ENVIRONMENTAL CENTER
University of Hawaii

EROSION MITIGATION AT FORT HASE BEACH AND AT PYRAMID ROCK RECREATIONAL AREAS

U.S. MARINE CORPS BASE HAWAII, KANEOHE BAY
KANEOHE, OAHU, HAWAII

FINAL REPORT
May 31, 2000

Prepared by
Jacquelin N. Miller, Principal Investigator
Peter J. Rappa, Project Manager
David A. Smith, Coastal Engineer
Karen Hui, GIS Specialist

for
Ogden Environmental and Energy Services Co., Inc.
680 Iwilei Road, Suite 660
Honolulu, Hawaii 96817

Environmental Center
2550 Campus Road, Honolulu, Hawaii 96822
(808) 956-7361

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Shoreline Management in Hawaii and Other States	1
Description of the Terrestrial Environment of the Study Areas	4
Pyramid Rock Recreational Subarea	4
Parking Lot, Recreational Pavilion, and Shower Stall	7
Fort Hase Beach Park	7
METHODS	13
RESULTS	18
Pyramid Rock Recreational Subarea	18
Vegetation	19
Problem Areas at Pyramid Rock Recreational Subarea	19
Possible Mitigative Solutions	21
Fort Hase Beach Recreational Area	22
Vegetation	23
Problem Areas at Fort Hase Beach Recreational Area	23
Possible Mitigative Solutions	23
Description of the Hydrographic Environments of the Study Areas	25
General Comments	25
Winds	25
Waves	26
Tides	26
Currents	26
Tsunamis	30
Storms	30
Detailed Comments	30
Pyramid Rock Beach	30
Fort Hase Beach	35
RECOMMENDATIONS	35
CONCLUSIONS	36
REFERENCES	38
APPENDIX A: Photographs	A-1
APPENDIX B1: Hawaii Coastal Zone Management Program Assessment Format	B1-1
APPENDIX B2: Annotated List of Birds Recorded at Marine Corps Air Station, Kaneohe Bay, 1947 to 1992	B2-1
APPENDIX C: Wayside Exhibit Fabricators	C-1

FIGURES

		Page
Figure 1.	Island of Oahu, Hawaii and location of U.S. Marine Corps Base Hawaii, Kaneohe. Note location of erosion study sites: Pyramid Rock and Fort Hase Recreational Areas	2
Figure 2.	Pyramid Rock Recreational Subarea. Aerial photograph courtesy of Air Survey Hawaii, taken in January 2000. Note vegetated sand dunes	5
Figure 3.	Pyramid Rock Recreational Subarea. Aerial photograph taken by the U.S. Geological Survey in 1927. Note lack of development and extensive dune system in the coastal uplands	6
Figure 4.	Pyramid Rock Recreational Subarea. Aerial photograph taken by Air Survey Hawaii in 1965. Note dune area bisected by a road and parking area	8
Figure 5.	Pyramid Rock Recreational Subarea. Aerial photograph taken by Air Survey Hawaii in 1993. Note dune area bisected by a road and parking area	9
Figure 6.	Pyramid Rock Recreational Subarea. Note location of parking lot, vegetated dunes, beach passageways, shower, picnic pavilion, and barrier rock wall	10
Figure 7.	Pyramid Rock Recreational Subarea. Historical/Archaeological resource areas. Abstracted from the Outdoor Recreational Management Plan, prepared by Wil Chee Planning, Inc	11
Figure 8.	Fort Hase Beach Recreational Area. Note drainage swale and proximity of archaeological site to picnic pavilion	12
Figure 9.	Fort Hase Beach Recreational Area. Aerial photograph taken by the U.S. Geological Survey in 1927. Note the lack of development in the coastal dune area with the exception of a road or track that parallels the shoreline in the approximate same location as the existing road.	14
Figure 10.	Fort Hase Beach Recreational Area. Aerial photograph taken by Air Survey Hawaii in 1963. Note tracks across dunes to beach	15
Figure 11.	Fort Hase Beach Recreational Area. Aerial photograph taken by Air Survey Hawaii in 1993. Note increasing development in the back-dune area and in the number of tracks across dunes to beach.	16

Figure 12.	Fort Hase Beach Recreational Area. Aerial photograph courtesy of Air Survey Hawaii, taken in January 2000. Note tracks across dunes to beach and overall development in the back-dune area.	17
Figure 13.	Wave Rose for Hawaiian Islands (from St. Denis, 1974). Figure compares average direction of approach under tradewinds and Kona conditions	29
Figure 14.	Pyramid Rock Recreational Subarea. Figure illustrates direction of coastal sediment transport under summer wave conditions.	32
Figure 15.	Pyramid Rock Recreational Subarea. Figure illustrates direction of coastal sediment transport under winter wave conditions. Note location of seasonal sand bar.	33
Figure 16.	Pyramid Rock Recreational Subarea. Figure illustrates direction of dominant wind direction (ENE) and location of hurricane run-up transect as calculated from model studies.	34

TABLES

Page

Table 1. Plants found at Pyramid Rock Recreational Subarea. Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name, plants that are endemic are noted with an (E), and alien species are noted with an (A) 20

Table 2. Plants found at Fort Hase Recreational Area. Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name, plants that are endemic are noted with an (E), and alien species are noted with an (A) 24

Table 3. Hourly climate summary for years 1945-1999 at the Kaneohe Marine Corps Air Facility. Station Location 21° 27' N Latitude, 157° 46' W Longitude. Elevation 17 ft. (5m). 27

Table 4. Hawaiian Wave Data (Homer, 1964). 27

Table 5. Surf Observations for North Beach, 1987-1994. 28

INTRODUCTION

The U.S. Marine Corps Base Hawaii is responsible for management of the military lands at Mokapu Peninsula in the Kaneohe Bay area, on the island of Oahu, including the shoreline recreational areas known as Fort Hase and Pyramid Rock Beaches (Figure 1). These two beach parks are popular recreational sites and are used extensively by military personnel. The beach at Pyramid Rock Recreational Subarea is also open to the general public on weekends. Unfortunately, this use has resulted in considerable stress to the physical characteristics of the parks. The lack of directional walkways has led to multiple paths across and through the dune vegetation. Inadequate drainage from a shower facility and rainfall runoff have led to erosion in the parking lot at Pyramid Rock Recreational Subarea. High waves have exacerbated the erosion caused by unregulated foot traffic at the Fort Hase beach park, in particular, and have led to the formation of a .5 meter coastal escarpment at the Fort Hase beach and the exposure of an archaeological site. To assure effective and informed management of their coastal and cultural resources, the Marine Corps Base Hawaii (MCBH) is interested in developing methods to mitigate coastal erosion problems and to simultaneously improve the recreational use of these beach parks in accordance with their administrative directives and need to comply with federal statutes. Hence, the purpose of this study has been to examine the environmental characteristics of the two recreational parks; Fort Hase and Pyramid Rock beaches, and to make recommendations on non-structural ways to mitigate both anthropogenic and natural impacts to these parks while assuring that historical and cultural resources are protected.

Shoreline Management in Hawaii and Other States

Coastal erosion is recognized as a significant and growing problem in the United States (NRC, 1990). The State of Hawaii is experiencing wide spread coastal erosion, with average erosion rates for the islands Oahu, Maui, and Kauai of between 0.1 and 0.4 m/yr. (Fletcher, 1992). Island wide, approximately 24 percent of the original sand shoreline has been lost or narrowed in the past 50 years (Coyne et al., 1996). The loss of sand beaches is significant since ocean recreation is an important component of Hawaii's number one industry, tourism. State estimates in 1990 were that Hawaii's ocean recreation industry was worth approximately $509 million and employed close to 5,800 people (MacDonald and Markrich, 1992). In addition, almost half the peak weekend recreation activity in Hawaii occurs at shoreline areas and the demand for coastal recreational opportunities is rising due to population growth, more leisure time, and other factors (Lowry, 1989).

While coastal erosion is responsible for land loss it is not always responsible for beach loss. As the shoreline retreats, sand is released from dunes and fossil shorelines. This keeps the beach wide and healthy (Fletcher et al., 1996). Shoreline hardening or armoring to stop coastal land erosion is most responsible for beach loss. Beach loss due to erosion is significant, not only from a recreational viewpoint, but also because beaches provide protection to coastal residents and infrastructure from storm-induced wave damage.

Coastal erosion becomes a problem when human activities, cultural resources, or structures are threatened. The matter of managing coastal erosion then becomes one of altering human

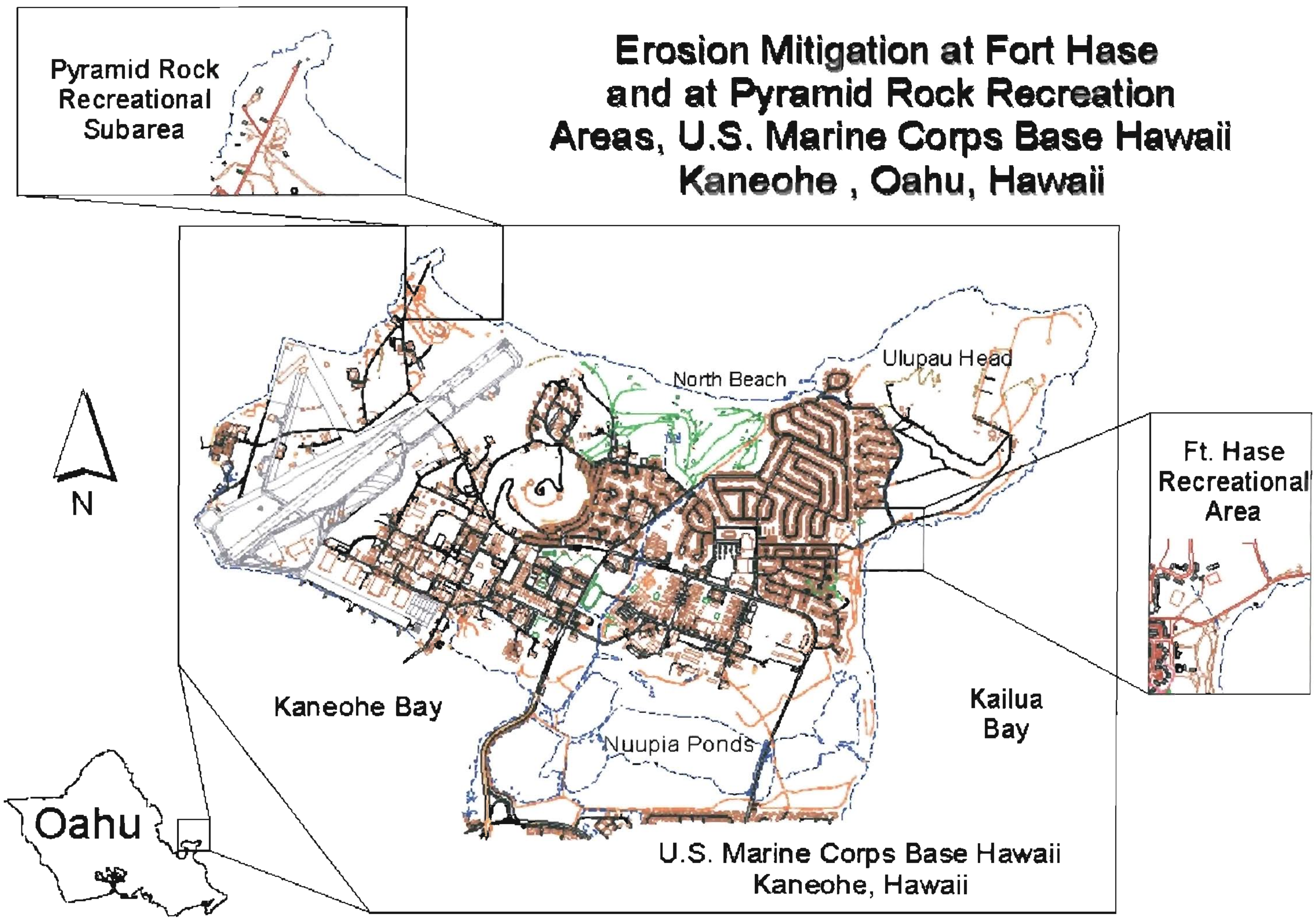


Figure 1. Island of Oahu, Hawaii and location of U.S. Marine Corps Base Hawaii, Kaneohe. Note location of erosion study sites: Pyramid Rock and Fort Hase Recreational Areas.

behavior in or near erosion-prone areas (Boyles, 1993). Thus, shoreline erosion can be thought of as a land use problem, and policy programs to address this problem can be evaluated as to how well they keep people from developing too close to the shoreline (Boyles, 1993). One of the prime methods for keeping people from developing too close to the shoreline is the use of shoreline setbacks. At least 13 states have some form of setback requirement for coastal development (Hildreth, 1992). A shoreline setback of not less than 20 feet and not more than 40 feet was established in Hawaii's land use law in 1970 (HRS 205A-43).

An undesirable effect of setback regulation is to encourage an owner to locate at the minimum required distance, even when a safer, more landward location is available (Stutts et al., 1985). Another problem in Hawaii is that the setback is static with no provision made for changes to the shoreline caused by erosion. The net effect is that in many cases structures are located too near eroding shorelines. Property owners in Hawaii have historically responded to the threat of erosion by building seawalls and revetments to armor the coastline. These structures temporarily postpone future loss of coastal uplands, but damage the beach itself (Coyne et al., 1996). The practice of armoring constitutes an ad hoc coastal management regime that lacks any comprehensive plan for mitigating beach loss due to coastal erosion. In most cases the practice of shoreline hardening exacerbates erosion. The result of Hawaii's setback policy is to hasten the erosion of beaches.

A statewide coastal policy requires that land use management practices and non-structural solutions to problems of erosion and floods be preferred over structural solutions (Marra, 1993). Hawaii's State Coastal Management Law seeks to minimize, where reasonable, "Any development which would reduce the size of any beach of other area usable for public recreation" (Lowry, 1989). Structures, including but not limited to seawalls, groins, and revetments, are not permitted within the shoreline area without a variance from the county planning authority. However, many variances have been approved, including a number being approved after the fact.

A basic problem of Hawaii's setback law is that it fails to take into account the variable nature of shorelines. The setback is applied equally in areas where erosion is high as well as low. In addition, the existing setback is not based on any criteria linked to rates of erosion. A better coastal policy would be one that took into account the dynamic nature of shorelines and developed a rational setback line based on predicted rates of erosion for a given area. Across the nation, state coastal managers use many different management techniques to address the problem of erosion. Several states have already begun to institute some form of a variable setback based on predicted erosion rates, including South Carolina, North Carolina (Hildreth, 1992), and Oregon (Good, 1992). In addition to erosion-based setbacks, a number of other techniques could become part of a statewide coastal policy including regulatory measures such as permits, zoning ordinances, and building codes as well as more direct methods such as beach monitoring, beach nourishment, strategic relocation and others (Hawaii DLNR, 1998). A number of states have instituted a policy of "rolling easements" including Texas, Maine, Rhode Islands and Massachusetts (Titus, 1999). The term "rolling easement" refers to a broad collection of institutional mechanisms that ensure that the shoreline's natural processes take precedence over people's desire to protect their land. This approach to managing the shoreline is a less draconian measure than setbacks because it allows development of the land with the condition that "the intertidal wetlands and beaches will not be eliminated" (Titus, 1999).

Changing the state's coastal policies will require more than simply defining rational setbacks. Any change may affect coastal landowners as well as state and county governments. In South Carolina for example, a change in their shoreline policy in 1988 instigated over 60 lawsuits filed by land owners alleging that the new policy constituted an invalid seizure of private property without compensation (Platt et al., 1991). Thus, states have moved cautiously to introduce more restrictive policies of shoreline management.

A more recent trend in shoreline management and one that has more bearing on the situations at theMCBH, is the preservation and restoration of sand dunes. Sand dunes trap windblown sand, store excess beach sand and serve as natural erosion buffers during storms and high wave events (University of Hawaii, 1997). The *Beach Management Plan for Maui*, for example, recommends the preservation of existing dunes and the restoration of degraded ones (University of Hawaii, 1997). Many of the problems at Pyramid Rock and some of the problems at Fort Hase could be alleviated by better dune management.

The preceding paragraphs have identified many of the generally recognized difficulties in managing coastal erosion problems while attempting to protect existing land uses and cultural resources in Hawaii. Pyramid Rock and Fort Hase beaches at the U.S. Marine Corps Base Hawaii at Kaneohe, on Oahu, Hawaii, require timely and practical solutions to coastal erosion at these popular beach recreation areas. This project seeks to identify environmentally responsible measures to stop or minimize beach and dune erosion at these two locations and to provide protection to archaeologically sensitive sites.

Description of the Terrestrial Environment of the Study Areas

The two beach parks covered by this study, Pyramid Rock and Fort Hase, are located at the Marine Corps Base Hawaii on the north eastern end of the island of Oahu. Hawaii.

Pyramid Rock Recreational Subarea

The Pyramid Rock Recreational Subarea is a part of the North Beach Recreational Area and is bounded on the west by a security fence from the base of Pyramid Rock inland approximately 300 hundred yards, and on the east by the Marine Corps Base Hawaii airport runway 4-22. It is bounded on the south by a radio facility which is no longer in use, and on the north by the Pacific Ocean. The area has a wide, steeply sloping sandy beach, backed by a series of large, vegetated sand dunes (Figure 2 and Appendix A).

