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.

Endemic Birds

These are birds that are restricted to the Hawaiian Islands; they are unique to the islands. At least 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 Waima'a Valley: Koa'a or Hawaiian Duck (*Anas wyvilliana*), Hawaiian Gallinule or 'Alae 'Ula (*Gallinula chloropus sandvicensis*), and Hawaiian Coot or 'Alae Ke'oke'o (*Fulica americana ala*). There is, however, no suitable habitat for these waterbirds in the project area.

Pu'eo or Hawaiian Owl (*Aegotheles flammeus sandvicensis*).

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 Pu'eo to be an endangered species on Oahu but not on the other islands. The Pu'eo 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 et al. (1986) wrote that the Pu'eo "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 Pahena Road on December 22, 1986 (Brower, 1987).

I did not see any Pu'eo during my field studies. However, one bird was found dead in Waima'a Valley several years ago.

The Mammals

1. Endemic Mammals

The only endemic land mammal in the Hawaiian Islands is the Hawaiian bat (*Lasiurus cinereus semotus*), 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 auromarginatus), 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 traps in order to sample the population. It is reasonable to assume that all of them occur in the project area (Tomicchi, 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-Bondolfi, et al. (1931) 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. J. Bryan (1947) said that 1,057 different species of exotic plants were tested in arboretums 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 (Kaper, et al., 1976). The Barn Owl is known to eat birds and their young on Kauai and Oahu, 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 Kauai 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 unforested 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 Kualoa Valley.

7. I know of no recent observations of the Fueo 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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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 1), 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 Pukulena 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 Pauaau 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 Pauaau Stream, A'alu Gulch and Kalekeiki Stream consisted primarily of mud with small pools of water. Kalekeiki Stream was completely dry from below Site J to where it joins Pauaau Stream (and is nearly impassable due to thick vegetation).

The lower portion of Pauaau 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. Kalanawalkalen 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 Pauaau Stream and one (Site Q) on its tributary, A'alu Gulch. Gobles 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 Kalekeiki Stream, also a tributary to Pauaau Stream. On Pauaau Stream five sampling sites were chosen. No samples were taken on Kalanawalkalen Stream as there was insufficient water.

**Site Q: A'alu Gulch.** This site is as far upstream as we were able to survey on A'alu Gulch because of dense vegetation. The area was very overgrown, with riparian cover 95%. 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: Pauaau 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 10cm. The deepest spot at this site was 20cm. Thiarid snails and amphipods were collected in the benthic sample.

**Site L: Pauaau 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: Pauaau 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, *Geotomas yunnanensis*, were observed at Site H.

**Site H. Papaulu Stream.** At Site H 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 G. Papaulu Stream.** Site G 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 2.4m and depth was 20cm. The only organism collected at this site was the introduced riparian Cynidae, *Geotomas yunnanensis*.

**Site P, R, and S: Papaulu Stream.** Post-larval gobies were observed in the lower portion of Papaulu Stream (See Figure 4). Gobies (*Glicopterus stipposhi*) 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: Papaulu Stream.** The jeep trail crosses Papaulu 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, *Geotomas yunnanensis* 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 Geotopus pygmaeus, an endemic Velidae (Microvelia vagans), an endemic Dytiscidae (Phaonius pacificus), the introduced mayfly Caenodes micropterus, flatworms, and thiarid snails.

**Site B: Pakalena Stream.** Upstream of Site B on Pakalena 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 in the benthic sample at this site.

**Site C: Pakalena 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: Pakalena Stream.** Very little water remained in the lower reaches of Pakalena Stream. Isopods were collected from a small pool of standing water at Site D. Isopods and the endemic Dytiscidae Phaonius pacificus were found in the benthic sample at Site E.

**Discussion**

Hawaiian stream gobies have an amphidromous life cycle (McDowell, 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 using the high flows that occur during spates (Manacop, 1953; Erdman, 1966; 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 *Aloxyopterus stimpsoni* that we observed in Pauamau Stream during this survey may have responded to the fresh water flowing into the ocean from Pauamau 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 Pauamau Watershed (Pauamau and Kaleleiki Stream) included isopods, amphipods, cyprids (*Geotopus pygmaeus*), thiarid snails, flatworms, and tadpoles, Benthic organisms collected from the Pakalena Watershed included the organisms listed above, plus waterstriders (*Microvelia vagans*), beetles (*Phaonius pacificus*), and mayflies (*Caenodes micropterus*). Post-larval gobies (*Aloxyopterus stimpsoni*) were present in the lower reaches of Pauamau Stream, the only place they
were observed during this survey.

As these streams are intermittent, water will be flowing primarily during heavy rainfall. Kaluawaiwai, and the lower portions of Pukalena and Kaleoleiki 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.

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Figure 1. Area covered during survey (indicated by bold). Dashed line is property boundary.
REFERENCES


Figure 4. Location of post larval gobies. (Dashed line is property boundary.)
INTRODUCTION

The proposed Lili‘uokalani Recreational Community Project, located at Pupukea in the Koolau District on the north shore of Oahu, consists of a gross area of 1,120 acres, with approximately 492 acres planned for actual development. The current planning concept includes an 18-hole golf course, a 125 lot subdivision, and 22 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 60 acres of the 156 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 irrigation 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/irrigation 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 Lili‘uokalani 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 benthic from alteration water chemistry.

An additional objective of the baseline assessment was to evaluate the degree of natural stresses (e.g. wave scours, 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-I and OP-II). 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 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 water 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 close 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$_3$), total phosphorus, Chlorophyll a (Chl a), turbidity, dissolved oxygen, temperature, pH, and salinity. In addition, orthophosphates phosphorus (PO$_4^{3-}$) and dissolved silicate (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, triplicate, 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$_2$ to terminate biological activity. Fixed samples were kept refrigerated until turbidity was measured on a Turner Designs nephelometer (No. 49) 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 an A.G.S. Model 2100 laboratory salinometer with a readability of 0.001 parts per thousand (ppt). 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 (WT) Model 55 meter with a readability of 0.01 milligrams per liter (mg/l) and 0.1 °C, respectively. pH was determined in the field with a Cole Parmer Digistage pH 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 bivalve 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 macroalgal 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 nearshore of the Hawaiian Islands. Within the nearshore area fronting the proposed development is the "Pipeline", a surfing area that is renowned worldwide for its quality and force of waves breaking on the nearshore reefs. Because all of the property frontage consists of open coastline, there is no region 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 sandstone cobbles (beachrock) that generally occur 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 interpersed 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 it 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. Interpersed 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 boulder 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 ULI Land 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 seen 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 NH₄⁺ + NO₂⁻. In the absence of stream flow or surface runoff (as was the case during the present survey), inflow 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 NH₄⁺) is expected.

NO₃⁻ + NO₂⁻ + 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 NO₃⁻ + NO₂⁻ and Si than samples collected farther offshore. The elevation in nutrient concentrations indicates a zone of sloping near the shoreline where input from groundwater excretion 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 (PO₄³⁻), there is no indication of increased levels of PO₄³⁻ near the shoreline or in surface layers. While the concentration of PO₄³⁻ 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 controlled by dilution and nearshore mixing.

Besides NO₃⁻ + NO₂⁻ 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) on transect 1 by about 0.5°/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. Min. In his report on groundwater conditions at Pupukea-Paumaunu, calculates a groundwater input of about 1.5 mgd per mile. Thus, in the following discussion DOH "dry" criteria are applied to the ULI Land data.

It can be seen by comparing Tables 1 and 3 that geometric means for 3 of the 6 measured specific water chemistry parameters (NO₃⁻ + NO₂⁻, turbidity and Chl a) exceed DOH standards for dry conditions. Measurements of NO₃⁻ + NO₂⁻ within 10 m of the shoreline on transect 1 also exceed the "more than 10% of the time" criteria.

**BIOLICAL 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 mobile organisms were not observed. It appears 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 hemalytic (reef building) corals also occur. Because corals are essentially “permanent” features of the benthic 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 encrusting, 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 seaward edge 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 accreting 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 algae species are listed in Table 4.

Most benthos, such as sea urchins (Echinoidea) and sea cucumbers (Holothuria) were generally rare off the subject site. The most common echinoid observed was Echinometra mathaei, 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 saddledback wrasse (Cultrae laba-will, Thalassoma diostomi) and small convict tang (manini, Acanthurus triostegus) were the most abundant species observed. Schooling surgeonfishes (Acanthurus) 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 (awele, Thalassoma diostomi) and the blackspot sergeant (kupi, Abudella scowas), as well as the aforementioned saddledback 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 (maoko, Acanthurus leucosternon), the orangeband surgeonfish (Kaihoo A. tigrinus) and the ringtail surgeonfish (pua, A. blochii).

Apparent overfishing in the survey area is evidenced by the virtual absence of some sought after fish groups such as groupers (luau and weke, Mullidae), jacks (xipho, Carangidae), squirelfishes (loa, Holocentridae) and parrotfishes (aha, 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 a two-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‰, 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 and 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 βS) 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 ($O_y$) can be represented by the equation:

$$R_y = O_y + O_y$$

where $O_y$ represents the net sources and sinks for $Y$ other than the golf course additions. Because $R_y$ and $O_y$ are known, $O_y$ can be determined. If $O_y$ is a net sink (negative value of $O_y$), then 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 source 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 concaveity 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 Okeoari State Park development. Conservative mixing lines are constructed by connecting end-point concentrations of open ocean samples and EWS well water. Materials considered are silicate (Si), a nutrient leached from basaltic lava and not supplied in large quantities with terrestrial, and the plant nutrients dissolved inorganic nitrogen (DIN) which includes NO$_3^-$, NH$_4^+$, and NO$_2^-$, 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 to sewage, lack of algalic organisms in the nearshore marine environment, and the relative speed of mixing processes relative to diagnostic 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 nutrients are not subject to biological and chemical uptake processes associated with percolation through the plant-soil zone that occur with leachate 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 Dollin and Smith 1998 for derivation of equations). The equation for calculating the magnitude of the net source is:

$$R_y = F_y \times (V_q + Y_T)(R_y + Y_T)$$

where $F$ equals the magnitude of groundwater flow discharging at the shoreline. Both estimates groundwater flow to be 1.4 million gallons per day (mgd) per mile of shoreline ($3 \times 10^8$ m$^3$ per km per day). The coastline length of the development property is approximately 1.5 km, thus groundwater effluence into the nearshore environment off the proposed development is approximately $4.1 \times 10^8$ m$^3$ per day. $V_q$ and $Y_T$ are DIN concentrations in ocean (0.3 ppm) and in groundwater (25.5 ppm), respectively. $Y_T$ is ocean salinity (35.27/6/35), while $Y_T$ equals 2.16 between salinities of 24/00 and 34/50, 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 168 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 3.6 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 168 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 loading contribution to the nearshore zone from the proposed golf course. Projected peak capacity of the project sewage treatment plant is 190,000 gpd ($7 \times 10^8$ per day). Sewage effluent nitrogen concentration at Lili`I`I is expected to be about 5.7 mg/L (Robert Geerhart, personal communication). If all sewage nitrogen generated by the STP is used as golf course irrigation, 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 fertilizers (Chang and Young 1977, Lae 1975). Thus, if 5% of applied N can percolate through the soil zone and reach groundwater, 13 miles 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 miles that are 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 15 miles of N per acre per day. Approximately 50 acres of golf course at Lihue (Kauai) will employ treated sewage as fertilizer. Distribution of the 370 miles of N produced by the sewage treatment plant will result in application rates of about 4 miles N per acre per day. Thus, only about 14% of the necessary fertilizer N will originate from sewage effluent, with the remainder from commercial mixtures.

Because sewage effluent does not differ qualitatively from commercial fertilizer mixtures, 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 x 10^4 m³/d for the shoreline length of the development, and groundwater DIN concentration of 35.5 µg, approximately 145 miles of DIN is delivered per day to the nearshore marine environment. Total application of N to the golf course is estimated at 3 x 10^5 miles per day (Murdoch and Green 1988). Thus, all nutrient material to be added to the courses constitutes about 20% of the nitrogen that enters the ocean through natural input. If the golf course grass/root complex takes up the expected 95% of material through biological and chemical processes, 150 miles per day can potentially enter groundwater. Such an input is about half of the estimated existing cesspool contribution to groundwater of approximately 320 miles.

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 cesspool to the effluent at the ocean. Perhaps the most important of these processes is denitrification, an anaerobic reduction of NO₃⁻ to N₂ 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 dry year will probably disperse any nutrient subsidies rapidly, with no alteration to water quality or benthic 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 coasts, nutrient enrichment to the nearshore marine environment from golf course operation is not occurring. Dollar and Smith (1983) 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 mixtures for fertilization. The only case where non-conservative behavior of DIN was noted was at Keelau Bay, located directly downwind from a 27-hole golf course. It appears that reduction in mixing in the semi-enclosed bay, as well as groundwater focusing results 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 coasts. Mining and dilution in open coastal areas is apparently sufficient to eliminate the detection of added fertilizers.

Equipping the survey results from the Big Island to the proposed Pupukea project provides a basis to estimate the effects from the subject development. Mining by nearshore processes at Pupukea is generally greater than the inshore areas where the Big Island golf courses are located. In addition, all 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, precipitation 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 prevents the largest 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 lb. (196 miles) in the 1 hr, 2 yr recurrence storm to a decrease of 121 lb (4 x 10³ miles) for the 24 hr, 100 yr recurrence storm. All of the 1 hr duration storms result in increases between about 12 and 20 lb. of nitrogen, while three of the 24 storms result in decreases of nitrogen in storm runoff.

Thus, as in 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 tons of N per day. By comparison, it appears that about 143 tons of N enter the ocean each day via natural groundwater input, with an additional 166 tons 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 (3.5 tons) for the 1 hr duration, 2 yr recurrence event, to 430 lbs (31,000 tons) 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 0.25 moles per day. Natural inputs of phosphorus from groundwater to the site are approximately 0.18 moles per day. Thus, the most severe event could result in an increase of about 15% 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 tissues. 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. Mining 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 into 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

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 pollution 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 mining 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 mining 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 Koh Lani recreational development is characterized by seasonal intense wave activity which limits the development of reef老百姓 to those assemblages which can withstand the impact of breaking waves. As a result coral community assemblages are limited to thick corals. 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 (NO₃⁻ + NO₂⁻ + 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 direct influence layer, and the entire water column appears to be well-mixed vertically.

3. Application of a conservative mining 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 benthic 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 to 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 decreases during most of the 24 hr duration events. These projected subsidies, however, will be episodic in nature and will not constitute chronic stressors. 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.

REFERENCES CITED


FIGURE 1. Map showing location of proposed LHI 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 influx. 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 E. 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 (34.97/0) and well water (0.2/0). 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 cesspool related material into the marine environment.
### Table 1: Water chemistry constituents in marine water samples collected off the proposed Lihir Lagoon development. For sampling locations, see Figure 1.

<table>
<thead>
<tr>
<th>TRANSVERSE NUMBER</th>
<th>DISTANCE FROM SHORE (m)</th>
<th>TOTAL NITRATES</th>
<th>NITRITE</th>
<th>ORGANIC NITROGEN</th>
<th>TOTAL NITROGEN</th>
<th>DIPHTHOCYANETIC Phosphorus</th>
<th>ORGANIC PHOSPHORUS</th>
<th>SOLUBILE SILICA</th>
<th>CAL. + TUMERIC pH</th>
<th>TEMPERATURE (deg. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>7.12</td>
<td>0.07</td>
<td>0.10</td>
<td>7.32</td>
<td>21.21</td>
<td>21.32</td>
<td>7.12</td>
<td>7.20</td>
<td>26.5</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>7.12</td>
<td>0.07</td>
<td>0.10</td>
<td>7.32</td>
<td>21.21</td>
<td>21.32</td>
<td>7.12</td>
<td>7.20</td>
<td>26.5</td>
</tr>
</tbody>
</table>

### Table 2: Non-specific water chemistry parameters listed in O&M water quality standards. For station locations, see Figure 1.

<table>
<thead>
<tr>
<th>TRANSVERSE NUMBER</th>
<th>DISTANCE FROM SHORE (m)</th>
<th>Dissolved Oxygen</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>Salinity (p.p.t.)</th>
<th>pH</th>
<th>Temperature (deg. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>6.32</td>
<td>34.44</td>
<td>0.170</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>6.32</td>
<td>34.44</td>
<td>0.170</td>
<td>26.5</td>
<td></td>
</tr>
</tbody>
</table>

---

*Note:* The tables and data are presented in a readable format with appropriate delimiters (|) and line breaks. The tables are aligned properly with headers in the first column and data in subsequent columns. The text is clear and concise, focusing on the key information provided in the tables.
TABLE 3. Specific criteria specified by CDM water quality standards for open coastal waters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Semiarid (not to exceed the given value)</th>
<th>Not to exceed the given value of the time</th>
<th>Not to exceed the given value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen (mg/L)</td>
<td>150.00</td>
<td>250.00</td>
<td>200.00</td>
</tr>
<tr>
<td>Ammonia Nitrogen (mg/L)</td>
<td>3.50</td>
<td>8.50</td>
<td>12.00</td>
</tr>
<tr>
<td>Nitrate Nitrite Nitrogen (mg/L)</td>
<td>5.00</td>
<td>14.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Total Phosphorus (mg/L)</td>
<td>20.00</td>
<td>40.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Chlorophyll a (mg/L)</td>
<td>0.30</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Turbidity (Nephelometric Turbidity Units)</td>
<td>0.50</td>
<td>1.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

a"Daily" criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile.
a"Dry" criteria apply when the open coastal waters receive less 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 of the proposed LHA land 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).

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porites lobata</td>
<td>XXX</td>
</tr>
<tr>
<td>Porites compressa</td>
<td>X</td>
</tr>
<tr>
<td>Pocillopora meandrina</td>
<td>XXX</td>
</tr>
<tr>
<td>Montipora phaneca</td>
<td>XX</td>
</tr>
<tr>
<td>Montipora verrucosa</td>
<td>X</td>
</tr>
<tr>
<td>Montipora faveolata</td>
<td>XX</td>
</tr>
<tr>
<td>Pavona varians</td>
<td>XX</td>
</tr>
<tr>
<td>Leptastrea purpurea</td>
<td>XX</td>
</tr>
<tr>
<td>Palythoa tuberculosa</td>
<td>XX</td>
</tr>
</tbody>
</table>

ALGAE

Green Algae
- Codium spp. | XX
- Enteromorpha spp. | XXX
- Halimeda opuntia | XXX

Brown Algae
- Dictyopinna spp. | XXX
- Discoria aculeata | XXX
- Lobophora variegata | X
- Padina japonica | X
- Ralfsia peniodea | XX
- Sargassum echinocarpum | XX
- Sphacelaria furcigera | XXX
- Turbinaria ornata | XX

Red Algae
- Corallina spp. | XX
- Gallaurea fessigera | XX
- Gallaurea rugosa | XXX
- Hymatisa alabandii | XXX
- Hymitea chordacea | XXX
- Lithothamnium spp. | XXX
- Mesophyllum mesomorphum | XXX
- Nephrocytium nutans | XXX
- Plocamium sandwicense | XXX
- Porothrix onkodes | XXX
## TABLE 4. continued.

**SEA URCHINS**
(Echinoidea)

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echinometra diadema</td>
<td></td>
</tr>
<tr>
<td>Tripneustes gratilla</td>
<td>X</td>
</tr>
<tr>
<td>Echinometra mathaei</td>
<td></td>
</tr>
<tr>
<td>Echinometra oblonga</td>
<td>XX</td>
</tr>
<tr>
<td>Echinostegus acuticaulus</td>
<td>X</td>
</tr>
</tbody>
</table>

**SEA CUCUMBERS**
(Notocididae)

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actinopyga mauiiana</td>
<td></td>
</tr>
<tr>
<td>Holoheria aza</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

## TABLE 5.

Fistulidae

- Fistulaster petalosa: X

Kyphosidae

- Kyphosus bigibbus: XX

Cerithidae

- Cerithium plumulatum: XX
- Paracerithium arenatus: X

Haliotidae

- Haliotis chlorina: X
- Heterostichus ruber: X

Lottiidae

- Lottia gigantea: X

Lepetidae

- Monaster grandocula: X

Chaetocinidae

- Chaetocinid limula: X
- Chaetocinid unicolor: X
- Chaetocinid multicruris: X
- Chaetocinid auriga: X
- Furcifer flavissimus: X

Pomacentridae

- Abudoraf abdominalis: XX
- A. nodosa: X
- Plectrobonus johnstoni: X
- P. impacipennis: X
- T. g. gaudis: fasciatus: X

Labridae

- Labrus aurora: X
- Bodianus hilina: X
- Cicla gaimard: X
- C. venusta: X
- Anampas cuvier: X
- Thalassoma duperrey: XXX
- T. teiho: X
- T. baillet: X
- Labroides phthirophagus: X
- Stethojulis balfour: X
<table>
<thead>
<tr>
<th>SCALIDAE</th>
<th>SCALENOIDEA</th>
<th>HOMOCOCCIDEA</th>
<th>BOLBIIDAE</th>
<th>VERNISCUCEAE</th>
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<tbody>
<tr>
<td>Acanthalus</td>
<td>Glycaspis</td>
<td>Podopterus</td>
<td>A. blanchard</td>
<td>Coccus sinensis</td>
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<tr>
<td>Aulacaspis</td>
<td>Podopterus</td>
<td>Podopterus</td>
<td>A. blanchard</td>
<td>Coccus sinensis</td>
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ARCHAEOLOGICAL RECONNAISSANCE SURVEY
AND LIMITED SUBSURFACE TESTING
PUUKEA-PAUMALU DEVELOPMENT PROJECT AREA

Lands of Pupukea and Paumalu
Koolau District, Island of Oahu
(TM:1-5-9-05:30; 1-5-9-06:1,10,24)

by
James D. Mayberry, M.A.
Supervisory Archaeologist
and
Alan E. Hanu, Ph.D.
Senior Archaeologist

Prepared for
Obayashi Hawaii Corporation
c/o Group 70
924 Bethel Street
Honolulu, Hawaii 96813

May 1988

SUMMARY

During the periods January 11-25, and January 29-March 10, 1988, Paul H. Rosenbahl, 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 Koolau, Island of Oahu (TM:1-5-9-05:30; 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-13 as an historic irrigation ditch. Subsurface probes (using hand trowels) were conducted at 10 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 Rath, staff archaeologist in the State Department of Land and Natural Resources-Historic Sites Section (DLNR-HSS) (January 21, and April 15, 1988). Dr. Rath 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. Those sites will not be affected by project development activity. The 54 sites within the project area appear to represent three temporal periods: 23 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, areas 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 most 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 (DHRI Neg.764:19).
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INTRODUCTION

BACKGROUND

As the request of Mr. Ralph Bormeier, project manager for Group 70, on behalf of Group 70 clients, Obayashi Hawaii Corporation, Paul H. Hoendahl, Ph.D., Inc. (PHI) conducted a combined surface (IGOS pedestrian reconnaissance) and subsurface (limited backhoe trenches) archaeological reconnaissance survey at the 1,130 acres Papahana-Kalualu Development project area, located in the lands of Pupukea and Punalu, Koalalana District, Island of Oahu (WTR-1-5-9-05318; 1-5-9-05118, 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, 1985, under the supervision of PHI Supervisory Archaeologist James D. Mayberry and PHI Senior Archaeologist Dr. Alan E. Heu. Approximately 185 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 23-April 13, 1985). 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 map-sheet 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 identifies 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-HSS 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 Papahana-Kalualu Development project area consists of 1,130 acres located in the lands of Pupukea and Punalu, Koalalana District, Island of Oahu (WTR-1-5-9-05318; 1-5-9-05118, 18, 24) (Figure 1). The project area ranges in elevation from 15' to 775' AGL (above mean sea level). It is bounded on the northeast by Papalu Stream; on the east by Papahana-Kalualu Forest Reserve; on the south and southeast by Kaluakoi Stream and on the west and northwest by residential districts.

The project area is characterized by three vegetation groups—sero-arboreal shrubs (in coastal lowlands), mixed open forest and shrubs (in western upland), and shrub and closed forest (in wet upland) (Negoto 1983). A recent botanical survey by Negoto (1983) illustrates the affinity of the vegetation with forest regions (in the project area). Negoto indicated 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 equisetfolia [L.]), some eucalyptus trees, and some open pasture comprised of grasses and 'olehaha (Gomphrena serrata [L.]). Vegetation in the wetter niches is generally comprised of strawberry guava (Psidium cattleianum Sabin), Chasteberry (Koelma teretirostris Roth), Java plum (Eugenia javanica Lam.), ironwood, grasses and 'olehaha. Vegetation in the SHA portion of the project area has been described as a "lowland wetland, a vegetation mosaic of ironwood, hala, grasses and a host of other estuarine trees and shrubs" (Negoto 1983).

According to Negoto (1983:6), there is very little native flora left in the project area. Only a few species can be found in any quantity: hau (Casuarina ferrocarpus Gould.) in the uplands and higher slopes, and viola (Nymphaea umbellata [L.] Lindl.) and with (Eriocactus spnurifolius [L.] Back.) mostly on exposed upper slopes. The few native trees in the project area include sandalwood (Santalum frugivorum), balata (Pipturus alamos), and four species of koa (Eugenia—only the examples known to exist.
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 suitable spring is said to have been present in Pahala Gulch (Nyark and Nany 1972:63), and the agriculture, may have relied on this water, and the availability of fresh water probably was not of the water constraint that it is today. In the past, the hydraulic 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 "one large plateau separated by a large gulch [created by Paokalena Stream] and bordered on either side by a large gulch [created by Pupukea Gulch and Kulupuu Stream]" (Nyark and Nany 1972:11). The project area contains four major streams—the three above and Kaleelekile Stream. These streams run into the sea, except for one in the west which goes into the Paokalena Stream. The bottom of the gulches, occupied entirely by streambeds, are usually dry. The plateau rises gently to the southeast. The plateau between Kalalekile and Paokalena streams rises to 730 ft AGUL (at Paa Waahio).

Most of the uplands of the project area are comprised of deep, moderately sloping well-drained soils. The uplands on either side of Pahala Gulch are comprised of Pahala Natural soil, which is a silty clay consisting of a loess profile and surface. Portions of the uplands have been eroded by wind and water (Due et al. 1972). Other portions of the uplands are comprised of either Waimanalo silty clay, Pahala silty clay, or Kalalekile silty clay. Presently in Pahala Gulch is a Waimanalo silty clay. Portions of Pahala Gulch and much of the western portion of the project area consists of exposed basalt beds, which cover 23% of the ground surface. The western portion lowlands, below the cliffs in the western portion, are comprised primarily of Kalalekile silty clay and Kalalekile clay and very sandy soil. The former found only near Kaneohe Highway. Waimanalo silty clay is restricted to the drainage of Kulupuu Stream.

PREVIOUS ARCHAEOLOGICAL WORK

Over the past 15 years, a number of archaeological investigations have been conducted in the lands of Pupukea and Pahala; however, most of these investigations have been specific to Waimanalo Valley—only a limited amount of work has been done outside of the valley.

Archaeological work within Waimanalo Valley includes work by Mitchell (1956, 1977), Moore and Leacham (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, 352-26, excavated in the
1970s, has been identified as a habitation site—a single-family habitation and farm, with agricultural terraces and small plows—thought to have been used for cultivating sweet potatoes (Mitchell 1977). Housed to about 1840, this site may be contemporary with a single-family structure tentatively identified in the present project area (Site T-13).

Archaeological investigations outside Waimanalo Valley include studies by Bard (1975), Rogers (1976), and Peterson (1976). Rogers excavated a burial cave in a narrow cliff less than half a kilometer southeast of the present project area. The cave, Site 30-04-71-106, though only 8.6 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 coffin. Remains of other individuals (long bones) were bundled in braids of awa. 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 Hawai‘i.

During the study by Daveson, a walled enclosure was identified a short distance southeast of the present project area (1974). 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 Trent, two burials were identified just northeast of the present project area, in the sand dunes at Sunset Beach (Trent 1979). Exposed by winter storms, the burials (disarticulated male and female bones) were later reinterred in the same stable inland portion of the dunes. Apparently due to the method of excavation, 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 Cary 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—male and female 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.

*P.B. Bishop Museum (BMH) site designation system: all site numbers prefixed by 30-04-71 (30-State of Hawaii, O‘ahu Island of O‘ahu, 44-District of Koolau, 14-Land of Pau‘alai).
case the loss of traditional Hawaiian crafts, due to metal becoming commonly available. By 1860, metal tools, once considered precious by Hawaiians, were replacing the traditional shell, bone, and lithic tools (Morgan 1940).

The early history of Hawaii also includes the bloody interisland war of Kamehameha I (1780-1814), and epidemics in 1860, 1865, 1867, and throughout the 1880s and 1900s, of European origin (Morgan 1940:116) which devastated the Hawaiian population (Atlas of Hawaii:103). 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-Pamala, the end of the Hawaiian religion was symbolized by the abandonment and destruction of the numerous heiau and the establishment in 1832 of a Protestant mission in Kealaulu (Taemore 1974:110).

During the 1860s, small-scale farming in the Pupukea-Pamala area gave way to large-scale plantation agriculture. Originally, sugarcane was produced in the coastal lowlands (Morgan 1940:187); from 1910-1910 the coastal highlands of the north shore, including the present project area, were opened up for pineapple production (Ketinho-Griffith 1980:22). Over the years, plantation agriculture on the north shore continued to expand, fueled in part by the extension of the Cahu Railroad & Land Co. railway along the coast from Kealaulu to Kahuku; the Cahu Railroad & Land Co. had been created specifically to encourage the production of first sugarcane, then after 1895, pineapples (Burkeford 1903). As shown on a 1966 railway schedule and map, the 9.5 mile run from Kealaulu to Kahuku took 24 minutes and passed through but did not stop at the village of Pamala (Burkeford 1903).

The plantations' greatest period of prosperity was 1920-1925 (Burkeford 1953:203). 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 line outside of Kealaulu 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-Pamala, to residential communities (Ketinho-Griffith 1980:223). 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 NMAI Supervisory Archaeologist James D. Mayberry, assisted by NMAI Field Archaeologists Nélie Feger, Edward Kaler, Barbara Sottong, and Diane Guerrieri. NMAI Senior Archaeologist Dr. Alan E. Bank...
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 survey crew members was 20-20 m, depending on vegetation cover, terrain, and extent of ground disturbance encountered. Identified sites were assigned a sequential RERI 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, T-12, T-14, T-61); some had been constructed within the last 20-25 years (T-39, T-48); 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:

<table>
<thead>
<tr>
<th>Former T-number</th>
<th>Presently assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-6</td>
<td>Feature 1 of T-13</td>
</tr>
<tr>
<td>T-9</td>
<td>Feature 6 of T-13</td>
</tr>
<tr>
<td>T-10</td>
<td>Feature 3 of T-13</td>
</tr>
<tr>
<td>T-11</td>
<td>Feature 9 of T-13</td>
</tr>
<tr>
<td>T-24</td>
<td>Feature 8 of T-22</td>
</tr>
<tr>
<td>T-26</td>
<td>Feature 8 of T-25</td>
</tr>
<tr>
<td>T-27</td>
<td>Feature 6 of T-30</td>
</tr>
<tr>
<td>T-28</td>
<td>Feature 6 of T-33</td>
</tr>
<tr>
<td>T-29</td>
<td>Feature 6 of T-33</td>
</tr>
<tr>
<td>T-37</td>
<td>Feature 6 of T-36</td>
</tr>
<tr>
<td>T-44</td>
<td>Feature 6 of T-45</td>
</tr>
<tr>
<td>T-51</td>
<td>Feature 6 of T-52</td>
</tr>
<tr>
<td>T-63</td>
<td>Feature 6 of T-49</td>
</tr>
</tbody>
</table>

All identified sites were plotted on 1:4000 scale maps and aerial photos provided by Group 70 and were recorded on standard RERI site record forms. Recording included (a) mapping all sites to scale using tape and compass, (b) at least one 35 mm black-and-white photograph of each site (RERI Roll No. 679), and (c) tagging of each site with an aluminum strip bearing the site number, RERI project number (07-503), and the date. Finally, strips of pink plastic flagging tape bearing the scale information 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 4.50 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 backfilling 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 Papaha-Kamalei Development project area, 60 previously unrecorded archaeological sites were identified. These sites are summarized in Table 1 according to site number, form, type, tentative functional interpretation, and cultural resource management value and assessment; and the locations of the sites are indicated on Figure 3.