The aerial photo taken in 1927 (Figure 3) by the U.S. Geological Survey (U.S.G.S.) appears to show that the coastal uplands area in the vicinity of Pyramid Rock was once a large dune system. However, the photograph is not particularly sharp so conclusions as to the true extent

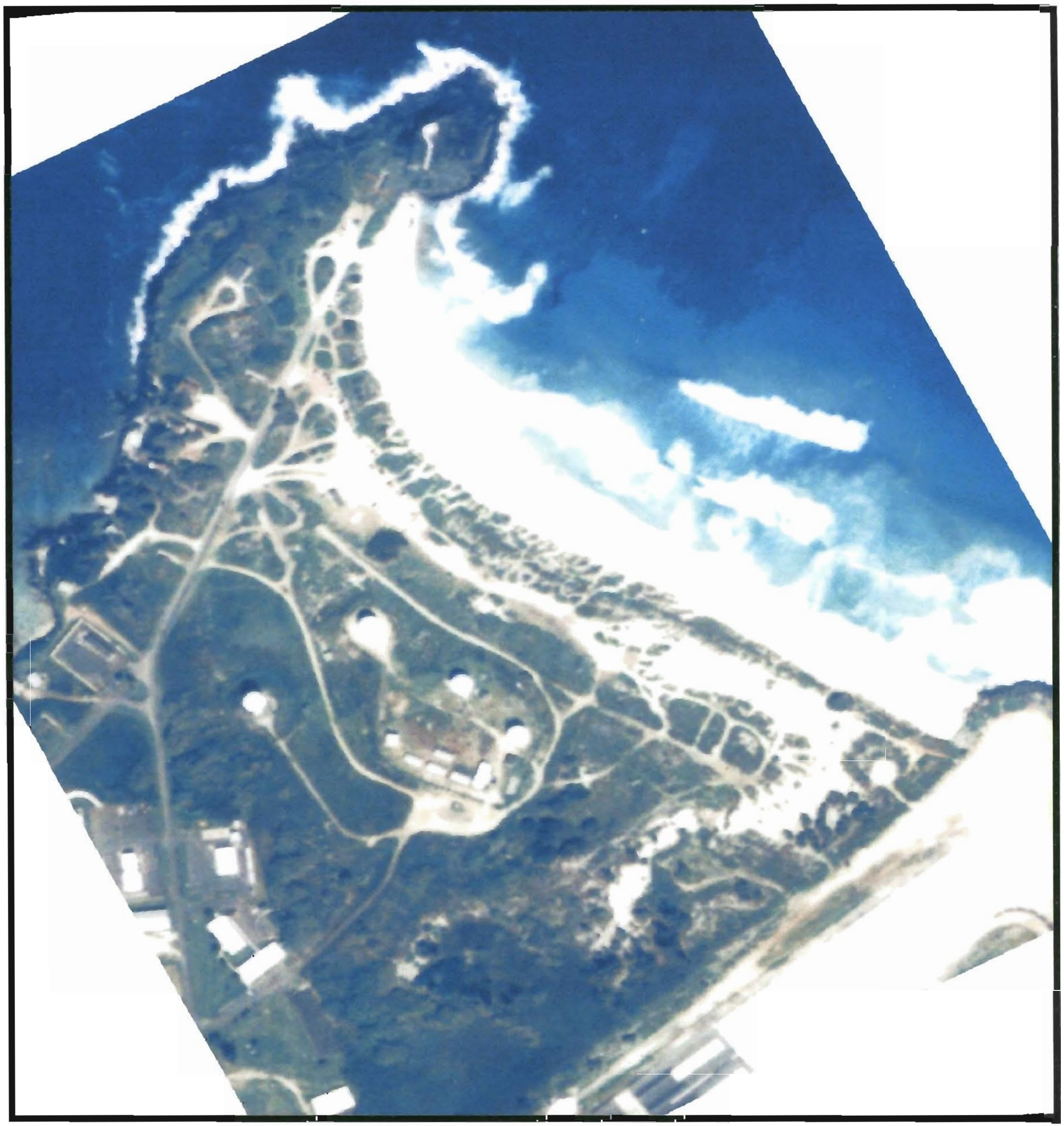


Figure 2. Pyramid Rock Recreational Subarea. Aerial photograph courtesy of Air Survey Hawaii, taken in January 2000. Note vegetated sand dunes.

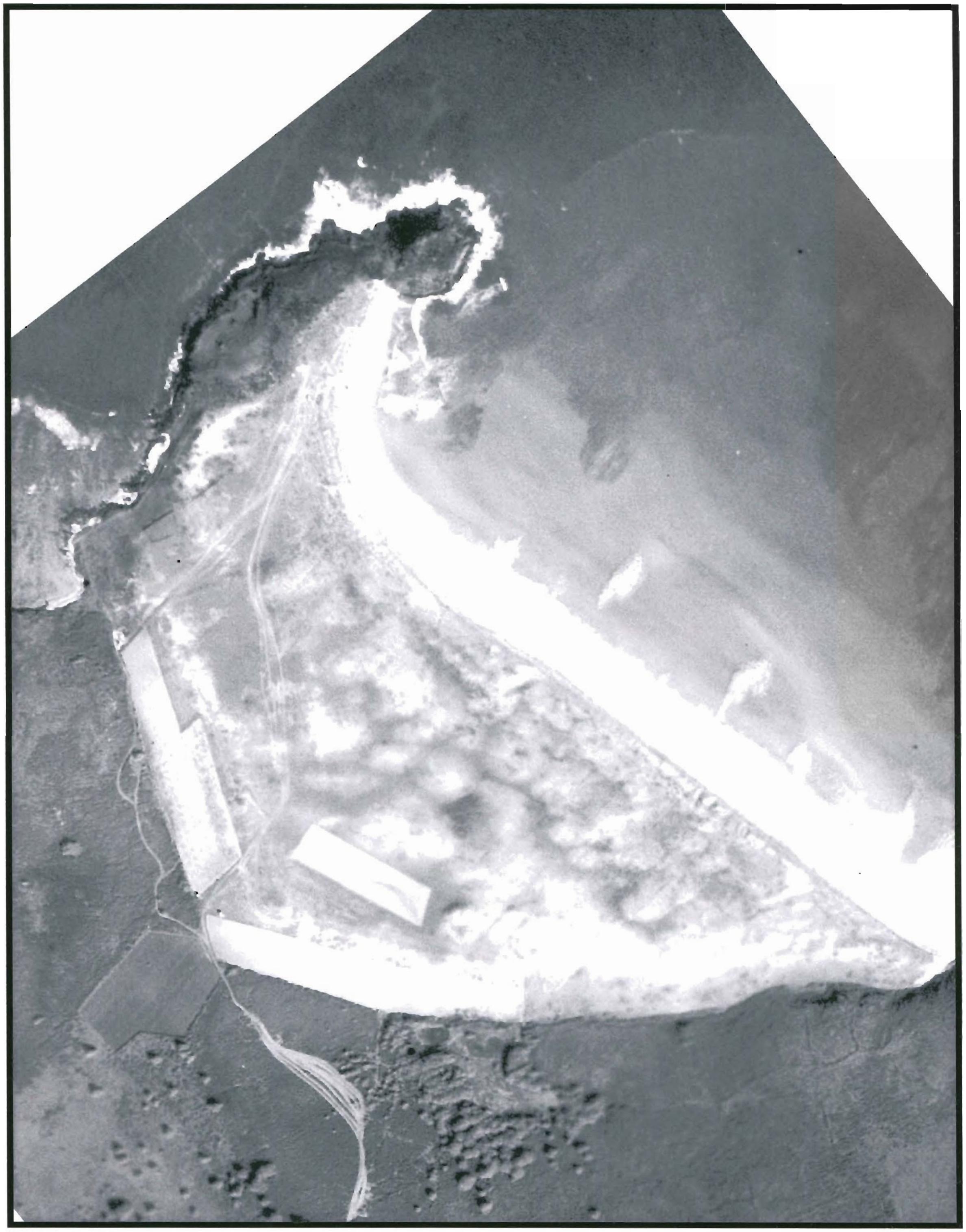


Figure 3. Pyramid Rock Recreational Subarea. Aerial photograph taken by the U.S. Geological Survey in 1927. Note lack of development and extensive dune system in the coastal uplands.

of the dune system at that time can not be drawn. Aerial photos taken in 1965 and 1993 (Figures 4 and 5) by Air Survey Hawaii show the dune area bisected by a road. A part of the upper dune area was used for the now defunct radio facility. A part of the lower dune area has been excavated for a parking lot, an open-air pavilion, and a shower stall on a concrete pad.

Entrance is provided to the parking area by three spurs off Mokapu Road. The middle spur has been blocked to prevent automotive traffic from using it. A roadway lying east towards the runway is also blocked by a low barrier wall at the eastern end of the parking lot (Figure 6).

The North Beach Recreational Area includes the Pyramid Rock Recreational Subarea and is an important archaeological region. Most of the North Beach area lies within the Mokapu Burial area, according to the Draft Outdoor Recreational Management Plan (Figure 7) (Wil Chee Planning, 1997). There are other archaeological resources of high value that are reported for this area. The dune areas adjacent to Fort Hase and Pyramid Rock Beaches on the Mokapu Peninsula are known to contain sensitive archaeological deposits. Native Hawaiian human remains occasionally surface from the dune areas due to disturbances of the soil by erosion and off-road vehicles (Wil Chee Planning, 1997). The State Historic Preservation Office and Native Hawaiian Organizations have been consulted and have given their approval to a cultural survey currently being conducted by Ogden Environmental and Energy Services (Ogden). The results of that survey will be provided by Ogden under separate cover.

Parking Lot, Recreational Pavilion, and Shower Stall

The parking lot is an unpaved open area set just behind the lower dune area (Figure 6). It is located on excavated sand dunes and is surfaced with crushed coral and other fill material. There are no marked stalls. It has a capacity of approximately 50 cars. Concrete stops are placed along the edge of the lot bordering the lower dune area. The parking lot is on a slight grade that rises from northwest to southeast. A part of the upper lot, nearest the lower sand dunes, is covered by several inches to over a foot of sand blown back from the beach. Cars parking in this area have become stuck in the sand due to loss of traction.

A second small parking area for approximately 8 vehicles is located 310 feet north of the main parking area, along Mokapu Road. This parking lot is constructed in the same manner as the main lot.

The recreational pavilion and shower stall are located on the southern boundary of the parking lot (Figure 6). The pavilion is a roofed over concrete slab with a picnic table and benches. The shower is located adjacent to the pavilion and contains a single showerhead over a concrete slab. There are several portable toilets located near the pavilion and shower stall.

Fort Hase Beach Park

The Fort Hase Recreational Area is located on the east side of the MCBH and is bounded on one side by Nuupia pond and on the other by Ulupau Head (Figures 1 and 8). The sand beach

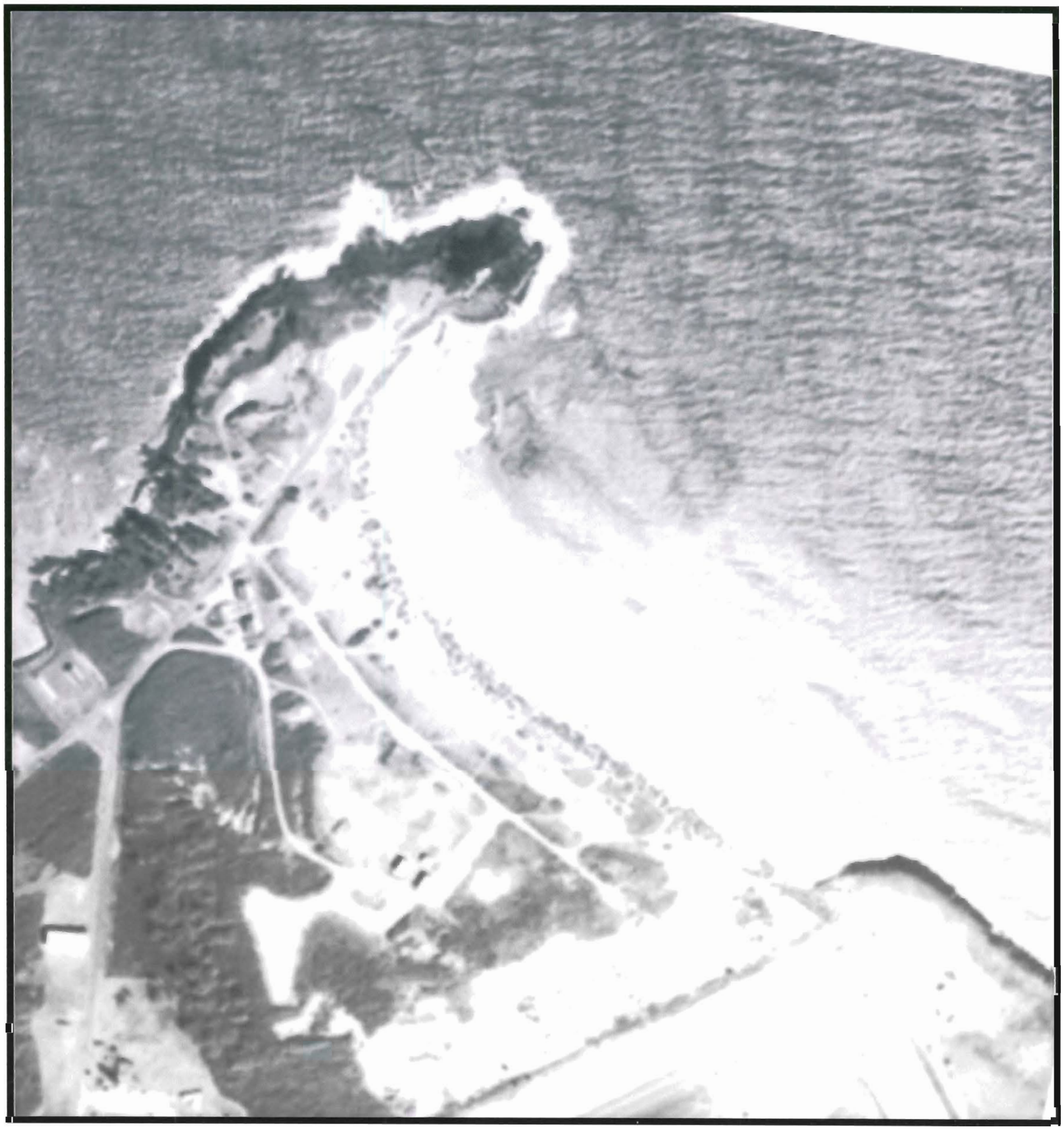


Figure 4. Pyramid Rock Recreational Subarea. Aerial photograph taken by Air Survey Hawaii in 1965. Note dune area bisected by a road and parking area.

Figure 5. Pyramid Rock Recreational Subarea. Aerial photograph taken by Air Survey Hawaii in 1993. Note dune area bisected by a road and parking area.

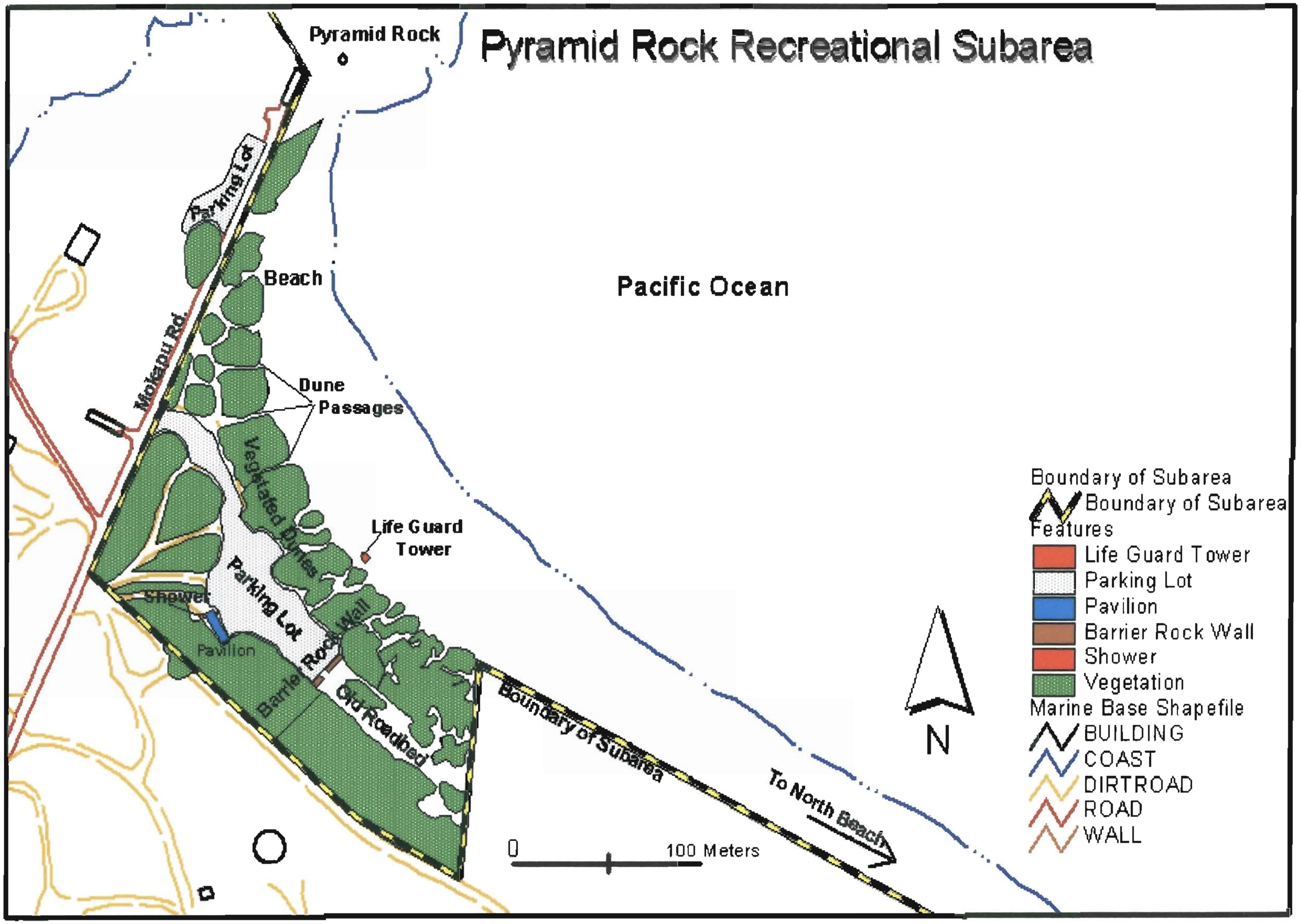
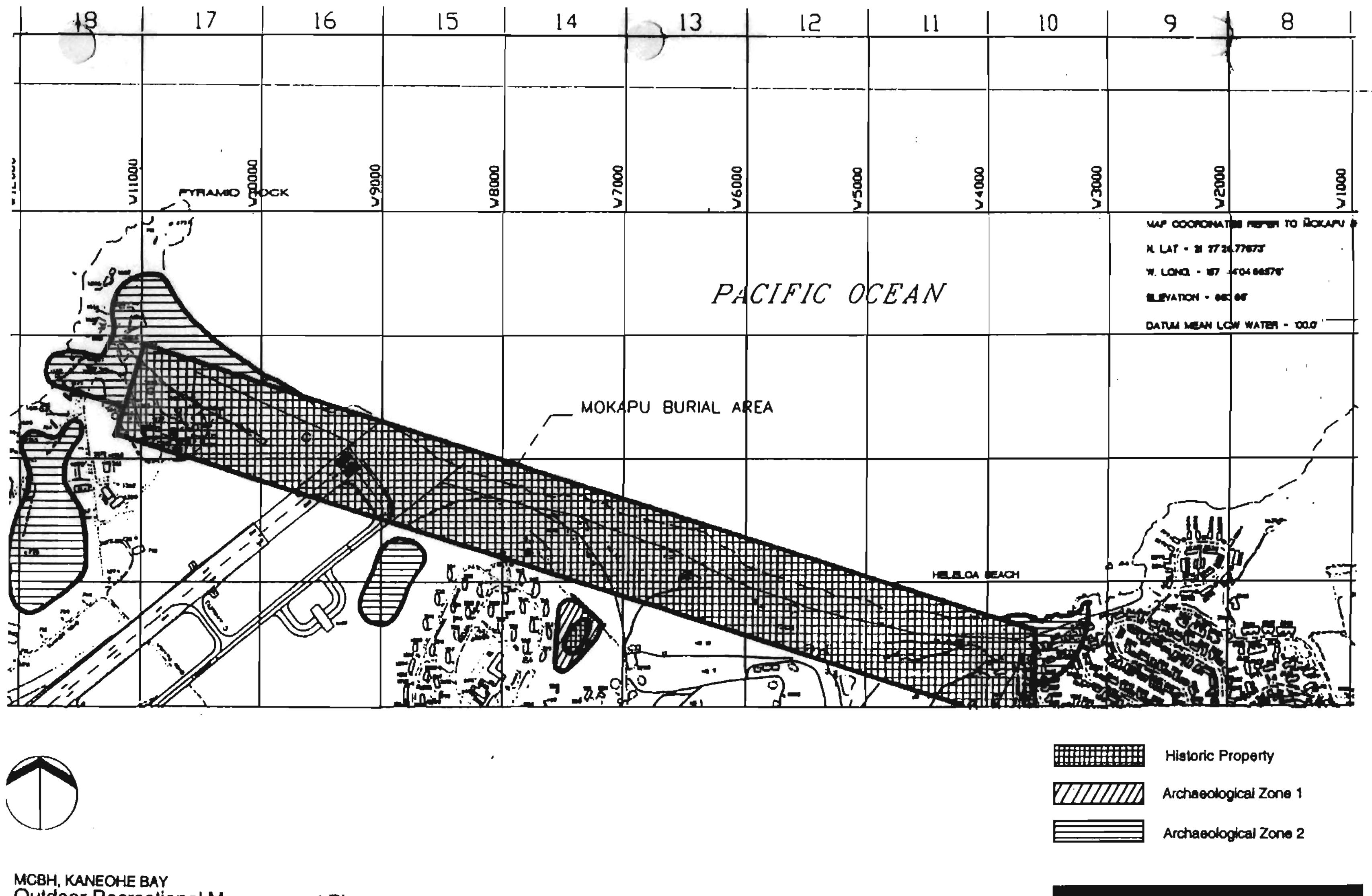


Figure 6. Pyramid Rock Recreational Subarea. Note location of parking lot, vegetated dunes, beach passageways, shower, picnic pavilion, and barrier rock wall.