The sites included the following formal feature types: monadnock alignments, modified cairns, terraces, freestanding walls, petroglyphs, rockshelters, concrete barriers, retaining walls, concrete slabs, a chimney, gun turret bases, stone, modern concrete and wood structures, a stone dam, modified trenches, a bottle, and rubber lamp, cobbled roads, water crossings, irrigation ditches, a stone-lined well, a large earthwork, 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 functional categories: agricultural, ceremonial or religious, transportation, water control, habitation, quarry, temporary habitation, coastal defense, burial, property lines, and rock art.

**PORTABLE REMAINS**

Prehistoric 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 obsidian, a small coral plaque, a polished basalt cobbles, a worked stone tool, and the remains of a burial cache. The small pieces of coral were found at Sites T-3, T-69, and T-79, where they were presumed to have been 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 obsidian. The two non-cortical volcanic glass flakes were collected for dating analysis. The cortical flakes and broken pieces (121 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 cortical glass flakes from Feature A at Site T-64 and the flake from Site T-18 were submitted to NRELAB, 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-64, and at Site T-9. 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 - PUNUHA-PAHUAI DEVELOPMENT PROJECT AREA

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Formal Site/Feature Type</th>
<th>Tentative Functional Interpretation</th>
<th>Cultural Value Assessment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>Linear mound</td>
<td>Agricultural(1); ceremonial(1)</td>
<td>L L L</td>
<td>Possible disturbed terrace; coral offerings</td>
</tr>
<tr>
<td>T-2</td>
<td>Alignment and baulk scatter</td>
<td>Agricultural(1)</td>
<td>L L L</td>
<td>Builtout/disturbed by cattle</td>
</tr>
<tr>
<td>T-3</td>
<td>Mod. outcrop</td>
<td>Agricultural(1)</td>
<td>L L L</td>
<td>Builtout</td>
</tr>
<tr>
<td>T-4</td>
<td>U-shaped earth berm</td>
<td>Railroad siding(1)</td>
<td>L L L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-5</td>
<td>Terrace</td>
<td>Agricultural</td>
<td>M L L</td>
<td>High, well-preserved terrace wall</td>
</tr>
<tr>
<td>T-7</td>
<td>Cairn</td>
<td>Trail or property marker(1)</td>
<td>L L L</td>
<td>Collapsed; early historic(1)</td>
</tr>
<tr>
<td>T-13</td>
<td>(Complex of 13 features)</td>
<td>Habitation; agricultural; rock art</td>
<td>M H H</td>
<td>Late prehistoric; early historic</td>
</tr>
<tr>
<td>T-14</td>
<td>Well and foundation</td>
<td>Water source</td>
<td>L L L</td>
<td>Early to mid-20th century(1)</td>
</tr>
<tr>
<td>T-15</td>
<td>Ditch</td>
<td>Irrigation</td>
<td>L L L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-16</td>
<td>Linear mound</td>
<td>Water diversion(1)</td>
<td>L L L</td>
<td>Pass. diverted water away from Site T-51 early historic or prehistoric</td>
</tr>
<tr>
<td>T-17</td>
<td>Ditch</td>
<td>Irrigation</td>
<td>L L L</td>
<td>Early 20th century(1)</td>
</tr>
</tbody>
</table>

*Cultural Resource Mgmt. Notes: R = scientific research, I = Interpretive, V = Value Node Assessment, C = Cultural. Degree: H = high, M = moderate, L = low

### Table 1. (Cont.)

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Formal Site/Feature Type</th>
<th>Tentative Functional Interpretation</th>
<th>Cultural Value Assessment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-10</td>
<td>Rockshelter</td>
<td>Temp. habitation; H L L</td>
<td>Short stone wall present near shelter</td>
<td></td>
</tr>
<tr>
<td>T-19</td>
<td>Rockshelters[2]</td>
<td>Temp. habitation; H L L</td>
<td>Artifacts include coral adzes, polished basalt</td>
<td></td>
</tr>
<tr>
<td>T-20</td>
<td>Reinforced concrete bunker</td>
<td></td>
<td>L M L</td>
<td>Outside project area</td>
</tr>
<tr>
<td>T-21</td>
<td>Retaining wall</td>
<td>RR or walled bed; H L L</td>
<td>From early 20th century plantation</td>
<td></td>
</tr>
<tr>
<td>T-22</td>
<td>(Complex of 4 features)</td>
<td>RR coastal defenses; H L L</td>
<td>Includes a tiered concrete bunker</td>
<td></td>
</tr>
<tr>
<td>T-23</td>
<td>(Complex of 9 features)</td>
<td>RR or walled bed; H L L</td>
<td>From early 20th century(1); in poor condition</td>
<td></td>
</tr>
<tr>
<td>T-25</td>
<td>Retaining walls (11)</td>
<td>RR or walled bed; H L L</td>
<td>Road is on 1904 map</td>
<td></td>
</tr>
<tr>
<td>T-30</td>
<td>Rockshelters[1]</td>
<td>Temp. habitation; H L L</td>
<td>Prehistoric with internal and external walls</td>
<td></td>
</tr>
<tr>
<td>T-31</td>
<td>(Complex of 6 features)</td>
<td>Agricultural; H H H</td>
<td>Outside project area; early historic(1)</td>
<td></td>
</tr>
<tr>
<td>T-32</td>
<td>Retaining wall</td>
<td>RR or walled bed; H L L</td>
<td>Road on 1904 map</td>
<td></td>
</tr>
<tr>
<td>T-33</td>
<td>(Complex of 4 features)</td>
<td>RR or walled bed; H L L</td>
<td>Portions of site on 1904 map</td>
<td></td>
</tr>
<tr>
<td>T-34</td>
<td>Cave</td>
<td>Burial</td>
<td>H L H Early historic; prehistoric previously recorded</td>
<td></td>
</tr>
</tbody>
</table>

*Number of features
<table>
<thead>
<tr>
<th>Site Number</th>
<th>Formal Site/Feature Type</th>
<th>Tentative Functional Interpretation</th>
<th>Late Intermediate</th>
<th>Early Intermediate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-35</td>
<td>Retaining wall</td>
<td>Indeterminate</td>
<td>L</td>
<td>L</td>
<td>Outside project area</td>
</tr>
<tr>
<td>T-37</td>
<td>Complex of 4 features</td>
<td>RR or wagenroad bed, retaining walls, water crossing</td>
<td>L</td>
<td>L</td>
<td>Early 20th century</td>
</tr>
<tr>
<td>T-38</td>
<td>Pumphouse</td>
<td>Water source</td>
<td>L</td>
<td>L</td>
<td>Operated 1850 to 1970</td>
</tr>
<tr>
<td>T-40</td>
<td>Complex of 2 features</td>
<td>WWII command post (1)</td>
<td>L</td>
<td>L</td>
<td>Includes collapsed shed, stacks, concrete slab</td>
</tr>
<tr>
<td>T-42</td>
<td>Dam</td>
<td>Agricultural</td>
<td>L</td>
<td>L</td>
<td>Outside project area; comprised of basalt boulders</td>
</tr>
<tr>
<td>T-43</td>
<td>Reinforced concrete bunker</td>
<td>WWII coastal defense</td>
<td>L</td>
<td>L</td>
<td>Part of system formed by T-20, -22, and -40</td>
</tr>
<tr>
<td>T-45</td>
<td>Complex of 3 features</td>
<td>Trench complex</td>
<td>L</td>
<td>L</td>
<td>WWII related; mostly outside project area</td>
</tr>
<tr>
<td>T-46</td>
<td>Retaining wall</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Early 20th century</td>
</tr>
<tr>
<td>T-47</td>
<td>Bottle and rubbish scatter</td>
<td>Trash dump</td>
<td>M</td>
<td>L</td>
<td>Early 20th century (1)</td>
</tr>
<tr>
<td>T-48</td>
<td>Mound (2)</td>
<td>Agricultural clearing (1)</td>
<td>L</td>
<td>L</td>
<td>Early 20th century</td>
</tr>
<tr>
<td>T-49</td>
<td>Retaining wall</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Early 20th century (1)</td>
</tr>
<tr>
<td>T-50</td>
<td>Complex of 3 features</td>
<td>Wagon road</td>
<td>L</td>
<td>L</td>
<td>Road on 1904 map</td>
</tr>
</tbody>
</table>

Table 1. (Cont.)

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Formal Site/Feature Type</th>
<th>Tentative Functional Interpretation</th>
<th>Late Intermediate</th>
<th>Early Intermediate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-52</td>
<td>Complex of 2 features</td>
<td>Animal pen</td>
<td>L</td>
<td>L</td>
<td>L. c. 1900(1)</td>
</tr>
<tr>
<td>T-53</td>
<td>Retaining wall</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-54</td>
<td>Rockshelter</td>
<td>Temp. habitation (1)</td>
<td>M</td>
<td>L</td>
<td>Prehistoric/early historic(1)</td>
</tr>
<tr>
<td>T-55</td>
<td>Wall</td>
<td>Boundary (1)</td>
<td>L</td>
<td>L</td>
<td>c. 1900(1)</td>
</tr>
<tr>
<td>T-56</td>
<td>Retaining wall</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-57</td>
<td>Enclosure</td>
<td>Animal control</td>
<td>L</td>
<td>L</td>
<td>Mostly outside project area</td>
</tr>
<tr>
<td>T-58</td>
<td>Complex of 3 features</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Road on 1904 map</td>
</tr>
<tr>
<td>T-59</td>
<td>Retaining wall</td>
<td>RR or wagenroad bed</td>
<td>L</td>
<td>L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-62</td>
<td>Linear mound</td>
<td>Agricultural clearing (1)</td>
<td>L</td>
<td>L</td>
<td>Early 20th century(1)</td>
</tr>
<tr>
<td>T-64</td>
<td>Rockshelter with wall</td>
<td>Temp. habitation</td>
<td>M</td>
<td>L</td>
<td>Early historic/prehistoric; vole, glass collected</td>
</tr>
<tr>
<td>T-65</td>
<td>Rockshelter with wall</td>
<td>Temp. habitation</td>
<td>M</td>
<td>L</td>
<td>Early historic/prehistoric(1)</td>
</tr>
<tr>
<td>T-66</td>
<td>Rockshelter</td>
<td>Temp. habitation</td>
<td>M</td>
<td>L</td>
<td>Early historic/prehistoric scatter of extinct basal</td>
</tr>
<tr>
<td>T-67</td>
<td>Rockshelter</td>
<td>Burial/ temp. habitation (1)</td>
<td>M</td>
<td>L</td>
<td>Early historic/prehistoric</td>
</tr>
</tbody>
</table>
Table 1. (Cont.)

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Formal Site/Feature Type</th>
<th>Tentative Functional Interpretation</th>
<th>CN/Value Asses:</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-69</td>
<td>(Complex of 2 features)</td>
<td>Communal(1); agricultural; habitation(1)</td>
<td>H H H</td>
<td>Outside project area</td>
</tr>
<tr>
<td>T-70</td>
<td>(Complex of 5 features)</td>
<td>Burial; temp. habitation; rock art</td>
<td>H H H</td>
<td>Prehistoric/early historic</td>
</tr>
<tr>
<td>T-71</td>
<td>(Complex of 3 features)</td>
<td>Temp. habitation(1)</td>
<td>M L L</td>
<td>Prehistoric/early historic</td>
</tr>
<tr>
<td>T-72</td>
<td>Rockshelter</td>
<td>Temp. habitation; burial</td>
<td>H M H</td>
<td>Prehistoric/early historic</td>
</tr>
<tr>
<td>T-73</td>
<td>Rockshelter[2]</td>
<td>Temp. habitation</td>
<td>M L L</td>
<td>Prehistoric/early historic; may contain hearth deposit</td>
</tr>
<tr>
<td>T-74</td>
<td>Wall</td>
<td>Boundary</td>
<td>L L L</td>
<td>Outside project area</td>
</tr>
<tr>
<td>T-75</td>
<td>(Complex of 3 features)</td>
<td>Temp. habitation</td>
<td>M L L</td>
<td>Prehistoric/early historic; internal walls present</td>
</tr>
<tr>
<td>T-76</td>
<td>(Complex of 4 features)</td>
<td>Agricultural</td>
<td>L L L</td>
<td>Early 20th century</td>
</tr>
<tr>
<td>T-77</td>
<td>Rockshelter with wall</td>
<td>Burial (1)</td>
<td>M L L</td>
<td>Probably prehistoric</td>
</tr>
<tr>
<td>T-78</td>
<td>Cave</td>
<td>Temp. hab./quarry</td>
<td>M L L</td>
<td>Prehistoric</td>
</tr>
<tr>
<td>T-79</td>
<td>Cave</td>
<td>Shrine (1)</td>
<td>M L L</td>
<td>Prehistoric</td>
</tr>
<tr>
<td>T-80</td>
<td>Cave</td>
<td>Burial</td>
<td>M L H</td>
<td>Disturbed</td>
</tr>
</tbody>
</table>
The small coral abacaha and the polished basalt cobble were found in Feature B of Site T-19. The worked flaked tool was found in Feature A, Site T-20. The remains of the burial cave were found within Feature A (tipukahihi) at Site T-20. The cave remnants consist of three pieces of carved wood (kakahi). 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 cave's site, has been assembled, except in areas where rough holes 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 pipes. Present at Site T-47 is a 70-gallon bottle and rubbish dump which contains the remains of at least 24 bottles, plus earthware and other ceramics—some of which date to about 1860. Some of the bottles are buried under 15-20 cm of alluvium.

**Backhoe Trench Test Excavations**

Subsurface reconnaissance of the SDA 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 SDA portion survey area (Figure 4). The most western portion is a low lying area. Each trench was 4.5 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 overlaying the reef. Overall dimensions and stratigraphic summaries of the trenches are presented in Table 3. Trench 5, originally located between Trenches 3 and 7, was not excavated because it was felt its stratigraphy would only be a repetition of similar stratigraphies in Trenches 3 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 grayed deposits, lenses of orange, oxidized soil, and carbonized macrofossil. The soils present in the backhoe trenches in the SDA portion survey area roughly corresponded with the USDA soil survey description of Maluhi alfisol clay (Goto et al. 1972:118). The soils were fairly homogeneous and deep (150-210 cm). No cultural material or evidence for intensive fallow cultivation was observed in any trench. Four pollen samples were taken from sites in four different trenches (Trenches 1, 3, 6, and 9) where motived soils with small pockets of grayish clay and lenses of oxidized soil offered possible evidence of non-intensive agricultural practices.

![Figure 4. Backhoe Trench Location Map](image-url)
Table 2.
SUMMARY OF BACKHOE TRENCH TESTING RESULTS
SPECIAL MANAGEMENT AREA (SMA) POSITION
PUJUEEA-PAPUALI DEVELOPMENT PROJECT AREA

<table>
<thead>
<tr>
<th>Trench</th>
<th>No. of Layers</th>
<th>Length (m)</th>
<th>Depth (m)</th>
<th>Layer Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5.0</td>
<td>2.2</td>
<td>I=0-100 cm; II=100-135 cm; III=125-200 cm; IV=200-220 cm; V=220+ cm</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>5.0</td>
<td>2.0</td>
<td>I=0-110 cm; II=110-140 cm; III=140-180 cm; IV=180-195 cm; V=195+ cm</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4.0</td>
<td>2.0</td>
<td>I=0-120 cm; II=120-160 cm; III=160-210 cm; IV=210+ cm</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5.0</td>
<td>2.0</td>
<td>I=0-50 cm; II=50-90 cm; III=90-165 cm; IV=165-220 cm</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>5.0</td>
<td>1.6</td>
<td>I=0-50 cm; II=50-120 cm; III=120-175 cm</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Not excavated</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>5.0</td>
<td>1.2</td>
<td>I=0-20 cm; II=20-50 cm; III=50-90 cm; IV=90-120 cm</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>5.0</td>
<td>1.5</td>
<td>I=0-10 cm; VI=10-50 cm; VII=50-85 cm; VIII=85-110 cm; IX=110-150 cm</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>4.0</td>
<td>1.1</td>
<td>VII=5-50 cm; VIII=50-85 cm; IX=85-110 cm; X=110-150 cm</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>5.0</td>
<td>1.0</td>
<td>See text for description</td>
</tr>
</tbody>
</table>

*cm=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-dug through the sandstone substratum was found; this channel measured 35 cm deep and 65 cm wide (Figure 5). Trench 10 was filled with a dense deposit (Layer 1). 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 (1-9, 7-10) were faced and described; five trenches (Nos. 1, 4, 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:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Dark brown to dark reddish-brown silty and clay loam; coarse-grained recent alluvium 10 to 120 cm deep. Extensive root zone. Present in Trenches 1-9, 7, 8, and 10;</td>
</tr>
<tr>
<td>II</td>
<td>Bottled dark reddish-brown clay loam with lenses of oxidized soil and small amounts of charcoal, small pockets of gray clayey 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 I1 was present in Trenches 1-5 and 7. In the layer is agricultural in origin, it does not appear to represent irrigation agriculture;</td>
</tr>
<tr>
<td>III</td>
<td>Reddish-brown fine-grained clay to clay-loam. Quite moist with some basalt rocks and occasional small lenses of oxidized sandy silt. 40-75 cm thick; no roots. No samples were taken from this layer. Layer III was present in Trenches 1-3 and 7;</td>
</tr>
<tr>
<td>IV</td>
<td>Compact reddish-brown fine to coarse-grained clay with small amounts of gray coral regolith. Thickness is 20-35 cm. Layer IV was present in Trenches 1-4;</td>
</tr>
<tr>
<td>V</td>
<td>Underlying fossil coral reef. Gray to very pale brown. This layer was encountered in Trenches 1 and 2 at 172-220 cm;</td>
</tr>
<tr>
<td>VI</td>
<td>An unusual stratum of crushed coral rocks immediately below the Afo-horizon in Trench 8. Extending from 10-30 cm, 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 readhead dating to c. 1900;</td>
</tr>
</tbody>
</table>
FIGURE 6. SITE T-10, TRENCH 10, NORTH FACE

SITE DESCRIPTIONS

Site T-1 - Linear Mound

Site T-1 is a roughly linear mound comprised of waterworn basalt cobbles and small builders. 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 northeast 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. 165 m southeast of T-1. The alignment, 1.6 meters long, is comprised of waterworn basalt builders and cobbles. Surrounding the alignment is a thin, c. 270-sq m scatter of broken, angular fine-grained 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 Barn

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 (pikes) 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 canal 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 wall below a sheer basalt coastal cliff (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 sides of the terrace and its 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 6) 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
forms part of the downslope 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 10.0 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 up slope, 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 architectural terrace or as a wall to restrict access to Feature D.

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 partly altered natural talus alignment of basalt boulders (2.7 m maximum height). Some stones of Feature D are grafted downwards, and the east side of the feature climes steeply upwards (35 degrees). The upper part 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 upper surface is an area of rocky loam which measures c. 60 sq m. Feature D is assumed to have been an architectural terrace.

Feature E is a terrace measuring c. 5.0 by 6.0 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 architectural feature.

Feature F is a 66.0 meter long, roughly J-shaped core-filled wall which runs downslope and above 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 6). Four of the boulders are located immediately south of Feature H, the fifth boulder is situated southeast of Feature H. The petroglyphs are incised 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
cobble and boulder; it extends c. 32.0 m downslope from the southeast 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 X. 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 H and may have functioned as an animal or garden enclosure wall.

Feature L is a c. 100.0-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 ramplike. While the structural form of the feature suggests it was an agricultural terrace wall, Feature L may have been an animal enclosure wall or at least abutted with Features H 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 H and abuts Feature L. Feature M is probably an enclosure wall.

Feature H 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 SW terminus of Feature L and extends 26.0 m up the steep slope toward a sheer basalt escarpment. Feature H 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 H.

Site T-14 - Well

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 0.60 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 m high (overall); presently, the foundation is filled with sand. The site probably dates to the latter half of the 20th century.

Site T-15 - Irrigation Ditch

Site T-15 is a c.1900-1935 irrigation ditch which probably delivered water from Paholea 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 southeast-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 103) was excavated through T-15, c. 8.0 m west of the southeast 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 alluvial portion of the survey area; it may have functioned as a water-deduction 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 150 m long; it is located c. 65.0 m from Site T-12—which is roughly parallel. 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 augen-gneiss 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 2.0 m deep (maximum) by 1.3 m high (maximum), and a wall (Feature B). The rockshelter is situated 5.0 m west of the outer edge 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 talus of the cliff. 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. Feature B wall measures 2.0 m long by 0.70 m high and is composed 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 run-off 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.
Site T-19 - Rockshelter

This site is located approximately 45.0 m southwest of Site T-18, at the base of the same cliff T-18 is on. 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 1.6 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 abraded, 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 2.0 m high. No artifacts were observed at Feature A; however, the floor of the shelter, covered with brown silty loam, may contain buried cultural deposits. Site T-19 is interpreted to have functioned as an early prehistoric/ceramic 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. The bunker faces the ocean and is present in each tier. The site is well-preserved, due in part to maintenance by 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 Pakulene and Kalumawaika Culches, on the edge of pasturage that was used for agriculture in the early 20th century (A. Aoki, pers. comm.). The site consists of a sloping wall composed of basalt rocks. The wall measures about 2.5 m long by 1.5 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 700 feet above sea level at the crest of a steep cliff, provides a commanding view of the ocean. Site T-22 covers an area which measures 49.5 m (N-S) by 30.0 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.

Feature B consists of a tangle 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 2.5 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 35.0 m north of Feature B. Feature C measures approximately 2.0 m in diameter by 0.35 m high (top of a thin steel plate 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 about 30.0 m north 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 mouth of Kalumawaika and Pakulene Culches. A site similar to T-22 is Site T-20, situated southeast 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 Pakulene and Pakulene Culches just inland of Site T-23, consists of nine features. This 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 0.40 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 0.75 by 0.35 m by approximately 0.60 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 10.0 m west of Feature A. Slab CI measures 0.60 m long by 0.25 m wide by 0.15 m thick. Slab C2I measured about 0.30 m square from slab CI, measures 0.60 by 0.60 m by 0.15 m thick. Both slabs are thought to have once 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 2.0 m beyond the end of the short arm of the L, measures approximately 3.5 by 9.0 m. Feature D may have once been a structural foundation.

Feature E, a rectangular concrete slab, is situated approximately 24.0 m east southeast of Feature X. The slab is 2.45 m square in area; it is 0.15 m high. Feature E probably was a foundation for a small shed or outbuilding.

Feature F is a linear alignment of watertown basalt rocks. The alignment measures 39.0 m long by 0.30 m wide by 0.20 m high. One end of Feature F is located 24.0 m southeast of Feature E. 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 E. Feature G is a loosely stacked mound of watertown basalt rocks and small boulders. The mound is oval in plan view and measures approximately 2.0 by 2.0 m by 1.0 m high. The age and function of Feature G are unknown.

Feature H, situated 19.5 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 0.60 m by 1.5 m deep. Of the depressions on the Site T-23 hill, only Feature H contained potter's 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 18.0 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 0.20 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 platform covers an area which measures 3.0 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 slates. 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 the margins of the area enclosed. Feature A is located 1.400 m north, northwest of Feature B, and Feature A is on the northeast 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 Kekaha Gulch. Feature A is approximately 14.0 ft above sea level; Feature B is approximately 350 ft above sea level.

Feature A is a curved retaining wall comprised of watertown basalt cobbles and boulders. The wall measures 9.50 m long by 0.50 m high by 0.40 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. Aniki, pers. comm.). One side of the feature (uphill side) acts to retain soil.

Feature B is a linear retaining wall comprised of watertown basalt rocks. Feature B measures 6.0 m long by 0.5 m high (3.5 courses) by 0.6 m wide. It runs along the edge of a cow pasture, perpendicular to the steep slopes of Kekaha Gulch. Like Feature A, Feature B retains soil on its approximate 0.6 m wide. The location of Feature B, on the edge of an area intensively cultivated during the first half of the 20th century, is a remnant of either a railroad or wagon road that circled the cultivated area.

Site T-30 - Rockshelter

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 base of Kekaha Gulch, at the base of a basalt cliff. The shelter measures 3.0 m wide by 1.0 m deep by 0.90 m high (2 courses). Present is a small semicircular wall 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 north 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 2.5 sq m. Feature C may have been a short-term temporary habitation shelter. Feature B 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 area was not cleared to the extent necessary for proper recording. 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-19, 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 100.0 m, and ends at a point about 200 feet above sea level. Most part 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 northern bank. Segment 2 varies in height, from 0.69-1.30 m (4-5 courses), and is c. 0.60 m wide and 120.0 m long.

Segment 3 is situated in the middle of Pakulena Stream, about 50.0 m upstream of the mouth and 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 roadway located between the stream and the cliffs of Pakulena Gulch. The connecting portion was probably eroded away by the stream.

**Site T-35 - Cove**

Site T-35 is situated on the lower slopes and bottom of Pakulena Gulch. Site T-35 contains of four spatially discrete walls (Features A-D). These walls, which retain rock and wall, are thought to be part of a road system which serviced the agricultural plateau bordering both sides of Pakulena Gulch. In situ excavation at the site was conducted in 1960 and used up to about the time of WWI.

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 B 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 overrun and semi-eroded) crossed the streambed.

Feature B is 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 cobble 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 had 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, continued 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 0.30-0.60 m of recent alluvium. The exposed portion of the feature measures about 12.0 meters long by 0.80 meters high (maximum 2-5 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 valley. The cave was reportedly recorded in the early 1880s by the Bishop Museum after it was accidentally discovered (Gary McCarty, pers. comm.). The cave measures 7.75 m wide by 3.00 m deep by 0.60 m high. Within the cave are two human burials, the remains of a burial cave, 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 canopy) and two pig sandstone (perhaps offerings). The largest canoe fragment measures 1.30 m long by 0.25 m wide by 0.01 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 were 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 Kalumawakahia 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 46 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. Feature A and B are situated at the bottom of Kalumawakahia 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 Kalumawakahia Stream, and parallel to the stream. Feature A measures about 75.0 m long by 4.00 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 Kalumawakahia 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 Kalumawakahia Stream, measures about 80.0 m long by 0.50 m wide by 0.75 m high.

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(2-5 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 2-8 courses high. The wall measures 0.75 m high by 0.20 m long by 0.30 m thick. Feature D is probably part of a former roadbed which extended from Kalumawakahia 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 Kalumawakahia Stream. The site consists of a small, rectangular concrete and wood structure with a tin roof. The structure measures 4.5 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 m by 2.0 m by 2.0 m high. Two wooden power poles are present 4.5 m northwest 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 1931. The well, which serviced a plantation camp south of Site T-34, 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 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 (Wii bunker) and 45.0 m 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. 1.6 m wide by 1.2 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 acres southeast of Feature A. Feature B is comprised of three rectangular (plan view) concrete foundations which lie parallel to each other. The foundations are of unequal length, and they lie perpendicular to the slope they are on. The foundations 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 southeast of Feature A. Feature C consists of a concrete steinblock (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
run 45.0 meters to Site T-20. Site T-40 may have been a communication post or artillery spotters post associated with Site T-20.

Site T-42 - Dam

Site T-40 is situated immediately outside the project area, in Kaluamakala Gulch, at approximately 270' above sea level. The site consists of a dam built with weathered basalt boulders. The dam, which spans the bottom of the gulch, measure 19.00 m long by 1.25 m wide (triply-stacked) by 1.46 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 northeast 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 316' 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 230-710 ft above sea level on a ridgecrest between Pakalana and Kalekuku 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 34.0 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.
Site T-46 - Retaining Wall

Site T-46 is situated between Paaumalou and Pahalena Gulches at the base of Pua Waiakea, which is southeast of the site. Site T-46 is a slightly curved retaining wall composed of waterworn basalt rocks. The wall measures approximately 15.00 m long by 2.00 m wide by 0.50 m (2-3 courses) high. The wall, which is immediately downhill of a dirt road still in use, acts as a retaining for the roadbed. Site T-46 probably dates to c. 1900-1920. The wall may have originally serviced agricultural areas of the nearby plateau (A. Aoki, pers. comm.).

Site T-47 - Bottle and Rubbish Scattering

Site T-47 is situated about 125.0 m northwest of Site T-46. It is comprised of a small scattering of broken bottles, earthenware, pottery, porcelain, and metal fragments. The exposed area of the scatter, which is present in an eroded face of a bank, measures 10.0 m by 7.0 m (long axis running horizontally across the eroded bank). The scatter includes green, brown, and purple fragments of 12 or more wine and medicine-type bottles. One bottle bears the date "1818," 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 were 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 was associated with plantation cultivation on the plateau c. 1900-1950.

Site T-48 - Mound

Site T-48 is situated approximately 380' above sea level, on the plateau between Paaumalou and Pahalena Gulches, immediately north of a small drainage. The site consists of two mounds (Features A and B) composed 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 3.0 m away from Feature A. Feature B is oval in plan and measures 5.0 by 3.0 m by 1.0 m high. Boulders are loosely stacked. Features A and B are probably agricultural clearing mounds associated with early to mid-20th century agriculture. Several smaller probable agricultural sounds were noted west of Feature B.

Site T-49 - Retaining Wall

Site T-49 is situated on the plateau between Paaumalou Gulch (to the north), Kaleleiki Gulch (to the east), and Pua Waiakea (to the south). The site consists of two retaining walls (Features A and B). Both walls are composed 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 3.0 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 4.00 m long by 0.60 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, G. 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 roadbed. The segments, comprised of rough waterworn basalt cobbles, run adjacent to Paaumalou 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 Paaumalou 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 Paaumalou Stream; it measures 12.0 m long by 1.5 m wide. Segment B 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 Paaumalou Stream. Feature B starts where Segment 1 of Feature A crosses Paaumalou Stream and from that point extends upstream. Feature B measures about 45.0 m long by 0.60 m wide by 0.50 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 Feature A and B. The channel measures about 75.00 m long by 1.40 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 Paaumalou Stream loops to the
Site T-52 – Complex

Site T-52 is situated on a gently sloping portion of a talus immediately southwest of Pamatulü Gulch. Site T-52 consists of a rectangular enclosure (Feature A) and a wall which surrounds the enclosure (Feature B). The walls of Feature A are single- and double-stacked. The walls are comprised of rough weathered basalt boulders and cobbles. Two of the feature’s walls incorporate basalt bedrock outcrops and very large boulders. The walls measure 0.10-1.00 m high (too close to brush-covered) except where they incorporate the bedrock and boulders, and they enclose an area which measures approximately 35.0 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. 1800-1940.

Feature B is core-filled wall which adjacent northern corner of Feature A. Feature B is 60.0 meters long by 1.0 m high (3 courses) by 3.0 m wide. It extends from Feature A northeast down a slope and ends near a dirt road at the bottom of Pamatulü Gulch. The interior and exterior faces of the feature are comprised of rough weathered 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 contemporaneous with Feature A.

Site T-55 – Retaining Wall

Site T-55 is situated about 150° above sea level on the lower slope immediately southeast of Pamatulü Gulch. The site consists of a small remnant of a stone retaining wall. The remnant consists of weathered basalt rocks, and it measures 3.0 m long by 5.0 m wide (due to its slope) by 1.0 m high. Site T-55 has been heavily disturbed by cattle. Site T-55 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 Pamatulü Gulch, approximately 50.0 m above Pamatulü Stream, at the base of a small cliff. The rockshelter measures approximately 3.75 wide by 1.00 m deep by 0.60 m high. The floor of the shelter is littered with the remains of a wild pig (including a skull, mandible, tibia and scapula). No cultural remains were noted on the floor. A crowbar probe was informally placed into the floor. The probe yielded large pieces of charcoal and grayish-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 Pamatulü Gulch. The wall is core-filled. Both faces of the wall are comprised of rough weathered 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 0.20 m wide by 0.50 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 Pamatulü Stream’s flood plain, approximately 8.0 m south of and parallel to Pamatulü Stream. Site T-56 consists of a well-preserved flat-standing retaining wall. It is comprised of rough weathered basalt cobbles and small boulders. The wall extends for 220.0 m in a roughly north-south direction, from the downhill terminus of Site T-55 up past Pamatulü 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 probably functions to retain a well-preserved roadbed which was probably used between 1800-1950.

Site T-57 – Enclosure

Site T-57 is situated on the lowest slope immediately north of Pamatulü 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 1,700 sq m. The walls of the enclosure are core-filled, and the walls in several places incorporate bedrock outcrops and three stone features. Two sides of the walls are faced with rough weathered basalt rocks, and the core of the wall is filled with rubble. The walls measure about 1.0 m (3-3 courses) high by 3.0-4.0 m wide by 50-65.0 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 1800-1950.

Site T-58 – Complex

Site T-58 is situated immediately northeast of the juncture of Pamatulü Stream 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 3.50 m long by 0.60 m wide by 0.40-1.00 m high.
Feature B is situated 16.0 m southeast of Feature A. Feature B is a retaining wall composed of waterworn basalt cobbles. The wall runs along a steep earthen bank next to the flood plain of Kauhale Stream and retains a roadway. Feature B measures 10.0 m long by 0.50-1.00 m wide by 0.55-0.80 m (3-4 courses) high.

Feature C is a wall very similar to Feature A. Feature C is situated 1.5 m northeast 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 0.30-1.30 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 roadway 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. 1800-1950.

Site T-59 - Retaining Wall

Site T-59 is situated in the base of Pamalol Gulch, just downstream of the mouth of Kauhale Stream. It consists of a retaining wall composed of waterworn basalt cobbles and small boulders. The wall, which is discontinuous (in two segments—Segments 1 and 2) parallel to Pamalol 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 near the mouth of Segment 1, is 12.0 m long and is much better preserved. Both segments retain on their uphill side a flat earthen roadway. Site T-59, like the other Pamalol Gulch roadways probably was constructed between the late 1800s and early 1900s.

Site T-62 - Linear Mound

Site T-62 is situated on the plateau between Pakulama and Pamalol Gulches, next to a small drainage a short way upstream (east) of Site T-64. The mound parallels the drainage channel, which is 4.0 m south of the mound. Site T-62 measures 20.0 m long by 3.0 m wide by 0.80 m high. It is composed of loosely stacked, uncalied waterworn basalt rocks. Some of the rocks have builder's blade marks 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 Kauhalemauna 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 1063-1069 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, composed of rough basalt rocks, is a wall built; it measures 6.0 m long by 1.5 m wide by 1.5 m high and lies perpendicular to a flat ledge that itself runs perpendicular to the slope. Feature B, situated about 10.0 m northwest of Feature B, 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 (1.0 m by 1.25 m) and two mesquite tree roots. Two tunnel 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 Kauhalemauna Stream, in an area about 100' 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 2.5 m wide by 2.3 m deep by 0.70 m high. The smaller chamber measures 1.7 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 to twenty pieces of angular, fine-grained basalt, which were scattered over the floor 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 Hohal 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 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 partially blocked by rafts of basalt units. Site T-67 measures 8.0 m wide by 9.5 m deep by 5.5 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 bone scatter which included teeth, an ulna, a cranium, and other bone fragments. Within the unidentified bone fragments, a small basalt boulder in the midst of the rock pile was a relatively undisturbed burial consisting of the lower mandible, a femur, a tibia, one tooth, and a rib of a juvenile. A person present in the shelter were recent dog, pig, and some bones; this suggests area of the human remains may have been disturbed by animals. Present within the west side of the shelter was an area uninfested by the rock fall. This area (c. 2.0 m) contained fine-grained silty brown loam, which suggests cultural material may reside under the rock fall. 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 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 5), and a rectangular enclosure (Feature 3). Feature 5 is an east-northwest trending terrace which adjoins the western corner of the Feature 3. Feature 5, comprised of rough basaltic boulders, measure 8.2 m wide by 2.4 m wide by 0.8 m (7.4 courses) high. Feature 3 is a rectangular enclosure which measures about 12.0 by 16.0 meters (overall). The enclosure, constructed of 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 basalt boulders and cobbles. The top of the segment on the uphill side is in place 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 southeast end of Segment 1.
Segment 2 comprises the southeastern 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 wall is very much more than a wall. Segment 3 measures about 16.0 m long. 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. Interpretated in the eastern end of the segment is a large boulder (1.0 by 3.5 m). Two pieces of rock were found in about the middle of Segment 4.

Site T-46 structural form, massive walls, and presence of coral suggest it functioned as a shrine or small habitation. Its apparent isolation from residential structures supports a habitation interpretation.

Site T-70 Complex

Site T-70 is situated at about 160-175' above sea level, at the top of a gradually sloping hillside of a mesa Elementary School, at the base of a large cliff boasts north and east of the mouth of Fabian's Gulch. Immediately inside the project area Figure 13. Site T-70 is comprised of two petroglyph galleries (Feature A) and four rock shelters (Features B-E). It covers an area of 60 m north to south.

Feature A consists of two small groups of petroglyphs. One group, situated on an uneven bedrock cliff, covers an area which extends from about 1.0 m above ground surface up to at least 5.0 m up the cliff face. This group includes six or more small anthropomorphic figures and two petroglyphs of a horse-like or rabbit-like. Twelve meters north of the first group is another group of petroglyphs; this second group is more accessible without special equipment. One petroglyph in the second group depicts a dog, which is typical of traditional Hawaiian 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 located about 4.0 m south of the main group of petroglyphs comprising Feature A. Feature B measures about 11.0 m high by 3.5 m wide by 2.5 m deep. Present on the floor of the feature was a stone tool of a basalt flake. Present within Feature B, comprised of brown soil, are numerous cultural deposits.

Feature C is situated about 21.0 m south 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 rib, two vertebrae, and a radius which together comprised at least one skeleton. Also present were two flaked stone cores, fragments of the pelvic girdle of a possibly juvenile, an incisor, and two unidentified bones.
fragments. All the remains were probably once protected by a wall comprised of rough basalt cobble—the remains of which are on either side of the shelter's entrance. Adjacent to Feature C, to the northeast is a small basin which may have been used as a storage area. No soil buildup used exclusively 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 south of Feature D were two features, a few fragments, a radius, a scapula fragment, a pelvic fragment, and at least 17 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 period. 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 has a 1.5 m wide, 1.4 m deep, and 0.8 m high. The other chamber is 1.35 m wide (at entrance) by 3.25 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 0.20 m thick by 0.20 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 Kalamuvalaika Gulch, almost immediately above Site T-74. 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-73 - Rockshelter

Site T-73 is situated immediately above and southeast of Site T-72. It consists of two rockshelters (Features A and B) approximately 1.0 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 travel probe was excavated into the 1.2 sq in. silt, and a small soil floor of Feature A. The probe yielded charcoal at approximately 0.20 m, suggesting there may be intact materials buried in the floor.

Feature B is 3.0 m wide, 2.5 m deep, and 1.4 m high. An informal travel probe was excavated into the 0.5 sq in. silt, and a small soil floor of Feature B. The probe yielded abundant charcoal at 10-15 cm. 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 slope immediately northeast of Sunset Beach Elementary School 1.0-2.0 m southeast of the project area boundary, which it parallels. Site T-74 is comprised of rough waterworn basalt rock; it measures 1.20 m high by 0.40 m thick, and is about 50.0 m long (extending from 30-100° 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 100 ft above sea level, in a sheer basalt cliff near the bottom of Fabolous 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 4.75 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 eastern edge of the entrance to Feature B. Feature A consists of single-stacked wall comprised of rough basalt cobbles. It may have once joined 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 0.3 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 Pauma and Kaleskeck Fingers. The site covers an area measuring about 30.0 m north-south by 25.0 m east-west. Site T-76 consists of four wood and metal features (A-D).

Feature A consists of a large wooden platform nestled into telephone pole stumps. It is 12 inumber, and 55-gallon drums partially supported by two pre-fabricated porcelain insulators and topped with pieces of tin roofing. Feature A measures about 6.3 m by 5.3 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 bonded 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 southeast of Feature C. The southeastern water tank is the northern corner of Feature D. Feature D consists of a wooden corral and cattle-loading chute. The corral and chutes 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. Alawi, pers. comm.).
Site T-79 - Cave

Site T-79 is a narrow cave situated in the steep slope on the south side of Pahole Gulch, approximately 25.0 m above the gulch floor, and wide at the mouth, tapering to c. 0.50 m wide at the back of the cave, the mouth and tapering to c. 0.10 m as 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 weathered coral cobbles entrance. A weathered 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 cobbles) suggest a religious function for the site, either as a shrine or for burial. The lack of visible skeletal remains may indicate that they have been removed, or 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 3.0 m below the top of the cliff and 15.0 m above the base of the cliff. The cave fronts onto a ledge approximately 3.0 m long and 1.0-2.0 m wide. The cave has two openings separated by a pillar of rock. The cave is approximately 2.0-2.5 m wide, 3.0-4.0 m deep, and 1.5-2.5 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.

DISCUSSION

During the combined surface and subsurface reconnaissance survey of the Paukeke-Puamau Development project area 60 sites were identified. Nineteen trenches were excavated, and hand-trowel probes were conducted at 10 cobblesites. Of the 60 identified sites, 50 are totally 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, canoe, 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 (sw1) - 11 sites
- Military (mid-20th century) - 5 sites
- Burials (early historic/prehistoric) - 4 sites
- Quarry (prehistoric) - 2 sites
- Ranching (historic) - 6 sites
- Trail or property markers (all periods) - 3 sites
- Ceremonial sites (prehistoric/early historic) - 2 sites
- Political habitation (all periods) - 2 sites
- Rock art (early historic/prehistoric) - 2 sites
- Dam (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 independent 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 - Swett's Cliffs

The eight sites comprising Cluster A (Sites T-14, T-65, -66, -67, -71, -72, -73, and -80) are situated either on the cliffs that line the coast...
Table 3.

SUMMARY OF SITE CLUSTERS

<table>
<thead>
<tr>
<th>CLUSTER</th>
<th>SITES (No.)</th>
<th>DATE</th>
<th>TYPE OF SITES</th>
</tr>
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<tbody>
<tr>
<td>A. Seaward Cliffs</td>
<td>T-64, -65, -66, -67, -71, -72, -73, -80 (No.8)</td>
<td>Early historic</td>
<td>Temp. occupation; burial</td>
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<td>B. Talus Slope</td>
<td>T-3, -7, -12, -16, -18, -19, -31, -34, -70 (No.4)</td>
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<td>Agric., burial</td>
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<td></td>
<td></td>
<td>prehistoric</td>
<td>habitation,</td>
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<td></td>
<td></td>
<td></td>
<td>rock art</td>
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<td>C. Paumalu Gulch</td>
<td>T-50, -52, -55, -55, -56, -57, -58, -59 (No.8)</td>
<td>Historic</td>
<td>Transportation,</td>
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<td></td>
<td></td>
<td></td>
<td>ranching</td>
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<td>D. Upper Plantation</td>
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<td>Early 20th Century</td>
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<td></td>
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<td></td>
<td>Habitation</td>
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<td>E. Lower Plantation</td>
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<td>Late 19th-early 20th</td>
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<td></td>
<td>century (1860-1910)</td>
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<td></td>
<td>transportation</td>
</tr>
<tr>
<td>F. WWII Coastal Defense</td>
<td>T-20, -22, -40, -43, -45 (No.5)</td>
<td>WWII</td>
<td>Military</td>
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<td>burials (1)</td>
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<td>b. Roads</td>
<td>b. 1900s to mid 1940s</td>
<td>b. Transportation</td>
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<tr>
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<td>T-32, -33 (No.2)</td>
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<td></td>
</tr>
<tr>
<td>H. Kalonuiakalei Gulch</td>
<td>T-35, -37, -38 (No.3)</td>
<td>20th century</td>
<td>Transportation,</td>
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<td></td>
<td></td>
<td>(1900-1970)</td>
<td>agriculture</td>
</tr>
</tbody>
</table>

(Outside of any cluster – Sites T-1, -2, -3, -21, -42, -54, -69, and -76)
from Kaluweiivina to Faaaluii Guohe, or at the top of the talus facing the cliffs. Cluster A covers 350.0 m (51.5) by 55.0 m (6.5). 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, T-72, and possibly at Sites T-65, T-66, and T-72. Sites T-67 and T-72 each contained one or more human burials. Features present at the sites include internal and external walls (at Sites T-64, T-65, and T-72), a possible hearth (at Site T-72), and human burials (at Sites T-67, T-72, and T-64). Possible intact cultural deposits were noted at Sites T-64, T-66, T-67, T-72, and T-73.

Site T-64 - Evidence for occupation of Site T-64 includes two subangular flakes of high-grade volcanic glass and 10+ angular, broken pieces of fine-grained basalt. The feature A is well-suited for temporary occupation as attested by the fact that it has been recently used - modem artifacts litter the floor. Feature B of the site, a mound or wall remnant, is dated later than Feature A. The function of Feature B is unknown.

Site T-65 - There is presently little evidence of temporary habitation at Feature B (rockshelter) of Site T-65. Two trowel probe excavations 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 meso-archon cultural material is present at the feature.

Site T-65 - A site at 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 that 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 little 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 reflect intermittent brief periods of occupation during the late 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 alluvial 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 floors of Site T-67 may contain more intact 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 (Feature B and D), 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 only intermittently. The lack of historic artifacts at the site indicates that occupation took place only 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 sq m area which stains the shelter (this area could have been used for storage), and c) the somewhat unique soil in the shelter floor. Evidence which suggests the site was used for a burial 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 site 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 of both shelters uncovered charcoal, 20 cops in Feature A and 15 cops 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 this 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 - Taloa'epo'e

Site Cluster B is located on the slopes of the talus immediately north and west of the mouth of Falealupu Gulch. It consists of nine sites: T-9,
7. -13. -16. -18. -19. -31. -34. and -70. Sites T-2 and -71 are agricultural features; Site T-7 is a cairn. Site T-15 is a mound; Site T-13 is a habitation, agricultural, and rock art complex. Sites T-10 and T-18 may have been used as a volcanic glass quarry; Site T-34 is a burial 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 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 Site T-2, -16, and -31 (-31 being out of the project area) are recommended for further data collection.

Site T-2, T-7, and T-16 - Site T-2, a terrace, may be associated with Site T-10, a rock 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 to a small drainage; the site is likely protected by encircling walls, and it would have been an early historic/prehistoric habitation site. As such, it would have been occupied by a small, single-family dwelling probably occupied on a permanent basis. The petroglyphs at Site T-2, the site is assumed to date to the early historic period at the latest.

Site T-23 - The largest site in Cluster B is Site T-13, a complex of at least 14 stone features. Site T-12 may have been a single-family structure with an extended period of early historic occupation. Site T-23 is the most complete occupation site in Cluster B and dates to the early historic period.

Feature A of Site T-13, a low wall, may have retained soil for an activity area. This activity area was probably used by occupants of nearby Feature B.

Feature B, a terrace and possible house site, was probably used for occupation at Site T-13 and may have been a less 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 occupation of historic artefacts at the site 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 contains a terrace area to its northeast. This terrace may have been used for agriculture. Feature C is a large terrace which retains a c. 50-m wide deposit of lava rock. Feature D is assumed to have been an agricultural terrace. Feature E is interpreted as an agricultural terrace.

(Figure D discussed below.)

Feature F consists of five basalt boulders on which are pegged seven small taut rope-like 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. These petroglyphs, such as at Feature C, have been associated with early historic and prehistoric habitation sites. Feature G is probably associated with use of Feature B. That the petroglyphs are in use of Feature B.

Feature H, a single-tone alignment, is thought to be the foundation of a now vanished wall. As such, it would have been used as an enclosure with Features A, E, and F - an enclosure which would have surrounded Feature B. The historic petroglyphs at Site T-23 (1985:111) suggest Feature G dates to the prehistoric period.

Feature J, 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, M) 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 been used as a campsite. Features K and M are in an enclosure. This enclosure may have been used for agriculture. Feature L retains a deposit of early historic rock art. The feature does not have walls forming the possible enclosure. Features K and M are in an enclosure. This enclosure may have been used for agriculture. The size and height of the boulders suggest they were constructed to contain cattle rather than to form pre-contact domesticates such as pigs, which could have been penned in such nodes walls.
The walls that form the two possible enclosures are well-preserved, which suggests the walls post date the rest of Site T-13. In 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, B, and C seem more typical of pre-contact structures at nearby Umea Canyon (M. Mitchell, pers. comm.)—structures which were designed for pre-contact activities 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 domestic habitation during the prehistoric to early historic period, and the newer portion is possibly related to 19th century or later cattle or goat ranching.

**Sites T-18 and T-19** — Feature A of Site T-19 contained a coral abrader and a polished basalt cobbles fragment. Site T-18 contained, scattered on its floor, low grade volcanic glass. The presence of such artifacts, and the depth of historic artifacts at the sites indicate occupation of the sites probably predates the 19th century.

**Site T-31** — Site T-31 is an agricultural complex. Because it is outside the project area it was only currently recorded. An embankment 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.

**Site T-34** — 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.

**Site T-70** — 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 site lacks 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 cobbles found on its surface. 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 scattered and unsorted, multiple burials and bones were found near one another. Feature 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.

**Cluster C — Paumalu Colch**

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-52, -55, -56, -58, and -59 (road segments and complex); Site T-52 and -57 (walled animal enclosures); and Site T-55, a property or field boundary wall. Features present at Cluster C include cobbles roadsides, low water channels, 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 Colch. Initial large-scale agriculture in north shore upland plateaus began about 1900 (K. K. Griffin, 1988:123), thus 1900 is taken as the earliest possible date for the wagon roads. Large-scale agriculture continued in the area into the 1960s (A. Aubel, 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, T-55, and T-57 were probably related to the wagon roads. Site T-55 is a short core-filled wall sheltering Site T-50, a road segment; Sites T-52 and T-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.

**Cluster D — Upper Plantation**

Cluster D sites (T-23, -25, -46, -47, -48, -49, -62) are situated on the seaward half of the plateaus between Paumalu and Folkers Gulch. The sites are scattered over an area which measures 1,500 m (R-E) by 800 m (U-D). Cluster D sites are related to agricultural and transportation systems that once covered the plateaus in the project area (J. Ritchie, pers. comm.).
Site T-23 is a complex of nine concrete and stone features that local residents refer to as "the plantation manager's house" (A. Aoki and J. Harunara, pers. comm.). Other Cluster D sites are either retaining walls for old railroad or wagon road beds (Sites T-25, T-40, and T-42) or are agricultural earthen mounds (Sites T-46 and T-62). Cluster D sites are thought to date to the same period as Cluster E sites—from about the turn of the century to the period shortly after 1920. However, Cluster D sites were probably used longer than Cluster E 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 (988) by 180 m (600). Feature types at the cluster include irrigation ditches (Sites T-15 and T-17), a stone-lined well and concrete foundation (Site T-16), a large earthen berm (Site T-4), and a rock wall (Site T-74).

Sites T-15 and T-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-15, T-17, and T-17. Adjacent to the well is a rectangular concrete slab. The slab may be a former pumphouse foundation. Site T-74, a short curb-rubble wall, may date slightly earlier than the other Cluster E sites (c. 1890-1900?). 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 - Well Coastal Defense

This cluster is comprised of Sites T-20, T-22, T-40, T-42, and T-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, T-40, and T-42) 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 (500) by 100.0 m (300). All but Site T-45 are situated at the edge of the upland plateau, overlooking the coast.

Sites T-20, T-22, and T-42 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 be 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 downhill. 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-35, T-37, T-38, T-39, and T-43, 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 680.0 m (2200) by 100.0 m (350).

Sites T-32 and T-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 21); 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.

Site T-30, T-35, T-37, T-38, T-39, and T-43 represent the only evidence of prehistoric occupation inland of the coastal zone of the project area. Site T-30 and T-35 contain structural modifications. This indicates the shelters were used for some function. At T-35, the southeast walls may once have been joined together, as two a 1.5 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 solid deposit at the cave's entrance. Both Site T-30 and T-35 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-37 is partially covered by a shallow deposit of reddish-brown clay loam and rock-fall cobbles. No portable remains were visible in the floor. The smoothness of the rockshell, its relatively inaccessible location, combined with the presence of an enclosing wall suggest the rockshell may have been used for burial. The face 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 rockshell.

Portable remains at Site T-38 consisted of several volcanic glass flakes scattered around two exposures of surface chili volcanic glass. The flakes were present on the surface of the second bedrock ledge. The exposures showed evidence of flaking/scrapping activity. Other remains in the cave consisted of a sparse scatter of middens and one piece of volcanic glass. The piece of volcanic glass was situated at the east end of the sheltered outer ledge, in an adjacent to a small niche (c. 0.75 m deep, 0.50-0.60 m wide, and 0.30-0.40 m high) in the cliff face. The middle
consisted of Echinoids mouth parts, a Turbo shell fragment, kahui 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-78, combined with the presence of a possible offering (coral rubble) 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 II - Kukumwihiaka Gulch

Cluster II sites consist of three twentieth century sites—Sites T-35, -37, and -39. The sites, situated in the base or on the lower slopes of Kukumwihiaka Gulch, cover an area of about 350.0 m (964) by 50.0 m (160).

Site T-35 is a short rock retaining wall situated outside the project area. This wall, which is associated with Site T-37, predates 1950 (C.J. Hitch, pers. comm.). Site T-37, a multi-segment retaining wall is downstream of Site T-35 and 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 plateau to the north and south of Kukumwihiaka 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-39 is a wood and concrete pump house. According to J. Hitch, a life-long resident of the area, the pump house was built in 1921 and was used until 1970. The well serviced a large camp on Pupeoa Road, and then was abandoned due to the increased salinity of the water.

Site 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-9, T-31, 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 southeast 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 a 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 plateau 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 plateau. Site T-42 is probably contemporary with sites at Cluster D.

Site T-54 is a rock benches in steep cliff just south of Femalula Gulch. The floor of Site T-54 is covered with brown clay loam. When a trowel probe was excavated into the floor, it yielded charcoal and a grey-brown soil o. 15 cm. The absence of artifacts at the site suggests the site predates 1050.

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 interpreted as a shrine or heiau.

Site T-76 consists of two wooden water tanks, a large wood and metal platform, and a wooden coral. Site T-76 was used for 20th century ranching. The modern artifacts at the site suggest the period of ranching ended sometime after 1951, perhaps about 1960.

TEMPORAL PERIODS

The 60 identified sites within Pupukea-Femalula 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

<table>
<thead>
<tr>
<th>Group I - Prehistoric/Early Historic (Pre-1600s) (N=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Rockshelters (temporary occupation) (N=11) Sites T-18,</td>
</tr>
<tr>
<td>-19, -30, -64, -65, -66, -71, -73, -75, -76, (T-18 and</td>
</tr>
<tr>
<td>T-39 are also quarries)</td>
</tr>
<tr>
<td>B. Agricultural features (N=5) Sites T-2, -3, -5, -16, -31</td>
</tr>
<tr>
<td>C. Burial caves (N=3) Sites T-34, -57, -72, -77 (T), -70</td>
</tr>
<tr>
<td>D. Helm/shelters (T) (N=3) Sites T-1, -69, -76</td>
</tr>
<tr>
<td>E. Complex - habitation, agriculture, rock art (N=1) Site T-13</td>
</tr>
<tr>
<td>F. Complex - 4 rockshelters, 3 grooves, rock art (N=1) Site T-70</td>
</tr>
<tr>
<td>G. Cliff (boundary or property marker) (N=1) Site T-7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II - Sites Dating to 1600s to Mid-1940s (N=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Retaining walls (for roadsides) (N=11) Sites T-31,</td>
</tr>
<tr>
<td>-25, -32, -33, -37, -45, -49, -53, -55, -56, -59</td>
</tr>
<tr>
<td>B. Irrigation ditches (N=2) Sites T-15, -17</td>
</tr>
<tr>
<td>C. Earthen cause (railroad siding) (N=1) Site T-4</td>
</tr>
<tr>
<td>D. Rock-lined animal enclosures (N=2) Sites T-52, -57</td>
</tr>
<tr>
<td>E. Agricultural terraces (N=2) Sites T-46, -51</td>
</tr>
<tr>
<td>F. Rock walls (boundary) (N=2) Sites T-35, -74</td>
</tr>
<tr>
<td>G. Complex - habitation, irrigation (N=1) Site T-23</td>
</tr>
<tr>
<td>H. Transportation (N=1) Site T-50</td>
</tr>
<tr>
<td>I. Rubbish dump (N=1) Site T-67</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Group III - Sites Dating to Mid-1940s to Present (N=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. WWII coastal defense (N=5) Sites T-25, -32, -40, -43, -45</td>
</tr>
<tr>
<td>B. Well and foundation (N=1) Site T-14</td>
</tr>
<tr>
<td>C. Pumphouse (N=1) Site T-38</td>
</tr>
<tr>
<td>D. Ram (agricultural) (N=1) Site T-62</td>
</tr>
<tr>
<td>E. Agricultural/camping (N=1) Site T-76</td>
</tr>
<tr>
<td>F. Retaining wall (unknown function) (N=1) Site T-35</td>
</tr>
</tbody>
</table>

*Outside project area

Prehistoric and/or Early Historic Sites (Pre-1600s)

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 shard?) found in three 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 be 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 cemeteries. One cave contained three fragments of a burial cemeteries. Further data collection, especially of stratigraphic samples, may establish the exact dates of the Cluster B sites.

Prehistoric and/or early historic sites in island portions of the project area include six rockshelters. Five of these shelters are in lower Pakalua Gulch; the other shelter is in Pamilo Gulch. One shelter, Site T-30, contains a small wall which encloses a possible storage area and an earthen terrace.

Sites Dating to 1600s to Mid-1940s

During this period, occupation in the project area moved inland, from the exposed cliffs and talus to the top of the gulches and the plateau. Large-scale pineapple agriculture on the plateau, sugarcane cultivation in the coastal lowlands, and cattle ranching in other areas such as Pamilo Gulch characterize this period. Most of the twenty-four sites which date to this period are associated with the roads which served agriculture/reaching on the upper plateau. As shown in a 1954 map (Figure 2) there were in Pamilo and Pakalua Gulches roads leading to agricultural areas on the plateau. Seven sites in the project area are thought to be remnants of this road system. The plateau were also serviced by wagon roads, and according to local informants A. Ahiki and C. Orcis, a small-gauge railway. Four sites recorded in the project area are thought to be remnants of the wagon roads or railways; 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 ORL railroad(k).

Two sites which date to this period are agricultural clearing mounds. These two sites are representative of the numerous clearing mounds situated on the plains. Two other sites which date to this period are animal enclosures linked to ranching. Site T-42 of this period consists of a small rubbish dump (mainly bottles) which is eroding out of a hillside. Site T-37 was probably associated with temporary occupation (labor camp?) in nearby agricultural areas.

Site Dating to Mid-1940s to Present

This period includes 9 sites—sites mostly associated with NII defense or agriculture. The sites include NII coastal defense (sites T-20, -22, -40, -43, -45), a wall and foundation (site T-34), a pump house (site T-39), a dam (site T-42), and an agricultural/ranching camp (site T-76). Almost all the sites in the project area belong to this period are of little archaeological value. Sites T-20, -22, -40, -43, and -45 date to NII, 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 1950s, the avocado orchards and pineapple fields atop the plains 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 ranching structures. Site T-76 includes a four-footed, two-wheeled water tank, 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 (16 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 B, which defines significant resources as ones which "...have yielded, or are likely to yield, information important in prehistory or history." Sites potentially significant as representative examples

<table>
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<th>Site Number</th>
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General Significance Categories:

A: Important for information content, further data collection necessary (DLNR-research value);
B: Important for information content, no further data collection necessary (DLNR-research value, DLNR-HSS not significant);
C: Excellent example of site type at local, region, island, State, or National level (DLNR-interpretive value); and
D: Culturally significant (DLNR-cultural value).

Recommended General Treatments:

FP: Further data collection necessary (intensive survey and testing, and possibly subsequent data recovery/mitigation exclosures);
D: Documentation of further work of any kind necessary, sufficient data collected, archaeological clearance recommended, no preservation potential;
P: Preservation of some level of interpretive development recommended for consideration (including appropriate related data recovery work); and
F: Preservation as is, with no further work (and possible inclusion into landscaping), or further data collection necessary.
### Table 5. (Cont.)

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*Provisional assessment pending results of further data collection.

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 Reviews" (ACHP 1988). 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" (1988:11). The guidelines further specify that "[t]he property need not have been in consistent use since antiquity by a cultural system in order to have traditional cultural value" (1988:17).

Of the total 36 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 models which are derived from the previously mentioned sites 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
资源用于研究和理解文化历史、过去生活方式和文化过程。区域层面的组织。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-4 - 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 wall 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 F: Preservation of boulders in place, or relocation of boulders.

Feature G: 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 Feature A and B to further define period and nature of occupation.

T-23 - Detailed recording, surface collection, and test excavation of pits, including cultural and soil samples. 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 artifacts.

T-47 - Collection of diagnostic artifacts, especially pottery. Also, limited subsurface testing. If testing yields significant cultural material, controlled excavation of c. 4-5.0 meters is recommended.

T-56 - Excavation of 1.0-2.0 square meters.

T-64 - Excavation of one 1.0 m sq unit to refine nature and age of occupation.

T-65 - Subsurface shovel testing, possibly followed by excavation at Feature B.

T-68 - Excavation of 1.0 m sq 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 central soil deposit. If subsurface cultural material is present, other areas may require excavation. The entire area at the site should be photographed, mapped, then removed for analysis.

T-20 - 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 cases 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-21 - 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-23 - Excavation of three 1.0 sq m units-two units in Feature B, one in Feature A.

T-24 - Excavation of one or two sq m in area of brown silty loam at mouth of shelter.

T-25 - Detailed recording and test excavation (1 sq m) to determine if the site was used as a burial.

T-26 - Detailed recording, surface collection, and test excavation (1 sq m) to determine if a cultural deposit is present. Dating of volcanic glass, charcoal if recovered during excavation, in order to determine age of use.