MCBH, KANEOHE BAY
Outdoor Recreational Management Plan

prepared for:
U.S. Army Engineer District
Pacific Ocean Division
Fort Shafter, Hawaii

prepared by:
Wil Chee - Planning, Inc.

0 1000 Feet

0 300 Meters

Figure 7. Pyramid Rock Recreational Subarea. Historical/Archaeological resource areas. Abstracted from the Outdoor Recreational Management Plan, prepared by Will Chee Planning, Inc.

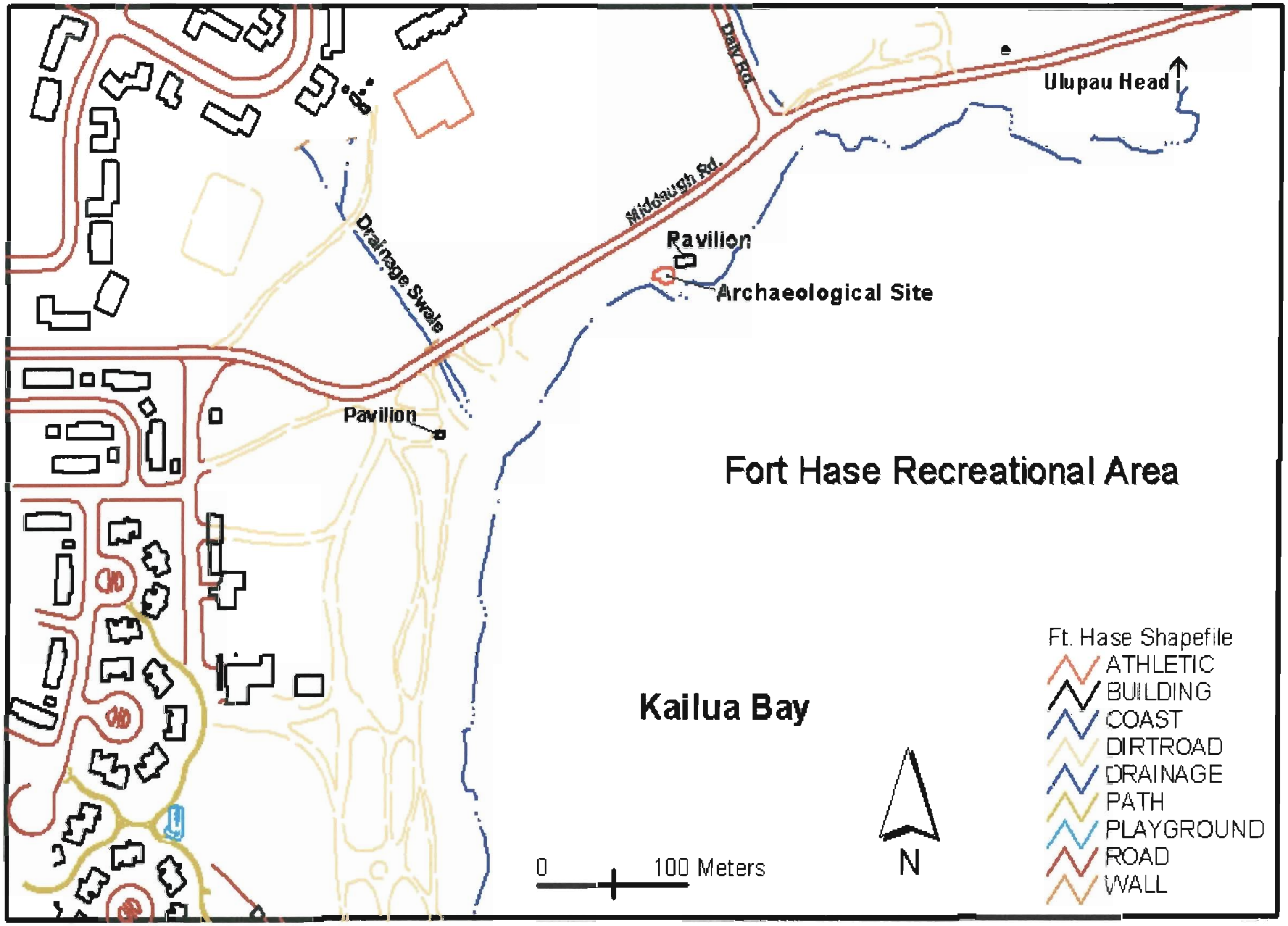


Figure 8. Fort Hase Beach Recreational Area. Note drainage swale and proximity of archaeological site to picnic pavilion.

extends southward several miles along the shoreline of Kailua Bay. The northern edge of the beach park is characterized by rocky outcrops of basalt and remnant reef and a rocky reef extends seaward. Only small sand pockets occur in this northern area and these are confined to the occasional "tide pool".

The study in the Fort Hase Recreational Area is limited to the area between the outdoor "picnic" pavilion near the foot of Ulupau Head and the drainage ditch approximately one-half mile southwest from the pavilion. The exposed cultural deposit of concern cited earlier is just landward of the beginning of this exposed rocky shoreline near the pavilion (Figure 8 and Appendix A).

An aerial photo taken in 1927 (Figure 9) by the U.S.G.S. shows that little or no development had occurred in this area. A road or a track parallels the shoreline in approximately the same location as tracks that are present today. Excavations for the parking area and the small open-air pavilion are located in an area where some type of shoreline structure was located according to the 1927 photo. Aerial photos from 1963, 1993, and 2000 (Figures 10, 11 and 12) taken by Air Survey Hawaii show that gradually a number of tracks cut through the dunes. Large rocks or boulders have recently been strategically placed to prevent or minimize vehicle access to the beach and have attempted to minimize further destruction of the adjacent dune vegetation.

Of specific concern to the coastal erosion study is an exposed cultural site at Fort Hase Beach Park (Figure 8 and Appendix A). This site is located at the shoreline above a rocky outcrop and directly seaward of a concrete block pavilion. Cultural remains, including shell, bone, and charcoal, are visible in an approximately 1 meter high escarpment that is currently exposed to attack by storm waves. These deposits are presently under investigation by the Ogden team. The Ogden studies will cover the cultural investigations while our efforts will address the erosion aspects of this site.

METHODS

Archival research was undertaken to gather background data on the natural and ministerial problems associated with coastal erosion as a means of determining possible non-structural mitigation alternatives.

Historic air photographs were acquired from the U.S. Army Corps of Engineers and reviewed to determine changes, if any, in vegetation and dune structure over the years. Field and library research led to the development of a number of spatial maps of the area. Special emphasis was placed on locating and analyzing historic aerial photographs of the two beach sites. A photographic record of the area was made to provide a visual baseline of the area for subsequent comparisons (Appendix A).

Personal interviews were conducted with beach lifeguards and resource managers at the Marine Corps Base Hawaii to corroborate published information on beach characteristics and

Figure 9. Fort Hase Beach Recreational Area. Aerial photograph taken by the U.S. Geological Survey in 1927. Note the lack of development in the coastal dune area with the exception of a road or track that parallels the shoreline in the approximate same location as the existing road.

Figure 10. Fort Hase Beach Recreational Area. Aerial photograph taken by Air Survey Hawaii in 1963. Note tracks across dunes to beach.

Figure 11. Fort Hase Beach Recreational Area. Aerial photograph taken by Air Survey Hawaii in 1993. Note increasing development in the back-dune area and in the number of tracks across dunes to beach.

Figure 12. Fort Hase Beach Recreational Area. Aerial photograph courtesy of Air Survey Hawaii, taken in January 2000. Note tracks across dunes to beach and overall development in the back-dune area.

use with direct personal observations. In addition, hydrographic data were assembled from existing materials and validated, where possible, by in-field observations and discussions with resource managers and lifeguards at the two sites. Site visits included botanical surveys of both sites and the mapping of the vegetation line at the shore.

Individuals with special expertise in beach management techniques and direct knowledge of the two areas were interviewed and participated in site visits to assist in developing the background information necessary for informed management recommendations. Templates for non-structural alternatives for erosion control were developed along with appropriate educational signage that should be effective in teaching and encouraging beach users to be more environmentally aware of their impacts to the beach ecosystems. Some mitigation measures being considered for these areas are: pedestrian walkways, vegetative plantings, modification and relocation of the shower system (at Pyramid Rock beach), surface improvements to the parking lots, construction of both surface and sub-surface drainage systems, the use of sand bags or geo-textile materials and beach replenishment techniques. Information needed for a Federal Coastal Zone Management determination was gathered and is included as Appendix B of this final report.

RESULTS

The results of these efforts have led to a fuller understanding of the erosion problems faced by the Pyramid Rock and Fort Hase beach recreational areas and suggest some mechanisms for improving the situation. A visual overview of the conditions at these two sites is presented in a series of photographs included as Appendix A.

Pyramid Rock Recreational Subarea

Erosion from the shower pad and natural run-off from rain have generated a drainage swale that impacts the road into the parking area, the parking area itself, and the nearshore strand vegetation. Furthermore, because of the lack of directional access to the beach, foot traffic has created numerous paths across the strand vegetation to the adjacent beach. This foot traffic has severely damaged the coastal vegetation, has encouraged the introduction of alien species, and has resulted in additional erosion of the underlying friable soil and sand. The paths to the beach have also served to funnel sand blown from the beach by the prevailing tradewinds on to the parking area in several places. Where this "blowback" has occurred, the depth of sand makes it difficult to use this area for parking.

Even in its degraded condition, the sand dune system still affords shoreline protection in case of severe storms. With some care and proper management, the dunes can recover and continue to function. A final purpose of this section of the report is to recommend ways to restore the dunes to a less degraded state.

Vegetation

The vegetation at Pyramid Rock was identified during three walk-through surveys. Plants were identified by their Hawaiian, common, and species names when available. Dr. Mark Merlin, Department of Biology, University of Hawaii, and author of *Hawaiian Coastal Plants* (1999), was primarily responsible for identifying plants in the field. Lance Bookless, Natural Resource Manager for the U.S. Marine Corps Base Hawaii, assisted in identifying existing vegetation. The results of the surveys at Pyramid Rock Beach are listed in Table 1.

The vegetation is typical of a tropical coastal dune ecosystem. *Naupaka* and *aki'aki* grass dominate and stabilize the dunes. However, due to the disturbed nature of the land there were a number of invasive alien species. The Chinese violet and the Indian pluchea were two alien invaders that seemed to be established on the dunes and competing for the same space as the *aki'aki* grass. Purslane and swollen finger grass are two other aliens that have covered substantial areas.

The existing naupaka stands appeared dry and brittle with approximately one-third to one-half lacking leaf cover. According to the Lifeguards at the Pyramid Rock beach, the poor appearance of the *naupaka* is due to drought conditions over the past two years, rather than to anthropogenic induced stress. Compared with many other beach and dune areas in urban Oahu, this system looked intact and thriving.

The two areas that were formerly used for vehicular traffic are now closed and appear to be recovering. The "Y" shaped middle access to the parking lot (Figure 6) that is now closed at both ends with large boulders is being re-vegetated with *aki'aki* grass. The roadway that formerly extended past the eastern end of the parking area, has also been closed by a low rock wall and a makeshift fence. Revegetation is occurring along the former road. Several relatively large clumps of the small, unique *nama* have become established. *Nama*, though not endangered or threatened, is an endemic species. Indian pulchea was also observed growing in this area.

Problem Areas at Pyramid Rock Recreational Subarea

The dunes fronting the parking lot have at least eight passageways to the beach. The passages are generally straight and parallel to each other. Near the eastern end of the parking lot there are a series of three passageways to the beach that are connected by lateral trails. Past the end of the parking lot and on the other side of the low wall are a dozen trails, many with perpendicular branching connections (Figure 6). The vegetative cover has been worn away in these areas by pedestrian traffic to the beach.

The parking lot is subject to erosion from periodic rains and the shower. Swales and gullies can be easily distinguished in all parts of the lot especially in the lower parking area. A considerable amount of erosion can be traced to the shower. The shower is located at the highest point in the parking lot and has no designated drain. When the shower is in use, water runs off the shower slab and drains through the parking lot, cutting gullies across the lot and

**Table 1. Plants found at Pyramid Rock Recreational Subarea.
Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name, plants that are endemic are noted with an (E), and alien species are noted with an (A).**

Hawaiian	Common	Scientific
Pohuehue	Beach Morning Glory	*Ipomoea pes-caprae*
Hinahina	Beach Heliotrope	*Heliotropium anomalum*
Naupaka-Kahakai (I)	Beach Naupaka	*Scaevola taccada*
Pau-o-Hiiaka	Skirt of Hiiaka	*Jacquemontia sandwicensis*
Nehe		*Lipochaeta integrifolia*
Nama (E)	Hawaiian Nama	*Nama sandwicensis*
Niu	Coconut Palm	*Cocos nucifera*
Milo	Milo	*Thespesia populnea*
Alena		*Boerhavia spp.*
Waina Kahakai	Sea Grape	*Coccoloba uvifera*
	Indian Pluchea	*Pluchea indica (carolinensis?)*
	Chinese Violet (A)	*Asystasia gangetica*
Akulikuli-kai	Pickleweed	*Batis martima*
Nena, Kipukai, Hinahina	Seaside Heliotrope	*Heliotropium curassavicum*
	Australian Saltbush	*Atriplex semibaccata*
Ironwood Paina	Ironwood	*Casuarina spp.*
Kiawe	Mesquite	*Propopis pallida*
Koa Haole		*Leucaena leucocephala*
Aki'aki (I)	Grass	*Sporobolus virginicus*
	White-petaled (A) sunflower herb	*Bidens alba*
	Red flowered bean vine (NA)	*Canavalia sericea*
'Ilima (I)		*Sida fallax*
	small, low lying succulent, small red/purple fls. (A)	*Portulaca pilosa*
	Pig weed (A)	*Portulaca oleracea*
	Swollen finger grass (A)	*Cloris barbata*
Hau (?)		*Hibiscus tiliaceous*
	Lantana (A)	*Lantana camara*
'Akoko (E)		*Chamaesyce degeneri*
		Waltheria indica L.
	Yellow-petaled sunflower (A)	*Sonchus oleracea*
	goosefoot (not sure if this is native or the alien weed? I think, on basis of leaf shape that it is C. oahuense, endemic goosefoot)	Chenopodium sp.
	(probably not B. repens, an indigenous species; maybe B. coccinea, an alien)	Boerhavia sp.

draining into several of the passageways through the sand dunes. During the afternoons and on weekends, when the beach is more heavily used, the shower is almost always running. As the water enters the lower dune area, it widens the passageways at the southern end of the dunes. Erosion due to rainwater is also very significant in the lower portion of the parking lot. The westernmost passageway from the parking lot to the beach shows signs of heavy erosion (Figure 6). The photograph, taken in December after heavy rainfalls, shows severe erosion of the gully with water pipes exposed (Appendix A).

Beach users are the prime cause for the degradation of the dune ecosystem. Their movement to and from the beach traversing so many passageways has opened up the dunes to increased wind erosion and made it easier for alien species to gain footholds on the dunes. Off-road vehicles also contribute to the degradation, crushing plants as they drive through the area and leave large ruts.

Possible Mitigative Solutions

There are several problems caused by the present use of the Pyramid Rock Recreational Subarea:

1. **Parking Lot Erosion**. As parts of the parking lot erode, it becomes more difficult to use the lot.

2. **Passageway Erosion**. Drainage from the parking lot, from rainfall or the shower, has widened and deepened parts of two passageways through the dunes.

3. **Degradation of the Sand Dunes**. With so many passageways through the sand dunes, the vegetative cover is being pushed back.

4. **Off-Road Vehicles**. Off-road vehicles destroy the substrate and eventually kill the sensitive vegetation, exposing the underlying sand.

We recommend the use of the following mitigative measures:

1. **Surface the parking lot**. As long as the parking lot remains unsurfaced, it will continue to erode. We suggest that the parking lot be surfaced with some material that will stop, or significantly reduce, erosion. Possible choices of surfacing materials include concrete or macadam, crushed coral aggregate or gravel. Among the choices we favor the use of gravel. Gravel's irregular shape will slow any flow across its surface and permeability will allow the water to drain into the sandy soil before it reaches the edge of the lot. Crushed gravel, particularly, basalt gravel is a suitable fill material because it is physically hard (i.e. does not abrade) and is much more chemically stable. Hence permeability is not compromised. This reduces runoff and promotes drainage into the underlying sands.

Coral aggregate is less desireable than basalt gravel for parking lot fill for several reasons. These reasons are especially true for parking lots near the shoreline. Coral aggregate is less chemically and physically stable than basalt gravel. A not insignificant percentage of the material in crushed coral tends to physically break down into a limey mud. The presence of this fine grained sediment fills intergrain pore space and makes the fill less permeable. During and after rains percolation is reduced leading to silt and mud laden sheet flow runoff and ponding. Runoff reaching the ocean can degrade nearshore water quality. Coral aggregate also has the propensity to cement itself, also decreasing permeability. The aragonite and high-magnesium calcite components in such fill are not chemically stable in fresh water environments. Rain water tends to partially dissolve these components, and then they reprecipitate at low-magnesium calcite. This is what happened when crushed coral sand fill was used at Fort DeRussy Beach and at Keehi Lagoon beach (Mullane, 1999).