T-27 - Detailed recording and test excavation (1 sq m) to define nature of any possible religious use.

T-28 - Detailed recording, surface collection, and excavation to remove burial.

While preservation "as is" is recommended as one option for sites containing human remains, in this present project area this option is less preferable to disinterment, analysis, and reinterment. This is because all burial sites show evidence of post 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 Puupuea-Panaulu 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 or 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, T-13 and T-16, and are the features contemporary with each other or with Feature B of Site T-17?
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 group?
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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LIHI LANI RECREATIONAL COMMUNITY PROJECT

TRAFFIC IMPACT ASSESSMENT REPORT

LIHI LANI RECREATIONAL COMMUNITY

Pupukoa, Oahu, Hawaii
TMI 5-9-05:38 and 5-9-06: 18 & 24

January 3, 1991

Prepared for:
Group 70

Prepared by:
Pacific Planning & Engineering, Inc.
1221 Kapolei Boulevard, Suite 140
Honolulu, Hawaii 96814
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 Hawai‘i Corporation is proposing to develop the Lihi Lani Recreational Community project at Pu’ukea in the Koolau 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) Kuli‘ole 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 bottleneck due to parking maneuvers,
Drivers slowing down to watch the surf, and
City buses stepping 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 streets 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.

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<td>1%</td>
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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 indicates 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 bayside 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 20 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 Koalulau 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>
<thead>
<tr>
<th>Description of Land Use</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable Homes</td>
<td>180</td>
<td>units</td>
</tr>
<tr>
<td>Market Homes</td>
<td>120</td>
<td>units</td>
</tr>
<tr>
<td>Golf Course</td>
<td>159</td>
<td>acres</td>
</tr>
<tr>
<td>Tennis Center</td>
<td>12</td>
<td>courts</td>
</tr>
<tr>
<td>Campground</td>
<td>15</td>
<td>acres</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>19</td>
<td>acres</td>
</tr>
<tr>
<td>Horse Pasture</td>
<td>78</td>
<td>acres</td>
</tr>
<tr>
<td>Community Facilities</td>
<td>10</td>
<td>acres</td>
</tr>
</tbody>
</table>
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.
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. Kamahameha 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 area attractions such as the Polynesian Cultural Center in Laie, the Kahuku Sugar Mill, the Turtle Bay Resort Hotel, and Kulima (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. Kamahameha 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 limits 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 Waimanu 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 Wai'anae Bay.
• Queues of cars would extend through the intersection due to bus blockage in the Kualoa 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.
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>
<thead>
<tr>
<th>Development</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koolina Resort Expansion</td>
<td>2,185 rooms</td>
</tr>
<tr>
<td>Koolina Hotel</td>
<td>300 units</td>
</tr>
<tr>
<td>Koolina Resort Condominiums</td>
<td>49,000 square feet</td>
</tr>
<tr>
<td>Koolina Shopping Center</td>
<td>200 acres</td>
</tr>
<tr>
<td>Kahuku Golf Course</td>
<td>177 units</td>
</tr>
<tr>
<td>Kahuku Villages</td>
<td>87 units</td>
</tr>
</tbody>
</table>

Future Roadway Facilities

There are no roadway improvements planned in the study area for Kahuku Highway, except for the Haliwa Bypass which will provide an alternative route for drivers bypassing Haliwa Town.

PROJECTED TRAFFIC CONDITIONS

Future traffic was forecast to determine traffic conditions without and with the Lahi 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 Kahuku Highway due to tourist and local traffic; and (3) traffic generated by other developments in the north shore area that will be completed by 1997.

Through-Traffic Growth along Kahuku Highway

Through-traffic describes vehicular traffic without an origin or destination point near the project site such as tourist driving along the north shore sightseeing.

The growth in through traffic was forecasted based upon the growth trend of vehicular traffic along Kahuku 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 Kahuku 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 Kuliima Resort's expansion during the weekday afternoon and weekend (Sunday) peak hours were based upon a traffic study prepared by Austin Tatsuami and Associates (ATA). 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 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

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuliima Resort Expansion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotel</td>
<td>2,183 rooms</td>
<td>304</td>
<td>243</td>
</tr>
<tr>
<td>Resort Condominiums</td>
<td>300 units</td>
<td>46</td>
<td>29</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>40,000 GLA</td>
<td>28</td>
<td>79</td>
</tr>
<tr>
<td>Golf Course</td>
<td>200 acres</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Kahuku Village</td>
<td>177 units</td>
<td>24</td>
<td>88</td>
</tr>
<tr>
<td>Kahuku Residential</td>
<td>87 units</td>
<td>12</td>
<td>45</td>
</tr>
</tbody>
</table>

- Weekend Peak Hour

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Sunday Peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuliima Resort Expansion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotel</td>
<td>2,183 rooms</td>
<td>245</td>
</tr>
<tr>
<td>Resort Condominiums</td>
<td>300 units</td>
<td>30</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>40,000 GLA</td>
<td>106</td>
</tr>
<tr>
<td>Golf Course</td>
<td>200 acres</td>
<td>29</td>
</tr>
<tr>
<td>Kahuku Village</td>
<td>177 units</td>
<td>55</td>
</tr>
<tr>
<td>Kahuku Residential</td>
<td>87 units</td>
<td>31</td>
</tr>
</tbody>
</table>

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 Kuliama's expansion. The distribution for trips generated by the Kuliama 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 Kamakanehu Highway is the primary roadway providing vehicular access to these developments, all vehicle trips were assigned to the highway.

Table 6. Trip Distribution Percentages for Future Developments

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>Weekday Morning Peak Hour</th>
<th>Weekday Afternoon Peak Hour</th>
<th>Weekend (Sunday) Peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From Halina</td>
<td>To Lihue</td>
<td>From Lihue</td>
</tr>
<tr>
<td>Kuliama Resort Expansion</td>
<td>65%</td>
<td>35%</td>
<td>65%</td>
</tr>
<tr>
<td>Kahuku Villages</td>
<td>70%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Kahuku Residential</td>
<td>70%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Kuliama Resort Expansion</td>
<td>55%</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Kahuku Villages</td>
<td>70%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Kahuku Residential</td>
<td>70%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Kuliama Resort Expansion</td>
<td>55%</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Kahuku Villages</td>
<td>60%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Kahuku Residential</td>
<td>60%</td>
<td>40%</td>
<td>60%</td>
</tr>
</tbody>
</table>

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 7. 1997 Weekend 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 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>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Units</th>
<th>Morning Enter</th>
<th>Morning Exit</th>
<th>Afternoon Enter</th>
<th>Afternoon Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-Time Market Homes</td>
<td>60</td>
<td>units</td>
<td>9</td>
<td>24</td>
<td>32</td>
<td>19</td>
</tr>
<tr>
<td>Part-Time Market Homes</td>
<td>60</td>
<td>units</td>
<td>7</td>
<td>3</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Affordable Homes</td>
<td>180</td>
<td>units</td>
<td>24</td>
<td>64</td>
<td>89</td>
<td>53</td>
</tr>
<tr>
<td>Community Facility</td>
<td>10</td>
<td>acres</td>
<td>17</td>
<td>7</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Campground</td>
<td>15</td>
<td>acres</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Golf Course</td>
<td>133</td>
<td>acres</td>
<td>30</td>
<td>7</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>100</td>
<td>staffs</td>
<td>18</td>
<td>7</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Tennis Complex</td>
<td>12</td>
<td>courts</td>
<td>12</td>
<td>5</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Total Trips</td>
<td></td>
<td></td>
<td>115</td>
<td>119</td>
<td>170</td>
<td>193</td>
</tr>
</tbody>
</table>

Weekend Peak Hour

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Units</th>
<th>Enter</th>
<th>Exit</th>
<th>Enter</th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-Time Market Homes</td>
<td>60</td>
<td>units</td>
<td>73</td>
<td>21</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Part-Time Market Homes</td>
<td>60</td>
<td>units</td>
<td>19</td>
<td>23</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Affordable Homes</td>
<td>180</td>
<td>units</td>
<td>56</td>
<td>52</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Community Facility</td>
<td>10</td>
<td>acres</td>
<td>22</td>
<td>22</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Campground</td>
<td>15</td>
<td>acres</td>
<td>5</td>
<td>5</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Golf Course</td>
<td>133</td>
<td>acres</td>
<td>41</td>
<td>41</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>100</td>
<td>staffs</td>
<td>12</td>
<td>12</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Tennis Complex</td>
<td>12</td>
<td>courts</td>
<td>15</td>
<td>18</td>
<td>-2%</td>
<td></td>
</tr>
<tr>
<td>Total Trips</td>
<td></td>
<td></td>
<td>194</td>
<td>192</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

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 Kuliwai'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 fewer 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>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Units</th>
<th>Morning Enter</th>
<th>Morning Exit</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>60 units</td>
<td>9</td>
<td>24</td>
<td>14%</td>
<td>32</td>
<td>19</td>
</tr>
<tr>
<td>Part-Time Market Homes</td>
<td>60 units</td>
<td>7</td>
<td>3</td>
<td>4%</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Affordable Homes</td>
<td>180 units</td>
<td>24</td>
<td>66</td>
<td>39%</td>
<td>89</td>
<td>53</td>
</tr>
<tr>
<td>Community Facility</td>
<td>10 acres</td>
<td>17</td>
<td>7</td>
<td>10%</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Campground</td>
<td>15 acres</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Golf Course</td>
<td>139 acres</td>
<td>30</td>
<td>7</td>
<td>16%</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>100 stalls</td>
<td>18</td>
<td>7</td>
<td>11%</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Tennis Complex</td>
<td>12 courts</td>
<td>10</td>
<td>5</td>
<td>6%</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total Trips</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>115</td>
<td>115</td>
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</tbody>
</table>

Weekend Peak Hour

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>Amount</th>
<th>Units</th>
<th>Enter</th>
<th>Exit</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-Time Market Homes</td>
<td>60 units</td>
<td>23</td>
<td>21</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Part-Time Market Homes</td>
<td>60 units</td>
<td>19</td>
<td>23</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Affordable Homes</td>
<td>180 units</td>
<td>56</td>
<td>52</td>
<td>28%</td>
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</tr>
<tr>
<td>Community Facility</td>
<td>10 acres</td>
<td>22</td>
<td>22</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Campground</td>
<td>15 acres</td>
<td>5</td>
<td>5</td>
<td>3%</td>
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</tr>
<tr>
<td>Golf Course</td>
<td>139 acres</td>
<td>41</td>
<td>41</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Equestrian Ranch</td>
<td>100 stalls</td>
<td>12</td>
<td>17</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Tennis Complex</td>
<td>12 courts</td>
<td>16</td>
<td>15</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td><strong>Total Trips</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>194</td>
</tr>
</tbody>
</table>

Sunday Peak Hour

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 Koilima 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.
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 8. 1997 Forecast Traffic Volumes
#### Afternoon Peak Hour

<table>
<thead>
<tr>
<th>Intersection</th>
<th>1997</th>
<th>1997</th>
<th>Incremental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m/s Project</td>
<td>m/s Project</td>
<td>Increase</td>
</tr>
<tr>
<td>Kamahana Highway near Hickam Beach Park</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound (to lali)</td>
<td>TH 1035</td>
<td>TH 1119</td>
<td>84</td>
</tr>
<tr>
<td>Southbound (to laloa)</td>
<td>TH 1031</td>
<td>TH 1129</td>
<td>98</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Pupukea Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>LT 4</td>
<td>LT 4</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>871</td>
<td>915</td>
<td>44</td>
</tr>
<tr>
<td>BT</td>
<td>316</td>
<td>316</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT 4</td>
<td>LT 4</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>837</td>
<td>935</td>
<td>98</td>
</tr>
<tr>
<td>BT</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Pupukea Beach Park Drive</td>
<td>Eastbound (Ma'ili)</td>
<td>LT 5</td>
<td>LT 5</td>
</tr>
<tr>
<td>TH</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Westbound (Ma'ili)</td>
<td>LT 63</td>
<td>LT 63</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
<td>64</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Sunset Beach Elementary School Drive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>TH 875</td>
<td>TH 919</td>
<td>44</td>
</tr>
<tr>
<td>BT</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT 4</td>
<td>LT 4</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>963</td>
<td>963</td>
<td>0</td>
</tr>
<tr>
<td>Sunset Beach Elementary School Drive</td>
<td>Westbound (Ma'ili)</td>
<td>LT 24</td>
<td>LT 24</td>
</tr>
<tr>
<td>TH</td>
<td>24</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
<td>24</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Project Access Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>TH</td>
<td>899</td>
<td>899</td>
</tr>
<tr>
<td>BT</td>
<td>n/a</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT</td>
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<td>876</td>
</tr>
<tr>
<td>TH</td>
<td>876</td>
<td>876</td>
<td>0</td>
</tr>
<tr>
<td>Project Access Road</td>
<td>Westbound (Ma'ili)</td>
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<td>n/a</td>
</tr>
<tr>
<td>TH</td>
<td>680</td>
<td>737</td>
<td>57</td>
</tr>
<tr>
<td>Kamahana Highway near Kahuku Sugar Mill</td>
<td>Northbound (to laloa)</td>
<td>TH 680</td>
<td>TH 725</td>
</tr>
<tr>
<td>Southbound (to laloa)</td>
<td>TH 680</td>
<td>TH 737</td>
<td>57</td>
</tr>
</tbody>
</table>

n/s = not applicable

### Table 9. 1997 Forecast Traffic Volumes
#### Weekend (Sunday) Peak Hour

<table>
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<tr>
<th>Intersection</th>
<th>1997</th>
<th>1997</th>
<th>Incremental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m/s Project</td>
<td>m/s Project</td>
<td>Increase</td>
</tr>
<tr>
<td>Kamahana Highway near Hickam Beach Park</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound (to lali)</td>
<td>TH 1251</td>
<td>TH 1236</td>
<td>15</td>
</tr>
<tr>
<td>Southbound (to laloa)</td>
<td>TH 1065</td>
<td>TH 1187</td>
<td>122</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Pupukea Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamahana Highway</td>
<td>LT 16</td>
<td>LT 16</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>960</td>
<td>1014</td>
<td>54</td>
</tr>
<tr>
<td>BT</td>
<td>70</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT 49</td>
<td>LT 49</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>946</td>
<td>1068</td>
<td>122</td>
</tr>
<tr>
<td>BT</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Pupukea Beach Park Drive</td>
<td>Eastbound (Ma'ili)</td>
<td>LT 11</td>
<td>LT 11</td>
</tr>
<tr>
<td>TH</td>
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<td>2</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
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<td>7</td>
<td>0</td>
</tr>
<tr>
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</tr>
<tr>
<td>TH</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Sunset Beach Elementary School Drive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>TH</td>
<td>1033</td>
<td>1136</td>
</tr>
<tr>
<td>BT</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>1022</td>
<td>1124</td>
<td>102</td>
</tr>
<tr>
<td>Sunset Beach Elementary School Drive</td>
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<td>LT</td>
<td>0</td>
</tr>
<tr>
<td>TH</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BT</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Intersection of Kamahana Highway with Project Access Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamahana Highway</td>
<td>TH</td>
<td>1033</td>
<td>1033</td>
</tr>
<tr>
<td>BT</td>
<td>n/a</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Southbound</td>
<td>LT</td>
<td>n/a</td>
<td>55</td>
</tr>
<tr>
<td>TH</td>
<td>1023</td>
<td>1022</td>
<td>0</td>
</tr>
<tr>
<td>Project Access Road</td>
<td>Westbound (Ma'ili)</td>
<td>LT</td>
<td>n/a</td>
</tr>
<tr>
<td>TH</td>
<td>680</td>
<td>725</td>
<td>47</td>
</tr>
<tr>
<td>BT</td>
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<td>54</td>
<td>54</td>
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<tr>
<td>Kamahana Highway near Kahuku Sugar Mill</td>
<td>Northbound (to laloa)</td>
<td>TH 745</td>
<td>TH 845</td>
</tr>
<tr>
<td>Southbound (to laloa)</td>
<td>TH 848</td>
<td>TH 929</td>
<td>81</td>
</tr>
</tbody>
</table>

n/s = not applicable
Figure 10. 1997 Weekday Afternoon Peak Hour Traffic With Project

Figure 11. 1997 Weekend Peak Hour Traffic With Project
TRAFFIC IMPACTS

Analysis 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, 1985.

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 unsignaled intersection analysis are shown in Tables 11, 12, and 13.

<table>
<thead>
<tr>
<th>Highway Segment</th>
<th>1990</th>
<th>1997</th>
<th>1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday Morning Peak Hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Haleiwa Beach Park</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Pupukea Road</td>
<td>C</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Sunset Beach Elementary School</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Kailua Sugar Mill</td>
<td>B</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Weekday Afternoon Peak Hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Haleiwa Beach Park</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Pupukea Road</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Sunset Beach Elementary School</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Kailua Sugar Mill</td>
<td>C</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Weekend (Sunday) Peak Hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Haleiwa Beach Park</td>
<td>E</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>Near Pupukea Road</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Sunset Beach Elementary School</td>
<td>D</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Near Kailua Sugar Mill</td>
<td>C</td>
<td>E</td>
<td>E</td>
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</table>

Table 11. Level of Service for Unsignalized Intersections

<table>
<thead>
<tr>
<th>Intersection</th>
<th>1990 Existing</th>
<th>1997 Without Project</th>
<th>1997 With Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamehameha Highway with Pupukea Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway Northbound (Makai)</td>
<td>LT</td>
<td>A A</td>
<td>A</td>
</tr>
<tr>
<td>Southbound (Makua)</td>
<td>LT</td>
<td>A A</td>
<td>A</td>
</tr>
<tr>
<td>Pupukea Beach Park Drive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastbound (Makua)</td>
<td>LT</td>
<td>B D</td>
<td>E</td>
</tr>
<tr>
<td>TH</td>
<td>B D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>B D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Pupukea Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Westbound (Makai)</td>
<td>LT</td>
<td>C E</td>
<td>E</td>
</tr>
<tr>
<td>TH</td>
<td>A B</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>A B</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway with Sunset Beach Elementary School Drive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway Southbound (Makau)</td>
<td>LT</td>
<td>A A</td>
<td>A</td>
</tr>
<tr>
<td>Sunset Beach Elementary School Drive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Westbound (Atsaka)</td>
<td>LT</td>
<td>B E</td>
<td>E</td>
</tr>
<tr>
<td>RT</td>
<td>B E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway with Project Access Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway Southbound (Makau)</td>
<td>LT</td>
<td>n/a n/a</td>
<td>E</td>
</tr>
<tr>
<td>Project Access Road</td>
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<td>Westbound (Atsaka)</td>
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n/a - Not Applicable
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<th>1997</th>
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<td><strong>With Project</strong></td>
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</tr>
<tr>
<td>Kamehameha Highway with Pupukea Rd</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Northbound (Makai)</td>
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<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Southbound (Makai)</td>
<td>LT</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Papakea Beach Park Driveway</td>
<td>Eastbound (Makai)</td>
<td>LT</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>TH</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
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<td>Westbound (Makai)</td>
<td>LT</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>TH</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Kamehameha Highway with Sunset Beach Elementary School Driveway</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway</td>
<td>Southbound (Makai)</td>
<td>LT</td>
<td>A</td>
</tr>
<tr>
<td>Sunset Beach Elementary School Driveway</td>
<td>Westbound (Makai)</td>
<td>LT</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
<td>Kamehameha Highway with Project Access Rd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway</td>
<td>Southbound (Makai)</td>
<td>LT</td>
<td>n/a</td>
</tr>
<tr>
<td>Project Access Rd</td>
<td>Westbound (Makai)</td>
<td>LT</td>
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n/a - Not Applicable

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<th>1997</th>
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</thead>
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<td><strong>Without Project</strong></td>
<td><strong>With Project</strong></td>
<td></td>
</tr>
<tr>
<td>Kamehameha Highway with Pupukea Rd</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Northbound (Makai)</td>
<td>LT</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Southbound (Makai)</td>
<td>LT</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Papakea Beach Park Driveway</td>
<td>Eastbound (Makai)</td>
<td>LT</td>
<td>D</td>
</tr>
<tr>
<td></td>
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<td>D</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>D</td>
<td>F</td>
</tr>
<tr>
<td>Kamehameha Road</td>
<td>Westbound (Makai)</td>
<td>LT</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>TH</td>
<td>A</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>A</td>
<td>E</td>
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<td>Kamehameha Highway with Project Access Rd</td>
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<tr>
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<td>Southbound (Makai)</td>
<td>LT</td>
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<td>Westbound (Makai)</td>
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<tr>
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<td>RT</td>
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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 Lili‘uokalani 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

<table>
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<tr>
<th>Development</th>
<th>Morning Peak Hour</th>
<th>Afternoon Peak Hour</th>
<th>Sunday Peak Hour</th>
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<tr>
<td>Kamehameha Hwy.</td>
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<td>65%</td>
<td>65%</td>
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<tr>
<td>Kailua Village</td>
<td>3%</td>
<td>4%</td>
<td>3%</td>
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<tr>
<td>Kahuku Residential</td>
<td>3%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Kulina Ridge Expansion</td>
<td>23%</td>
<td>21%</td>
<td>15%</td>
</tr>
<tr>
<td>Liholiho Community</td>
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<td>.3%</td>
<td>.3%</td>
</tr>
<tr>
<td>Total Percentage</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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</table>

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 busyards 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 20 workers daily.
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.

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.

# APPENDIX B

## MANUAL TRAFFIC COUNT DATA

### Kamohamea Highway at Pupukea Road

**Thursday, November 15, 1990**

<table>
<thead>
<tr>
<th>Time</th>
<th>LT</th>
<th>TH</th>
<th>RT</th>
<th>LT</th>
<th>TH</th>
<th>RT</th>
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**Peak Hour Total**

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**Peak Hour Total**

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### Kamehameha Highway at Pupukea Road (continued)

*Sunday, November 25, 1990*

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### Kamehameha Highway at Sunset Beach Elementary School Driveway

*Thursday, November 15, 1990*

<table>
<thead>
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<th>TIME</th>
<th>Haleiwa Bound</th>
<th>Lai Bound</th>
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### Kamehameha Highway

<table>
<thead>
<tr>
<th>TIME</th>
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<th>Late Bound</th>
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<td><strong>Peak Hour Total (for end of school)</strong></td>
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<td>TIME</td>
<td>KAMEHAMEHA HIGHWAY</td>
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<td>LT     TH   RH   RT</td>
<td>LT     TH   RH   RT</td>
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<tr>
<td>1515-1530</td>
<td>1   93   69   2</td>
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<td>1530-1545</td>
<td>5   128  114  4</td>
<td>10    9</td>
</tr>
<tr>
<td>1545-1600</td>
<td>2   98   119  2</td>
<td>3     7</td>
</tr>
<tr>
<td>1600-1615</td>
<td>3   112  134  3</td>
<td>7     3</td>
</tr>
<tr>
<td>1615-1630</td>
<td>4   140  135  7</td>
<td>4     5</td>
</tr>
<tr>
<td>1630-1645</td>
<td>6   93   107  3</td>
<td>4     4</td>
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<tr>
<td>TIME</td>
<td>NEAR KAHUlkU SUGAR MILL</td>
</tr>
<tr>
<td>--------------</td>
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<td><strong>Peak Hour Total</strong></td>
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<td><strong>Peak Hour Total</strong></td>
<td><strong>296</strong></td>
<td><strong>315</strong></td>
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# APPENDIX C

## TRIP GENERATION CALCULATIONS

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Ind</th>
<th>Var</th>
<th>Total Number of Trips</th>
<th>Enter</th>
<th>Exit</th>
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<tbody>
<tr>
<td>Single Family units</td>
<td>AM</td>
<td>$T = \exp(0.91x\ln(A)+0.2)$</td>
<td>27%</td>
<td>73%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>$T = \exp(0.94\ln(A)+0.5)$</td>
<td>63%</td>
<td>37%</td>
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</tr>
<tr>
<td></td>
<td>SUNDAY</td>
<td>$T = \exp(0.83\ln(A)+0.6)$</td>
<td>53%</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>Recreational units</td>
<td>AM</td>
<td>$T = 0.16xA$</td>
<td>67%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>$T = 0.262xA$</td>
<td>41%</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUNDAY</td>
<td>$T = 0.032xA$</td>
<td>48%</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>Golf Course acres</td>
<td>AM</td>
<td>$T = 0.265xA$</td>
<td>89%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>$T = 0.292xA$</td>
<td>8%</td>
<td>92%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUNDAY</td>
<td>$T = 0.867xA$</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Campground acres</td>
<td>AM</td>
<td>$T = 2.431xA$</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>$T = 3.770xA$</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUNDAY</td>
<td>$T = 4.492xA$</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Tennis Court acres</td>
<td>AM</td>
<td>$T = 1.286xA$</td>
<td>60%</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>$T = 3.429xA$</td>
<td>40%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUNDAY</td>
<td>$T = 2.643xA$</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>

$T =$ 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 Popukea Road showed actual trips generated by homes in the area to be about 20% lower. As a result, trips generated by the single-family units were reduced by 25%.
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. **SUMMARY**

1.1 The existing acoustical conditions in the vicinity of the sections 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 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 dBA, 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 dBA, 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 dBA at the homes closest to the highway, regardless of the project development. It is estimated that the traffic-generated 65 dBA 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 dBA.

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 Camground 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 action by the 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, if occurring during the school hours, the occupancy 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 (LUG) 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 control 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 Maka side of Kaneohe Highway across from the Sunset Beach Park. It consists of about 1,246 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 HDP 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.
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 (Leq60 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 dBA. Homes located at a distance of 75 feet or greater are currently exposed to an estimated Ldn of 65 dBA or less.

At the existing residential areas located on the wakura 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 dog barking, children playing, etc. The measured noise levels which were exceeded 50% of the time (Leq50) ranged from 30 to 40 dBA.

At Locations D and E, wakura side of Kanazawa 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. ASSESSMENT OF POTENTIAL NOISE IMPACT

5.1 Traffic Noise -- Traffic noise calculations were performed using the previously mentioned calibrated traffic noise prediction model along with traffic data provided in Reference 5. Results of the calculations for the existing and future (1997) years with and without the project at various segments of Kanazawa 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 dBA. 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 dBA. The Ldn levels at these homes are estimated to increase to about 72 to 73 dBA in the future (year 1997), regardless of the project development. The future 65 dBA 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 dBA limit. Therefore, specifying setback distances for the housing should not be necessary. Note that traffic noise from Kanazawa Highway will not contribute significantly to the overall acoustical environment at any of the residences within the project.

5.2 Golf Course Clubhouse Activity Noise -- 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 Golf Course Ground Maintenance Noise -- 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 that 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 60 or 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 [5 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 DON noise regulations. About the only practical measure to comply with the regulations is to keep such activities away from the closest noise sensitive area and possibly use the cabins or other structures as noise barriers.

5.5 Tennis Center Activity Noise -- The primary source 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 fee noise data, a typical doubles tennis game could generate an L10 (10% exceedance level) of about 70 dBA at the nearest property line of the tennis court. This exceeds both the DON's daytime (7 a.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m. and 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 DON regulations.

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 Noise -- 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 grading, 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 are given in DBA 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 90 dBA at 50 feet is indicated as being typical of rock 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) deflecting 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 muted "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. NOISE MITIGATION MEASURES

The design of the proposed Lihiki 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:

- no amplified sound systems allowed on the campground
- no tennis games allowed after 10 pm or before 7 am at the courts located near the future homes.
- no boisterous activities allowed on any portion of the campground

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: cas1
REFERENCES:


5. Traffic Data from Pacific Planning & Engineering, Inc., received December 7, 1980.


---

**TABLE 1**

EXISTING AND FUTURE (1995) TRAFFIC NOISE LEVELS

AT SELECTED LOCATIONS

<table>
<thead>
<tr>
<th>Location (See Figure 4)</th>
<th>Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
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**Figure 3**

LDN vs DISTANCE
HALFWAY SIDE OF THE PROJ. ACCESS RD.

**Figure 4**

Locations of the Selected Reaches Used for the Traffic Noise Calculations
No Scale

---

**Figure Texts:**

- **Figure 3**: LDN Levels at Various Distances from the Centerline of Kamehameha Highway, Existing Case
- **Figure 4**: Locations of the selected reaches used for the traffic noise calculations.
<table>
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Noise: Based on limited available data samples.
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 exemption 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 1-1.
AIR QUALITY STUDY
FOR THE PROPOSED
LIH LIAN RECREATIONAL COMMUNITY PROJECT
YUPOEGA, KOKOLINO, OAHU

Prepared for:
Qeysaii Haaii Corporation

January 1991

B. D. NEAL & ASSOCIATES

P.O. Box 5052, Captiva, COCO, WA 98660
P.O. Box 3150, Captiva, COCO, WA 98660
TELEPHONE: 438-5317, 438-5970
FAX: 438-5095
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6 Estimated Indirect Air Pollutant Emissions from Lihi Lani Recreational Community Project Electrical Demand

7 Uncontrolled Air Pollution Emission Factors for Municipal Refuse Incinerators
1.0 INTRODUCTION AND PROJECT DESCRIPTION

Obayashi Hawai Corporation is proposing for development the Lihi Lani Recreational Community Project at Papukoa, 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 Papukoa Road and mauka of Kamakahua 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., soil erosion, 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 Manana 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 north shore 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 Waialua, 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 as 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 sea breeze 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 Puuua include the ocean (sea spray), plants (aeroallergens), 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 92 micrograms per cubic meter. These values are well within the State AQDS 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 AQDS 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 AQDS. 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 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 slit 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 Puupee 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 often times 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 volumes. 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, no new 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 NAAQS), 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 macroscale problem, whereas nitrogen oxides air pollution most often is a regional issue. This is reflected in the fact that the NAAQS 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 were also selected for air quality analysis. These include: Kanehaoa Highway at Pupukea Road, Kaneheka Hwy at Sunset School and Kanehaoa 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, Kanehaoa 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 AQIS. 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, 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 queueing 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 Kanehama Highway accelerated to 35 mph in the vicinity of Pipukea 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 Kanehama 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 sidewalks along Kanehama 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/m³. This is predicted to occur along Kanehena 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/m³ at the location of the future intersection of the project access road and Kanehena Highway during the afternoon to 4.1 mg/m³ at the Kanehena Highway/Pupukua Road intersection during the morning. For the weekend afternoon case, the highest predicted 1-hour concentration (3.2 mg/m³) was predicted to occur near the intersection of Kanehena Highway and Pupukua 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/m³, was predicted to occur during a weekday morning near the Kanehena 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/m³ along through sections of Kanehena Highway during the afternoon on a weekday to 4.7 mg/m³ during the morning on a weekday along Kanehena Highway near Pupukua 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/m³ during the afternoon near Kanehena Highway at Sunset School to 9.9 mg/m³ during the afternoon near the intersection of Kanehena 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/m³ occurring near intersection of the project access road with Kanehena 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 monitoring 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 modelling [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-
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 3.2 mg/m³. This occurred on a weekday near the intersection of Kaaahana Highway and Sunset School Road. Estimated maximum 8-hour concentrations for 1991 at other locations and times varied from 0.6 mg/m³ to 2.0 mg/m³. In the year 1997 without project case, the predicted maximum 8-hour value was 3.2 mg/m³. This would occur on a weekday at the Kaaahana Highway/Sunset School Road intersection. With the project in 1997, a maximum value of 6.6 mg/m³ is estimated to occur near the intersection of the project access road and Kaaahana Highway during the weekend. With project concentrations will be higher than without the project, especially near the intersection of the project access road and Kaaahana 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 N-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 N-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 course 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 Kaneohe 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 90 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 Kaneohe 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 M-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.
REFERENCES


11. CALINE4 - A Dispersion Model for Predicting Air Pollutant Concentrations Near Roadways, FHWA/CA/TD-84/15, California State Department of Transportation, November 1984 with June 1989 Revisions.