2. **Move the Shower**. The shower is at the highest point in the parking lot. This increases the velocity of the runoff. There is also no designated drainage area to capture the runoff. Relocating the shower facility to the edge of the vegetation in the lower parking area will decrease the speed of the runoff and provide a place to drain the water. Shower water could be used to irrigate the access road that has been closed off so it can be revegetated.

3. **Fence Off Passageways.** There is no need to have so many passageways to the beach. Fencing off the front and the rear of at least five or six of the passageways will leave 3-4 walkways across the dunes. The closed off areas should, in time, revegetate.

4. **Place Interpretative Signage in Key Locations**. Users will more readily understand and use designated walkways if they are given the rationale for their placement and requested use.

5. **Provide designated walkways.** Use materials such as recycled plastic timbers and construct surface mounted pathways to the beach from the parking lots. These timbers will offer readily visible pathways and centralized locations for educational signage as well as help to stabilize the underlying dune sands.

Fort Hase Beach Recreational Area

Parking along the seaward (makai) side of the road by beach users has severally degraded the vegetative cover and in some cases removed it and exposed bare sail. The bare areas erode during heavy rainfall and contribute sediments to the near shore water. The grounds around the pavilion and the shoulder area along the road are the worst areas. Ground cover in the area between the road and the beach for about 75 to 100 meters west of the pavilion is minimal and is composed mostly of alien species. Revegetation of the bare areas and redirection of access to the beach is essential to reduce soil loss.

Vegetation

Vegetation was much more sparse at the Fort Hase Beach area as compared to Pyramid Rock. The strip between the beach and the roadway is much narrower than the dunes at Pyramid rock. The vegetation at Fort Hase was identified in a walk through survey in March 2000. The area surveyed was from a point on the shoreline across from Daly Road to a drainage ditch approximately 200 meters west. Dr. Mark Merlin was primarily responsible for identifying plants in the field. A list of the plants found at Fort Hase is presented in Table 2.

Beach users who park their vehicles close to the shoreline have heavily impacted the area. This has eliminated most of the native vegetation and in some areas all the vegetation down to the bare soil along the area surveyed. In the rocky eastern portion of the surveyed area, near the intersection with Daly Road, a number of indigenous coastal plants were found, including the ohelo kai (*Lycium sandwicense*), pohuehue (*Ipomea pes-caprae*), hinahina (*Heliotrpoium anomalum*), and the akulikuli (*Sesuvium portulacastrum*).

Near the pavilion, an area cordoned off to protect a coastal archaeological site has also allowed regrowth of vegetation in an area that is otherwise degraded or bare. This area contains a mix of alien species such as the Australian saltbush (*Atriplex semibaccata*), Chinese violet (*Asystasia gangetica*), and native species such as aki'aki (*Sporobolus virginicus*). The area surrounding the archaeological site and down Middaugh Road was vegetated primarily by weedy alien grass such as swollen finger grass (*Chloris barbata*) and bunch grass (*Eleusine indica*). Where the beach curves away from the road marks the beginning of the sand dunes and their associated vegetation. This area is dominated by the alien species, koa haole (*Leucaena leucocephala*), kiawe (*Propopis pallida*), and the indigenous naupaka kahakai (*Scaevola taccada*). One unusual species, the American mangrove (*Rhizophora mangle*) was spotted in the drainage ditch that marked the western boundary of the study area.

Problem Areas at Fort Hase Beach Recreational Area

Native and alien flora have been substantially degraded in this area by pedestrian and vehicular movement. There are no designated or organized parking areas, and vehicles are allowed to park very close to the edge of the shoreline (Wil Chee Planning, 1997). In some areas, vehicle and pedestrian traffic have cleared all vegetation down to bare soil. These areas erode during storms causing sediments to enter the near shore waters. Off-road, or four wheel drive vehicles, have also contributed to the degradation of the local flora, although this form of recreation has been curtailed somewhat by an order from the base commander to stop this activity and by boulders blocking access points into shoreline areas (Bookless, pers. comm.). There are no designated pedestrian passageways to the beach.

Possible Mitigative Solutions

Parking areas should be designated for the Fort Hase Recreational Area. The areas around the pavilion and along Middaugh Road are two areas that should be assigned. A post fence

Table 2. Plants found at Fort Hase Recreational Area.
Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name, plants that are endemic are noted with an (E), and alien species are noted with an (A).

Hawaiian	Common	Scientific
Ohelo kai (I)	Sea Berry	*Lycium sandwicense*
	American Mangrove (A)	*Rhizophora mangle*
	Tree Heliotrope (A)	*Tournefortia argentea*
Pohuehue (I)	Beach Morning Glory	*Ipomoea pes-caprae*
Hinahina (I)	Beach Heliotrope	*Heliotropium anomalum*
Naupaka-Kahakai (I)	Beach Naupaka	*Scaevola taccada*
Milo	Milo	*Thespesia populnea*
	Indian Pluchea (A)	*Pluchea indica (carolinensis?)*
	Chinese Violet (A)	*Asystasia gangetica*
Akulikuli-kai (A)	Pickleweed	*Batis martima*
Nena, Kipukai (I)	Seaside Heliotrope	*Heliotropium curassavicum*
	Australian Saltbush (A)	*Atriplex semibaccata*
Ironwood Paina (A)	Ironwood	*Casuarina spp.*
Kiawe (A)	Mesquite	*Propopis pallida*
Koa Haole (A)		*Leucaena leucocephala*
Aki'aki (I)	Grass	*Sporobolus virginicus*
	White-petaled (A) sunflower herb	*Bidens alba*
'Ilima (I)	Ilima	*Sida fallax*
	small, low lying succulent, small red/purple fls. (A)	*Portulaca pilosa*
Akulikuli kula (A)	Pig weed	*Portulaca oleracea*
Mauu lei (A)	Swollen finger grass	*Cloris barbata*
	Bunch grass	*Eleusine indica*
	(common weed)	*Desmanthus virgatus*

should be erected between the makai boundary of the parking areas and the beach. Several openings in the fence can funnel beach users into designated accessways. The area between the parking area and the shoreline can then be revegetated with native plants. The parking areas should be covered with gravel to eliminate sheet flow from the compacted surface and thus stop the sediment flow from the uncovered areas during rainfall.

Several interpretive displays should be placed at strategic locations to inform users of the necessity to use designated accessways to the beach, and the importance of protecting native vegetation. Voluntary compliance with conservation practices is often the result of the use of interpretive signage. At least one sign should be placed in the vicinity of the pavilion and another along the Middaugh Road near the start of the dunes.

Description of the Hydrographic Environments of the Study Areas

General Comments

The hydrographic conditions of the Pyramid Rock and Fort Hase Beach Areas are quite similar, despite the fact that they are located on opposite sides of a relatively narrow promontory on the eastern side of the island of Oahu. Wind direction and intensity, wave heights, periods, and directions, tides, currents, storms, and tsunamis all have general characteristics or impacts that are not greatly different at one site or the other. In general, the hydrographic conditions at the two sites can be described as follows:

Winds

The dominant winds around Hawaii are the northeast tradewinds, produced by a stationary high pressure system located northeast of the Hawaiian islands. The tradewinds are present approximately 75% of the time and their frequency of occurrence is greatest during the months of May through October. The tradewinds generally blow from ENE and have daily average speeds of 10 knots, as measured at the air facility. The winds are typically stronger during the day, averaging approximately 15 knots. Since MCBH is situated on the eastern side of Oahu, it is directly exposed to the effects of the tradewinds. Monthly averages of hourly observations of climatological conditions, including winds, have been collected at the MCBH air facility for the years of 1945-1999 (Table 3), along with miscellaneous wind observations for windward Oahu for 1988-1999 (Caldwell, pers. Comm.).

During the winter months of November through April, the winds can be light and variable or strong from the southwest, as the weather systems change throughout the season. Winds from the southwest are termed Kona winds and are usually associated with Kona storms, which are low pressure storms moving east across the Pacific Ocean. Kona winds vary in intensity and have the ability to cause considerable damage.

Waves

Homer (1964) analyzed and tabulated statistics for Hawaiian waves based on observations and hindcasts. The data are presented in Table 4. Similarly, St. Denis (1974) presented wave data in Hawaiian waters in the form of a wave rose (Figure 13). Daily surf heights around Oahu have been compiled since 1987 (Caldwell, pers. comm.). The data report the highest daily breaking wave heights as stated by the National Weather Service and other miscellaneous sources. Surf observations for North Beach (adjacent to Pyramid Rock Beach) are available through 1994. Monthly and seasonal—summer (April through September) and winter (October through March)—data are shown in Table 5.

The project sites at MCBH typically experience waves from two sources. The most common waves are generated by the tradewinds discussed in the previous section. These waves are present approximately 75% of the time and have significant periods ranging from 8 to 10 seconds with offshore significant wave heights averaging 4 to 5 feet.

Swell waves generated by North Pacific storms reach MCBH in the winter months. These waves have an average significant period of about 14 seconds and offshore significant wave heights of about 5 feet. The winter swell waves approach Oahu from the north to northwest direction and create large surf on Oahu's north and west shores, with a somewhat lesser amount of energy reaching the Windward shore. The wave energy reaching MCBH is less than that at the North Shore because the waves refract and diffract extensively before reaching Pyramid Rock Beach and Fort Hase Beach. Large surf occurs at Pyramid Rock Beach when the swell direction is more easterly.

Tides

The tides in Hawaii are strongly influenced by both the sun and the moon, resulting in a mixed diurnal/semi-diurnal tide pattern. There are two high and low tides per cycle, which is 24 hours and 50 minutes long. Predicted tides at the nearby Hawaii Institute of Marine Biology in Kaneohe Bay can be used in place of tides at MCBH. Tide predictions are referenced to Honolulu Harbor. High and low tides at Coconut Island occur 1.4 hours and 1.23 hours before Honolulu Harbor with height adjustments of +0.1 and +0.2 feet. Extreme high water is 3.0 feet above mean lower low water.

Currents

Coastal currents can be generated by waves or tides. The tidal currents are generally weak in the nearshore region and transport only very fine material suspended in the water column. The coastal currents generated by the tides themselves contribute little to the sediment transport, but the rise in water level associated with high tide allows increased wave energy to reach shore. Waves and wave-generated currents are the driving forces behind sediment transport. The radiation stress due to the presence of waves, the approach of waves at an angle to the shoreline, and the mass transport of water due to breaking waves cause an increase in water level inside the surf zone, which is balanced by longshore and cross-shore

Table 3. Hourly climate summary for years 1945-1999 at the Kaneohe Marine Corps Air Facility. Station Location 21° 27' N Latitude, 157° 46' W Longitude. Elevation 17 ft. (5 m).

Month	Temperature (F)					Precipitation (in)				Relative Humidity		Wind (kts)		
	Means			Extreme				24 hr		am	pm	Prevailing		Max
	Max	Min	Avg	Max	Min	Mean	Max	Min	Max	700	1400	Dir	Spd	Gust
January	78	69	74	89	55	5.3	15.5	0.4	8.4	79	70	ENE	10	83
February	78	69	74	88	56	5.7	10.9	0.3	3.9	78	69	ENE	11	65
March	79	69	74	89	59	3.6	14.3	0.2	12	78	70	ENE	11	54
April	79	70	75	88	60	3.8	22.2	0.6	7.3	78	70	ENE	11	52
May	81	72	76	88	60	2.1	7	0.2	3.6	78	70	ENE	10	38
June	82	73	78	90	67	1.4	4.7	0.4	2.6	78	69	ENE	10	36
July	83	74	79	89	67	1.9	4.8	0.2	1.7	78	69	ENE	10	40
August	84	75	80	93	68	1.9	5.8	0.3	2.8	78	69	ENE	10	46
September	84	75	80	91	66	2.1	4.9	0.4	2.2	78	70	ENE	9	55
October	83	74	79	91	65	3.1	10.3	0.7	7	78	71	ENE	9	47
November	81	72	77	90	62	4.8	24.9	0.7	9.1	79	72	ENE	10	80
December	79	70	75	90	56	4.5	15.7	0.4	4.9	78	71	ENE	11	56
Annual	81	72	77	93	55	40.3	117.0	16.0	80.0	78	70	ENE	10	83

Table 4. Hawaiian Wave Data (Homer, 1964).

Wave Type	Expected Frequency of Occurrence (%)	Significant Wave Height (ft.)	Significant Wave Period (sec)
Tradewind Waves	75.3	4.79	8.63
Kona Storm Waves	10.3	3.52	6.18
North Pacific Swell	74.0	4.79	13.89
South Pacific Swell	53.0	2.60	13.07

Table 5. Surf Observations for North Beach, 1987-1994.

Observation Period	Average Surf Height (ft)
January	4.3
February	3.9
March	3.8
April	3.2
May	2.9
June	2.9
July	2.9
August	2.7
September	2.6
October	3.1
November	4.4
December	4.2
Summer	2.9
Winter	3.9
All Observations	3.4

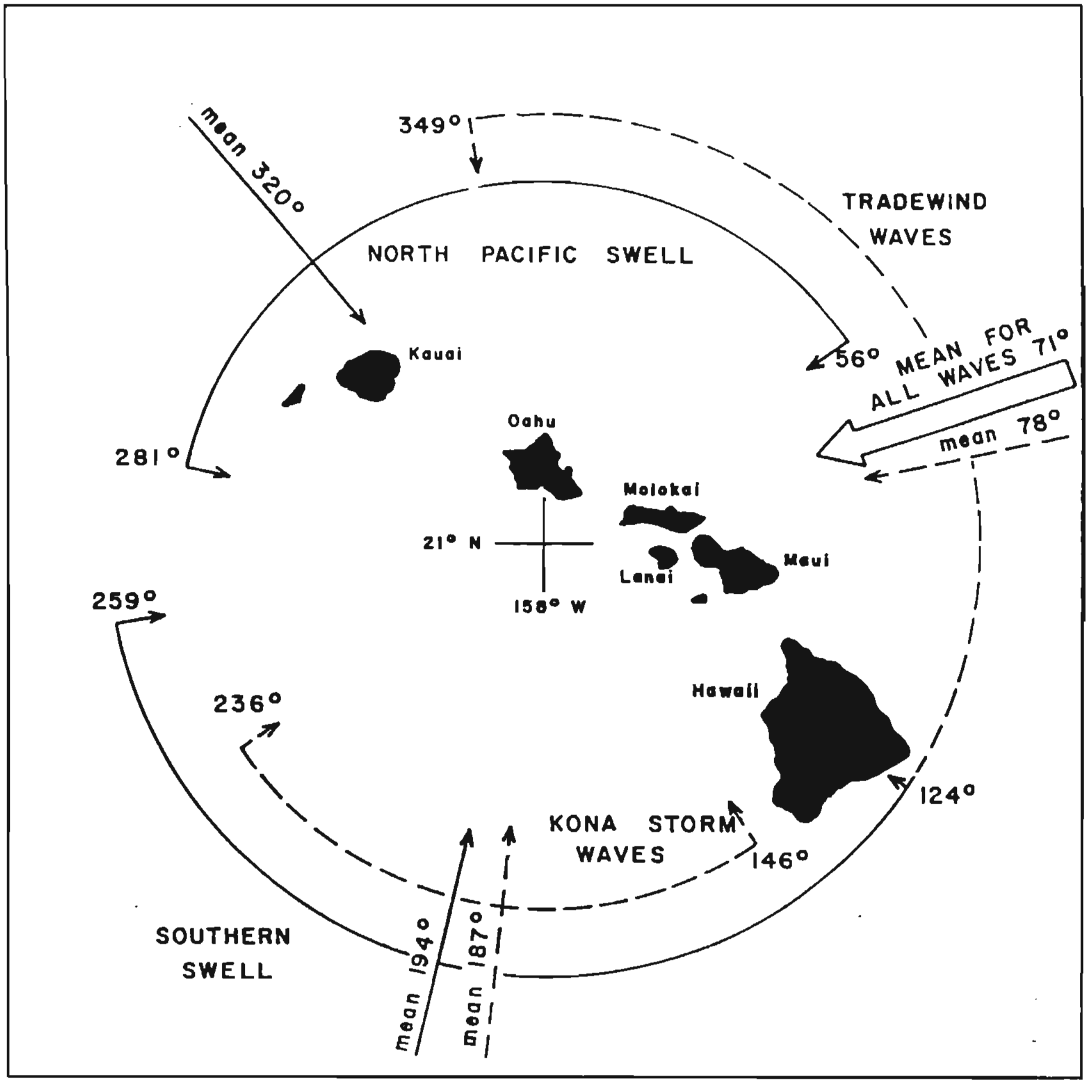


Figure 13. Wave Rose for Hawaiian Islands (from St. Denis, 1974). Figure compares average direction of approach under tradewinds and Kona conditions.

currents. The interaction of these currents results in a system of longshore and cross-shore sediment transport.

Tsunamis

Hawaii is susceptible to the effects of tsunamis generated locally or around the Pacific rim. A number of catastrophic tsunamis have hit Hawaii, including those in the years 1946, 1952, 1957, 1960, and 1964 (Loomis, 1976). Tsunami inundation was measured at Pyramid Rock Beach for the 1946 and 1952 events and the respective run-up elevations were 19 feet and 6 feet. The run-up elevation of the 1952 event was measured at Fort Hase Beach to be 17 feet. The data collected following these events were used to determine the tsunami evacuation zones for the Hawaiian islands. The tsunami evacuation zones can be found in the disaster preparedness information section of the telephone book.

Storms

The erosion rates and factors that determine the erosion rate of the vegetation line are of interest in this study. From an oceanographic viewpoint, the most important factor is the effect of storm waves. During storms, especially hurricanes, there is a rise in water level due to wind stress, decreased atmospheric pressure, and breaking wave set-up. Sea Engineering, Inc. (1990) performed an analysis of the potential extent of flooding due to hurricanes. Model and worst-case hurricanes approaching from two directions were studied. The results give an approximate extent of flooding for Civil Defense purposes. The results for the model hurricanes are adapted for estimating the flooding potential at the Fort Hase and Pyramid Rock project sites.

Detailed Comments

More specific hydrographic characteristics of the two beach areas are described in greater detail in the paragraphs that follow.

Pyramid Rock Beach

Pyramid Rock Beach is classified as a medium energy beach. The sand has a median diameter of 0.33 mm, coarser than Kailua Beach, a true low energy beach, but finer than the high energy beaches of the north and west shores of Oahu. The beach is arcuate shaped, facing east-southeast nearest Pyramid Rock and curving around to face north-northeast near the MCBH airport runway.

Beaches can experience rapid loss of sand when the surf is large. These conditions prevail at MCBH during the winter months when large swell waves from north Pacific storms travel to Hawaii and create large surf on the north and west shores of Oahu. Pyramid Rock Beach exhibits the greatest seasonal variation of the two sites. Although the winter swell does reach the site, the beach does not react to the swell as much as north shore beaches do. A significant amount of wave energy is lost from refraction and diffraction around Pyramid Rock itself.

Beaches accrete when the harsh storm waves are replaced by less steep waves. These conditions occur during the summer months when the winter surf has diminished and tradewind swell waves dominate. The summer waves transport sediment toward shore and the beach gradually widens as the sand is distributed along the beach (Figure 14).

Wave and aerial photograph analysis was supplemented with interviews with lifeguards working at Pyramid Rock Beach. There is a pattern of seasonal beach loss and gain that is a function of the seasonal wave conditions. Pyramid Rock Beach is at its widest in early fall, before the winter swell begins to arrive. The winter surf generates longshore currents from the outer reaches of the beach, transporting sediment laterally toward the center of the beach. These currents converge opposite the present location of the lifeguard stand and create a cross-shore current away from the beach (Figure 15). The sediment is moved offshore and deposited in the form of a sand bar in the nearshore waters. This pattern was observed during a site visit on November 30, 1999, and confirmed by lifeguard observations.

The movement of the sand from the beach to the sand bar results in a retreat of the shoreline. Each winter the waterline is observed to move as far landward as the lifeguard stand and during high wave events the uprush of water can extend into the beach vegetation (naupaka). One such event occurred in November of 1996, when large surf generated by a storm east of Hawaii caused the waterline to move as much as 100 feet landward. The beach widened to its previous condition over the following summer.

The winds are also a factor in sediment transport at Pyramid Rock Beach. The nearly direct onshore winds transport beach sand landward. Between the beach parking lot and the airport runway, a number of distinct dune lines can be seen (Figure 16). The dunes serve as a supply of sand that can gradually and naturally be released to the beach during periods of substantial, and usually temporary, beach loss. Dunes can also serve to protect landward property from flooding. Wind analysis and rough extrapolation from the present locations of the dune lines indicates that the dunes extended toward Pyramid Rock and once existed at the present location of the pavilion and parking lot. This conclusion is supported by the accumulation of sand in the parking lot.

The model hurricane approaching from the East to Southeast had maximum sustained wind speeds of 65 knots at the shoreline. The flooding potential was assessed and the associated wave inundation reached an elevation of +10.1 feet above Mean Sea Level (MSL), corresponding to a distance of 108 feet from the shoreline. The location of the transect can be seen in Figure 16. The direction of approach and local topography suggests that the run-up will be approximately the same in the vicinity of the parking lot. The associated flooding is expected to extend as far as the vegetation, but not endanger the parking lot.

There is a distinct escarpment between the beach and parking lot, an indication that the parking lot was constructed of crushed coral and gravel. The naupaka at the back of the beach is growing mostly in the sand but also is growing into the fill material that makes up the parking lot. The naupaka serves to stabilize the sediment and prevent erosion.

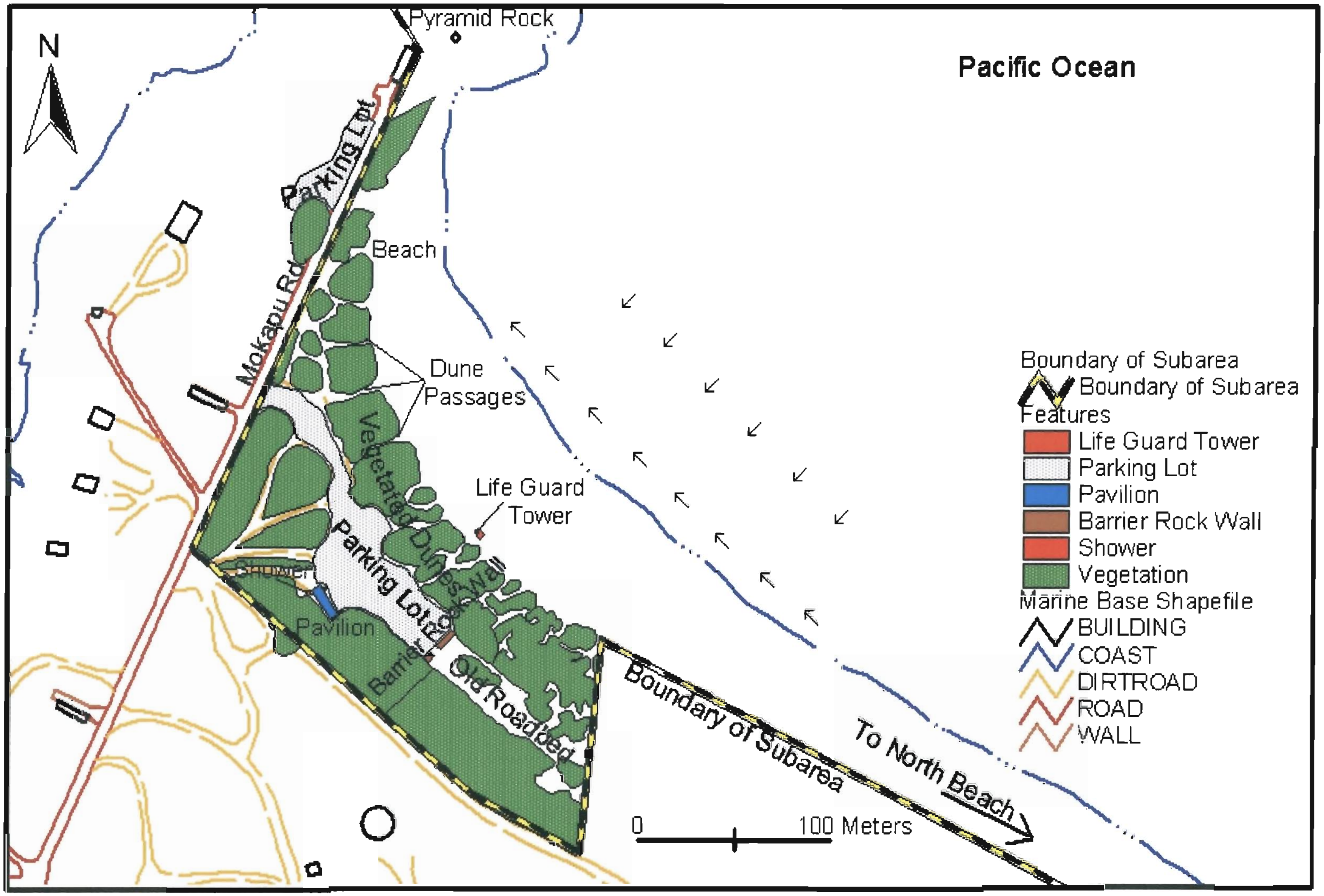


Figure 14. Pyramid Rock Recreational Subarea. Figure illustrates direction of coastal sediment transport under summer wave conditions.

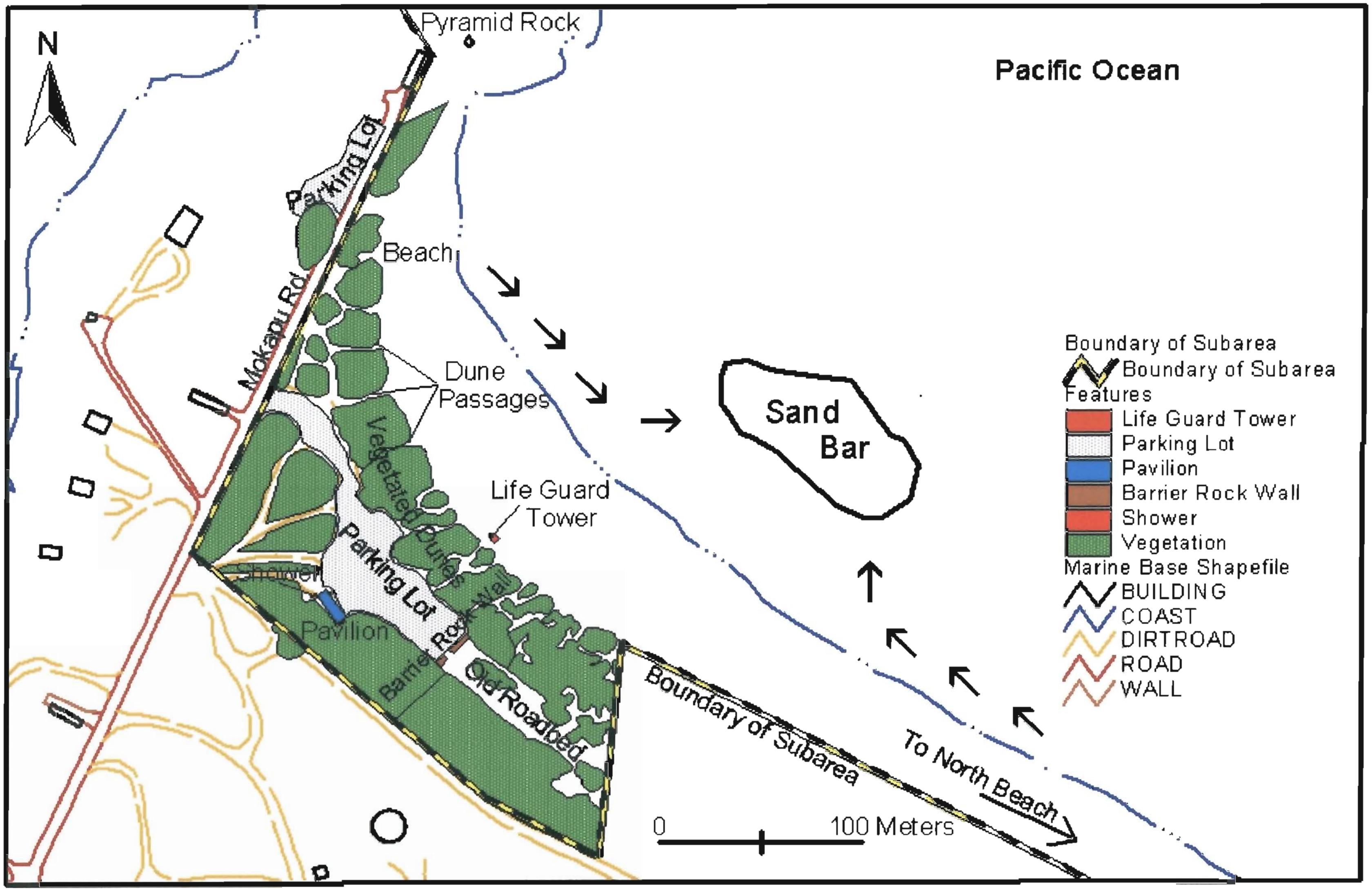


Figure 15. Pyramid Rock Recreational Subarea. Figure illustrates direction of coastal sediment transport under winter wave conditions. Note location of seasonal sand bar.

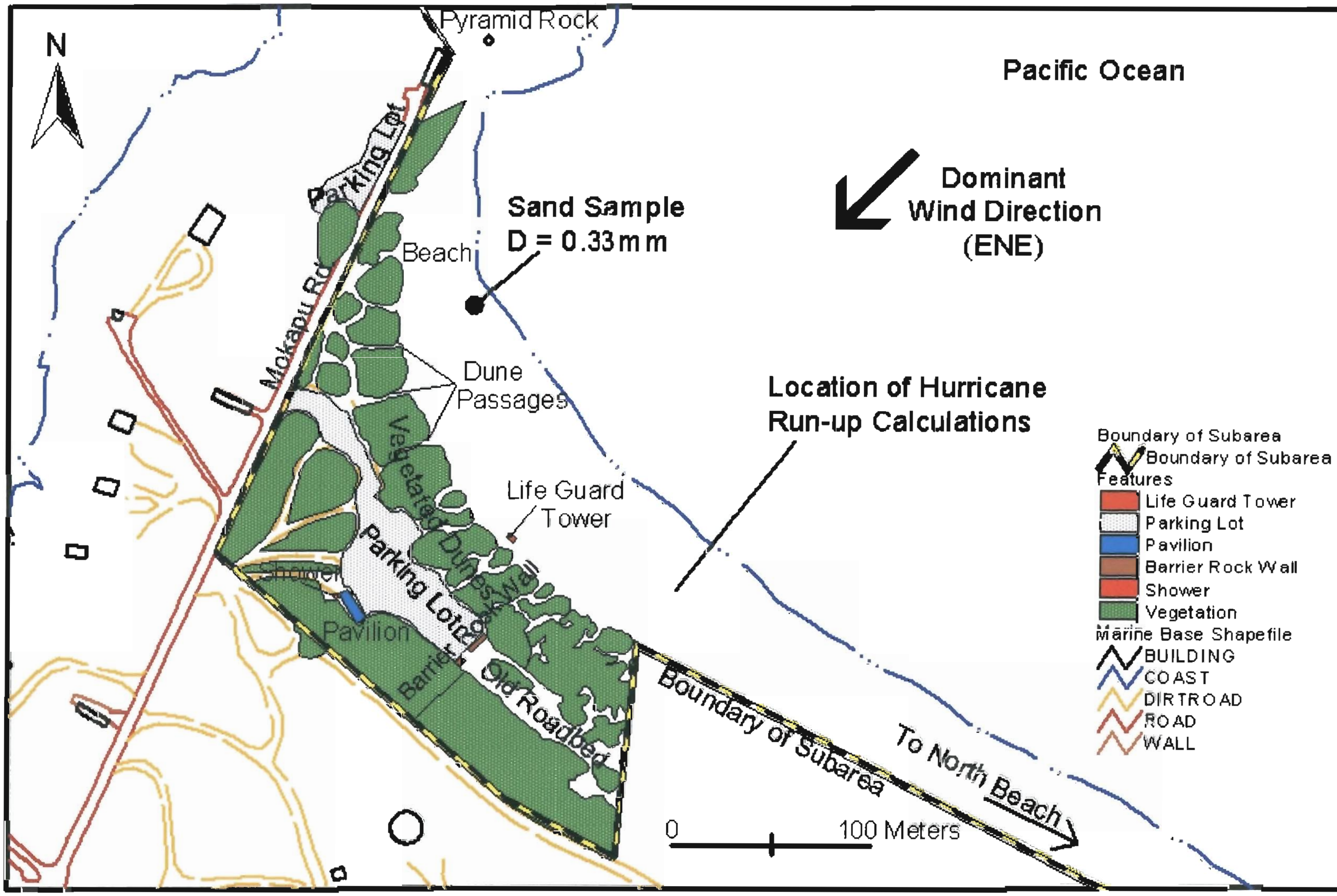


Figure 16. Pyramid Rock Recreational Subarea. Figure illustrates direction of dominant wind direction (ENE) and location of the hurricane run-up transect as calculated from model studies.

Fort Hase Beach

There are fewer sources of observations at Fort Hase Beach compared with Pyramid Rock Beach. Since the beach has no lifeguards and fewer regular users, less is known about the beach dynamics. The beach faces southeast and is bordered on the north by rocky headlands. The transition from sand to vegetation is marked by a distinct escarpment that is approximately 18 inches high (46cm). The face of the escarpment appears to contain a mixture of coarse coral chunks, shells, and soil. The historical development of this region is unknown, making it difficult to explain the composition of the ground. The 1927 aerial photo is inconclusive as to the extent of the dune system at that time.

The beach presently varies in width to about 30 feet at MSL. The sand is well sorted with median grain size of 0.86 mm, placing it in the coarse sand range of the Wentworth scale (Shore Protection Manual, 1984). The coarseness of the sand compared with the sand at Pyramid Rock Beach suggests that Fort Hase Beach is a higher energy beach, which is not the case. Fort Hase Beach receives significantly less wave energy than Pyramid Rock Beach, but the reef is very near the shoreline and the particles undergo less weathering before reaching the beach.

The sediment transport pattern is not obvious from observing the beach. Aerial photographs, wind, and wave analysis indicate that there is a small amount of transport to the north, near the archaeological site. Transport is mostly a function of tradewind waves rather than north or south swell, since the swell would have to undergo considerable refraction before reaching the site. The nearshore bathymetry is very complex making simple wave analysis difficult.

Fort Hase Beach is more vulnerable when a hurricane approaches from the south-southwesterly (SSW) direction. The model hurricane approaching from SSW has sustained winds of 65 knots at the shoreline. The transect location is shown in Figure 15. The estimated wave run-up reached an elevation of 5.5 feet above MSL and an inundation of 243 feet. The wave run-up may be different in the vicinity of the archaeological site due to the steep rocky headlands on which the site is located. A rise of 4.9 feet in the still water level with wave run-up beyond that level can be expected.

RECOMMENDATIONS

Pyramid Rock Beach is a system in dynamic equilibrium. Although extensive beach loss may occur during the winter months, the beach subsequently accretes during the summer to its approximate previous width. The erosion of concern is along the seaward limit of the parking lot and is caused by vehicle and foot traffic and rain runoff. Erosion factors are shore-based and stabilization of the vegetation line is essential. Erosion solutions should be directed toward the causes, but with foresight to implement those solutions with the understanding that there are ocean-based hazards (e.g., hurricanes) that can affect their success. Hardening of the vegetation line is discouraged, since this solution should be considered only in the case of impending disaster.

There are two erosion concerns at Fort Hase Beach. The first is adjacent to the northern extent of the beach, where a site of archaeological significance has been discovered. The site consists of rocky headlands, up to 2-3 feet above MSL, with another few feet of soil on top. The archaeological find is in the soil, so the entire upper layer needs protection. High wave events will directly threaten this site, so immediate action is recommended. The most direct method of protection is a rock revetment extending laterally from the northern extent of the parking lot/pavilion southward to the beach. An alternative solution involves protecting the site with geotextiles and stabilizing plants like beach naupaka. This solution is environmentally friendly, but it will be longer before maximum protection is accomplished. Even as the naupaka becomes established it is not likely to provide adequate protection during large wave events.

CONCLUSIONS

Library and field studies have been completed to determine the sources and possible environmentally responsible solutions to coastal erosion problems at Pyramid Rock and Fort Hase beach recreation areas at the Marine Corps Base Hawaii, Kaneohe, Oahu. These studies included an examination of previous coastal erosion studies both in Hawaii and on the mainland, as well as interviews with knowledgeable authorities at both sites, for their insight into causes and potential solutions to the erosion problems. Lack of porous surfacing material on the parking lots has been identified as a primary culprit in the erosion problem at both beach parks. Water falling on the parking lots tends to sheet flow across the lots and into the pathways to the shore. Furthermore, inadequately directed runoff from the shower facility at Pyramid Rock beach park also leads to erosion of the coastal dunes and vegetation. Lack of directional guidance to the runoff between the parking lots and the beaches has encouraged the creation of multiple pathways across the coastal dunes and vegetation to the shore. These pathways increase the introduction of alien species and exacerbate erosion due to destruction of the stabilizing beach vegetation (naupaka).

To counter these largely man-made erosion problems, we have recommended the following:

1. The parking lots at both beaches should be surfaced with a porous, non-compacting material such as crushed rock or gravel that will eliminate or significantly reduce sheet flow.

2. The shower facility at Pyramid Rock Beach should be moved to an existing lower level (Figure 16) there, its waste water can be controlled and recycled for use in irrigating landscaping in the vicinity.

3. Passageways to the beach from the parking lots should be limited to 3 or 4 at each site.

4. The remaining multiple walkways should be temporarily barricaded with educational signage so that re-vegetation of these excess walkways can be initiated.