### Table 1
SUMMARY OF STATE OF HAWAII AND NATIONAL AIR QUALITY STANDARDS

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Units</th>
<th>Annual</th>
<th>24 Hours</th>
<th>3 Hours</th>
<th>Maximum Allowable Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended Particulate Matter</td>
<td>µg/m³</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60⁹</td>
</tr>
<tr>
<td>Particulate Matter</td>
<td>µg/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
<td>150⁹</td>
</tr>
<tr>
<td>24 Hours</td>
<td>150²⁹</td>
<td>150²⁹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>µg/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>80</td>
<td>80</td>
<td></td>
<td></td>
<td>365³⁹</td>
</tr>
<tr>
<td>24 Hours</td>
<td>365³⁹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Hours</td>
<td>130³⁹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>µg/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>mg/m³</td>
<td>8 Hours</td>
<td>10⁴</td>
<td></td>
<td>5⁵</td>
</tr>
<tr>
<td>1 Hour</td>
<td>40³⁴</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>µg/m³</td>
<td>1 Hour</td>
<td>235⁴</td>
<td>235⁴</td>
<td>100⁴</td>
</tr>
<tr>
<td>Lead</td>
<td>µg/m³</td>
<td>Calendar</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>

³⁹Geometric mean
²⁹Not to be exceeded more than once per year
⁴Particles less than or equal to 10 microns aerodynamic diameter
### Table 2

**AIR POLLUTANT EMISSIONS BY INDUSTRY FOR CITY AND COUNTY OF HUMBOLDT, 1990**

<table>
<thead>
<tr>
<th>Source Category</th>
<th>Particulate</th>
<th>Sulfur Dioxide</th>
<th>Carbon Hydrocarbon</th>
<th>Nonmethane Hydrocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Electric Power Plants</td>
<td>2,092</td>
<td>34,756</td>
<td>12,435</td>
<td>1,665</td>
</tr>
<tr>
<td>Gas Utilities</td>
<td>14</td>
<td>91</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>Fuel Combustion in Agriculture Industry</td>
<td>1,068</td>
<td>14,971</td>
<td>358</td>
<td>0</td>
</tr>
<tr>
<td>Refinery Industry</td>
<td>192</td>
<td>7,266</td>
<td>214</td>
<td>366</td>
</tr>
<tr>
<td>Petroleum Storage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,020</td>
</tr>
<tr>
<td>Metallurgical Industry</td>
<td>28</td>
<td>96</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Mineral Products Industry</td>
<td>4,386</td>
<td>11,025</td>
<td>587</td>
<td>0</td>
</tr>
<tr>
<td>Municipal Intermittent</td>
<td>43</td>
<td>113</td>
<td>2,009</td>
<td>0</td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>1,143</td>
<td>1,419</td>
<td>17,270</td>
<td>23,408</td>
</tr>
<tr>
<td>Combustion, farm and industrial vehicles</td>
<td>184</td>
<td>193</td>
<td>2,507</td>
<td>3,220</td>
</tr>
<tr>
<td>Aircraft</td>
<td>82</td>
<td>148</td>
<td>1,753</td>
<td>5,506</td>
</tr>
<tr>
<td>Vessels</td>
<td>43</td>
<td>114</td>
<td>458</td>
<td>333</td>
</tr>
<tr>
<td>Agricultural field</td>
<td>1,079</td>
<td>0</td>
<td>0</td>
<td>15,982</td>
</tr>
<tr>
<td>Beaches</td>
<td>15,300</td>
<td>26,375</td>
<td>35,725</td>
<td>266,367</td>
</tr>
</tbody>
</table>

Source: State of Humboldt, Department of Health

### Table 3

**ANNUAL SUMMARY OF AIR QUALITY MEASUREMENTS AT UNADILLA MONITORING STATION**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate</td>
<td>No. of 24-Hr Samples</td>
<td>57</td>
<td>50</td>
<td>46</td>
<td>60</td>
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<tr>
<td></td>
<td>Range of 24-Hr Value (µg/m³)</td>
<td>15-52</td>
<td>10-72</td>
<td>12-75</td>
<td>10-80</td>
</tr>
<tr>
<td></td>
<td>Average Daily Value (µg/m³)</td>
<td>26</td>
<td>28</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>No. of State AER Exceedances</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: State of Humboldt Department of Health
**Table 4**

<table>
<thead>
<tr>
<th>Roadway Intersection</th>
<th>1991/1997</th>
<th>Year/Scenario</th>
<th>Present</th>
<th>Without Project</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaneohe Highway at Pupukea Road</td>
<td>4.1 3.2</td>
<td>AM PM</td>
<td>4.7 3.0</td>
<td>7.2 3.8</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Sunset School</td>
<td>4.4 2.0</td>
<td>AM PM</td>
<td>6.3 1.8</td>
<td>8.6 2.1</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Project Access Road</td>
<td>1.5&lt;sup&gt;a&lt;/sup&gt; 1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>AM 1.0&lt;sup&gt;c&lt;/sup&gt; PM 1.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;bc&lt;/sup&gt; 1.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;d&lt;/sup&gt; 9.9&lt;sup&gt;d&lt;/sup&gt;</td>
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**Weekend:**

<table>
<thead>
<tr>
<th>Roadway Intersection</th>
<th>1991/1997</th>
<th>Year/Scenario</th>
<th>Present</th>
<th>Without Project</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaneohe Highway at Pupukea Road</td>
<td>- 3.2</td>
<td>AM PM</td>
<td>4.1 4.8</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Sunset School</td>
<td>- 1.3</td>
<td>AM PM</td>
<td>1.4 1.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Project Access Road</td>
<td>- 1.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>AM 1.4&lt;sup&gt;d&lt;/sup&gt; PM 1.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6.6&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Hawaii State AQES: 10
National AQES: 40

<sup>a</sup>Assumes through traffic only on Kaneohe Highway.

<sup>b</sup>Assumes left turn lane provided both on Kaneohe Highway and Project Access Road speed limit on Kaneohe Highway reduced to 35 mph.

**Table 5**

<table>
<thead>
<tr>
<th>Roadway Intersection</th>
<th>1991/1997</th>
<th>Year/Scenario</th>
<th>Present</th>
<th>Without Project</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaneohe Highway at Pupukea Road</td>
<td>2.0 2.4 3.6</td>
<td>AM PM</td>
<td>2.0 3.2</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Sunset School</td>
<td>2.2 2.2 4.3</td>
<td>AM PM</td>
<td>2.2 3.2</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Project Access Road</td>
<td>0.6&lt;sup&gt;a&lt;/sup&gt; 0.9&lt;sup&gt;a&lt;/sup&gt; 5.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>AM 0.9&lt;sup&gt;a&lt;/sup&gt; PM 5.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.9&lt;sup&gt;a&lt;/sup&gt; 5.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
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</table>

**Weekend:**

<table>
<thead>
<tr>
<th>Roadway Intersection</th>
<th>1991/1997</th>
<th>Year/Scenario</th>
<th>Present</th>
<th>Without Project</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaneohe Highway at Pupukea Road</td>
<td>1.6 2.0 2.4</td>
<td>AM PM</td>
<td>1.6 2.0</td>
<td>2.4</td>
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</tr>
<tr>
<td>Kaneohe Highway at Sunset School</td>
<td>0.6 0.7 0.8</td>
<td>AM 0.7&lt;sup&gt;a&lt;/sup&gt; PM 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.7&lt;sup&gt;a&lt;/sup&gt; 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Kaneohe Highway at Project Access Road</td>
<td>0.6&lt;sup&gt;a&lt;/sup&gt; 0.7&lt;sup&gt;a&lt;/sup&gt; 6.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>AM 0.7&lt;sup&gt;a&lt;/sup&gt; PM 6.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.7&lt;sup&gt;a&lt;/sup&gt; 6.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Hawaii State AQES: 5
National AQES: 10

<sup>a</sup>Assumes through traffic only on Kaneohe Highway.

<sup>b</sup>Assumes left turn lane provided both on Kaneohe Highway and Project Access Road speed limit on Kaneohe Highway reduced to 35 mph.
### Table 6
**Estimated Indirect Air Pollution Emissions From Lehi Lani Recreational Community Project Electrical Demand**

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Emission Rate (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>10</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>3</td>
</tr>
</tbody>
</table>

*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)**

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate</td>
<td>14†</td>
</tr>
<tr>
<td>Sulfur Oxides</td>
<td>2.5</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>35†</td>
</tr>
<tr>
<td>Organics</td>
<td>1.5</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>3†</td>
</tr>
</tbody>
</table>

*Emission factors are given in terms of weight of material emitted per unit weight of refuse material charged.

†Assumes incinerator equipped with settling chamber and water spray.

Source: U.S. Environmental Protection Agency [5]
LANDSCAPE DESIGN CONCEPTS
FOR THE
PROPOSED ACCESS ROAD TO THE
PUPUKEA RECREATIONAL COMMUNITY

Submitted to:
Hubbard Hawaiian Corporation
1030 Bishop Street
Pacific Tower, Suite 2680
Honolulu, HI 96813

Prepared by:
WALTERS, KINU & ASSOCIATES, INC.
649 Sheridan Street
Honolulu, HI 96814

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 Kamahina 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.
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:

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Land Form</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100' - 200'</td>
<td>Bluff base</td>
<td>Kiale (Prosopis pallida)</td>
</tr>
<tr>
<td>200' - 300'</td>
<td>Bluff face</td>
<td>Christmas Berry (Schinus terebinthifolius)</td>
</tr>
<tr>
<td>300' - 400'+</td>
<td>Ridge line</td>
<td>Chinese Rainy (Ficus retusa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ironwood (Casuarina equisetifolia)</td>
</tr>
</tbody>
</table>

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-2 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 hairpin 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. Section 2 (Exhibits L-5 and L-6)

1. Visual Impact: This "cut" condition will create three 15-foot high terraces along the roadway's mauka edge. Because the mauka 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 mauka 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. Section 3 (Exhibits L-7 and L-8)

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 existing 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 Banyan 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. Section 4 (Exhibits L-9 and L-10)

1. Visual Impact: This "cut" portion will be depressed 30 feet below existing grade with three 15-foot high terraces on both sides, one along the mauka side and two along the makai 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.
CONCEPTUAL LANDSCAPE TREATMENT ALONG PUPUKEA BLUFF

EXHIBIT L-6

ALONG PUPUKEA BLUFF

EXHIBIT L-5
CONCEPTUAL LANDSCAPE TREATMENT
ALONG PUPUKEA BLUFF

ALONG PUPUKEA BLUFF
CONCEPTUAL LANDSCAPE TREATMENT ALONG PUPUKEA BLUFF

EXHIBIT L-10

ACCESS ROAD

ALONG PUPUKEA BLUFF
EXECUTIVE SUMMARY

Community Resources, Inc. (CRI) has prepared a Socio-Economic Assessment Impact for Obayashi Hawaii’s proposed Lili Lani Recreational Community.

Existing Conditions

The proposed project site is located on the plateau east of Pupukea Road and mauku of Kaneohe 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 Waialua. The total study area includes the City’s North Shore Development Plan (NDP) Area and the neighboring Koolauloa NDP Area.

Population trends and socio-economic characteristics of the region include:

- The 1980 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 Hawaiian-born, and a third were Mainland-born. While Caucasians formed a majority of the ethnic make-up of the region in 1980, 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 Koolaulo town of Laie.

- In 1980, average study area income was well below the island-wide 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 1980, 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 Ohana 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:

- Koolina 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.

- Kailua/Kaneohe. Kaneohe 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.

- Pokolea. Long-term plans envision two golf courses, and a low-key lodge for golfer accommodation.

Other courses have been proposed for the region, at Haleiwa, Panana, 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, playgrounds, and a conservation park;
- A new wastewater management plan;
- Proposed community facilities, including a community center, a baseball/softball 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.

Racial, Economic Impacts and Mitigation

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 143 person-years during the first period, and an annual average of 65 person-years during the second.

By 1995, operations on-site will provide 45 jobs. After completion, 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 building 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 Lahaina, including new community residents and new employees, is estimated at less than 50 persons.

The project will add 300 units to the study area housing stock. However, some additional demand for housing is likely as other new project employees and their families move into the study area. The housing impact of employees in-migration to the study area is likely to amount to between 10 and 25 housing units after building.

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 RAIN riding team;
- A baseball/softball field;
- Making tennis facilities available to area residents;
- A community children's playground;
- Extra parking space for the community, and for Lahiai 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 Lahiai trail system will remain adequate.

Residents have expressed concern that the project's golf course will increase nearby land values and, hence, property
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1.0 INTRODUCTION

1.1 LIHI LANI RECREATIONAL COMMUNITY

Ohayashi 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 the times reserved for resident golfers at reduced rates), with a clubhouse and driving range;
- A tennis center;
- An equestrian ranch with additional areas for pastureage;
- 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 site 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. Ohayashi 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.
1.3 PURPOSE AND SCOPE OF THIS REPORT

This report provides an independent consultant's assessment of the socio-economic impacts of the proposed Lihiliili project. It has been prepared for Charanlani Hawaiian, 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 NGC 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.

Community Resources, Inc.  LIIHI LIILI RECREATIONAL COMMUNITY

1-4
2.0 EXISTING CONDITIONS

This section reviews the existing socio-economic situation in the region surrounding the Lihik 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, 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/Waimanalo 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/Kualoa region (Census Tracts 99.02, 99.03, 100, 101, 102.01 and 102.02). It extends from Kamehameha to Kohala.

The boundary between the North Shore and Kualoa 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 Kualoa District does not include the Primary Study Area, which is within the Kualoa District. The City's North Shore Development Plan Area includes the Primary Study Area. The City's Kualoa Development Plan Area includes the Kualoa 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...
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 these 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 along and mostly below Kamehameha Highway begins about a mile southeast of Hulisu 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-Papaikou Beach Tract was subdivided and sold in 1910-20. It became known as the Sunset Tract since the sunsets were spectacular. Since then, the area 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 Hakalau. Today, the Kealakekua 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.

Community Resources, Inc.

2-4
While parts of the project site belonged to the Hawaiian Avocado Company and the Hawaiian Pineapple Company until the 1960'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 lease 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 uppermost section of the property, because Ohahului Ranch intends to start test plantings on the upper field section.

The project site is shown on the 1967 Detailed Land Use Map (under Ordinance 2551 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 converted to Agricultural-1 (Zoning Map of June, 1970, under Ordinance 3214). The 1984 Zoning Map similarly shows the area as Agricultural. Under Ordinance 86-119 (October 25, 1986), the zoning of the project site was established as Agricultural-2. That zoning continues in force at present.

2.2.3 The Past of the North Shore Development Plan Area

The City and County's North Shore Development Plan area begins about two miles to the west of the Kailua Highway area and extends to the east, towards Kaneohe. The plan area is a coastal strip with a narrow coastal strip. The plan area includes the area near Kailua, and extends to the east, towards Kaneohe. The plan area is a coastal strip with a narrow coastal strip. The plan area includes the area near Kailua, and extends to the east, towards Kaneohe. The plan area is a coastal strip with a narrow coastal strip.

Some neighbors ride on or across the project site. Campers at the nearby Boy Scout camp have also hiked on-site.
The North Shore's largest centralised communities (Haleiwa and Waialua) are about ten miles from the Kullima Resort and the have more of a "country" character.

The North Shore has no visitor condominiums and only a few registered visitor units. (The Kullima Resort is in Koolau.) Still, tourists are present in large numbers. An estimated 35% were Japanese (OMC 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 Shore's famed high surf. Consequently, there is a strong youth orientation and higher visibility of Mainlanders - in this area than in much of Koolau.

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 the Waiahole (but separated by Waiakea Bay). It is similar in character, lifestyle, and values to Haleiwa, although it has fewer large houses and a slightly more "local" population.

Waialua 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 Haliwai Hotel closed in 1932, and is now long gone. Still, residents are proud of the town's history and have 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 3,088 in 1989 (OMC Management Consulting, 1990). Household incomes are estimated as growing to the median of $25,120 in 1989. While this figure is in line with the estimate for the entire North Shore District, the rate of growth is lower than that of the Millani/Waialua area of Central Oahu.

Waialua is Oahu's last functioning plantation town. The predominantly Filipino community leads a traditional Hawaiian plantation lifestyle, in which the IIAU 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.

Koolua includes beach homes, many of which are occupied only part-time. It is the site of Pillihime 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 Keena Point is used by motorcycle riders. Fishermen, hikers, and picnickers also visit the area. Part of Koolua 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 2.3).

2.2.3 The Koolua Development Plan Area

The Koolua area consists mainly of a strip of land bounded by mountains and the sea. A series of residential communities - Kualoa, Kauai, Kualoa South, Leahi, and Kahuku - are spaced out along Kamehameha Highway, the region's single major roadway. Haunui, Lalei, and Kahuku are the major population centers. Villages are not densely populated. At the northern tip of Oahu, the coastal region becomes a broader plain, between Koolua and Leahi.

Earlier in this century, much land was planted in sugar. Sugar production in Kooloa ended, however, in 1931. Major sources of employment and revenue now include tourism, aquaculture, and specialized agriculture. Major employers are the Koolua Resort outside Kahuku and the Polynesian Cultural Center in Lalei.

The Koolua labor force largely works within the region, unlike workers living in other rural areas of Oahu (Honolulu Department of General Planning, 1988, vol. 1). Employment is discussed further in Section 2.3.

From north to south, Koolua population centers are:

- The Koolua 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 the hotel. Hilton continues to retain Hilton as operator of the hotel known as the Turtle Bay Hilton. The Hilton currently offers 486 hotel and oceanfront units.

- The facilities at Koolua also include two low-rise condominium complexes, a golf course and clubhouse, a riding stable, and tennis courts.

Community Resources, Inc.  LEST LEST RECREATIONAL COMMUNITY

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The mix of users and occupants in the condominium has varied over time. In early 1989, property managers estimated that about 401 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 Kulihea Resort in the late 1970's. Land use permits for expansion have been granted, and work has begun on the first phase. (See Section 1 for discussion of the expansion timetable.)

Bordering the Kulihea resort on the western side of Kaawela Bay are approximately 24 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 Koolau and employed residents of other towns, the mill and company headquarters were in Kahuku itself. Consequently, Kahuku is one of the sites 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 IWP---fought to keep the community alive. They supported the new Kulihea 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 long-time residents, resulting in a substantial number of new residents who do not have 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 269 housing units in 1987, and has completed over 100 of these (personal communication, Mel Menhenn, 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, and corn and other produce.

Two other economic ventures in Kahuku involve developing technologies --- wind-generated electricity and aquaculture. Shaka Kulihea 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).

Lai'a is Koolau's largest community. Its 1980 population was 4,600. The iru'au of Lai'a 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 Lai'a Temple was dedicated in 1919. Renovations of the Temple were recently completed.

Lai'a 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 in Hawaii. The Polynesian Cultural Center is closely related to the University, as it provides both jobs for students and income for the school.

Lai'a 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 (Islam Securities Corp., 1981) found that nearly 70 percent of employed residents were working within Lai'a itself. Residents report a variety of socio-economic differences between the predominantly Mainland-originating college faculty and the largely Polynesian rank and file Lai'a working class.
The Mormon Church has historically encouraged community self-sufficiency, so that Lale 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 Lale as "self-contained" and having little contact with other towns (Community Resources, Inc., 1989a).

However, Lale residents may be growing more independent of the church on land/economic issues and also more involved with nearby communities. The Lale Community Association has taken the initiative in expressing its preference to Zions Securities Corp. for future community development. Pearson, an urban-based Hawaiian activist group, has expressed anger and sorrow over dealings with Zions Securities (Koolau Area Neighborhood Board minutes, November 1990). A lack of new housing in Lale itself is resulting in many Mormon families moving to Kailua and Waipahu.

A survey for Zions Securities (Community Resources, Inc., 1987) found widespread reported crowding of existing Lale housing units. Most Lale respondents said they care more about both new jobs and affordable housing than about keeping Lale "like it is now."

Lale 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.

Kaaawa is a Hawaiian residential community with high poverty rates and reported shortages of affordable housing. With a "village-style" "community" rather than the more "country-like" Kaaawa and Punalu'u areas to the south, Kaaawa has a large shopping center and satellite City Hall. Its residents have historically been interested in new employment opportunities.

Punalu'u is a generally rural, lightly-populated area in which beachfront houses tend to be second residences for Honolulu people. However, some actual fishing and aquaculture activities take place in the valley. There is one major oceanfront condominium complex, 'Pal's at Punalu'u, and a few other scattered stores and restaurants.

Kaaawa was historically a Hawaiian agricultural area (Clark, 1979). Today, it contains few urban amenities or employment opportunities, and many residents commute to more urban Oahu areas. Beachfront houses 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. More recent information derives from estimates and surveys, notably the August 1990 survey of Lale community heads conducted for Kuilima Resort and the Kuilima/North Shore Strategy and Planning Committee (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 1990.

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 Koolau 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 1990, 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 1.01% 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 be somewhat higher.

Population growth was more rapid in the Koolau area of the study area. The total study area is home to 35% of the Oahu population, while it covers about 3% 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 2-1). 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

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:

**Primary Study Area**: Caucasians form a majority of the population in the Papakea/Sunset Beach/Malana 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.

**Secondary Study Area**: 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 Hawaiian-born slightly outnumber Mainland-born residents.

### 2.3.3 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 |
| Ko Olina Development Plan Area (72% of Oahu median) | $17,005 | $29,700 |

### Table 2-3: Demographic Characteristics, Study Area, 1990

<table>
<thead>
<tr>
<th>EQUITY</th>
<th>TOTAL STUDY AREA</th>
<th>SECONDARY STUDY AREA</th>
<th>PRIMARY STUDY AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AGE</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 25 years</td>
<td>4.9</td>
<td>10.3</td>
<td>7.6</td>
</tr>
<tr>
<td>25 to 44</td>
<td>26.9</td>
<td>26.6</td>
<td>22.9</td>
</tr>
<tr>
<td>45 to 64</td>
<td>22.2</td>
<td>22.3</td>
<td>22.6</td>
</tr>
<tr>
<td>65 or over</td>
<td>11.4</td>
<td>14.3</td>
<td>13.2</td>
</tr>
<tr>
<td>Female</td>
<td>24.6</td>
<td>26.3</td>
<td>27.6</td>
</tr>
<tr>
<td>65 or over</td>
<td>6.2</td>
<td>6.3</td>
<td>6.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLACE OF BIRTH</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nisei</td>
<td>41.5</td>
<td>41.9</td>
<td>56.7</td>
</tr>
<tr>
<td>Resident U.S.A.</td>
<td>41.0</td>
<td>37.0</td>
<td>40.4</td>
</tr>
<tr>
<td>Pacific Islands</td>
<td>6.5</td>
<td>7.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Philippines</td>
<td>4.4</td>
<td>4.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Other Asian countries</td>
<td>2.0</td>
<td>2.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Elsewhere</td>
<td>2.4</td>
<td>2.4</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LENGTH OF RESIDENCE OF HEAD OF HOUSEHOLD IN THE SAME HOUSE</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1 year</td>
<td>10.3</td>
<td>19.1</td>
<td>29.1</td>
</tr>
<tr>
<td>2-5 years</td>
<td>22.5</td>
<td>27.7</td>
<td>27.1</td>
</tr>
<tr>
<td>6-10 years</td>
<td>24.8</td>
<td>25.0</td>
<td>20.1</td>
</tr>
<tr>
<td>11-17 years</td>
<td>13.7</td>
<td>11.8</td>
<td>11.1</td>
</tr>
<tr>
<td>20 or more</td>
<td>20.7</td>
<td>31.5</td>
<td>21.3</td>
</tr>
<tr>
<td>Not sure/unknown</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EDUCATIONAL ATTAINMENT</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some high school</td>
<td>13.2</td>
<td>16.3</td>
<td>8.1</td>
</tr>
<tr>
<td>High school graduates</td>
<td>29.1</td>
<td>30.7</td>
<td>27.1</td>
</tr>
<tr>
<td>Some college</td>
<td>26.3</td>
<td>22.9</td>
<td>42.1</td>
</tr>
<tr>
<td>College graduates</td>
<td>22.5</td>
<td>21.8</td>
<td>21.3</td>
</tr>
<tr>
<td>Not sure/unknown</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAMPLE SIZE</th>
<th>811</th>
</tr>
</thead>
</table>

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 F1990 on Oahu is $41,260 (United States Department of Housing and Urban Development, 1990). Hence the survey strongly suggests that income remains 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 Koolau 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 Koolau Development Plan Area (Honolulu Department of General Planning, 1990):

<table>
<thead>
<tr>
<th>Number of Housing Units</th>
<th>Not Including Resort Condo Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1980</td>
</tr>
<tr>
<td>North Shore DP Area</td>
<td>4,787</td>
</tr>
<tr>
<td>Koolau DP Area</td>
<td>3,247</td>
</tr>
<tr>
<td>Total Study Area</td>
<td>8,034</td>
</tr>
<tr>
<td>Oahu (total)</td>
<td>255,499</td>
</tr>
</tbody>
</table>

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Community Resources, Inc. Liliuokalani Recreational Community 2-18
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 1985 vacancy rate is about 25%, according to the City and County -- a rate lower than in some urban areas on Oahu (Honolulu Department 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 island-wide and statewide averages (Community Resources, Inc., 1989b, 1990 for survey data from 1988 and 1990).

Average study area household sizes were above the island-wide median in 1980 (as shown in Table 2-6). The 1990 survey data indicate an important change within the study area, as North Shore respondents reported higher household sizes than Koolau respondents:

<table>
<thead>
<tr>
<th>Reported Household Size, 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Study Area</td>
</tr>
<tr>
<td>Rest of North Shore</td>
</tr>
<tr>
<td>Koolau DP Area</td>
</tr>
<tr>
<td>Total Study Area</td>
</tr>
</tbody>
</table>

(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, 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 Mullins survey.) These responses suggest that many -- perhaps most -- people in the study area are in living situations different from the urban 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 2-1: HOUSING CHARACTERISTICS, STUDY AREA, 1990

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>STUDY AREA</th>
<th>PRIMARY STUDY AREA</th>
<th>SECONDARY STUDY AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CITY AND COUNTY OF HONOLULU, AND STUDY AREA, 1990</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SOUTH SHORE DISTRICT</td>
<td>NORTH SHORE DISTRICT</td>
<td>DIGEST</td>
</tr>
<tr>
<td></td>
<td>254,164</td>
<td>12,871</td>
<td>3,095</td>
</tr>
<tr>
<td></td>
<td>254,164</td>
<td>12,871</td>
<td>3,095</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL YEAR-ROUND</td>
<td>254,164</td>
<td>12,871</td>
<td>3,095</td>
</tr>
<tr>
<td>SELECTED CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEDIUM VALUE</td>
<td>$279,590</td>
<td>$279,590</td>
<td>$279,590</td>
</tr>
<tr>
<td>MEDIUM RENT</td>
<td>$1,000</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>RENTAL COLONIES</td>
<td>1,238</td>
<td>1,238</td>
<td>1,238</td>
</tr>
<tr>
<td>OCCUPANCY RATE</td>
<td>95.2%</td>
<td>95.2%</td>
<td>95.2%</td>
</tr>
<tr>
<td>TENURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner-occupied</td>
<td>59.5</td>
<td>59.5</td>
<td>59.5</td>
</tr>
<tr>
<td>Rented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unoccupied</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>HOUSING COST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0-$99</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>$100-$299</td>
<td>11.6</td>
<td>11.6</td>
<td>11.6</td>
</tr>
<tr>
<td>$300-$499</td>
<td>15.3</td>
<td>15.3</td>
<td>15.3</td>
</tr>
<tr>
<td>$700-$899</td>
<td>15.2</td>
<td>15.2</td>
<td>15.2</td>
</tr>
<tr>
<td>$900-$999</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>TOTAL YEAR-ROUND</td>
<td>254,164</td>
<td>12,871</td>
<td>3,095</td>
</tr>
<tr>
<td>SELECTED CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEDIUM VALUE</td>
<td>$279,590</td>
<td>$279,590</td>
<td>$279,590</td>
</tr>
<tr>
<td>MEDIUM RENT</td>
<td>$1,000</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>RENTAL COLONIES</td>
<td>1,238</td>
<td>1,238</td>
<td>1,238</td>
</tr>
<tr>
<td>OCCUPANCY RATE</td>
<td>95.2%</td>
<td>95.2%</td>
<td>95.2%</td>
</tr>
<tr>
<td>TENURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner-occupied</td>
<td>59.5</td>
<td>59.5</td>
<td>59.5</td>
</tr>
<tr>
<td>Rented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unoccupied</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>HOUSING COST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0-$99</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>$100-$299</td>
<td>11.6</td>
<td>11.6</td>
<td>11.6</td>
</tr>
<tr>
<td>$300-$499</td>
<td>15.3</td>
<td>15.3</td>
<td>15.3</td>
</tr>
<tr>
<td>$700-$899</td>
<td>15.2</td>
<td>15.2</td>
<td>15.2</td>
</tr>
<tr>
<td>$900-$999</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
</tr>
</tbody>
</table>


SPECIAL NOTE: 254,164 is the sum of the June 1, 1990, population estimate multiplied by the housing unit to person ratio for June 1, 1990.

TABLE 2-2: HOUSING CHARACTERISTICS, STUDY AREA, 1990

<table>
<thead>
<tr>
<th>TYPE OF HOUSING</th>
<th>TOTAL STUDY AREA</th>
<th>PRIMARY STUDY AREA</th>
<th>SECONDARY STUDY AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detached house</td>
<td>29.2</td>
<td>35.1</td>
<td>20.1</td>
</tr>
<tr>
<td>Multi-family</td>
<td>65.8</td>
<td>65.1</td>
<td>65.3</td>
</tr>
<tr>
<td>Unoccupied</td>
<td>6.4</td>
<td>5.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Occupied</td>
<td>6.6</td>
<td>6.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Divided house</td>
<td>1.4</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Occupied</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Rented</td>
<td>0.0</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>OCCUPANCY RATE</td>
<td>95.2%</td>
<td>95.2%</td>
<td>95.2%</td>
</tr>
<tr>
<td>TENURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner-occupied</td>
<td>59.5</td>
<td>59.5</td>
<td>59.5</td>
</tr>
<tr>
<td>Rented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unoccupied</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>HOUSING COST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0-$99</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>$100-$299</td>
<td>11.6</td>
<td>11.6</td>
<td>11.6</td>
</tr>
<tr>
<td>$300-$499</td>
<td>15.3</td>
<td>15.3</td>
<td>15.3</td>
</tr>
<tr>
<td>$500-$699</td>
<td>21.2</td>
<td>21.2</td>
<td>21.2</td>
</tr>
<tr>
<td>$700-$899</td>
<td>15.2</td>
<td>15.2</td>
<td>15.2</td>
</tr>
<tr>
<td>$900-$999</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
</tr>
</tbody>
</table>


2-23
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 of the households surveyed in 1980 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 areas (as shown in Table 2-8). The 1980 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 1985 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 Kailua 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 1980 Kailua 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 1980 survey is striking.
| TABLE 2-101: SELECTED LABOR FORCE CHARACTERISTICS, STATEWIDE TOU RISM IMPACT CORE SURVEY, 1988 | CITY AND COUNTY | STATE OF HAWAII | HONOLULU AREA |
|-----------------------------------|-----------------|-----------------|----------------|-----------------|
| CIVILIAN LABOR FORCE participation rate | 69%  | 69%  | 68%  |
| Workers with more than one full-time job | 3%  | 3%  | 3%  |
| Usually working 40 or more hours per week | 22%  | 21%  | 19%  |
| Usually working weekends | 39%  | 38%  | 40%  |
| Usually working evenings | 29%  | 30%  | 28%  |
| Usually working weekends & evenings | 22%  | 22%  | 27%  |
| Primary job is in visitor industry | 24%  | 21%  | 24%  |
| 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 30 minutes | 20%  | 20%  | 20%  |
| 40 minutes or more | 13%  | 15%  | 29%  |
| SAMPLE SIZE | (3,904) | (1,005) | (162) |

NOTES: * Percentages may not add to 100% due to some "no response" answers.