5. The designated walkways should incorporate the use of surface mounted recycled plastic timbers and clearly marked signs to educate the public and emphasize the importance of protecting the coastal vegetation, sand dunes, and beaches.

In implementing these recommendations, attention must be given to the hydrographic conditions described for each site. The effects of climatic and hydrographic conditions such as high winds, rain, salt spray, sand transport, tides, wave run-up, storm surf, and hurricane and tsunami inundation should be taken into consideration when designing the supporting and anchoring mechanisms for the educational signs and pathways at each site.

The only permanent solution for protecting the exposed archaeological site at Fort Hase Beach would likely be the construction of a rock revetment parallel to shore from north of the site and extending southward to the beginning of the beach side of the site. Non-structural methods for the protection of the site are limited and not likely to be permanent, long-term solutions. However, modest maintenance may make these non-structural methods feasible. For example, the use of geotextile materials or sand bags placed in front of the escarpment with a modest amount of back fill materials, sufficient to support the growth of naupaka or other known, hearty, native coastal plant species, could likely stabilize the escarpment under all but extreme wave or storm conditions.

Necessary background data have been gathered and assembled to develop an application for a Federal Coastal Zone Management Consistency Determination. This information is included in Appendix B1 and B2.

Examples of signage content and materials have been gathered and are included in Appendix C for reference.

REFERENCES

Boyles, R., 1993. *The Economics of Managing Coastal Erosion.* Coastal Zone '93: Proceedings of the Eighth Annual Symposium on Coastal and Ocean Management. New Orleans, Louisiana, pp. 791-798.

Caldwell, Patrick, 2000. Personal communications.

Coyne, M., R. Mullane, C. Fletcher, and B. Richmond, 1996, *Losing Oahu: Erosion on the Hawaiian Coast.* Geotimes, vol. 41, no. 12, pp. 23-26.

Fletcher, C.H., 1992. *Sea-Level Trends and Physical Consequences: Application to the U.S. Shore.* Earth-Science Reviews, vol. 33, pp. 73-109.

Fletcher, C., R. Mullane, M. Coyne, 1996. *Coastal Erosion Management in the State of Hawaii: Executive Summary* - Volume 1. Honolulu: Department of Land and Natural Resources. Draft.

Good, J. W., 1992. *Ocean Shore Protection and Practices in Oregon*, pp. 156-162, In J.W. Good and S.S. Ridlington (eds.) Coastal Natural Hazards: Science, Engineering, and Public Policy. Corvallis Oregon: Sea Grant College Program.

Hawaii Department of Land and Natural Resources, Coastal Lands Program, 1998. Coastal Erosion Management Plan (COEMAP). Honolulu: School of Ocean and Earth Science and Technology, University of Hawaii.

Hildreth, R.G, 1992. *Recent Legal Development in Coastal Natural Hazard Policy*, pp. 121-126, In J.W. Good and S.S. Ridlington (eds.) Coastal Natural Hazards: Science, Engineering, and Public Policy. Corvallis Oregon: Sea Grant College Program.

Homer, P.S., 1964. *Characteristics of Deep Water Waves in Oahu Area for a Typical Year.* Prepared for the Board of Harbor Commissioners, State of Hawaii. Contract No. 5772. Marine Advisors, La Jolla, CA.

Loomis, H. G., 1976. *Tsunami Wave Runup Heights in Hawaii.* HIG-76-5, Hawaii Institute of Geophysics, University of Hawaii, Honolulu.

Lowry, K., 1989. *Coastal Area Management: A Hawaii Case Study, pp. 103-115.* In, T.E. Chua and D. Pauly (eds.) Coastal Area Management in Southeast Asia: Policies, management strategies and Case Studies. ICLARM Conference Proceedings 19. Manila: International Center for Living and Aquatic Resources Management.

MacDonald, C. D. and M. Markrich, 1992. *Hawaii's Ocean Recreation Industry: Economic Growth (1981-1995) and Management Considerations*, pp. 371-377, In MTS '92 Proceedings, Washington, D.C.: Marine Technology Society.

Marra, J. J., 1993. *Sand Management Planning in Oregon*. Coastal Zone '93: Proceedings of the Eighth Annual Symposium on Coastal and Ocean Management, New Orleans, Louisiana, pp. 1913 -

Merlin, M., 1999. *Hawaiian Coastal Plants: An Illustrated Field Guide*. Honolulu: Pacific Guide Books.

Mullane, R., 2000. Personal Communication on the use of gravel and coral cover materials, from Sea Grant Coastal Processes Extension Agent, Maui Community College.

National Research Council, 1990. *Managing Coastal Erosion*. Washington, D.C.: National Academy of Science.

Platt, R.H., T. Beatley, and H.C. Miller, 1991. *The Folly at Folly Beach and Other Failings of U.S. Coastal Erosion Policy*. Environment, vol. 33, no. 9, pp. 6-32.

Sea Engineering, Inc., 1990. *Windward Oahu Vulnerability Study*. Prepared for the State of Hawaii Department of Defense.

Shore Protection Manual, 1984. U.S. Army Waterways Experiment Station, Vicksburg, Mississippi.

St. Denis, M., 1974. *Hawaii's Floating City Development Program: the winds, currents, and waves at the site of the floating city off Waikiki*. UNIHI-SEAGRANT-CR-75-01, Sea Grant College Program, University of Hawaii, Honolulu.

Stutts, A.T., C.D. Siderlis, and S.M. Rogers, 1985. *Effect of Ocean Setback Standards on Location of Permanent Structures*. Coastal Zone '85: Proceedings of the Fourth Annual Symposium on Coastal and Ocean Management.

Titus, J. G., 1999. *Rising Seas, Coastal Erosion, and the Takings Clause*. Coastlines, issue 9.6, December, 1999 pp. 1-5.

University of Hawaii, Sea Grant Extension Service, 1997. *Beach Management Plan for Maui*. Sea Grant College Program, University of Hawaii, Honolulu.

Wil Chee Planning, 1997. Outdoor Recreational Management Plan, Marine Corps Base Hawaii, Kaneohe Bay, Oahu, Hawaii, Draft. Honolulu: Wil Chee Planning, Inc. pp. 18-29.

APPENDIX A

PHOTOGRAPHS OF

FORT HASE RECREATIONAL AREA
AND
PYRAMID ROCK RECREATIONAL SUBAREA

Photo 1. Picnic Pavillion at Fort Hase Beach Recreational Area. Note archaeological excavation in eroded dune bank in center of photo. Exposed volcanics and coral rubble are shown in foreground.

Photo 2. Rocky shoreline and small pocket beach at north side of Fort Hase Beach Recreational Area just seaward of the Picnic Pavillion shown above.

Photo 3. Fort Hase Beach Recreational Area. Exposed reef and rocky shoreline at northern limit of the beach park.

Photo 4. Fort Hase Beach Recreational Area. Tide pools just seaward of the picnic pavilion and exposed archaeological site. Note rocky substratum. Photo taken at moderately low tide.

Photo 5. Fort Hase Beach Recreational Subarea. Dune erosional escarpment near picnic pavilion showing proliferation of beach morning glory *Ipomoea pes-caprae*.

Photo 6. Fort Hase Beach Recreational Subarea. Dune erosion in the vicinity of the exposed archaeological site. Area is subject to foot traffic from beach park visitors as they walk from the parking area to the shoreline.

Photos 7. Fort Hase Beach Recreational Subarea. Wide sand beach lying south of the rocky headlands to the north. Note steep beach scarp somewhat protected by coastal vegetation. Scarp likely reflects the upper reach of storm waves. Note also the buildings on the previous dune reservoir area.

Photo 8. Fort Hase Beach Recreational Subarea. See above caption.

Photo 9. Fort Hase Beach Recreational Subarea. Beach Naupaka (right) and Australian Saltbush (middle and left). Demonstration of healthy revegetation of backshore dune area when foot and car traffic is controlled.

Photo 10. Pyramid Rock Recreational Subarea. Vigorous stand of beach Naupaka and akiaki grass in the foreground covering the back beach dune area.

Photo 11. Pyramid Rock Recreational Subarea. Note sand beach between upper dune and shoreline. Substantial growth of beach Naupaka in the foreground. "Pyramid Rock" is shown in the distance.

Photo 12. Concrete barricades to minimize (prevent) vehicle access to the beach at Pyramid Rock Recreational Subarea. Note movement of barrier toward beach and presence of sand blown into the parking area from the beach path.

Photo 13. View of parking lot and path to beach through Naupaka at the Pyramid Rock Recreational Subarea. Note barely visible concrete barrier on the left that defines the seaward edge of the parking lot. Note also the quantity and depth of sand blown onto the parking lot. Vehicles are frequently stuck in this sand.

Photo 14. One of many pathways to the beach at Pyramid Rock Recreational Subarea. Note the split to two paths in the center of the photo. The presence of wind blown sand at the edge of the parking area is also visible in the foreground.

Photo 15. The shower at Pyramid Rock Recreational Subarea. Note the lack of a designated drainage channel. Water flows from the concrete shower pad across the coral limestone parking lot causing the development of eroded drainage swales across the parking area and through the upper beach dunes.

Photo 16. Erosion of pathway to the beach from the parking lot at Pyramid Rock Recreational Subarea. Note depth of gully.

Photo 17. Pyramid Rock Recreation Subarea. Note severe erosion along beach access path from parking lot. Path is subject to runoff from the parking lot during heavy rains as well as chronic flows from the shower.

APPENDIX B1

HAWAII COASTAL ZONE MANAGEMENT PROGRAM
ASSESSMENT FORMAT

RECREATIONAL RESOURCES

Objective: Provide coastal recreational activities accessible to the public.

Policies:

(1) Improve coordination and funding of coastal recreation planning and management.

(2) Provide adequate, accessible and diverse recreational opportunities in the coastal management area by:

  (a) Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;

  (b) Requiring replacement of coastal resources having significant recreational value, including, but not limited to surfing site and sandy beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;

  (c) Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;

  (d) Encouraging expanded public recreational use of County, State, and Federally owned or controlled shoreline lands having recreational value;

  (e) Adopting water quality standards and regulating non-point sources of pollution to protect and where feasible, restore the recreational value of coastal waters;

  Developing new shoreline recreational opportunities, where appropriate, such as artificial reefs of surfing and fishing;

  (g) Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the State Land Use Commission, Board of Land and Natural Resources, county planning commissions; and crediting such dedication against the requirements of section 46-6.

Check either 'Yes' or 'No" for each of the following questions.	Yes	No
1) Will the proposed Action involve or be near a dedicated public right-of-way?	X	
2) Does the project site abut the shoreline?	X	
3) Is the project near a State or County park?		X
4) Is the project site near a perennial stream?	X	
5) Will the proposed action occur in or affect a surf site?		X
6) Will the proposed project occur in or affect a popular fishing area?	X	
7) Will the proposed action occur in or affect a recreational boating area?		X
8) Is the project site near a sandy beach?	X	
9) Are there swimming or other recreational uses in the area?	X	

DISCUSSION:

This project involves two public recreational beaches, Fort Hase and Pyramid Rock beach parks, located at the U.S. Marine Base, Kaneohe, Oahu, Hawaii. Ft. Hase beach park is located at the eastern edge of the Mokapu peninsula at the western edge of Kailua Bay. Pyramid Rock is on the northern edge of the Marine Base, near the western side of the peninsula (Figure 1). Two basic problems are present at these two sites. Archaeological remains have been identified and are currently being mapped at the northeast corner of the Fort Hase Beach Park (Anderson, 2000). These remains consist of shell, coral, and charcoal fragments in a shore side berm. This berm is just inland from a rocky coastline and is subject to erosion from high surf and is also just seaward of a public recreational picnic shelter, hence it receives considerable foot traffic from park users going to and from the shoreline. The second public recreational park site is at Pyramid Rock beach. In this case, a comparison of historical data (1927 aerial photography) with present aerial photographs shows major loss of an extensive sand dune habitat due to airport runway development and road and parking lot construction. Erosion at this beach park is exacerbated by uncontrolled foot traffic across the existing dunes and its vegetation and the frequent presence of off-road vehicles (albeit in most cases illegally), and the absence of shoreline dunes. The latter formerly had served as sand reservoirs, particularly at Pyramid Rock Beach, to offset occasional periods of beach erosion. The project seeks to identify erosion mitigation measures that will protect the archaeological site at Ft. Hase Beach Park and to eliminate the multiple random sites of erosion caused by foot traffic through the remaining dunes by establishing a few, well marked and educationally focused trails to the shore. Recreational activities at both sites include the usual sunbathing, swimming, shore fishing and some surfing, however, the coastal erosion mitigation and management actions under consideration will have no effects on the surf sites or other uses of the coastal waters.

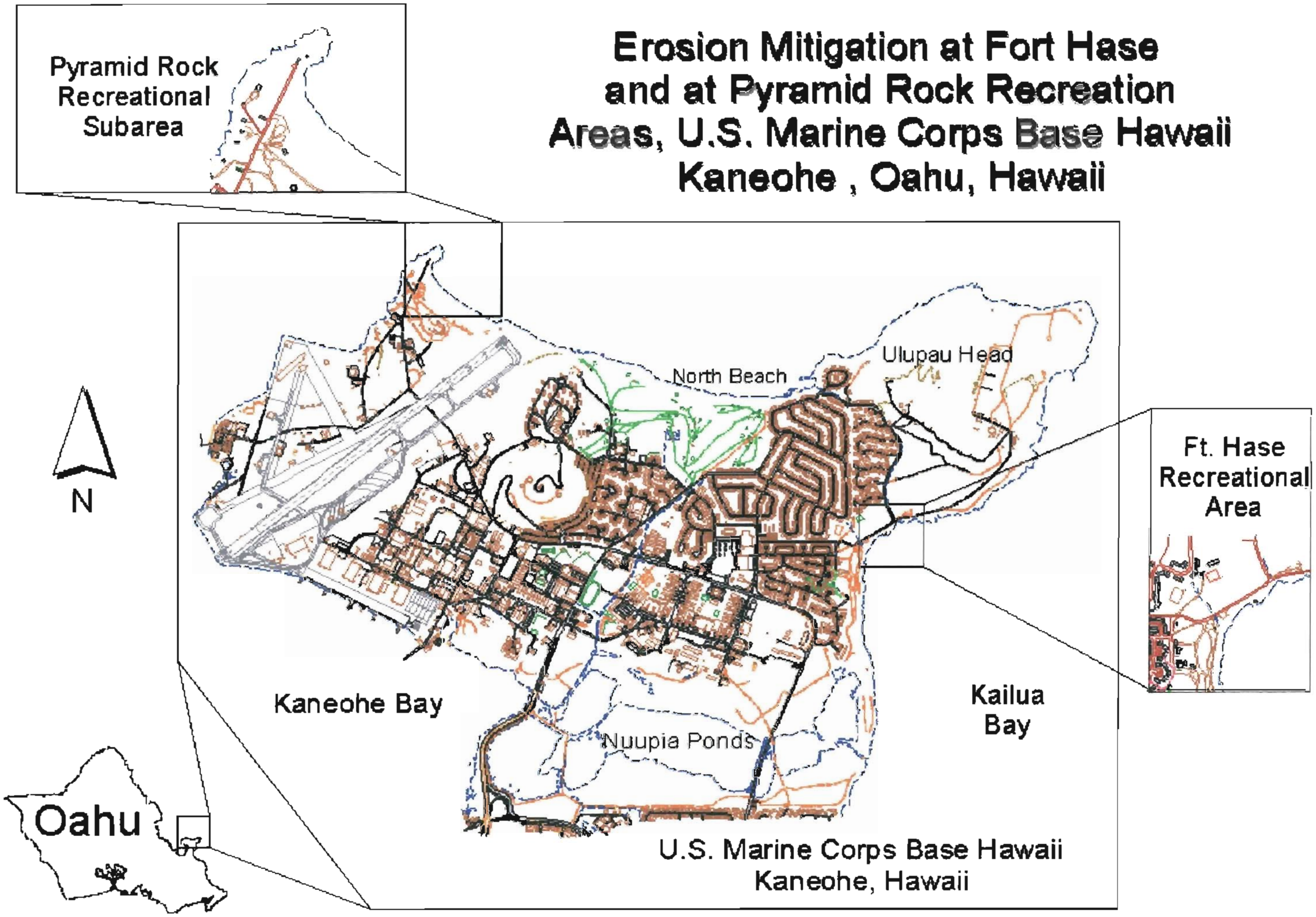


Figure 1. Island of Oahu, Hawaii and location of United States Marine Corps Base Hawaii, Kaneohe. Note location of erosion study sites: Pyramid Rock and Fort Hase Recreational Areas.

HISTORIC RESOURCES

Objective: Protect, preserve, and where desirable, restore those natural and man-made historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

Policies

(1) Identify and analyze significant archaeological resources;

(2) Maximize information retention through preservation of remains and artifacts or salvage operations;

(3) Support state goals for protection, restoration, interpretation, and display of historic resources.

Check either 'Yes' or `No' for each of the following questions.	Yes	No
1) Is the project within a historic/cultural district?		X
2) Is the project site listed or nominated to the Hawaii or National Register of Historic Places?	X(?)	
3) Does the project site include undeveloped land which has not been surveyed by an archaeologist?	X(?)	
4) Has a site survey revealed any information on historic or archaeological resources?	X	
5) Is the project site within or near a Hawaiian fishpond or historic settlement area?	X	

DISCUSSION:

Archaeological remains have been identified and are currently being mapped at the northeastern corner of the Fort Hase Beach Park (Anderson, 2000) (Figure 2). These remains consist of shell, coral, and charcoal fragments in an approximately 1 meter high, shore side escarpment. This escarpment is just inland from a rocky coastline and is subject to erosion from high surf and is also just seaward of a public recreational picnic shelter, hence it receives considerable foot traffic from park users going to and from the shoreline. Pyramid Rock Beach recreational parking lots are located within the Archaeological Zone 1 area and the Fort Hase Beach parking lots are designated as a Historic Property.

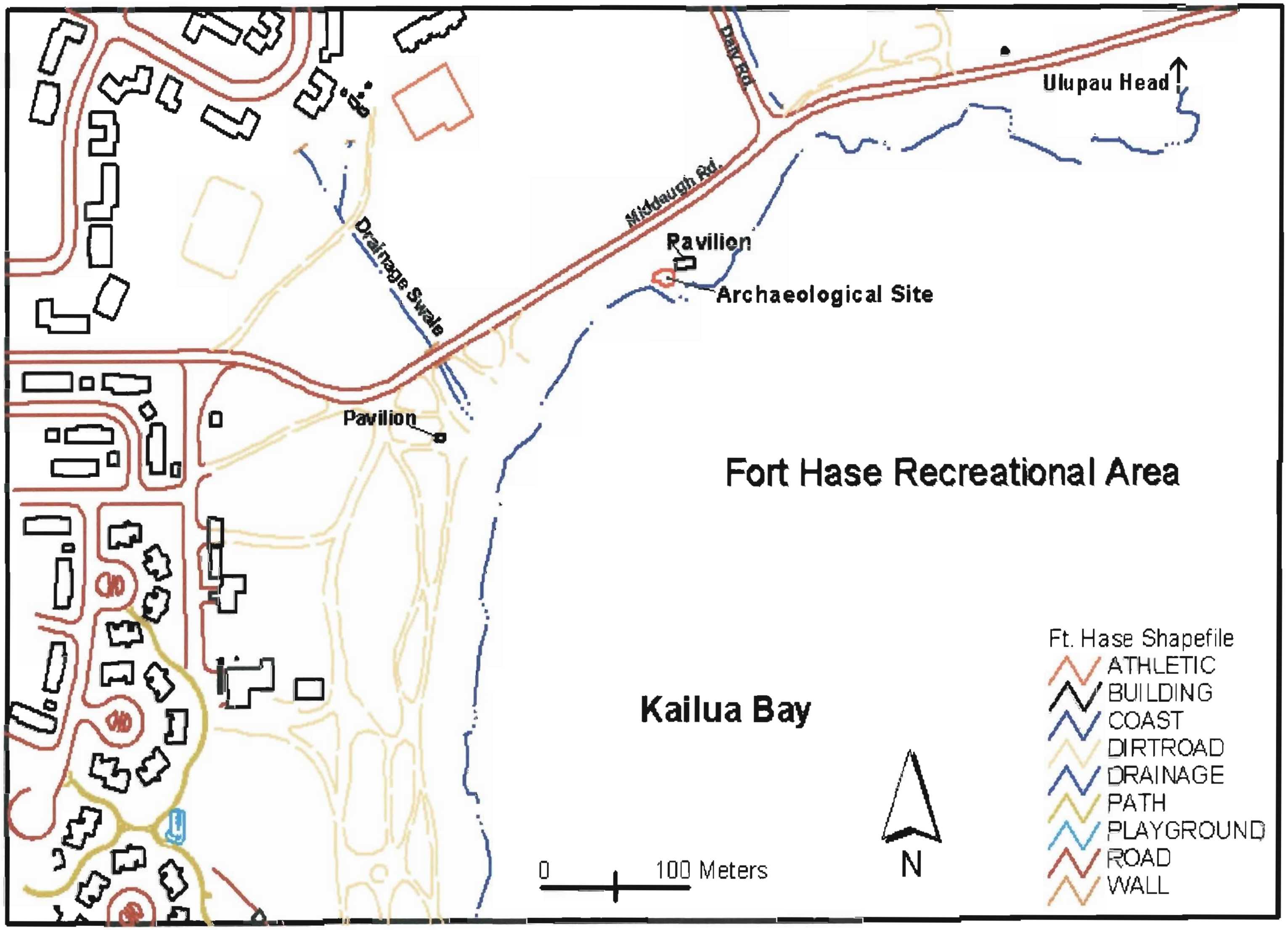


Figure 2. Fort Hase Beach Recreational Area. Note drainage swale and proximity of archaeological site to picnic pavilion.

SCENIC AND OPEN SPACE RESOURCES

Objective: Protect, preserve, and where desirable, restore or improve the quality of coastal scenic and open space resources.

Policies

(1) Identify valued scenic resources in the coastal zone management area;

(2) Ensure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of the natural landforms and existing public views to and along the shoreline;

(3) Preserve, maintain and, where desirable, improve and restore shoreline open space and scenic resources;

(4) Encourage those developments which are not coastal dependent to locate in inland areas.

Check either 'Yes' or "No' for each of the following questions.	Yes	No
1) Does the project site abut a scenic landmark?		X
2) Does the proposed action involve the construction of a multi-story structure or structures?		X
3) Is the project adjacent to undeveloped parcels?	X	
4) Does the proposed action involve construction of structures visible between the nearest coastal roadway and the shoreline?	X	
5) Will the proposed action involve construction in or on waters seaward of the shoreline?		X

DISCUSSION:

As can be seen in Figure 1, the project will involve two beach parks that could be considered part of the overall scenic area of the coastline of Mokapu peninsula. However, no major structural improvements are planned. The only activity proposed between the road and the beach will be the construction of modest, low level, walkways and educational signs or plaques to educate the public on taking care of the beach and dune resources. Areas adjacent to the beach park are, for the most part, left in open space and are only sparsely developed. Since both sites are fully controlled by the U.S. Marine Corps, residential construction near the sites is not likely.

ECONOMIC USES

Objective: Provide public or private facilities and improvements important to the state's economy in suitable locations.

Policies

(1) Concentrate in appropriate areas the location of coastal dependent development necessary to the State's economy.

(2) Ensure that coastal dependent development such as harbors and ports, visitor industry facilities, and energy generating facilities are located, designed and constructed to minimize adverse social, visual and environmental impacts in the coastal zone management area; and

(3) Direct the location and expansion of coastal dependent development to areas presently designated and used for such development and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:

- (a) Utilization of presently designed facilities is not feasible;
- (b) Adverse environmental effects are minimized; and
- (c) Important to the State's economy.

Check either 'Yes' or 'No' for each of the following questions.	Yes	No
1) Does the project involve a harbor or port?		X
2) Is the project site within a designated tourist destination area?		X
3) Does the project site include lands used/designated for agriculture?		X
4) Does the proposed activity relate to commercial fishing or seafood production?		X
5) Does the proposed activity relate to energy production?		X
6) Does the proposed activity relate to seabed mining?		X

DISCUSSION:

No commercial or other economic uses are proposed or planned for these two sites. They are recreational beach sites and are not used for commercial fishing, seafood production, energy, or mining.

COASTAL ECOSYSTEMS

Objective: Protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems.

Policies:

(1) Improve the technical basis for natural resources management;

(2) Preserve valuable coastal ecosystems of significant biological or economic importance;

(3) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land and water uses, recognizing competing needs; and

(4) Promote water quantity and quality planning and management practices which reflect the tolerance of fresh water and marine ecosystems and prohibit land and water uses which violate State water quality standards.

Check either 'Yes' or 'No' for each of the following questions.	Yes	No
1) Does the proposed action involve dredge or fill activities?		X
2) Is the project site within a Shoreline Setback Area?	X	
3) Will the proposed action require some form of effluent discharge into a body of water?		X
4) Will the proposed project require earthwork beyond clearing and grubbing?	X(?)	
5) Will the proposed action involve the construction of special waste treatment facilities, such as injection wells, discharge pipes or cesspools?		X
6) Is an intermittent or perennial stream located on or near the project site?	X	
7) Does the project site provide habitat of endangered species of plants, birds or mammals?	X	
8) Is any such habitat located nearby?	X	
9) Is there a wetland on the project site?		X
10) Is the project situated on or abutting a Natural Area Reserve?		X
11) Is the project site on or abutting a Marine Life Conservation District?	X	
12) Is the project situated on or abutting an estuary?		X

DISCUSSION:

The erosion mitigation plans being proposed for these two sites that both lie within the shoreline setback area will not involve any dredging activities. There may be a need to rearrange or add to the existing boulders that currently define the access roads, driveways and parking areas. To minimize runoff from the parking areas, it is anticipated that parking lots may be graded and leveled or surfaced with gravel to improve drainage. This excavation for the parking areas and possible rearrangement of the boulders is expected to be of minimal extent. Any significant parking lot grading or trenching for waterlines or wastewater discharges, and the planting of trees or shrubs, will be done under the supervision of a qualified archaeologist to assure that subsurface deposits are not jeopardized. Wildlife known to occur in and around the two beach parks includes occasional reports of sea turtles, monk seals, birds (see Appendix B2), mongoose and feral cats. A wide variety of plants occur in the Pyramid Rock area including a few indigenous and at least two endemic species. Naupaka *Scaevola taccada* and akiaki grass *Sporobolus virginicus* are the dominate species to stabilize the dunes. However, several alien species such as Chinese violet, *Asystasia gangetica,* Indian pluchea, *Pluchea indica (carolinensis*?), Pig weed *Portulaca oleracea* and swollen finger grass, *Cloris barbata*, are becoming well established on the dunes and are competing with the akiaki grass. A complete list of the coastal dune ecosystem plants identified in the Pyramid Rock Beach area and at Fort Hase is given in Tables 1 and 2. One of the areas of concern for these areas is the control or management of rainwater runoff and in the case of Pyramid Rock, drainage from an outside shower stall. This project will remediate the current drainage problems at the sites by recommending a gravel surface for the parking areas. This will encourage rainwater to percolate into the porous subsurface rather than running off the hard-packed surfaces as presently occurs in the parking areas. Drainage from the shower stall will be controlled both through moving the shower stall and its concrete foundation pad to a lower level and locating it in an existing swale where the runoff will be semi-contained and allowed to seep into the ground. No discharge to the coastal waters will be allowed. No injection wells or cesspools will be required. There is a small intermittent stream at Fort Hase but no perennial streams located in or near the sites and no estuaries. There are no Natural Area Reserves or Marine Life Conservation Districts adjacent to the two beach parks. The Nuupia Ponds wet lands are approximately 2.5 miles south of the two sites and neither the ponds nor their inhabitants will be affected by actions proposed to control erosion at the Ft. Hase or Pyramid Rock Beach Parks. A list of the birds, know to frequent the Marine Base, is attached for your information. While it is possible that some of the waterfowl may occasionally visit the areas being considered for erosion control, no evidence of nesting or feeding was directly observed. Given the vegetation and frequency of human activity in the dune and shore area, we would not expect this habitat to be particularly desirable to the water birds listed.

Table 1. Plants found at Pyramid Rock Recreational Subarea.
Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name,
plants that are endemic are noted with an (E), and alien species are noted with an (A).

Hawaiian	Common	Scientific
Pohuehue	Beach Morning Glory	*Ipomoea pes-caprae*
Hinahina	Beach Heliotrope	*Heliotropium anomalum*
Naupaka-Kahakai (I)	Beach Naupaka	*Scaevola taccada*
Pau-o-Hiiaka	Skirt of Hiiaka	*Jacquemontia sandwicensis*
Nehe		*Lipochaeta integrifolia*
Nama (E)	Hawaiian Nama	*Nama sandwicensis*
Niu	Coconut Palm	*Cocos nucifera*
Milo	Milo	*Thespesia populnea*
Alena		*Boerhavia spp.*
Waina Kahakai	Sea Grape	*Coccoloba uvifera*
	Indian Pluchea	*Pluchea indica (carolinensis?)*
	Chinese Violet (A)	*Asystasia gangetica*
Akulikuli-kai	Pickleweed	*Batis martima*
Nena, Kipukai, Hinahina	Seaside Heliotrope	*Heliotropium curassavicum*
	Australian Saltbush	*Atriplex semibaccata*
Ironwood Paina	Ironwood	*Casuarina spp.*
Kiawe	Mesquite	*Propopis pallida*
Koa Haole		*Leucaena leucocephala*
Aki'aki (I)	Grass	*Sporobolus virginicus*
	White-petaled (A) sunflower herb	*Bidens alba*
	Red flowered bean vine (NA)	*Canavalia sericea*
'Ilima (I)		*Sida fallax*
	small, low lying succulent, small red/purple fls. (A)	*Portulaca pilosa*
	Pig weed (A)	*Portulaca oleracea*
	Swollen finger grass (A)	*Cloris barbata*
Hau (?)		*Hibiscus tiliaceous*
	Lantana (A)	*Lantana camara*
'Akoko (E)		*Chamaesyce degeneri*
		Waltheria indica L.
	Yellow-petaled sunflower (A)	*Sonchus oleracea*
	goosefoot (not sure if this is native or the alien weed? I think, on basis of leaf shape that it is C. oahuense, endemic goosefoot)	Chenopodium sp.
	(probably not B. repens, an indigenous species; maybe B. coccinea, an alien)	Boerhavia sp.

Table 2. Plants found at Fort Hase Recreational Area.
Plants indigenous to Hawaii are noted with an (I) after their Hawaiian name, plants that are endemic are noted with an (E), and alien species are noted with an (A).

Hawaiian	Common	Scientific
Ohelo kai (I)	Sea Berry	*Lycium sandwicense*
	American Mangrove (A)	*Rhizophora mangle*
	Tree Heliotrope (A)	*Tournefortia argentea*
Pohuehue (I)	Beach Morning Glory	*Ipomoea pes-caprae*
Hinahina (I)	Beach Heliotrope	*Heliotropium anomalum*
Naupaka-Kahakai (I)	Beach Naupaka	*Scaevola taccada*
Milo	Milo	*Thespesia populnea*
	Indian Pluchea (A)	*Pluchea indica (carolinensis?)*
	Chinese Violet (A)	*Asystasia gangetica*
Akulikuli-kai (A)	Pickleweed	*Batis martima*
Nena, Kipukai (I)	Seaside Heliotrope	*Heliotropium curassavicum*
	Australian Saltbush (A)	*Atriplex semibaccata*
Ironwood Paina (A)	Ironwood	*Casuarina spp.*
Kiawe (A)	Mesquite	*Propopis pallida*
Koa Haole (A)		*Leucaena leucocephala*
Aki'aki (I)	Grass	*Sporobolus virginicus*
	White-petaled (A) sunflower herb	*Bidens alba*
'Ilima (I)	Ilima	*Sida fallax*
	small, low lying succulent, small red/purple fls. (A)	*Portulaca pilosa*
Akulikuli kula (A)	Pig weed	*Portulaca oleracea*
Mauu lei (A)	Swollen finger grass	*Cloris barbata*
	Bunch grass	*Eleusine indica*
	(common weed)	*Desmanthus virgatus*

COASTAL HAZARDS

Objective: Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion and subsidence.

Policies

(1) Develop and communicate adequate information on storm wave, tsunami, erosion and subsidence hazard;
(2) Control development in areas subject to storm wave, tsunami, erosion and subsidence hazard;
(3) Ensure that developments comply with the requirements of the Federal Flood Insurance Program; and
(4) Prevent coastal flooding from inland projects.

Check either "Yes" or 'No' for each of the following questions.	Yes	No
1) Is the project abutting a sandy beach?	X	
2) Is the project within a potential tsunami inundation area as depicted on the National Flood Insurance Program flood hazard	X	
3) Is the project within a potential flood inundation area according to a flood hazard map?	X	
4) Is the project within a potential subsidence hazard area according to a subsidence hazard map?		X
5) Has the project site or nearby shoreline areas experienced shoreline erosion?	X?	

DISCUSSION:

With the minor exception of a small rocky reef area at the eastern edge of Ft. Hase Beach Park, the two sites are characterized by sand beaches. The Fort Hase Beach site and a portion of the Pyramid Rock Beach site are within the 100 year flood zone. Both sites are within the tsunami hazard area as identified by the Flood Insurance Rate Map and the Marine Corps Air Station (MCAS) Kaneohe Bay Master Plan (May 1993). While both sites are in the tsunami inundation zone the Hawaii Tsunami Warning System provides fully adequate warning time for any distantly generated tsunamis to assure full evacuation of hazardous areas. Locally generated tsunamis do pose some risk. However, public education efforts by both the state and military focus on alerting beach users to seek high ground immediately in the event of any noticeable ground movement (earthquake). Such a prompt response should be sufficient to avoid significant harm. The area is not in any historically documented subsidence zone. According to a comparison of historical aerial photographs taken in 1927 with current aerial photographs taken January 30, 2000, there has been little net change in either beach area.

MANAGING DEVELOPMENT

Objective: Improve the development and review process, communication, and public participation in the management of coastal resources and hazards.

Policies

(1) Effectively utilize and implement existing law to the maximum extent possible in managing present and future coastal zone development;

(2) Facilitate timely processing of applications for permits and resolve conflicting permit requirements; and

(3) Communicate the short- and long-term impacts of proposed significant coastal developments early in their life cycle in terms understandable to the general public to facilitate public participation in the planning and review process.

Check either 'Yes' or 'No" for each of the following questions.	Yes	No
1) Will the proposed activity require more than two (2) permits or approvals?	X(?)	
2) Does the proposed activity conform with the State and County land use designations of the site?	X(?)	
3) Has or will the public be notified of the proposed activity?	X	
4) Has a draft or final environmental impact statement or an environmental assessment been prepared?		X

DISCUSSION:

The proposed activity will require a Conservation District Use Permit from the Department of Land and Natural Resources and may require a Shoreline Management Area permit from the City and County of Honolulu. Because the land in question is under federal control by the Military, jurisdiction of state or county authorities may not be recognized. Maintenance and renovation of recreational areas, including non-structural erosion control measures to stabilize shorelines, conforms with State and County land use designations for the sites. The public will be notified of the proposed activity through publication of permit applications in the Environmental Notice issued by the Office of Environmental Quality Control. Public notification will also take place through the regular state public notice section of *Midweek Magazine.* A request for Categorical Exclusion from the preparation of an Environmental Assessment was compiled and submitted by Lance Bookless on February 5, 1997.

FEDERAL CONSISTENCY
SUPPLEMENTAL INFORMATION

Date:

Project/Activity Title or Description:

Location: Kaneohe Marine Corps Base, Kaneohe, Island of Oahu

Tax Map Key No.
Other applicable area(s), if appropriate:
Estimated Start Date: **Estimated Duration:**

APPLICANT

Name and Title:

Agency/Organization:

Address:

Telephone No. during Business Hours:

AGENT
Name and Title:
Agency/Organization:
Address:
Telephone No. during Business Hours:

CATEGORY OF APPLICATION (check only one)

[X] 1. Federal Activity III. OCS Plan Permit
II. Permit or License IV. Grants & Assistance

TYPE OF STATEMENT (check only one)

[X] Consistency
General Consistency (Category I only)
Negative Determination (Category I only)
Non-Consistency (Category I only)

APPROVING FEDERAL AGENCY (Categories 11, III and IV only)
Agency:
Contact Person:
Telephone Number during Business Hours:

FEDERAL AUTHORITY FOR ACTIVITY
National Coastal Zone Management Act of 1972, 15 CFR Part 930

OTHER STATE AND COUNTY APPROVALS REQUIRED

Agency	Type of Approval	Date of Application	Status

APPENDIX B2

ANNOTATED LIST OF BIRDS RECORDED AT MARINE CORPS AIR STATION, KANEOHE BAY 1947 to 1992

(except those for which specific management will occur)

Reformatted for the Erosion Study by
Jacquelin N. Miller
May 31, 2000

Reference taken from Appendicies to the Fish and Wildlife Management Plan, for the Marine Corps Station, Kaneohe Bay, Oahu, Hawaii, updated by Mark J. Rauzon, vol. 2, December 1992.