TABLE 2-11: ESTIMATED STUDY AREA LABOR FORCE AND EMPLOYMENT

<table>
<thead>
<tr>
<th></th>
<th>1989 Average Labor Force and Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City and County of Honolulu</td>
</tr>
<tr>
<td>Civilian labor force</td>
<td>384,500</td>
</tr>
<tr>
<td>Number employed</td>
<td>375,950</td>
</tr>
<tr>
<td>Number unemployed</td>
<td>8,550</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>2.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>October 1990 Labor Force and Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City and County of Honolulu</td>
</tr>
<tr>
<td>Civilian labor force</td>
<td>395,991</td>
</tr>
<tr>
<td>Number employed</td>
<td>387,785</td>
</tr>
<tr>
<td>Number unemployed</td>
<td>10,206</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

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 — e.g., Waialua, Haleiwa, Kahuku, Laie, and Haiku. The remainder lived in more isolated settings or in strip-development neighborhoods such as Sunset Beach, Waialua, Punalu‘u, and Kawela.

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 cohesionness. 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 Haiku, 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 Koolau 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.

2.3 ISSUES AND CONCERNS INDEPENDENT OF THE PROJECT

2.3.1 Survey Data

Respondents to the 1990 Pulliam 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 is.” Primary Study Area respondents differed from others in the study areas:

<table>
<thead>
<tr>
<th>Total Study Area</th>
<th>Primary Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>More important:</td>
<td></td>
</tr>
<tr>
<td>Affordable housing</td>
<td>38%</td>
</tr>
<tr>
<td>Keeping “as is”</td>
<td>53%</td>
</tr>
<tr>
<td>No answer or Don’t know</td>
<td>9%</td>
</tr>
</tbody>
</table>

In 1990, 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 problem 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 1990, 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>
<thead>
<tr>
<th>COMMUNITY ISSUES 5’5 RATED “1” PROBLEM IN YOUR PART OF THE ISLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of housing</td>
</tr>
<tr>
<td>Cost of food and clothing</td>
</tr>
<tr>
<td>Lack of nearby jobs</td>
</tr>
<tr>
<td>Traffic</td>
</tr>
<tr>
<td>Pollution of streams</td>
</tr>
<tr>
<td>Population growth too fast</td>
</tr>
<tr>
<td>Lack of access to recreation areas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPARISON OF LIFE IN THIS PART OF THE ISLAND VS. FIVE YEARS AGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today is ... Better</td>
</tr>
<tr>
<td>Worse</td>
</tr>
<tr>
<td>Same</td>
</tr>
<tr>
<td>Not sure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOURISM GROWTH: 5% AGREEING WITH VARIOUS STATEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>In my part of the Island, it is more important to keep things like they are than to have more tourism jobs.</td>
</tr>
<tr>
<td>To stop new hotel development</td>
</tr>
<tr>
<td>We need more tourism jobs on this island</td>
</tr>
</tbody>
</table>

Survey Date: 2,354

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 case the Haleiwa Bypass Road and preservation of the rural character of this region.

2.3.2 Indicators 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 Kaneohe 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 Haleiwa to Waimanalo.

- Haleiwa Bypass Road: North Shore residents in general supported the Haleiwa Bypass Road (scheduled for completion in 1991) as a way to ease the congestion in Haleiwa Town. However, some residents oppose the current plan because of danger to swimming 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 region. 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 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 requires all applicants for golf course development to submit a plan 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 opposed city acquisition of beachfront areas for development and expansion of beach parks. Both expressed concern about beach access and showed interest in rules being developed by the Department of Parks and Recreation to control surfing, scuba diving, and other ocean activities.

- Protection 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 system in the Waimanalo Beach area.

- Transient Rentals: The North Shore Neighborhood Board expressed concern about the need for licensing and subdividing of buildings near Waimanalo Beach. It supports the City’s position that rentals for less than 30 days are permitted only on resort-designated areas, and that bed and breakfast units must be occupied, with no more than four guests per place.

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 had 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 above the General Plan guidelines for growth in the next 20 years.

- Drainage: Both Boards want to see improvement in the drainage system of the region. The Kailua Neighborhood Board talked about the flood control problem in Lai, and the North Shore Board expressed concern that the delay of the city-funded, Teedale, 1984; full Flood Study would put residents on Kualoa 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, 74% 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 time 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 residents believe to be true of golf courses and golf-related developments.


Socio-economic issues arising with regard to the Lihiki Lani Recreational Community will be identified in Section 4 and, if appropriate, discussed further in Section 5. (Other concerns addressed in technical studies included in the project Environmental Impact Statement.) Table 2-13 provides a partial list of other 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 takes agricultural land too expensive for housing development. In specific cases, many of the course has been of concern, and some think that golf courses generally are displacing agriculture.

(At a general level, economists have argued that golf courses could provide an income-generating land use, to the benefit of Hawaii.)
TABLE 3-13: FREQUENCY OF MENTION OF ISSUES IN CITY AND COUNTY HEARINGS ON GOLF COURSES AND OTHER ENVIRONMENTAL IMPACT STATEMENT LETTERS

<table>
<thead>
<tr>
<th>Public Hazards (1)</th>
<th>Environmental Impact Statements (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>Issue</td>
</tr>
<tr>
<td>Compatibility with land use policies</td>
<td>50%</td>
</tr>
<tr>
<td>Community Issues</td>
<td>25%</td>
</tr>
<tr>
<td>Hydrology, drainage</td>
<td>10%</td>
</tr>
<tr>
<td>Settlements, Agriculture</td>
<td>10%</td>
</tr>
<tr>
<td>Lifestyles</td>
<td>20%</td>
</tr>
<tr>
<td>Hazards</td>
<td>10%</td>
</tr>
<tr>
<td>Employment, economy</td>
<td>30%</td>
</tr>
<tr>
<td>Population and socio-economic character</td>
<td>25%</td>
</tr>
<tr>
<td>Public facilities</td>
<td>15%</td>
</tr>
<tr>
<td>Fiscal impacts</td>
<td>15%</td>
</tr>
<tr>
<td>Historical, archaeological and geographic issues</td>
<td>15%</td>
</tr>
<tr>
<td>Physiography, geology</td>
<td>15%</td>
</tr>
<tr>
<td>Flora and fauna</td>
<td>15%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>15%</td>
</tr>
<tr>
<td>Air quality</td>
<td>15%</td>
</tr>
</tbody>
</table>

Notes:
1. Adapted from Hawaii Real Estate Research and Education Center (1993), Table 2.
2. Adapted from (1994), Table 6, counting only the 11 cases of (1) 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 sanctions or development agreements should ensue that developers of new golf courses provide sizable sums to local communities or government bodies, to return to the islands some of the income made from golf course development.
- Demand for golf: How 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 too 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 disapproval with traffic congestion has led some to propose curbing 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 been that 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 Kuliouou 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 Kuliouou 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 these 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

Kuliouou Expansion: A major expansion of the resort is under way. The aim is 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:

<table>
<thead>
<tr>
<th>Major Facilities</th>
<th>Resort Units</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-2 Luxury Hotel</td>
<td>383</td>
<td>1992</td>
</tr>
<tr>
<td>G-2 Golf course, clubhouse</td>
<td>H/A</td>
<td>1992</td>
</tr>
<tr>
<td>Tennis club</td>
<td>H/A</td>
<td>1993</td>
</tr>
<tr>
<td>H-1 Activity-oriented hotel</td>
<td>650</td>
<td>1993</td>
</tr>
<tr>
<td>G-1 Golf course (renovation)</td>
<td>H/A</td>
<td>1993</td>
</tr>
<tr>
<td>H-4 Expansion of Turtle Bay</td>
<td>H/A</td>
<td>1994</td>
</tr>
<tr>
<td>Milton Shopping Village</td>
<td>H/A</td>
<td>1994</td>
</tr>
<tr>
<td>PHASE II AND III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-3 Hotel (1994)</td>
<td>530</td>
<td>H/A</td>
</tr>
<tr>
<td>H-5 Hotel (1994)</td>
<td>415</td>
<td>H/A</td>
</tr>
<tr>
<td>A-1 Apartments</td>
<td>250</td>
<td>H/A</td>
</tr>
<tr>
<td>A-2 to A-5 Apartments</td>
<td>750</td>
<td>H/A</td>
</tr>
<tr>
<td>PHASE III</td>
<td></td>
<td>3,599</td>
</tr>
</tbody>
</table>

Community Resources, Inc.  LILI HANI RECREATIONAL COMMUNITY

Community Resources, Inc.  LILI HANI RECREATIONAL COMMUNITY

2-30

3-1
Phase I began in 1986 and is scheduled for completion by 1995. Timing of the 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. The new course will be located on existing land that is currently used for farming. The new course will be open to the public for play. A single-story lodge is also being planned for the site. The lodge will accommodate for the prospective golfers. The land is currently being used for farming. It is expected to be completed for another ten to 15 years (personal communication, Kaulana Golf, Office Manager, Mokuleia Golf Company, December 11, 1990).

Mauna Loa: 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 to the public. A single-story lodge is also being considered for the prospective golfers. The land is currently being used for farming. It is expected to be completed for another ten to 15 years (personal communication, Kaulana Golf, Office Manager, Mokuleia Golf Company, December 11, 1990).

The more than 300 acres of KS/HI land at Waialua, leased by Meadow Gold Dairy until 1989, are to be leased for pasture in the short-term future. A tentative master plan for 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 the proposal for the study area were built, the total including the existing Kualoa course and the nine-hole Ho'omaluhia 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 3.1.1. Other proposals are:

- The Campbell Estate proposes four courses: three at Punalu'u (near Kualoa) and one at Waialua (near Haleiwa). All would be 18-hole courses open for public
play. Two clubhouses would service the Punaiao courses, while the Maleakahana course, being much further away, would require its own clubhouse and support facilities. Although an Environmental Impact Statement has been approved, no public announcement has yet been made. In any event, Campbell Estate hopes to have something underway within three years, with completion of the first phase of work being started by 1980.

- The company that owns the Punaiao Resort also has 225 acres of land on the west side of the island, which is zoned for residential development. This land was acquired in 1980, and construction is expected to begin shortly. (Personal communication, Alan Mill, General Counsel, Castle & Cooke Properties, Inc., December 10, 1980)

- Castle & Cooke Properties, Inc. also plans to construct a 18-hole golf course and clubhouse on this land, with construction to begin within the next year. (Personal communication, Wallace Miyahira, General Counsel, Castle & Cooke Properties, Inc., December 10, 1980)

It seems reasonable to conclude that the number of courses in the study area in 1980 will be fewer than the number now existing and proposed, due in part to critical pressures by Oahu citizens and government, in part to the likelihood that the new course will be used for existing courses, whether in the study area or elsewhere in the state. Consequently, some developers say they will not develop land unless it is more advantageous in the future than it now seems.

Parks: Since Koalaloa and the North Shore are two of the few areas left on the island with undeveloped land, there is potential for expansion in the study area. (Personal communication, Don Griffin, Assistant Director of Parks and Recreation, December 10, 1980)

Additional parcels have recently been acquired for Hanauma Beach Park and Koalaloa Beach Park, where expansion will occur. The City also recently acquired Hikaka Beach Park, which is 15 acres of which the City hopes to use as a campground. Demolition and rebuilding are scheduled for the Hanauma, Koalaloa, and Koikololo beach parks. Other expansion projects for the future include the following beach parks: Likelike, Makaha, Makua, Puili, and Sunset. (Personal communication, Don Griffin, December 10, 1980)

The only privately funded park project in the study area is the Punaiao Resort plan to dedicate a 186-acre public park at first. This project is also scheduled to begin construction by 1980. (Personal communication, Chuck Ehrhorn, Development Manager, Castle & Cooke Properties, Inc., December 10, 1980)

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 interest. (Personal communication, Robert Leinane, General Manager, Wailea Falls Park, December 10, 1980)

- Wailea Falls Park: A potential site for a new park development in the study area is at the Wailea Falls Park, which is 186 acres of undeveloped land. A private developer plans to construct a 186-acre public park at this location. (Personal communication, Chuck Ehrhorn, Development Manager, Campbell Estate, December 12, 1980)

Community Resources, Inc.

LIHI LANI RECREATIONAL COMMUNITY

Community Resources, Inc.

LIHI LANI RECREATIONAL COMMUNITY
3.3 HOUSING AND POPULATION TRENDS

Besides the Lihiklohili project, there are no major proposals for additions to the Primary Study Area's housing stock. Elsewhere in the study area, Kuliiluma Resort proposes to erect approximately 200 affordable units outside the resort.

One major ongoing residential development is in Kahu. The Kahu Housing Corporation began construction of 282 units in 1987. Current construction is now overseen by the Kahu Village Association. Approximately 177 units remain to be built by 1989, 156 of which are reserved for Kahu sugar plantation families (personal communication, Mel Wagner, Manager, Kahu Village Association, December 19, 1990).

The need for additional housing in Lahi has been recognized by the State, the county, and the community. Plans for growth of the town, including new housing, have yet to be finalized. In Ha'awi, plans for a low- to moderate-income rental housing development of 114 units and a school for autistic children are on hold, due to infrastructure 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):

<table>
<thead>
<tr>
<th>Area</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore DP Area</td>
<td>1,266</td>
</tr>
<tr>
<td>Koolau DP Area</td>
<td>1,215</td>
</tr>
<tr>
<td>Total Study Area</td>
<td>2,481</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Area</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore DP Area</td>
<td>4,000</td>
</tr>
<tr>
<td>Koolau DP Area</td>
<td>4,000</td>
</tr>
<tr>
<td>Total Study Area</td>
<td>8,000</td>
</tr>
</tbody>
</table>

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.

Community Resources, Inc.  LIHILAHI RECREATIONAL COMMUNITY
3.4 PUBLIC FACILITIES AND INFRASTRUCTURE

Roads. The largest proposed infrastructural change affecting the North Shore is the State's 2.3-miia Haleiwa Bypass Road. The project, which includes five bridges, will divert circal-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-1992, given sufficient funding (personal communication, Herbert Ten, Project Manager, State Department of Transportation, December 11, 1990).

In Haleiwa itself, the City proposes to widen Kaneohe Highway to 50 to 60 feet, and improve the sidewalks along the Highway. Eventually, the City intends to upgrade Haleiwa Road and portions of Waialua Beach Road.

Extensive realignment and improvement of the Kaneohe Highway fronting the Kuliua 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 Haulea-Punalu and Kukuiula. 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 Kaneohe.

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 Kukuiula site, for example, processed effluent likely can be used to create a wetlands bird sanctuary (personal communication, J. Hamel, Civil Engineer, Planning Section, Department of Public Works, December 11, 1990).

The Kuliua 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. Hamel, Civil Engineer, Planning Section, Department of Public Works, December 14, 1990).

In Lai, 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 Lai district (personal communication, Don Kleinman, Project Coordinator, Zion 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 Koolauan-Koolau Pali boundary, but wells are slated for much of the study area. Also, a new main will be installed from Puka Road to Crawford's Convalescent Home.

Fire Protection. The City has long-term plans to build fire stations at Kauai and Lai, and to replace the existing station at Kauai. Funds have been appropriated to replace the existing Sunset Beach station in the next two years in order to provide improved services (personal communication, Chief Leonard, Battalion Chief, Administrative and Service 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 study area who work with the project's representatives to identify ways the project can be made compatible with community character and desires. Following are the issues and concerns expressed by community members and 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 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;
- 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 included nearly exclusively 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 Lili 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 study area residents occurred at that time. Next, CRI staff reviewed the project files kept by Group 30 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. 21), 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 5.2.7.)

Community Advisory Group Meetings. In February, 1989, 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 40 to 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 CAC: 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 CAC 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 Papakea. 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 community property.

Additional Presentations and Community Involvement. 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 313 acres, with the explicit aim of developing stronger community involvement with the project. The withdrawal was made a year after the petition was resubmitted. A newsletter, Lihia Lani News, was first circulated in March, 1989. In May, the Lihia Lani Information Center opened in the Kalewa Shopping Center.

Throughout the spring, summer, and fall of 1988, 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 consisted of members of the Sunset Beach Community Association, four from Pupukea Highland Community Association, and 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 1988. 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 5.3.)

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 ranked the highest were: managed conservation areas, preserved ecological 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.)

Community Resources, Inc. LIHIA LANI RECREATIONAL COMMUNITY 4-3

Community Resources, Inc. LIHIA LANI RECREATIONAL COMMUNITY 4-4
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 Olana 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 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 - 228 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:
   - 250 lots, minimum size 2 acres
   - community facilities

3. Recreational:
   - golf course and golf clubhouse
   - tennis/health club
   - equestrian center
   - summer camp/casino/ground
   - 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

Source: JPC UPDATE, June 1990
TABLE 4-1. JOINT PLANNING COMMITTEE GUIDELINES

Any future use of the property shall comply with the following minimum requirements:

1. It shall not cause an increase in soil erosion.
2. It shall not cause an increase in sediment runoff from the property.
3. It shall not cause an increase in the rate of storm water runoff from the property.
4. It shall not result in the reduction of size or shape of the property.
5. It shall utilize landscaped areas to reduce the visual impact of the property and provide for open space.
6. It shall minimize the amount of water run-off from the property.
7. It shall control the application of fertilizers, pesticides, and other substances to prevent contamination of local water supplies.
8. It shall preserve the most significant archaeological, historical, or cultural resources on the property, and property documents any other sites that would be affected.
9. It shall control the impact on vehicles through traffic along local roads.
10. The visual impact of any new use of the property shall be included.
11. It shall ensure that any trees, groves, and other natural features are preserved.
12. It shall include no recreational uses.
13. It shall include no recreational uses.
14. It shall create an overall design that is consistent with the existing landscape and overall development of the area.
15. Disposal of sewage shall not cause serious damage effects on the surrounding ecosystems, including the ocean. Any waste systems shall be designed to dispose of sewage effluent.
16. It shall not cause an adverse impact on ocean water quality and ocean ecosystems.

4-7

(6) Country Zoning/Two Golf Courses, 156 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 showed 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 third open JPC meeting took place in August at the Sunset Beach Elementary School. Approximately 150 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 150 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" if an alternative concept was desired 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 results.)

Of the 102 surveys, 69 had comments. These were reviewed and summarized by CHI (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 were 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, Oahu Island Resource Planning and Development Council reviewed the information and comments. Drawing on indications of community support for specific land uses — one golf course, biking and hiking trails, affordable housing, community facilities, and campgrounds — Oahu Island Resource Planning and Development Council prepared a new master plan with that master plan as the basis for the current development proposal.
TABLE 4-21  LAND USE CONCEPTS REVIEWED AT AUGUST 1980 JPC
COMMUNITY MEETING

<table>
<thead>
<tr>
<th>Concept A1 Country Zoning/Recreational</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 market lots (one-acre minimum)</td>
</tr>
<tr>
<td>240 affordable lots (6,000 sq. ft. minimum)</td>
</tr>
<tr>
<td>equestrian center, tennis/health center, campground</td>
</tr>
</tbody>
</table>

Number of persons preferring: 9.

**SURVEY COMMENTS**

(*) indicates number of people with the comment

1. no development
2. agriculture land
3. Fever units
4. larger affordable lots (1/4 acre)

<table>
<thead>
<tr>
<th>Concept A2 Country Zoning/One Golf Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 market lots (one-acre minimum)</td>
</tr>
<tr>
<td>150 affordable lots (5,000 sq. ft. minimum)</td>
</tr>
<tr>
<td>equestrian center, tennis/health center, campground</td>
</tr>
<tr>
<td>one 18-hole golf course, clubhouse &amp; driving range</td>
</tr>
</tbody>
</table>

Number of persons preferring: 33.

**SURVEY COMMENTS**

(*) indicates number of people with the comment

1. add 1 golf course
2. open pavilion/campground with cabins/soccer baseball/field
3. affordable golf
4. area for children (swings/see-saw)
5. affordable housing
6. community facilities
7. if roads can be developed to handle traffic
8. affordable housing off-site
9. no golf course
10. protect archaeological & historical sites
11. emergency shelter
12. agriculture not viable
13. equestrian area not small

Community Resources, Inc.  LAKI LAMI RECREATIONAL COMMUNITY
4-10
TABLE 6-2 (Cont.)

**Concept #3 Country Living/One Golf Course/Agriculture**

- 120 market lots (one-acre minimum)
- 150 affordable lots (6,000 sq. ft. minimum)
- 100 acres agricultural lands conserved
- equestrian center, tennis/health center, campground
- 18-hole golf course, clubhouse & driving range

Number of persons preferring: 12.

**Survey Comments**

(*) indicates number of people with the comment

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Best feasible but need more definition</td>
</tr>
<tr>
<td>(1)</td>
<td>Eliminate golf course</td>
</tr>
<tr>
<td>(1)</td>
<td>Community facilities</td>
</tr>
<tr>
<td>(1)</td>
<td>Day care center</td>
</tr>
<tr>
<td>(1)</td>
<td>Elder care center</td>
</tr>
<tr>
<td>(1)</td>
<td>Low density housing</td>
</tr>
<tr>
<td>(1)</td>
<td>Add one golf course</td>
</tr>
<tr>
<td>(1)</td>
<td>Good because ag homes and 1 golf course</td>
</tr>
</tbody>
</table>

**Concept #4 Other**

Number of persons preferring: 48.

Suggestions:
- Residential/Conservation/Agriculture
- Residential/Two Golf Course
- Agriculture/Cluster
- Affordable Housing Only
- Agriculture/Recreation
- Ecológico Research Site
- Recreation Only

**Survey Comments**

(*) indicates number of people with the comment

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>(15)</td>
<td>No zoning change</td>
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<tr>
<td>(13)</td>
<td>Traffic/Access</td>
</tr>
<tr>
<td>(9)</td>
<td>No opinion/Need more data</td>
</tr>
<tr>
<td>(6)</td>
<td>Improve infrastructure first</td>
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<tr>
<td>(4)</td>
<td>Study area impacts first</td>
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<tr>
<td>(4)</td>
<td>Recreational only/leave alone</td>
</tr>
<tr>
<td>(4)</td>
<td>Affordable housing</td>
</tr>
<tr>
<td>(4)</td>
<td>Density less than 400 houses</td>
</tr>
<tr>
<td>(3)</td>
<td>Sewage, Erosion, Run-off</td>
</tr>
<tr>
<td>(2)</td>
<td>Need for agriculture lots</td>
</tr>
<tr>
<td>(1)</td>
<td>No golf course</td>
</tr>
<tr>
<td>(1)</td>
<td>Two golf courses</td>
</tr>
<tr>
<td>(1)</td>
<td>Chemical usage</td>
</tr>
</tbody>
</table>

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 ones 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 Manolo, a task force to initiate a regional master plan for Central Maui 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 1994.

4.3 ISSUES AND CONCERNS RAISED WITH REGARD TO DEVELOPMENT PROPOSALS AT LIIHI 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 Liihi Lani elicited response from residents along the North Shore. The cluster’s objections centered around the need 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 further 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 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 development 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 savage 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, like many of the social concerns described here, rarely 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 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.

4.3.3 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 housing development by and for the Japanese. Because of the foreign ownership, residents were concerned that the project would cater to affluent Japanese nationals and not be affordable for North Shore residents.

Residents were concerned that golf memberships would be sold to only the Japanese.
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 acceptable for the project and should be built off-site.

4.3.4 Concerns Regarding Adjacent Areas

Displacement: Area residents have had some concern about the displacement of the current tenants 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. Some residents from either Lihani 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.

4.3.4 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 time 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 set out for one and a half years and made four hikes on the property. Topics for discussion included:

- trail guide and rules preparation
- packing 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 much-visited 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 Nahuku side of the property

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.

Swinge: 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 stages 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 with 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.

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4.4 JPC INTERPRETATION OF COMMUNITY INPUT

The Joint Planning Committee has received continuing community input. In the latest JPC update, of September 1980, 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 1980 and December 1989. The overall input led the JPC to the conclusion that there is no clear consensus about the use of the project site 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:

- open spaces, 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

Obyashi Hawai'i 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, CHI 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, Obyashi Hawai'i 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 1997 plan called for 180 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. Obyashi Hawai'i 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 affordable units 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 housing 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 JFC guidelines for the development of the property. This issue will be addressed in the draft of the development plan. The North Shore community, or area residents, will impose restrictions on lot buyers.

Recreational. Obayashi Hawaii has proposed a tentative plan to dedicate the 10-acre site to the Sunset Beach elementary school to the 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 rooms 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 will be partially subsidized by Obayashi through a funding program tied to golf course fees. Each golfer will 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.

Another one-acre site is proposed for dedication to the city to allow residents to participate in the City's "Community Gardening Program.

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 tax break. The development will "create an oasis of the same kind of recreation proposed by Obayashi. The developer 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.

Another reason that a golf course was eliminated was in response to environmental concerns of area residents. Community concerns about pesticides, chemical run-off, and depletion of water supplies 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 too expensive for them to afford. Obayashi has proposed a golf course that will be available and affordable to area residents. It has been proposed that 20% 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 Committee, 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.

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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. Ohauhili Hawaii has proposed an environmentally sound wastewater management plan for the Lihilihi 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, Ohauhili Hawaii eliminated one 18-hole golf course from the project proposal. The other major component that was dropped from the proposed development was the golf course. The golf course was dropped at least partly in response to community concerns about noise and perceptions that the golf course 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 Lihili 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 (Kessler, 1989). 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 2, future conditions in the combined study areas include:

- The creation of at least 4,000 new jobs (compared to an estimated 1632 study area labor force of 15,500 and a projected study area maximum population of 22,000 in 2000);
- Development of the Kuliulani Resort and, possibly, of other residential developments; 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 overcrowding 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 potential 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 Lihili 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 1992 to 1995, and an annual average of 79 person-years from 1994 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 123 person-years in the first period, and an annual average of 51 person-years in the second period. After 2000, construction is projected as ending.

The Lihia 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 Kuliama 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 $110,000 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 assure that local enterprises compete for business from Lihia Lani.

Currently, unemployment in the study area is under 4% -- 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 Kuliama expansion will bring many new jobs to the study area, so the future outlook is for a tight labor market. The challenges, for facilities operators at Lihia Lani as for other employers in the area, will be to find and encourage a stable workforce.

Employment at Lihia 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 Lihia Lani, increasing the likelihood that the project can find and retain much of its staff among residents of the study area.

Workforce development at Lihia Lani will likely include the following components:

- Active recruitment of workers from nearby communities;

- 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 Lihia 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.

- Customers, 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, Waihulua
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 Lili Lani residents and staff. At buildout, an average daily population of some 27 Lili 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, as much as project employees and project residents are counted separately. However, Lili Lani employees and their families, including ones not 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 500 units to the study area housing supply. However, in light of the estimate that 25 employees and their families will likely move into the Koolau/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 employees in-migration to the combined study areas is likely to amount to about 10 to 15 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/Koolau 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 15% of the current population of the combined study areas. In relation to the population of the Primary Study Area — 3,212 in 1990 — the project is a significant development. However, it is smaller in size than the adjacent Sunset Beach and Puukalei communities (as shown in Table 5-1).

The proposed population and housing at Lili Lani are, in relation to the total Lili 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...
denses than the Waialae 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 rule, that each DP Area continues to be less to a set proportion of the island wide 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 guidelines 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 2-2) show the current population as well within the upper limits shown in Table 5-2:

<table>
<thead>
<tr>
<th>1989 Population est.</th>
<th>Percentage of 1989 City and County Population</th>
<th>Percentage of 2010 Upper Limit for Area(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore DP Area</td>
<td>1.7%</td>
<td>77.9%</td>
</tr>
<tr>
<td>Koolau DP Area</td>
<td>1.5%</td>
<td>88.5%</td>
</tr>
<tr>
<td>Combined Areas</td>
<td>3.1%</td>
<td>82.4%</td>
</tr>
</tbody>
</table>

In short, the current population density in North Shore is within the guideline of 1.6% to 1.8%, while Koolau's official population exceeds the guideline of 1.7% to 1.8%. 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 69 persons in employee households identified by KPMG Ernst Harwick as moving to the study area will likely live in the Koolau DP Area. That additional population amounts to less than 20% of the difference between the estimated 1989 population level and the upper limit for the North Shore DP Area.)

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A question arises about the overall density of population in the North Shore DP Area if the Lihikani project is built, and whether other land which is zoned for possible residential uses 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 Lihikani built out.

It is difficult to estimate whether additional 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 Lihikani 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 guidelines by 2010 even if little new housing were built -- many people would live in more crowded conditions than now. Hence Lihikani 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 and recreational and educational activities, not as a full-time business venture. The lessees 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 lessees may be able to continue to keep horses and to train young people.

The Lihikani site has been used by some nearby residents for riding and hiking. Development of the site will not cause 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 the 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 Hawai'i has sponsored a local golf tournament to support local youth groups, including the Kanuku 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. Līhi Lani will allow 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 progress on-site will encourage participation of people from the surrounding area.
- Obayashi has sponsored a polo 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 Līhi Lani.
- The baseball/softball field included in the community facilities will allow young people increased participation in sports.
- The Līhi 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 Eunker Beach Park, or by surfers at sites 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 ACCESS

The project will have little impact on current uses of adjacent lands. (See Section 5.7.2 for discussion of relations between Līhi 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 Makaha 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 Līhi 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 LAND VALUES AND PROPERTY TAXES

Both nearby residents and the islandwide public largely expect that golf courses and upscale developments such as Līhi 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 Līhi Lani.

Summary. Golf courses and golf-related communities (as distinct from resort destinations) in Hawai'i have very limited impacts on nearby property values. A few nearby properties may increase in value due to physical improvements, such as advantage due to having a golf course as an extension of one's impact of golf courses on land values in the larger communities surrounding them.

Līhi Lani's golf courses 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.

Community Resources, Inc.  LĪHI LANI RECREATIONAL COMMUNITY  5-10
Any judgment as to whether the development of Lih"i Lani will, over the long term, affect values in nearby areas must be tentative. However, both existing studies and the pricing policy minimal impacts or no impact on existing residential values in Papukaa, 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 assessor;
- 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 Lih"i 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 the property that shares the improvement.
  - Amenities: A development can make nearby properties more marketable. Assessors do not assess 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, gain a sense of open space from golf course development, have a specific amenity. Agricultural and the same apply do not gain an amenity, since golf course views do not help in raising crops. Again, residential properties at a reasonable distance from a golf course 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 value) 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 why prices rise or fall. Changes in prices 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 or other development such as beachfront homes. The impact of a rise in values confined to properties with a similar quality, ocean frontage, in not automatically treated as applying to other properties nearby.

Lih"i 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 Lih"i Lani market) start to rise, they might well be treated as a single neighborhood.

Implications for Lih"i Lani's Neighbors: Lih"i 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 Lih"i 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. Pastureage and project residential areas are situated between the golf course and existing residential areas. The Converse site, on the Kahuku side of the Lihiki 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 gulley separates Pupukea and Lihiki 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 Lihiki Lani to have an impact on existing real estate values. The following were interviewed in December 1990:

- Marianne Abrigo
  President, Marianne Abrigo Properties
- Indra Andrews-Moe
  President, Mokualei Management, Inc.
- Marlene Lindsey
  Principal, Marlene Realty
- Jacqueline Manard
  Principal, Jacqueline Manard Realty
- Ron Scott
  Principal, Scott Cooperative Realty
- Richard Sternan
  President, Sternan Realty

Major findings from the most recent interviews were:

- Real estate prices in Koolaupoa 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 Kahuku may have led some Kahuku 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 income is available.

- The scheduled Kailua 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, 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 Lihiki Lani project was seen as simply adding to the impact of the Kailua Resort expansion. For those who saw Kailua as having little or no further impact on the market, Lihiki...
Lani was similarly lacking in impacts. For the minority who foresaw major changes due to the Kuliua expansion, Liihi 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 in Liihi Lani itself.

In 1989, realtors did agree that any upscale housing which included 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 (1991a, 1991b). Major findings of these studies include:

- For the North Shore/Ecualoia area, average single-family sales prices for oceanfront homes suddenly soared in 1989, to more than double the 1987 averages. But off-water 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 Waialae and also some non-resort projects.)

In all cases from three different islands, the new upscale golf/residential developments had no apparent impacts on single-family home sales prices in neighboring areas by early 1989. Values in those 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.

Islandwide economic market conditions seemed to far outweigh nearby improvements such as golf courses in affecting values of existing housing stock.

More recent data, reflecting the acceleration of real estate values throughout Hawaii in 1989-90, are less dramatic. Neighbor Island residential areas near proposed golf developments have seen increases in value at levels similar to or just above island averages. On Oahu, the value of neighborhoods near golf-related developments still is increasing more slowly than the islandwide average.

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 courses 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 Ke'ahuku on the Big Island, is an example of a residential/golf development that has seen a slow appreciation in on-site values, and no off-site impact.)

The forecast by one real estate professional that land values in Liihi Lani could affect Pupukea Highlands, and vice versa, implies that the creation of Liihi 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 Kuliua and the severity of traffic congestion on Kamuela Highway -- both factors separate from Liihi 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 stands out 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: Keana Point along the North Shore coast to Waialua Stream, down the Ko‘olau Mountain Ridge to Kapaa Stream, across to Waialua Ditch near Kualoa, and up the Kualoa Mountain Ridge back to Keana Point. Police protection is provided to the project area from the Waialua Substation.

The boundary of the second District encompasses an area of approximately 190 square miles. This area is covered by 71 field officers. Response time to the Papake’o area fluctuates over time, but was recently estimated to be 2 to 2.5 minutes (personal communication, Captain William Benetti, Waialua Substation, Dec 11, 1990).

Anticipated Impacts. It is estimated that a de facto population of about 1,900 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 pedestrian.

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 will be provided by event sponsors, in coordination with local police officials. If the project were designated as a “hot” by the city and County, up to 6 additional officers would be required by the Waialua 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 Moyle, 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 24-bed Kahuku Hospital, approximately ten to fifteen minutes from the project site. The hospital offers comprehensive medical services on a 24-hour emergency 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 the 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.

S.6.4 Schools

Existing Conditions. The nearest elementary school to the project is the Sunset Beach Elementary School (grades kindergarten to six), which is located adjacent to the main 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 houses on large lots and 180 affordable houses. The current schedule anticipates that all housing could be built by 1997. Upon completion, the project could produce an approximate enrollment of 75 to 100 students in grades kindergarten 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 Lili 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 (KBHSF of Hawaii, 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 $500,000. Contributions plus interest would go to study area schools and students.

S.7 COMMUNITY CHARACTER AND CHANGE

S.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., 1989a.)

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 by residents 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 Maili, Lili 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. Lili Lani would intensify the existing trend for many nearby residents to treat the area as surrounding Sunset Beach Elementary -- which already offers playing fields and some parking spaces -- as a community focus.
5.7.2 Integration of Lihiki Lani with the Surrounding Community

As described in Section 4.4, the master plan for Lihiki 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 Lihiki Lani into the larger North Shore population include:

- Conformance with the guidelines established by the JFC, 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 hillside 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 "pali" 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 "pali" 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 benefiting 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 Lihiki Lani is accessible to the North Shore community will likely follow:

- Recreational programs and events such as rodeos will make Lihiki Lani a venue for different sectors of the community;
- Lihiki 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 employers 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, Lihiki 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 cut off from 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, Lihiki Lani will make the more affluent segments of the population more visible. Whether these 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 Lihiki Lani could include:

- Formation of a community group in which residents of both the market lots and the affordable housing at Lihiki Lani have a voice.
- Establishment of a structure for joint discussions and community action bringing together Lihiki Lani residents with residents of nearby communities. The JFC is an example of the possibility of such co-operative action.
Programs to encourage more affluent residents of Lahi Lani to come to know their neighbors in recreational contests. 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, Lahi 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 our surf beaches, and character. As newcomers have been integrated into the "country" community in the past, so Lahi 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 Community

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, Lahi 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, Lahi Lani would tend to attract residents sharing area 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


Community Resources, Inc.  

LIHII LANI RECREATIONAL COMMUNITY 

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January 7, 1991

Mr. Toshiharu Hino, President
Ookayashi Hawaii Corporation
c/o Mr. Craig Yamagushi
Pukalani Tower
1601 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 Koolau 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

January 1991

Economic and Fiscal Impact Assessment for the Proposed Lihi Lani Master-planned Community Pupukea, Oahu, Hawaii

Prepared for

OBA YASHI HAWAII CORPORATION
## LIHI LANI RECREATIONAL COMMUNITY

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<td>IV-F Projected Annual State Government Operating Expenditures Attributable to In-Migrant Population of the Lihi Lani Residential Community</td>
<td>IV-2</td>
</tr>
<tr>
<td>IV-G County Government Revenue and Expenditure Comparison</td>
<td>IV-3</td>
</tr>
<tr>
<td>IV-H State Government Revenue and Expenditure Comparison</td>
<td>IV-3</td>
</tr>
</tbody>
</table>
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 Lili`Lani or the "Edge of Heaven." It will be located on a 1,124-acre parcel at Pupukea in the Ko`olaulus Census Division of Oahu.

In December 1990 KHMS Peer Warwick assessed the market for the project in a report entitled "Market Assessment for the Proposed Lili`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, county, 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 Ko`olaulus division in Oahu, defined as the area from Kaneohe to Waimea Bay. The site is about 50 minutes by car from Honolulu and overlooks the Sunset Beach area, affording spectacular ocean and sunsets views from the majority of the site.

Lili`Lani is proposed to be a recreation-oriented community with one semi-private 18-hole golf course, a clubhouse, tennis center, equestrian ranch, campgrounds, cabins, 110 one-acre and larger country lots and 360 affordable homes. The availability of this variety of facilities and amenities is expected to establish Lili`Lani as a recreational community area. Lili`Lani could provide family-oriented activities with golf, tennis, horseback riding, hiking and centralized facilities at which to meet before and after activities. Lili`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 $15.1 million in direct annual consumer expenditures by 1995, $65.1 million per year in 2000 and about $67.0 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 $24.6 million by 1995, $127.1 million in 2000 and stabilizing at $118.8 million by 2001, in 1990 dollars.

Construction and Operational Employment

Lili`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 500 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 Lili`Lani (Average annual person-years)

<table>
<thead>
<tr>
<th></th>
<th>1993 to 1996</th>
<th>Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>204</td>
<td>79</td>
</tr>
<tr>
<td>Total</td>
<td>367</td>
<td>162</td>
</tr>
<tr>
<td>Operational:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td>102</td>
</tr>
<tr>
<td>Total</td>
<td>249</td>
<td>139</td>
</tr>
<tr>
<td>Total</td>
<td>445</td>
<td>244</td>
</tr>
</tbody>
</table>

Personal Income

Wages and salaries paid to direct employees of the project could be anticipated to represent about $0.4 million by 1995 and $4.4 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 Lili`Lani

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th>1993 to 1996</th>
<th>Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>8.4</td>
<td>4.0</td>
</tr>
</tbody>
</table>
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 Koolauos 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 Koolauos 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 "permanent," population growth.

The population impact for the island as a whole would be somewhat less than for the North Shore and Koolauos 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 Koolauos region de facto population is projected to increase by about 578 persons by 1995, 1,097 persons by 2000 and 1,012 persons at stabilization, in 2001. Projected new residents attracted to Oahu by Lili Hani has been estimated at 14 by 1995 and 45 by 2000, as summarized below:

<table>
<thead>
<tr>
<th>Projected Project Impacts</th>
<th>North Shore and Koolauos De Facto and Island of Oahu Resident Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore and Koolauos</td>
<td>578 1,097 1,012</td>
</tr>
<tr>
<td>Island of Oahu</td>
<td>14 45 45</td>
</tr>
</tbody>
</table>

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 $100,000 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) |
|---------------------------------------------------------------------------------------------|-------|
| County government:                                                                       |       |
| Net additional revenues                                                                  | $2.1  |
| Revenue/expenditure ratio                                                                 | 0.88  |
| Stabilization                                                                             | 13.0  |
| State government:                                                                        |       |
| Net additional revenues                                                                  | $0.18 |
| Revenue/expenditure ratio                                                                 | 0.11  |
| Stabilization                                                                             | 1.6   |
II - PROJECT OVERVIEW AND REGIONAL SETTING

This chapter describes the proposed Lihiliili master-planned community at Pupukea and surveys economic and demographic trends for the Island of Oahu as a whole and the North Shore and Koalauloa 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

O'ahu Hawaii Corporation plans to develop a residential community named Lihiliili or the "Edge of Heaven" on about 1,163 acres of land in the Pupukea area in the Koalauloa region of Oahu, as shown in Exhibit II-2. The development would be a recreation-oriented community with facilities and amenities, as shown in Exhibit II-3. The project would feature one 18-hole golf course, golf course clubhouse, tennis center, equestrian center, campground, cabins, and new homes. The development is proposed to be built in three phases. The first phase of development would include the golf course, clubhouse, equestrian center, and community facilities. The first increment of about 125 lots, 150 affordable homes and major infrastructure improvements by 1992. The second phase would encompass the tennis center and the second increment of about 30 lots and 40 affordable homes to be completed by 1995. The final increment of about 20 lots and 40 affordable homes would complete the final phase of the development of Lihiliili 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-3, based on information from the "Market Assessment for the Proposed Lihiliili Master-planned Community" prepared by KPMG Peat Marwick in December 1990. Development is 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 commuting time by car to the area's white, sandy beaches and the nearby Kualoa Resort. Lihiliili residents and other Hawaii residents would also have access to golf, tennis, equestrian activities, campgrounds, parks, and dining at the project's clubhouse.
### LIHE LANI RECREATIONAL COMMUNITY
Projected Cumulative Development Upon Build-out at LIHI Lani Master-planned Community

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf course development:</td>
<td>18</td>
</tr>
<tr>
<td>Number of holes</td>
<td></td>
</tr>
<tr>
<td>Clubhouses</td>
<td>1</td>
</tr>
<tr>
<td>Tennis courts</td>
<td>4</td>
</tr>
<tr>
<td>Other recreational development:</td>
<td></td>
</tr>
<tr>
<td>Tennis center (number of courts)</td>
<td>12</td>
</tr>
<tr>
<td>Equestrian ranch (number of stalls)</td>
<td>100</td>
</tr>
<tr>
<td>Camp cabins</td>
<td>12</td>
</tr>
<tr>
<td>Single-family lots(I)</td>
<td>120</td>
</tr>
<tr>
<td>Affordable housing units</td>
<td>180</td>
</tr>
</tbody>
</table>

(1) Assumes incentives applied for total build-out of houses by 2000: Quan - Yanagishii Partnership.

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 566,000 of Hawaii's resident population although it comprises only about 10% of the state's land area. As of July 1999, Oahu was estimated to have a resident population of 841,000, 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 1981 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 316,000 reflected an average daily visitor population of 74,600 for the island, with a stable visitor base located primarily in Waikiki.

In 1989 the total Oahu visitor arrivals reached 5.5 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 $599 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 54% in 1978 to 48% 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 7.1 million visitors in 1990 and 2000, respectively, each capturing approximately half of the visitors. This would represent a visitor growth rate on Oahu of about 3.4% compounded annually.

NORTH SHORE AND KOOLAU LAKE REGIONS

The subject site is located near the North Shore edge of the Koolau Lake region which is defined as U.S. census districts 101, 102.01 and 102.02. The area constitutes the northern half of Oahu's windward coast bounded by the north end of the Ko'olau Mountains and extends from Waiau Stream to Haena Bay. Kamehameha Highway is the main roadway linking this area with the adjacent North Shore communities. Residential communities bordering the highway include Kane'oh, Kahana, Punalu'u, Hauula, Laie, Kahuku, Sunset Beach and Waimea.
**Exhibit II-B**

**LIHII LANI RECREATIONAL COMMUNITY**

**Historical and Projected Resident Population of the North Shore and Ko'olaau Regions of Oahu**

1970 to 1989

<table>
<thead>
<tr>
<th>Year</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>13,000</td>
<td>10,000</td>
<td>23,000</td>
</tr>
<tr>
<td>1980</td>
<td>15,000</td>
<td>14,000</td>
<td>29,000</td>
</tr>
</tbody>
</table>

Estimated - 1999(3)

<table>
<thead>
<tr>
<th>Compounded annual percentage increase:</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970 to 1999</td>
<td>0.6%</td>
<td>2.2%</td>
<td>1.9%</td>
</tr>
<tr>
<td>1980 to 1999</td>
<td>1.8%</td>
<td>2.0%</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

(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, respectively, for North Shore and Ko'olaau Development Plan areas as of June 1989.


---

**Exhibit II-C**

**LIHII LANI RECREATIONAL COMMUNITY**

**Labor Force Characteristics of the North Shore and Ko'olaau Regions and City and County of Honolulu**

1970 and 1980

<table>
<thead>
<tr>
<th>Potential labor force (persons aged 16+)</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>9,000</td>
<td>7,370</td>
<td>16,370</td>
</tr>
<tr>
<td>1980</td>
<td>12,000</td>
<td>10,600</td>
<td>22,600</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Civilian labor force</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>3,510</td>
<td>3,940</td>
<td>7,450</td>
</tr>
<tr>
<td>1980</td>
<td>5,510</td>
<td>4,960</td>
<td>10,470</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage distribution:</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armed services</td>
<td>-%</td>
<td>-%</td>
<td>-%</td>
</tr>
<tr>
<td>Civilian labor force</td>
<td>59.0%</td>
<td>52.0%</td>
<td>55.5%</td>
</tr>
<tr>
<td>Not in labor force</td>
<td>41.0%</td>
<td>48.0%</td>
<td>44.5%</td>
</tr>
</tbody>
</table>

| Total                                    | 100.0%         | 100.0%      | 100.0% |

<table>
<thead>
<tr>
<th>Civilian labor force participation rates:</th>
<th>North Shore(1)</th>
<th>Ko'olaau(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>76.0%</td>
<td>64.0%</td>
<td>70.0%</td>
</tr>
<tr>
<td>Female</td>
<td>24.0%</td>
<td>36.0%</td>
<td>30.0%</td>
</tr>
</tbody>
</table>

| Total                                    | 100.0%         | 100.0%      | 100.0% |

| Average                                  | 57.0%          | 57.0%       | 57.0%  |

(1) Defined as census tracts 99.01, 99.02 and 100.
(2) Defined as census tracts 101, 102.02 and 102.01.

**Exhibit II-F**

LIHI LIHI RECREATIONAL COMMUNITY  
Average Annual Labor Force Estimates of the City and County of Honolulu  
1980 and 1989

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>1989</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civilian labor force</td>
<td>340,050</td>
<td>384,500</td>
<td>1.4%</td>
</tr>
<tr>
<td>Percent unemployed</td>
<td>4.6%</td>
<td>2.2%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Nonagricultural wage and salary jobs by industry:

<table>
<thead>
<tr>
<th>Industry</th>
<th>1980</th>
<th>1989</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>19,000</td>
<td>22,450</td>
<td>1.8%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>17,100</td>
<td>16,050</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Trade</td>
<td>26,000</td>
<td>32,650</td>
<td>2.6%</td>
</tr>
<tr>
<td>Wholesale</td>
<td>16,100</td>
<td>18,600</td>
<td>2.2%</td>
</tr>
<tr>
<td>Retail</td>
<td>71,000</td>
<td>63,500</td>
<td>-0.9%</td>
</tr>
<tr>
<td>Services and miscellaneous:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotels</td>
<td>15,200</td>
<td>18,700</td>
<td>2.3%</td>
</tr>
<tr>
<td>Other services and miscellaneous:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance, insurance and real estate</td>
<td>64,100</td>
<td>90,250</td>
<td>3.9%</td>
</tr>
<tr>
<td>Government</td>
<td>29,000</td>
<td>35,100</td>
<td>2.1%</td>
</tr>
<tr>
<td>Total</td>
<td>333,000</td>
<td>395,600</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

N/A Not applicable.

**Sources:** State of Hawaii, Department of Labor and Industrial Relations, Labor Force Data Book, annually updated, and Labor Area Area (December), 1989.

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 1989 in the North Shore and Ko'olauloa 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 Ko'olauloa 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-G

**LEHI LARA RECREATIONAL COMMUNITY**

**Median Household Income in the North Shore and Koolaua Regions and City and County of Honolulu**

1979

<table>
<thead>
<tr>
<th>Area</th>
<th>Median household income(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Shore</td>
<td>$17,900</td>
</tr>
<tr>
<td>Koolaua</td>
<td>$16,400</td>
</tr>
<tr>
<td>City and County of Honolulu</td>
<td>$21,100</td>
</tr>
<tr>
<td>State of Hawaii</td>
<td>$20,500</td>
</tr>
</tbody>
</table>


### Exhibit II-H

**LEHI LARA RECREATIONAL COMMUNITY**

**Social Characteristics of the North Shore and Koolaua Regions and City and County of Honolulu**

1970 and 1980

<table>
<thead>
<tr>
<th></th>
<th>North Shore</th>
<th>Koolaua</th>
<th>City and County of Honolulu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total population</strong></td>
<td>9,200</td>
<td>13,100</td>
<td>10,600</td>
</tr>
<tr>
<td><strong>Education (population aged 25+)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 8 years</td>
<td>35.7%</td>
<td>25.6%</td>
<td>31.4%</td>
</tr>
<tr>
<td>12 years</td>
<td>31.1%</td>
<td>37.0%</td>
<td>31.1%</td>
</tr>
<tr>
<td>16 or more years</td>
<td>33.2%</td>
<td>15.0%</td>
<td>37.5%</td>
</tr>
</tbody>
</table>

(1) Estimates based on 15% sample.

III - ECONOMIC IMPACTS

The proposed Lili'uokalani 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 Lili'uokalani 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 Lili'uokalani 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 residents 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 Lili'uokalani, 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 (DOED) 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 for was derived from the most recent DOED model. The projected direct expenditures could be expected to generate indirect and induced expenditures throughout the state amounting to $5.0 million in 1995, $6.1 million in 2000 and stabilizing at $6.0 million per year, as also shown in Exhibit III-D.

---

IIII Assumes incentives applied for total build-out by 2000: Oahu - Yamagishi Partnership.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Golf memberships</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lihue Lani lot owners</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Other Oahu residents</td>
<td>60</td>
<td>295</td>
</tr>
<tr>
<td>Out-of-state residents</td>
<td>30</td>
<td>125</td>
</tr>
<tr>
<td><strong>Total golf memberships</strong></td>
<td>110</td>
<td>500</td>
</tr>
<tr>
<td><strong>Tennis memberships (1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td><strong>Daily rounds of golf</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmember Oahu residents</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Members</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Visitors</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total rounds</strong></td>
<td>75</td>
<td>130</td>
</tr>
<tr>
<td><strong>Daily tennis court reservations (2)</strong></td>
<td>0</td>
<td>94</td>
</tr>
<tr>
<td><strong>Equestrian center stable rentals (3)</strong></td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td><strong>Cabin occupancy percentage (4)</strong></td>
<td>98</td>
<td>9%</td>
</tr>
</tbody>
</table>

---

(1) Assumed number of memberships sold based on number of courts at the complex and a suggested 60% ratio of 35 club members per court with absorption at 3 courts in year one and one court per year thereafter until 2005.

(2) Projection based on following assumptions: 5 a.m. to 1 p.m. tennis hours, one-hour reservations, number of courts and a 46% utilization rate based on rates of play at comparable facilities.

(3) Projection based on following assumptions: 100 stalls available for rental and an assumed 60% occupancy rate by 2005.

(4) Occupancy percentages estimated by Quon - Yamagushi Partnership at 65% occupancy on half of all weekends.

---

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Club membership fees (1)</strong>:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initiation</td>
<td>425,000</td>
<td>23,800</td>
</tr>
<tr>
<td>Monthly dues</td>
<td>350</td>
<td>150</td>
</tr>
<tr>
<td>Tennis</td>
<td>5,100</td>
<td>5,100</td>
</tr>
<tr>
<td>Monthly dues</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Greens and cart fees:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Members (2)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Non-members (3)</td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td><strong>Food and beverage/retail sales:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf club members (4)</td>
<td>3,400</td>
<td>3,400</td>
</tr>
<tr>
<td>Non-member course users (5)</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td><strong>Other revenues:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennis (6)</td>
<td>227,400</td>
<td>227,400</td>
</tr>
<tr>
<td>Equestrian (7)</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Cable rental (8)</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

---

(1) Based on weighted average membership fees.

(2) Per member per round. Cart fee only, two players per cart.

(3) Per round.

(4) Per round.

(5) Per round.

(6) Projected gross annual sales at tennis center based on comparable tennis facility revenues. Includes court fees, merchandise, memberships and other income.

(7) Per month.

(8) Per sight, including cabin rental, parking, and other fees estimated by Quon - Yamagushi Partnership.
### Exhibit III-9

**Lahi Lani Recreational Community**

Projected Total Annual Non-Lahi Lani Resident Expenditures Attributable to Lahi Lani Recreational Community

1995 to 2001

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct expenditures (1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf club and course (2)</td>
<td>5.76</td>
<td>5.29</td>
<td>5.29</td>
</tr>
<tr>
<td>Tennis (3)</td>
<td>0.20</td>
<td>0.47</td>
<td>0.24</td>
</tr>
<tr>
<td>Equestrian (4)</td>
<td>0.04</td>
<td>0.16</td>
<td>0.18</td>
</tr>
<tr>
<td>Cabins</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>6.02</td>
<td>5.93</td>
<td>5.61</td>
</tr>
</tbody>
</table>

| **Indirect and induced expenditures** |       |       |
|--------------------------------------|-------|
| Indirect                             | 0.05  |
| Induced                              | 0.11  |
| **Total (5)**                        | 6.12  |

**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 commitment in support of 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 would occur at Lahi Lani. As for expenditures, however, indirect and induced employment resulting from the community may be supported through the entire 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, operators 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 recreational lots are constructed. Construction employment is estimated to average about 200 person-years per year from about 1993 to 1995 as shown in Exhibit III-9. 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 model 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-9. 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 130 person-years per year. Indirect and induced construction employment would then average about 62 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

**Lake Lake Recreational Community**

Projected Direct Employment for Facility Construction (Person-Years)

<table>
<thead>
<tr>
<th>Year</th>
<th>1993-1995</th>
<th>1995-2000</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf course(1)</td>
<td>27</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>Golf club and tennis courts (2)</td>
<td>30</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Equestrian (3) (3)</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Cabins (4)</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Single-family lots:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lot development (4)</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Home construction (5)</td>
<td>6</td>
<td>65</td>
<td>71</td>
</tr>
<tr>
<td>Affordable units:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land development (6)</td>
<td>6</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Unit construction (7)</td>
<td>42</td>
<td>7</td>
<td>49</td>
</tr>
<tr>
<td>Community facility (8)</td>
<td>9</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Infrastructure (8)</td>
<td>20</td>
<td>223</td>
<td>243</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>204</strong></td>
<td><strong>79</strong></td>
<td><strong>283</strong></td>
</tr>
</tbody>
</table>

(1) Estimated at 25 full-time equivalent jobs per year construction, planting and grading with a two year construction period based upon comparable golf course projects.

(2) Employment demand estimate assumes labor cost is 60% 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% lower person-years to account for trail and other site work.

(4) Demand calculated at 0.2 full-time equivalent jobs 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 $82,2 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

**Lake Lake Recreational Community**

Projected Indirect and Induced Employment for Facility Construction (Person-Years)

<table>
<thead>
<tr>
<th>Year</th>
<th>1993-1995</th>
<th>1995-2000</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total direct, indirect and induced employment</td>
<td>347</td>
<td>142</td>
<td>489</td>
</tr>
<tr>
<td>Less direct employment (1)</td>
<td>204</td>
<td>79</td>
<td>283</td>
</tr>
<tr>
<td>Indirect and induced employment (2)</td>
<td>143</td>
<td>63</td>
<td>206</td>
</tr>
</tbody>
</table>

(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 DEED Input-Output model, 1987: as reported in the 1989 State of Hawai'i Data Book.
Thus, the recreation-oriented community could be expected to have generated about 42 full-time equivalent direct operational positions by 1995 and about 60 full-time equivalent positions by 2000, as shown in Exhibit III-6.

**Indirect and Induced Operational Employment**

Facility operations at Lihia Land 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 retail trade industries by the UH-BB suggest that the activities at the community could be expected to support 42 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-6.

**Total Operational Employment**

Total direct, indirect and induced operational employment is estimated to represent about 75 full-time equivalent positions by 1995 increasing to 102 positions by 2000, as also shown in Exhibit III-6.

**PERSONAL INCOME**

Lihia Land 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 $5.3 million per year as construction activity ends and operational employment demands continue, as shown in Exhibit III-6.

**POPULATION**

The development of facilities will lead to a population increase at the Lihia 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 Hawaii 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-6**

**Lihia Land Recreational Community**

Projected Direct Operational Employment

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf club and course (1)</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Tennis (2)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Equestrian (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property management and sales (4)</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>45</td>
<td>60</td>
</tr>
</tbody>
</table>

---

(1) Operational employment based on 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 on employment patterns at comparable local club operations.

(3) Equestrian operational employment based on employment patterns of comparable local equestrian and stable operations.

(4) Property management and sales operational employment based on discussions with resort and developers. Includes clubhouse rental operations.

Source: Based on interviews and published information of selected local and national private club and resort operations, 1990.
### Exhibit III-H

**Limu Lane Recreational Community**

**Projected Direct, Indirect and Induced Operational Employment at the Limu Lane Residential Community**

1995 to 2000

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect and Induced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf club and course (2)</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>Tennis (2)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Equestrian (2)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Property management and sales (3)</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>36</td>
<td>42</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>78</td>
<td>102</td>
</tr>
</tbody>
</table>

---

### Exhibit III-I

**Limu Lane Recreational Community**

**Projected Total Annual Personal Income from Direct Employment**

1993 to 2001

(Thousands of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction (1)</td>
<td>10.12</td>
<td>13.21</td>
<td>45.60</td>
<td>3.28</td>
<td>56.79</td>
<td>0.70</td>
</tr>
<tr>
<td>Operational (2)</td>
<td>0.33</td>
<td>0.87</td>
<td>0.32</td>
<td>0.32</td>
<td>1.84</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10.45</td>
<td>14.08</td>
<td>46.92</td>
<td>3.60</td>
<td>58.52</td>
<td>0.77</td>
</tr>
</tbody>
</table>

---

(1) Average annual wage is projected at $39,005, comparable to the average annual income for the construction industry in the City and County of Honolulu, inflated from 1980 dollars using a total personal income inflation rate of 0.13 in 1988 and 0.15 in 1990.

(2) Excluding tips. Estimated at $11,160 per full-time equivalent position, based on weighted average of eating and drinking places, miscellaneous retail stores, in the city and county of Honolulu, inflated from 1980 dollars using an inflation rate as described above.

Day Visitor Population

Day visitors to the recreation-oriented community would be those using the golf course, golf clubhouse, tennis center, equestrian center, campgrounds, community facility or shops. The guest population was estimated by using the projected facility utilization shown in Exhibit III-A, less residents of the community. With these assumptions, the average daily visitor population is projected to be about 27 persons by 1995, increasing to about 84 persons per day by stabilization at 2000, as shown in Exhibit III-J.

Resident Population

Resident population at Lihiki 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-H. Thus, resident population at the community is projected to be about 279 persons by 1995, increasing to 867 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-D, 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 Kualoa Ranch proceeds with the expansion of its resort area, it has been estimated that permanent moving to the region from other parts of the island could amount to 300 persons by 2000, as shown in Exhibit III-J.

Total Projected On-Facto Population

The facility development at the Lihiki Lani recreational community is projected to generate total daily population growth of about 708 persons in 1995, increasing 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 about 27 new residents in 1995 and about 44 new residents in 2000, as shown in Exhibit III-J. In terms of in-migrant operational employees, estimated at about 156 of the total employees, and their accompanying household members, the in-migrant population impact is projected to be 14 persons in 1995 and stabilizing at about 16 persons in 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-K

#### Assumptions for On-site Resident Population

<table>
<thead>
<tr>
<th></th>
<th>Distribution (1)</th>
<th>Occupancy Size (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-family lot developments:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td>45%</td>
<td>95%</td>
</tr>
<tr>
<td>Other</td>
<td>5%</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>60%</strong></td>
<td><strong>95%</strong></td>
</tr>
<tr>
<td>Part-time:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td>35%</td>
<td>95%</td>
</tr>
<tr>
<td>Other</td>
<td>65%</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>100%</strong></td>
<td><strong>95%</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>95%</strong></td>
</tr>
</tbody>
</table>

Affordable unit development:

<table>
<thead>
<tr>
<th></th>
<th>100%</th>
<th>95%</th>
<th>2.0</th>
</tr>
</thead>
</table>

---

3. Based on published information and interviews with brokers at similar developments.

### Exhibit III-L

#### Projected In-migrant Population to the Island of Oahu (Average Daily Population)

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site community residents (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-site residents:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction employees (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational employees (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependents (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Total In-migrant population impact</td>
<td>14</td>
<td>45</td>
</tr>
</tbody>
</table>

---

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 Huli Huli 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 generated by the new facilities. Revenues to the state government would be generated primarily by the general and specific excise taxes on sales 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 at $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 $0.05 per $1,000 assessed value, while commercial properties are assessed at $9.45 per $1,000 assessed value. In addition, real property is assessed at $4.95 per $1,000 assessed value. Unimproved residential property is taxed at $4.95 per $1,000 assessed value.

Net new property taxes are projected according to assessed values for other comparable golf club facilities in the state, preliminary construction costs provided by Ohana Hawaii, and projected sales prices of the residential components. 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, cabin, and affordable homes, community facilities and other lands could be expected to generate net new property tax revenues for the County and City of Honolulu of about $500,000 per year by 1995 at 1990 dollars, and increase to about $900,000 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 Huli Huli. In addition, new residents attracted to the state by the employment or residential opportunities of the project would bring additional excise 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.
Using state tax receipts in fiscal 1989 and adjusting for inflation to 1990 dollars, individual income and other taxes mentioned above, averaged $566 per state resident. Thus, new total tax revenues to the state government attributable to the project's development are expected to be about $230,000 per year in 1990 dollars by 1995 and increase to about $240,000 in 2000 and stabilize at about $250,000 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, recreation 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 per-costs to the county and the state.

**County Expenditures**

The various county government 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 $600 per resident and $337 per visitor. Honolulu Consumer Price Indexes between 1989 and 1990 would be equivalent to $409 and $249 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 Lili'uokalani could be expected to total about $20,000 per year by 1995 and increase to about $70,000 per year by 2000, 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 $7,866 per resident and $574 per visitor, as shown in Exhibit IV-E. This is equivalent to about $2,000 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 $70,000 per year by 2000, as shown in Exhibit IV-F.

<table>
<thead>
<tr>
<th>LIL'IUOKALANI RECREATIONAL COMMUNITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projected Annual Revenues to the State</strong></td>
</tr>
<tr>
<td><strong>Government attributable to development and operation at Lili'uokalani Recreational Community</strong></td>
</tr>
<tr>
<td><strong>1995 to 2001</strong></td>
</tr>
<tr>
<td>(Millions of 1990 dollars)</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>1995</strong></td>
</tr>
<tr>
<td><strong>Number of in-migrant households (1)</strong></td>
</tr>
<tr>
<td>Full-time households</td>
</tr>
<tr>
<td>Part-time households</td>
</tr>
<tr>
<td>Employee households</td>
</tr>
<tr>
<td><strong>Total households</strong></td>
</tr>
<tr>
<td><strong>Full-time residents and employed in-migrant population (2)</strong></td>
</tr>
<tr>
<td>Full-time residents</td>
</tr>
<tr>
<td>Employees and dependents</td>
</tr>
<tr>
<td><strong>Total persons</strong></td>
</tr>
<tr>
<td><strong>Tax revenue sources (millions)</strong></td>
</tr>
<tr>
<td>Visitors: General excise tax on sales</td>
</tr>
<tr>
<td>Visitor accommodations tax (3)</td>
</tr>
<tr>
<td>In-migrant residents and in-migrant employees (4)</td>
</tr>
<tr>
<td>General excise tax (4)</td>
</tr>
<tr>
<td>Individual income (6)</td>
</tr>
<tr>
<td>Total tax revenues</td>
</tr>
</tbody>
</table>

(1) Based on Exhibits III-J, K, and L.
(2) Based on 0.05 of direct visitor expenditures at Lili'uokalani, as shown in Exhibit III-E.
(3) Based on 0.05 of visitor expenditures at Lili'uokalani, as shown in Exhibit III-E.
(4) Based on 0.05 of selected household budget items. Budget items estimated at 38% of household incomes over $150,000 for full-time residents, $250,000 for in-migrant residents, and $250,000 for number of households as shown above.
(5) Estimated at 0.05 per person for each full-time resident in 1990 based on inflated 1989 state revenue receipts per capita. Number of full-time residents as shown above.

### Exhibit IV-C

**Lihue Lani Recreational Community**

City & County of Honolulu Per Capita Government Expenditures

**Fiscal Years 1989 and 1990**

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Service</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>(GOV's)</td>
<td>Population</td>
<td>Per resident</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>General government</td>
<td>664.015</td>
<td>860.010</td>
</tr>
<tr>
<td>Public safety</td>
<td>139.004</td>
<td>906.120</td>
</tr>
<tr>
<td>Highways</td>
<td>29.883</td>
<td>906.120</td>
</tr>
<tr>
<td>Health and sanitation</td>
<td>58.707</td>
<td>840.010</td>
</tr>
<tr>
<td>Economic and urban development</td>
<td>30.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Recreation</td>
<td>30.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Interest</td>
<td>16.492</td>
<td>840.010</td>
</tr>
<tr>
<td>Bond redemption</td>
<td>36.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Retirement and pension</td>
<td>36.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Mass transit</td>
<td>36.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Land capital improvements</td>
<td>36.392</td>
<td>906.120</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>36.392</td>
<td>906.120</td>
</tr>
<tr>
<td><strong>Total, 1990 dollars</strong></td>
<td>$550,307</td>
<td>$607,337</td>
</tr>
<tr>
<td><strong>Estimated total, 1990 dollars (3)</strong></td>
<td>$620</td>
<td>$349</td>
</tr>
</tbody>
</table>

---

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

**Lihue Lani Recreational Community**

Projected Annual County Government Expenditures Attributable to In-migrant Population of the Lihue Lani Residential Community

1995 to 2000

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (projected)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average daily visitors (3)</td>
<td>75</td>
<td>256</td>
</tr>
<tr>
<td>Single-family net residents (2)</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>Operational employers and dependents (2)</td>
<td>12</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>80</td>
<td>300</td>
</tr>
<tr>
<td>Expenditures:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average daily visitors (3)</td>
<td>10.80</td>
<td>0.24</td>
</tr>
<tr>
<td>Single-family net residents (2)</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Operational employers and dependents (2)</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Total expenditures</strong></td>
<td>10.80</td>
<td>0.27</td>
</tr>
</tbody>
</table>

---

1. From Exhibits III-J less than three miles radius assumed to be from Oahu.
2. In-migrant full-time equivalent resident, as shown in Exhibit III-A. Construction workers anticipated to be a prior Oahu residents.
3. Visitors require 535 in 1990 dollars per capita per year. Lihue Lani day visitors allocated the equivalent of 5% of all the annual County expenditures per visitor basis since may be spending a significant portion of the day elsewhere on the Island.
4. Residents require 620 in 1990 dollars per capita annually in county government expenditures.
### Exhibit IV-E

#### LIHU E LANT RECREATIONAL COMMUNITY

State of Hawaii Per Capita Government Expenditures

**Fiscal Years 1989 and 1990**

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Service</th>
<th>Per Population</th>
<th>Per Resident Visitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>General government</td>
<td>128.002</td>
<td>1,105,270</td>
<td>120</td>
</tr>
<tr>
<td>Public safety</td>
<td>119,997</td>
<td>1,240,000</td>
<td>97</td>
</tr>
<tr>
<td>Highways</td>
<td>78,911</td>
<td>1,240,000</td>
<td>62</td>
</tr>
<tr>
<td>Natural resources</td>
<td>22,211</td>
<td>1,240,000</td>
<td>31</td>
</tr>
<tr>
<td>Health and sanitation</td>
<td>12.8</td>
<td>1,240,000</td>
<td>97</td>
</tr>
<tr>
<td>Hospitals and institutions</td>
<td>12.8</td>
<td>1,240,000</td>
<td>97</td>
</tr>
<tr>
<td>Public welfare</td>
<td>22,211</td>
<td>1,240,000</td>
<td>250</td>
</tr>
<tr>
<td>Education</td>
<td>908,500</td>
<td>1,240,000</td>
<td>843</td>
</tr>
<tr>
<td>Recreation</td>
<td>712,600</td>
<td>1,240,000</td>
<td>32</td>
</tr>
<tr>
<td>Utilities and other enterprises</td>
<td>174,257</td>
<td>1,240,000</td>
<td>140</td>
</tr>
<tr>
<td>Debt service</td>
<td>242,456</td>
<td>1,240,000</td>
<td>229</td>
</tr>
<tr>
<td>Retirements and pension</td>
<td>85,277</td>
<td>1,240,000</td>
<td>76</td>
</tr>
<tr>
<td>Employer's health insurance</td>
<td>10,032</td>
<td>1,240,000</td>
<td>1</td>
</tr>
<tr>
<td>Unemployment compensation</td>
<td>48,112</td>
<td>1,240,000</td>
<td>44</td>
</tr>
<tr>
<td>Grants-in-aid to counties</td>
<td>42,988</td>
<td>1,240,000</td>
<td>38</td>
</tr>
<tr>
<td>Urban redevelopment and housing</td>
<td>283,908</td>
<td>1,240,000</td>
<td>239</td>
</tr>
<tr>
<td>Cash capital improvements</td>
<td>155,288</td>
<td>1,240,000</td>
<td>125</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>44,921</td>
<td>1,240,000</td>
<td>42</td>
</tr>
</tbody>
</table>

**Total, 1989 dollars**

13,267,999 | 12,806 | 6574 |

**Estimated total, 1990 dollars (3)**

12,990 | 6555 |

---

1. State government operating expenditures for fiscal year ended June 30.
3. Resident or de facto population estimates for the state as of January 1, 1989.
4. 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

#### LIHU E LANT RECREATIONAL COMMUNITY

Projected Annual State Government Operating Expenditures Attributable to In-migrant Population of the LIHU E LANT Residential Community

1995 to 2000

(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th>Population (persons)</th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily visitors (1)</td>
<td>75</td>
<td>155</td>
</tr>
<tr>
<td>Single-family in-migrant residents (2)</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Operational employees and dependents (3)</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>99</td>
<td>186</td>
</tr>
</tbody>
</table>

**Expenditures**

| Average daily visitors (3) | 10.00 | 0.08 |
| Single-family in-migrant residents (4) | 0.00 | 0.00 |
| Operational employees and dependents (4) | 0.00 | 0.01 |
| **Total expenditures** | 0.00 | 0.17 |

---

1. From Exhibit III-2 less those stable renters assumed to be from Oahu.
2. In-migrant full-time equivalent residents, as shown in Exhibit III-4.
3. Construction workers anticipated to be prior Oahu residents.
4. Visitors require 1995 in 1990 dollars per resident per annum. LIHU E LANT day visitors allocated the equivalent of 50% of the annual state expenditure per visitor total.
5. Residents require $2,950 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 $810,000 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 about 3 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 $120,000 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 Kukuiola Resort and a planned 18-hole at Kukuiola Resort. Several other semi-private golf courses are also planned with some member 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

LINE LENS RECREATIONAL COMMUNITY
County Government Revenue and Expenditure Comparison
1995 to 2000
(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
<th>Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>New revenues (1)</td>
<td>0.57</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>New expenditures (2)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Net additional revenues</td>
<td>0.55</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Revenue/expenditure ratio (3)</td>
<td>29.5</td>
<td>13.0</td>
<td>13.0</td>
</tr>
</tbody>
</table>

(1) From Exhibit IV-A.
(2) From Exhibit IV-B.
(3) New revenues divided by new expenditures.
EXHIBIT IV-11

Liholiho Recreational Community
State Government Revenue and Expenditure Comparison
1995 to 2001
(Millions of 1990 dollars)

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
<th>Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>New revenues (1)</td>
<td>0.21</td>
<td>0.40</td>
<td>0.35</td>
</tr>
<tr>
<td>New expenditures (2)</td>
<td>0.13</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Net additional revenues</td>
<td>0.18</td>
<td>0.23</td>
<td>0.18</td>
</tr>
<tr>
<td>Revenue/expenditure ratio (3)</td>
<td>7.0</td>
<td>11.7</td>
<td>11.5</td>
</tr>
</tbody>
</table>

(1) From Exhibit IV-9.
(2) From Exhibit IV-7.
(3) New revenues divided by new expenditures.

The Liholiho Recreational Community, along with other existing and planned projects, would expand the recreational opportunities in the Koolau 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.
January 4, 1991

Mr. Jeff Cretson
924 Bethel Street
Honolulu, Hawaii 96813

Re: Popokes Northshore Golf Management Plan

Dear Jeff:

The following report will outline my thoughts on major aspects of golf course management at the Popokes 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 Popokes is no exception. Experience in managing the course acquired by the golf course superintendent will do little to avoid the changes that occur in this plan, and possibly lead to some subtle 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 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
- Pestides and Their Use
- Integrated Pest Management
- Fertilizers and Plant Nutrition
  - Irrigation of the Course
  - Other Cultural Practices

Creating a comprehensive management plan entails exactly what is to be done at a specific time is not possible. However, the following descriptions relating to these points should give any readers an outline of what the concept of golf course management is.
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 and related materials. There must be pesticide warning signs posted in all applicable languages adjacent 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 employee 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 an area covered with cement slabs 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 overhanging 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 so that fertilizers materials 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 drainage 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 pesticides 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. We 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 those critical concern areas is to prevent the discharge of pesticides, fertilizers, fuels, oils and grease into the outside environment. This may be considered 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 separate filtering and recovery system. This filter would allow for the separation of oils, greases, pesticides, or other material from the water before permitting their discharge into the environment. The unit can be configured into the basin design of the maintenance yard with minimal cost.
<table>
<thead>
<tr>
<th>QTY</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/2 Ton Pick-up Truck (Chevy E-10)</td>
</tr>
<tr>
<td>2</td>
<td>Cushman Truckster 530 13-wheel, 18 Hp, PTO, hydraulic pump</td>
</tr>
<tr>
<td>3</td>
<td>Dalnavo w/Dump Bed or Z-2 Go GT-7 Truckster Cushman Topdresser Attachment</td>
</tr>
<tr>
<td>1</td>
<td>1-1/2 Ton Dump Truck</td>
</tr>
<tr>
<td>1</td>
<td>Lely Spreader (ground driven, single, elongation times)</td>
</tr>
<tr>
<td>2</td>
<td>DGH Drop Spreader</td>
</tr>
<tr>
<td>1</td>
<td>Leco's Rotary Spreader</td>
</tr>
<tr>
<td>1</td>
<td>Jacobsen Triplex Greensower with Spiking Reels &amp; Turf groomer attachment</td>
</tr>
<tr>
<td>7</td>
<td>Jacobsen or John Deere Greensower (solid and folded rollers, brush, etc.)</td>
</tr>
<tr>
<td>1</td>
<td>Salthood Easy Rider Trap Rake</td>
</tr>
<tr>
<td>1</td>
<td>72&quot; Jacobsen Turf Cat or John Deere 2335 Riding Rotary Mower</td>
</tr>
<tr>
<td>1</td>
<td>Jacobsen 6-20 or John Deere 1050 Tractor (3 pt. hitch, PTO, draw bar, turf tires, etc.) or Jacobsen 4 x 4 32AP Tractor</td>
</tr>
</tbody>
</table>

**EQUIPMENT**

- Industrial Tractor (attachments: loader, backhoe, and fork lift attachment) John Deere 210C
- John Deere 1500 Utility Vehicle w/160 gallon sprayer w/18' folding boom, foam marker kit and spreader & agitator
- Chain Saw (28" blade)
- 1-1/2" John Deere Mudhog Pump
- 54" National Power rake, with high speed reel kit, 5-bladed reels, front rollers and special tire option
- John Deere Boxblade
- John Deere Yorkrake
- John Deere String Line Trimmers
- Flynn
- John Deere or Jacobsen Commercial 20" Rotary Mower
- Ohio Hand Roller (18" x 24")
- 8-2 Go UX900 Cart, (2er)
- Jacobsen Model 40 Blower
- Miscellaneous Equipment (shovels, rakes, picks, hammers, spades, axes, wheel barrow, etc.)
- Tractor-Drawn Drop Spreader (8'-8" flow or equivalent)
- Chain Saw (20" Blade)
<table>
<thead>
<tr>
<th>QTY</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leaf Blower (8 hp)</td>
</tr>
<tr>
<td>2</td>
<td>John Deere Back Pack Blower</td>
</tr>
<tr>
<td>2</td>
<td>EZ-Go C4-800 Tractor (4-wheel) or Honda TRX-250 w/Tow-Behind Trailer</td>
</tr>
<tr>
<td>1</td>
<td>Cushman Topdresser Attachment</td>
</tr>
<tr>
<td>1</td>
<td>Jacobsen Triplex Greenscaper (including verticut units and turf groomer attachment)</td>
</tr>
<tr>
<td>3</td>
<td>Jacobsen HP-1 Hydraulic 5-Gang Mower with 10 bladed reels and front wheel rollers</td>
</tr>
<tr>
<td>1</td>
<td>Jacobsen G-20 or John Deere 1050 Tractor w/3 pt. hitch, PTO, Draw Bar, Turf Times with 3-gang Ranshelt with 6-bladed fairway reals for roughs</td>
</tr>
<tr>
<td>1</td>
<td>Lely Dethatching Raka 10'</td>
</tr>
<tr>
<td>1</td>
<td>Smithon Easy Rider (manual blade)</td>
</tr>
<tr>
<td>1</td>
<td>Ryan 18' Mocutter</td>
</tr>
<tr>
<td>2</td>
<td>Ryan Greensaire II (window)</td>
</tr>
<tr>
<td>1</td>
<td>John Deere Trap Edger (4 hp)</td>
</tr>
<tr>
<td>3</td>
<td>John Deere Stringline Trimmers</td>
</tr>
<tr>
<td>2</td>
<td>Flymo Mowers</td>
</tr>
<tr>
<td>1</td>
<td>Ryan Hat-k-way</td>
</tr>
<tr>
<td>1</td>
<td>PWG 300-gallon Fairway Sprayer with 20 gpm pump</td>
</tr>
<tr>
<td>1</td>
<td>Sweeper 72&quot; 3-pt. Hitch Sweeper</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QTY</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jacobsen Model S90 Assessor with 3 pt. Hitch, 3/4&quot; coring tines, slicing tines</td>
</tr>
<tr>
<td>1</td>
<td>Toro Rake-O-Vac (PTO)</td>
</tr>
<tr>
<td>1</td>
<td>Mars Greens Sweeper</td>
</tr>
<tr>
<td>1</td>
<td>5-Gang Fairway Verticut 1 1/2&quot; Knife spacing-Ranshelt or Ranshelt</td>
</tr>
<tr>
<td>1</td>
<td>Mechanics Tools (large set, tool chest)</td>
</tr>
<tr>
<td>1</td>
<td>Mechanics Tools (small set, tool box)</td>
</tr>
<tr>
<td>1</td>
<td>Air Compressor (3 hp, 80-gallon tank) Upright</td>
</tr>
<tr>
<td>1</td>
<td>Grease Gun (air and manual)</td>
</tr>
<tr>
<td>1</td>
<td>AC Arc Welder</td>
</tr>
<tr>
<td>1</td>
<td>Battery Charger (fast and trickle), Booster cables</td>
</tr>
<tr>
<td>1</td>
<td>Large Grinder</td>
</tr>
<tr>
<td>1</td>
<td>Cutting Torch</td>
</tr>
<tr>
<td>1</td>
<td>2-Ton Hoist and Trolley</td>
</tr>
<tr>
<td>1</td>
<td>Large Vise</td>
</tr>
<tr>
<td>1</td>
<td>2-Ton Floor Jack (stands)</td>
</tr>
<tr>
<td>1</td>
<td>3/8&quot; Pneumatic Impact Wrench</td>
</tr>
<tr>
<td>1</td>
<td>Pressure Washer</td>
</tr>
<tr>
<td>2</td>
<td>Foley Lapping Machine</td>
</tr>
<tr>
<td>5</td>
<td>Work Benches (3' x 10')</td>
</tr>
</tbody>
</table>
daily at a height between 1/8 inch and 1/16 inch with standard grass seed. Grounds crews will do annual overseeding with Tifway 419 bermudagrass (same Latin designation) at a rate of 400 bushels per acre. The seed should be mixed at 1.5 to 2.0 inches, with the same type of tall fescue as the surround. Tall fescue seed will be planted with Tifway 419 bermudagrass at 30 bushels per 1,000 square feet. Tall fescue should be planted with Tifway 419 at 400 bushels per acre, and is used in the same manner as fairway. Tall fescue will be planted with Tifway 419 at a rate of 400 bushels per acre, and is used to maintain the turf at 1.5 to 2.0 inches as needed. Some areas of the golf course may also be used for ornamental purposes (e.g., roundabout areas). The area may be used for ornamental purposes, 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 tee will use 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 (i.e., the tolerable threshold), the pest management program cannot be totally eradicated. Some years may see virtually no pest-related problems, while in other seasons pest-related issues may be overwhelming. For example, if turf is healthy and there is no stressing or disease pressure, the area will tolerate 25 pounds per 1,000 square feet. However, if turf is unhealthy and disease pressure is heavy the turf may only tolerate 15 pounds per 1,000 square feet. Therefore, 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 the reliance on pesticides.

Pesticides are compounds which suppress the populations of pests. Common pests in turf situations include weeds, pathogenic microorganisms, insects, nematodes, and small animals. Attached to this document you will find a listing of probable pesticides which may be considered for use at Poplar. This list is very extensive but is not exclusive. There are many pesticides being developed and labeled all the time. These pesticides must be applied in strict accordance with the manufacturer’s label. Only those pesticides which are labeled and approved for use in Kansas 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 less 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 Kansas regional agronomist will persist. This relationship will lead to a 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 years. For example, consider the fungal disease dollar spot (Sclerotium sp.). 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, dollar spot can be controlled. The IPM concept can be applied to weeds, fungal pathogens, insects and nematodes, and small animals such as moles.

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 in 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 UAN. 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 chloride, or potassium chlorate. 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 cultivate 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 blood meal, manure, fish meal, urea, or urea formamide. These materials are considered slow-release N sources due to decreased water solubility compared to inorganic carriers such as ammonium nitrate, which essentially leach upon hydration. Slow-release N sources have been previously shown to minimize nutrient fertilizer leaching, which is an important consideration for maintaining turf. Use of complete fertilizer products, as well as single nutrient fertilizer 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 greenhouses. 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. One eliminates the chance for waste of these nutrients via leaching. The amount of N to be added is generally between 1 and 2 pounds N per 1,000 square feet with 50% to 60% being in a slow-release form (i.e., 10-0-0). 

Post-plant 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 of the growing season in May, 0.75 pounds of N per 1,000 square feet will be applied every other week. In the second month, a 20% slow-release carrier (10-0-0) will be applied twice monthly using a 20% slow-release carrier (10-0-0). From week 8 through week 15, there will be monthly applications of 0.5 pounds of N per 1,000 square feet alternating 50% and 70% slow-release carrier (10-0-0). From week 16 through week 20, there will be monthly applications of 0.5 pounds of N per 1,000 square feet alternating 50% and 70% slow-release carrier (10-0-0). In November, there will be monthly applications of 0.5 pounds of N per 1,000 square feet alternating 50% and 70% slow-release carrier (10-0-0). A liquid feed in November will consist of 1.0 pound of N per 1,000 square feet with 85% ECU. The 20% slow-release carrier (10-0-0) is an 18-0-12 analysis having 2.8% ECU, 0.5% urea, 3.8% nitrate and 0.5% ammoniacal N. The 50% slow-release carrier is an 18-0-12 analysis having 5.6% ECU, 1.5% urea, 6.3% nitrate. The 70% slow-release carrier is an 18-0-12 analysis having 11.9% ECU, 2.8% urea, 6.5% nitrate. The 85% ECU is a 31-0-0 analysis with 26.3% urea, 6.4% nitrate. Total P application will be 2.7 pounds or P per 1,000 square feet. 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, green will again receive P and K according to soil and plant tissue testing. Nitrogen will be applied twice monthly from May through October, with a dormant feed in November. Nitrogen will be applied at 0.5 pounds per 1,000 square feet in May using 20% slow-release (10-0-0). In June, N will alternate between 50% and 70% slow-release (10-0-0) also at 0.5 pounds per 1,000. For July through August, 0.5 pounds of N will be supplied as a 40% urea fertilizer application at 0.5 pounds per 1,000. In September and October, the N will again be supplied as a 50% slow-release (10-0-0) at 0.5 pounds per 1,000. In November and December, the N will again be supplied as a 50% slow-release (10-0-0) at 0.5 pounds per 1,000. In January, February, and March, the N will be supplied as a 20% slow-release (10-0-0) at 0.5 pounds per 1,000. Nitrogen applications will be 60% N, 35% ammoniacal N, and 5% nitrate N. Total ECU is 1.86-0-0. Total N is 1.05-0-0. Total K is 2.8-0-0. Total P is 2.7-0-0. Total S is 6.5-0-0. Total C is 26.3-0-0. Total H is 6.4-0-0. Total O is 6.5-0-0.

Pre-plant fertilization of fairways with P and K should be based on soil testing results. Addition of N during pre-plant fertilization is usually at 40 to 100 pounds of N per acre. 1/2 of the N should be in a slow-release form.

Post-plant guidelines for the first year would include applying 0.5 pounds of N per 1,000 square feet using 50% and 70% slow release (ECU), and 100% ammonium. Applications of 1.0 pounds 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% ammonium would be made. The 50% slow-release N is a 12-24-14 analysis with 6% ECU, 3% urea, 9% ammoniacal N, and 6% nitrate N. The ammonium is a 16-0-12 material with 76% ammoniacal N, and 6% nitrate N. The nutrient requirements 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 1 pounds of N per 1,000 square feet using the 50% and 55% slow release (ECU) N source, and the 100% ammonium N source. Applications of 0.5 pounds per 1,000 would be made monthly in May through October. A dormant feed of 0.5 pounds of N per 1,000 with ammonium 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 the initial and second year post-plant, rough turf (and anyport rough) would receive 0 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 12-14-14 analysis with 8.5% CaO, and 5.4% and 1.3% ammoniacal N. The 30% SCU is a 28-3-9 analysis with 26.7% SCU, and 1.3% ammoniacal N. Nitrogen is applied to 1,000 square feet of M, 0.5 pounds per 1,000 square feet, and 0.5 pounds per 1,000 square feet. 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 30% 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 evaporation (i.e., evaporation of the soil water plus water lost by the plant through transpiration), as well as 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 conditions. 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 aeration, vertical mowing, topdressing, aeration, and application of various wettability agents and organic amendments. These latter points of course management are generally up to the golf course superintendent to implement. However, as a general rule, core aeration 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 Maintenance Superintendent 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 Maintenance Superintendent.

Sincerely,

W. Lee Schmitz, Ph.D.
Director of Environmental Services/Agronomist

WLN/Wh

Attachment: List of Probable Pesticides

cc: Mr. Edward A. Michels
Mr. Warren F. Sasser
### Warm Season Turfgrass

#### Insecticides

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>benomyl (Tervan)</td>
<td>grubs, cutworms, leafhoppers</td>
</tr>
<tr>
<td>carbaryl (Sevin)</td>
<td>ants, cutworms, leafhoppers</td>
</tr>
<tr>
<td>carbofuran (Trithion)</td>
<td>brownmidge, grasshoppers, scale</td>
</tr>
<tr>
<td>chlorpyrifos (Mursban)</td>
<td>ants, billbugs, mole crickets</td>
</tr>
<tr>
<td>ethoprop (Mopra)</td>
<td>grubs, webworms</td>
</tr>
<tr>
<td>fensulfothion (Terranox)</td>
<td>grubs</td>
</tr>
<tr>
<td>lindane (Triumph)</td>
<td>mole crickets, grubs</td>
</tr>
<tr>
<td>metham (Methidathion)</td>
<td>grubs, turfgrass weevil</td>
</tr>
<tr>
<td>malathion (Malathion)</td>
<td>armyworms, grubs</td>
</tr>
<tr>
<td>trihexfenum (Deltos)</td>
<td></td>
</tr>
</tbody>
</table>

#### Fungicides

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>chloroxone (Pyrene)</td>
<td>dollar spot, rust</td>
</tr>
<tr>
<td>fenpropimorph (Terryban SP)</td>
<td>spring dead spot, brown patch</td>
</tr>
<tr>
<td>chlormequat (Benomil 270T)</td>
<td>leaf spot, brown rot</td>
</tr>
<tr>
<td>ethirimol (Kalan)</td>
<td>Pythium</td>
</tr>
<tr>
<td>fenarimol (Robyn)</td>
<td>Pythium</td>
</tr>
<tr>
<td>fenheximide (Folletto)</td>
<td>Pythium</td>
</tr>
<tr>
<td>fludioxonil (Prontos)</td>
<td>Pythium</td>
</tr>
<tr>
<td>iprodione (Champion 800W)</td>
<td>Pythium</td>
</tr>
<tr>
<td>mancozeb (Fret)</td>
<td>Pythium</td>
</tr>
<tr>
<td>mancozeb (Mancozeb)</td>
<td>Pythium</td>
</tr>
<tr>
<td>metalaxy (Deltam)</td>
<td>Pythium</td>
</tr>
<tr>
<td>propiconazole (Banana)</td>
<td>Pythium</td>
</tr>
<tr>
<td>propiconazole (Tango)</td>
<td>Pythium</td>
</tr>
<tr>
<td>thiophanate methyl (Clairy's 3396)</td>
<td>Pythium</td>
</tr>
<tr>
<td>thiophanate methyl (Prospect 55)</td>
<td>Pythium</td>
</tr>
<tr>
<td>thiram (Thiram T5)</td>
<td>ear, head, rust</td>
</tr>
<tr>
<td>triadimefon (Bayleton)</td>
<td>ear, head, rust</td>
</tr>
<tr>
<td>vinclozolin (Voritan)</td>
<td>ear, head, rust, dollar spot, melting out</td>
</tr>
</tbody>
</table>

*resistance is a problem

#### Herbicides

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>atrazine (Astral)</td>
<td>grassy weeds, broadleaves, grasses</td>
</tr>
<tr>
<td>bentazon (Basagran)</td>
<td>grassy weeds, broadleaves</td>
</tr>
<tr>
<td>bentazon (Basagran)</td>
<td>broadleaves</td>
</tr>
<tr>
<td>butralin (Boswell)</td>
<td>broadleaves</td>
</tr>
<tr>
<td>cyhalothrin (Biodan 2EC)</td>
<td>ermine moth</td>
</tr>
<tr>
<td>dicamba (Roundup)</td>
<td>dollar spot</td>
</tr>
<tr>
<td>fluazifop-P (Staple)</td>
<td>grassy weeds, broadleaves</td>
</tr>
<tr>
<td>glufosinate (Roundup Pro)</td>
<td>grassy weeds, broadleaves</td>
</tr>
<tr>
<td>MCPA (Mepron)</td>
<td>grassy weeds, broadleaves</td>
</tr>
<tr>
<td>MCP (Roundup)</td>
<td>clover, broadleaves</td>
</tr>
<tr>
<td>metribuzin (Sencor)</td>
<td>goosegrass</td>
</tr>
<tr>
<td>mesotrione (Systar)</td>
<td>grassy weeds</td>
</tr>
<tr>
<td>oxadiazon (Orange)</td>
<td>annual grasses</td>
</tr>
<tr>
<td>pyronamide (Amaz)</td>
<td>grassy weeds</td>
</tr>
<tr>
<td>sethoxydim (Pest)</td>
<td>grasses, broadleaves</td>
</tr>
<tr>
<td>simazine (Princip)</td>
<td>grasses, broadleaves</td>
</tr>
<tr>
<td>tetrachloruron (Turfon)</td>
<td>grasses, broadleaves</td>
</tr>
</tbody>
</table>

*preemergent control |
**many herbicides are sold as mixtures—these are not included

#### Fumigants

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merazodium (Japen)</td>
<td>non-selective, ground pearls</td>
</tr>
</tbody>
</table>

#### Nematocides

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>nemacur (Nemacur)</td>
<td>nematodes</td>
</tr>
</tbody>
</table>

#### Rodenticides

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Pest Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>warfarin (Warfarin)</td>
<td>rats, mice</td>
</tr>
<tr>
<td>pival (Pindon)</td>
<td>rodents</td>
</tr>
<tr>
<td>strychnine</td>
<td></td>
</tr>
</tbody>
</table>

*resistance is a problem