LIST OF BIRDS RECORDED AT MARINE CORPS AIR STATION, KANEOHE BAY

Albatross, Laysan
Booby, Brown
Booby, Red-footed*
Brant
Bufflehead
Bulbul, Red-vented
Cardinal, Northern
Cardinal, Red-crested
Cockatiel
Coot, American *
Curlew, Bristle-thighed
Dove, Rock
Dove, Spotted
Dove, Zebra (Barred)
Dowitcher spp.
Duck, "Hawaiian" *
Dunlin
Egret, Cattle
Egret, Snowy
Falcon, Peregrine
Finch, House
Finch, Orange Weaver
Frigatebird, Great
Gallinule, Common *
Goose, Canada
Gull, Franklin's
Gull, Laughing
Gull, Ring-billed
Heron, Black-crowned Night
Heron, Great Blue
Heron, Little Blue
Leiothrix, Red-billed
Mallard
Mannikin, Nutmeg
Merganser, Hooded
Mockingbird, Northern
Myna, Common
Noddy, Black
Noddy, Brown
Osprey
Owl, Barn
Owl, Short-eared
Pheasant, Ring-necked
Pintail
Plover, American Golden
Plover, Black-bellied
Plover, Pacific Golden
Plover, Semipalmated
Quail, California
Sanderling
Scaup, Greater
Scaup, Lesser
Shama
Shearwater, Wedge-tailed
Shoveler, Northern
Silverbill, Warbling
Skylark
Snipe, Common
Sparrow, House
Sparrow, Java
Stilt, Black-necked *
Tattler, Wandering
Teal, Green-winged
Tern, Caspian
Tern, Great Crested
Tern, Least
Tern, Sooty
Tern, White
Tropicbird, Red-tailed
Tropicbird, White-tailed
Turnstone, Ruddy
Whimbrel
White-eye, Japanese
Wigeon, American
Willet
Yellowlegs, Greater
Yellowlegs, Lesser

*Subject to specific management plans by the Marine Corps Air Station

ANNOTATED LIST OF BIRDS RECORDED AT MCAS, KANEOHE BAY

Albatross, Laysan (Diomedea immutablis)
Laysan albatross have expanded into the Main Hawaiian Islands in recent years. They appeared on the station around 1985 and have been seen annually since then. In 1991 at least eight pairs nested on the station near the runways. The military air command considers Albatrosses to be a hazard to aircraft consequently the eggs were removed and the birds encouraged to keep [sic]. Four birds were impounded by game wardens in 1990. Unfortunately 2 birds were killed in 1991 with minimal legal repercussions. Albatross have also been seen in the Ulupau Wildlife Management Area (WMA) and should be allowed to nest here. A minimal number should be allowed to nest. This will increase the educational value of the WMA and the number of birds in the air around the WMA would not increase significantly.

Booby, Brown (Sula leucogaster)
This species nests on nearby Moku Manu (Richardson and Fisher 1950), and roosts on the sea cliffs at Ulupa'u Head. Christmas counts at Ulupa'u Head (not including Moku Manu) have varied from 0 to 20 normally, but 60 were seen 22 December 1957 (CC). Up to 6 birds at a time are frequently observed feeding in Nu'upia Ponds, and the occasional bird roosts on one of the artificial islands there.

Booby, Red-footed (Sula sula rubripes)
Abundant on the sea cliffs at Ulupa'u Head.

Brant (Branta bernicla)
There are three records of the pacific coast brant (B.b. nigricians) for the station. Single birds occurred 26 December 1949 (CC), 22 November 1969 (Donaghho 1969), and 12 December 1975 to at least 15 January 1976 (CC and 'E field notes). One brant was recorded by DLNR during the winter count of 1986 in Nu'upia 'Ekolu and one on the Christmas Count in 1987 (R. L. Walker, pers. comm.).

Bufflehead (Bucephala albeola)
A single bufflehead seen on 26 December 1966 has been joined by another sighting on 14 January 1977 (DLNR).

Bulbul, Red-vented (Pyucnonotus cafer)
This introduced species has been spreading on Oahu particularly on the windward shore (Shallenberger 1981), a pattern clearly shown by counts at MCAS, Kaneohe Bay (Table A2-6). The species was first recorded at the Station in 1977 when 8 birds were seen (CC). Since 1983, counts have averaged 43 birds per count.

Cardinal, Northern (Cardinalis cardinalis)
This cardinal has been found on all but two Christmas Counts (Table A2-6). An unusually high count of 76 birds was recorded at the Station in 1955, but most counts have been less than 20 birds. The recent (1983-91) average is 5 birds per count.

Cardinal, Red crested (<u>Paroaria coronata</u>)
Christmas Count totals suggest a recent increase in this species may have occurred at MCAS, Kaneohe Bay (Table A2-6). Although four counts exceeded 20 birds prior to 1979, most totals were below 10 (overall average 8 birds/count). From 1983 to 1991 counts averaged 22 birds per count, a decrease from the last report.

Cockatiel (<u>Nymphicus hollandicus</u>)
Cockatiels are found on all islands of the state as escaped or released caged birds. They are rather infrequently seen in the wild and are not known to have established a breeding population, to date.

Coot, American (<u>Fulica americana alai</u>)
The American or Hawaiian Coot is an endemic race in Hawaii and occurs on all major islands. It is listed on the federal and state list of Endangered and Threatened Species. They are fairly common in fresh and brackish water habitats and, in particular, are frequent occupants of the Nu'upia ponds at the MCBH. Special management plans are in place at the MCBH to assist in the protection and maintenance of suitable habitats for these endangered birds.

Curlew, Bristle-thighed (<u>Numenius tahitiensis</u>)
This species is uncommon to rare in the main Hawaiian Islands in winter. A single bird has been seen on MCAS, Kaneohe Bay; 24 October 1968 ('E 29:72) and again in 1991.

Dove, Rock (<u>Columba livia</u>)
Feral rock doves are apparently increasing in Hawaii. The first sighting at the station was of 3 birds 27 December 1977 (CC). Subsequently, flocks of 13 and 18 birds were recorded on 20 December 1981 and 19 December 1982 respectively (CC).

Dove, Spotted (<u>Streptopelia chinensis</u>)
This large introduced dove is particularly common in koa haole areas because they feed on seeds of that and other plants. Since they occur in and near the shrub forest, doves are difficult to count. On Christmas counts (1947 to 1982 counts varied from 0 to 95 (Table A2-5). Particularly careful counts have been conducted in recent years so more birds have been found; 1974-1982 average 43 birds per Christmas Count (Table A2-5). A high count of 53 was made in 1992.

Dove, Zebra (Barred) (<u>Geopelia striata</u>)
This small tame, introduced dove feeds on all kinds of seeds and may be found as scattered individuals or in small flocks depending on the availability of food. Christmas count totals 1947 to 1992 have varied from 4 to 209 birds (Table A2-5). The average is around 80 birds per count.

Dowitcher (<u>Limnodromus</u> spp.)
Long-billed and short-billed dowitchers are very difficult to tell apart in winter, so almost all records in Hawaii are simply referred to the genus. These large shorebirds are confined to shallow ponds and exposed tidal flats. Single dowitchers have been recorded at Nu'upia

Ponds 31 December 1961 (CC), 21 December 1980 (CC) and again on 21 December 1991 (CC).

Duck, "Hawaiian" (Anas wyvilliana)
The Koloa Maoli or Hawaiian Duck has been observed in the Nu'upia Ponds where special management programs have been implemented.

Dunlin (Erolia alpina)
Lone birds were present at Nu'upia Ponds on 17 December 1978 (CC) and 16 December 1979 (CC). The latter bird was still there in January 1990 (DLNR). Two more birds were seen on 16 December 1984.

Egret, Cattle (Bubulcus ibis)
This species was first introduced to Hawaii in 1959 (Breese 1959). Egrets spend the night in communal roosts from which they disperse widely to feed during the day. Nesting also occurs in the roost areas. The first roost discovered at MCAS, Kaneohe Bay was in 1960, and by 1977 the roost, located in the kiawe forest west of the waste water treatment plant, was described as the largest in Hawaii (Shallenberger 1977). To get an accurate count of egrets using a roost it is necessary to count the birds present during the middle of the afternoon (sometimes a difficult task at roosts where trees are very dense) and then simply tally all birds arriving from then until darkness, when the movement stops. Only a very small percentage of the birds using a roost are present during the day (most of these are nesting birds), so quick counts produce highly variable results (Table A2-2).

The populations of egrets using the roost near the water reclamation facility plant included at least 1000 birds by 1971, and CC totals 1976 through 1979 were consistently within 200 birds of the mean, 1105 birds. No estimate of the number of nests per year is available, but Shallenberger (1977) reported the area containing nests expanded annually from 1970 to 1977. Shallenberger (pers. comm.) estimated there was 200-250 active nests in the colony on 31 July 1980. The colony remained active until at least November 1981, but in spring 1982 the egrets had moved to a spot 200 yards west of Mokapu Gate in the kiawes south of Nu'upia 'Ekolu Pond. The roost remained there for at least several months, but in November 1982 birds apparently were no longer using this area, except as a "morning roost". About 175-200 birds used this area in January 1983 from just after sunrise to midmorning when they dispersed to feed (G. V. Byrd and R. J. Shallenberger, pers. comm.). Apparently a new overnight roost had formed west of the station at He'eia Marsh and all the egrets in the area seemed to be roosting there.

Cattle Egrets are considered pest species when they congregate on the airfields and as such, 160 have been removed in 1990 by Animal Damage Control specialists under contract to the Station.

Egret, Snowy (Leucophovx thula)
A bird carefully identified as this species was present at Nu'upia Ponds 6-31 March 1980 ('E 41:75). This was the first confirmed record for the species in Hawaii.

Falcon, Peregrine (Falco peregrinus)
Ulupa'u Head is one of the few locations in Hawaii where this species has been found; lone birds on 10 April 1966 ('E 26:112), 28 December 1968 (Donaghho 1969), and 15 January 1980 ('E 41.74).

Finch, House (Carpodacus mexicanus)
The House Finch is ubiquitous on all the main Hawaiian Islands and its range extends from sea level to alpine shrub. It is most common in developed areas, hence the name "House Finch". At MCBH they are commonly scene on grassy lawns and open fields.

Finch, 0range Weaver (Pyromelana franziscana)
Three individuals of this species was [sic] first seen on Station drinking from a puddle in the barracks parking lot north of Nu'upia Ponds on 21 December 1991. It is probably an escaped cage bird (R. Walker. pers. comm.).

Frigatebird, Great (Fregata minor)
Hundreds of frigatebirds roost on Moku Manu Islands (Richardson and Fisher 1950), and dozens of birds are frequently seen soaring over MCAS, Kaneohe Bay or drinking at Nu'upia Ponds. CC totals have ranged from one (several years) to 71 (17 December 1979), but 65% of the counts have recorded between 10 and 30 individuals. The relationship between frigates and boobies is well known, Kleptoparasitic behavior is frequently seen at the Ulupa'u Head booby colony, particularly during the chick-rearing period when boobies are returning to the colony with food for their young.

Gallinule, Common (Gallinula chloropus sandvicensis)
The Hawaiian Gallinule or 'Alae'ula, is another federally listed endangered species and is widely distributed on Oahu and Kauai. They are found in both fresh and brackish water ponds and prefer ponds with considerable weed and grass cover. At MCBH they are protected under special management plans that serve to protect and maintain appropriate habitats for them in Nu'upia ponds.

Goose, Canada (Brant canadensis)
This rare migrant has been seen twice at the station; a single small Canada goose (probably B.c. minima) in June 1980 (Olsen 1970), and 4 birds called "Lesser types" (probably B.c. taverneri) were seen 20 December 1981 (R. L. Walker, pers. comm. and CC).

Gull, Franklin's (Larus pipixcan)
Two birds seen 23 December 1975 were identified as this species (CC), and a lone bird observed 6 June to 12 July 1980 was either this or a laughing gull ('E 41:75).

Gull, Laughing (Larus atricilla)
The only definite laughing gulls recorded at MCAS, Kaneohe Bay were 2 subadults seen 13 April 1980 ('E 41:7) through at least 31 July 1980 (DLNR).

Gull, Ring billed (Larus delawarensis)
Lone birds have been recorded at Nu'upia Ponds in January 1974 (DLNR) and on 17 December 1978 (CC).

Heron, Black-crowned Night (Nycticorax nycticorax)
Night herons are the most widespread of the native Hawaiian waterbirds. They feed in all types of wetlands from small puddles to large ponds. Herons roost in shrub forests near Nu'upia Ponds, and Shallenberger (1977) found a few nests mixed with cattle egrets at their rookery. Shallenberger (1977) analyzed the heron counts for Nu'upia Ponds over the period 1947-1977 and detected an increase in the counts from less than 10 birds prior to 1968 to an average of about 30 birds during the latter period. The two peak counts were 101 and 72 birds (Table A2-2).

Heron, Great Blue (Ardea herodias)
On 19 December 1982, R.L. Walker (DLNR) observed one of these birds at the northeast corner of Nu'upia 'Elau Pond, and others saw the same bird during the next 5 days. There are very few records of this species in Hawaii.

Heron, Little Blue (Egretta caerulea)
Seen on the semi-annual waterbird count on 29 January 1992 in Halekou Pond, this bird is an occasional visitor to the islands.

Leiothrix, Red-billed (Leiothrix lutea)
At least 4 Leiothrixes' were seen at Ulupa'u Head in 1965 ('E 26-112), but the species is now very scarce on Oahu and probably does not occur at the station.

Mallard (Anas platyrhynchus)
Mallards apparently occur rarely as migrants in Hawaii, but semi-domestic and feral mallards, muscovys, Pekings, and hybrids between the three are present at several wetland areas on Oahu and the other islands. A review of the records of mallards for the station reveals only three records that involved wary, free-flying birds; singles in late July 1979 and January 1980 (DLNR counts), 2 birds 16 December 1979 (CC), and 4 birds seen 20 December 1981 (CC). The number of domestic and semi-domestic ducks at the station has probably varied over the past decade, but at the beginning of 1992 their distribution was as follows: water reclamation facility, 3 muskovy, 1 mallard, 1 hybrid; runoff sump south of the maintenance compound, 1 hybrid; and golf course water hazard, 4 muscovy and 1 mallard. Feral ducks pose a potential threat to native Hawaiian ducks because they are capable of interbreeding and polluting the gene pool of the endangered species. Feral and domestic ducks may also transmit diseases to Hawaiian ducks. One of the mallard/muscovy hybrids was incubating 14 eggs at the wastewater treatment plant on 28 January 1983, and several records of broods have been reported (D. Pang, pers. comm.).

Mannikin, Nutmeg (Lonchura punctulata)
Like house finch, flocks of this species move around looking for food. Despite the potential for variable counts, it appears there has been a reduction in this species since 1967 (Table, A2-6). The averages for counts prior to and after that year are 97 and 27 birds per count respectively. A number of unoccupied mannikin nests were found in koa haole at Ulupa'u Head 10 October 1965 (Frings 1966).

Merganser, Hooded (Lophodytes cucullatus)
Six birds were present at Nu'upia onds from 4 December 1976 to at least 6 March 1967 (DLNR).

Mockingbird, Northern (Mimus polyglottos)
This introduced songbird been seen at MCAS, Kaneohe Bay on 4 Christmas counts: 1 bird each 2 January 1966, 31 December 19671, and 20 December 1977, and 3 birds 24 December 1974). A lone bird was also seen 19 January 1983 (G.V. Byrd and R. J. Shallenberger pers. comm.).

Myna, Common (Acridotheres tristis)
Counts of this species have varied between 0 and 334 from 1947 to 1982 (Table A2-6). Totals suggest population highs may have occurred in the mid-1950's, mid-1960's, and 1977-1982. Nevertheless, these relatively high counts may actually reflect more thorough coverage of count areas rather than higher populations. Recent (1977-1982) counts have averaged 178 birds per count.

Noddy, Black (Anous tenuirostris)
Black noddies nest on Moku Manu and other offshore islets in the vicinity of Mokapu Peninsula. They may also nest on the sea-facing cliff of Ulupau Head. Birds are seen over Nu'upia Ponds, where they feed, most of the year. There is probably considerable, daily and seasonal variation in numbers of birds at the ponds. The peak count is 62 birds (1982, DLNR). The average of seven counts since 1978 is 30 birds ((DLNR, CC).

Noddy, Brown (Anous stolidus)
Like sooty terns, this species nests on Moku Manu. One or two birds have been reported over Nu'upia Ponds on four of 36 Christmas Counts from 1947 to 1982.

Osprey (Pandion haliaetus)
This rare vagrant to Hawaii (Pyle 1977) has been seen several times at KMCAS: 2 birds flying over Nu'upia ponds 20 November 1971 (Kaigier 1971), a single bird in the same area January through at least May 1977 (Shallenberger 1977), a [sic] perhaps the same bird seen near the Station in August 1977 and at the Station on 1 October 1977 ('E 38:102).

Owl, Barn (Tyto alba)
This introduced owl probably occurs occasionally at the station, but it is inconspicuous since it hunts at night. Thus it has not been recorded on Christmas Counts or DLNR counts.

Owl, Short-eared (Asio flammeus sandwichensis)
This indigenous owl has been recorded in only two Christmas Counts 26 December 1949 and 31 October 1967). Owls are relatively inconspicuous so it almost certainly occurs more regularly than the counts suggest.

Pheasant, Ring-necked (Phasianus colchicus)
This introduced species was raised in the game farm on Mokapu Peninsula until WWII. It is not known how many birds were released on the peninsula. The species was recorded on 6 of

8 Christmas Counts from 1954 to 1961, but it has not been recorded since. A few pheasants may yet survive on the Station, but numbers are probably so low that they are seldom seen.

Pintail (<u>Anas acuta</u>)
From 1947 through 1956 pintails were common wintering birds at Nu'upia Ponds (Table A2-1). In most of these winters approximately 50 to 250 ducks were present, but over 1000 pintails were found in 1947-1948, 1951-1952, and 1952-1953 (the 906 unidentified ducks counted 28 December 1952 were almost certainly pintails -- see Table A2-1). Abruptly in 1957 pintails stopped using Nu'upia Ponds, and no pintails were seen there again for 10 years. Since 1967 these ducks have occurred fairly regularly, but in very small numbers (Table A2-1).

Plover, Black-bellied (<u>Squatarola squatarola</u>)
This plover was first seen at Nu'upia Ponds in 1977; 15 and 26 January, February, 2 October, and 20 December CE 38:57, 38:102, CC) when up to three were present. Another bird was recorded 17 December 1978 (CC) and on l2 December 1987.

Plover, Pacific Golden (<u>Pluvialis fulva</u>)
Golden plovers breed in the arctic and a major segment of the pacific population winters in Hawaii and the South Pacific. A small population of non-breeding plovers remains in Hawaii throughout the summer, but the majority of wintering birds arrive during the last two weeks of August with apparent annual synchrony (Henshaw 1910, Johnson et al. 1981, Morita and Walker 1964). Spring departure peaks in late April and early May. A segment of the wintering population of plovers maintains feeding territories on short grass areas (e.g., lawns, golf courses, parade fields on the station) while others, which may not be able to obtain territories, form flocks (Johnson et al. 1981) which frequent wetlands (e.g., Nu'upia Ponds). Plovers may roost at night on roofs of buildings (Johnson and Nakamura 1981) or offshore islets (Johnson et al. 1981),

Plover, Semipalmated (<u>Charadrius semiplamatus</u>)
This rare migrant to Hawaii has occurred at least twice at Nu'upia Ponds; a lone bird seen 28 December 1969 (CC) and another in breeding plumage was seen on 5 May 1991.

Quail, California (<u>Lophortvx californicus</u>)
Ten birds seen 26 December 1964 are the only record of this introduced species at the station. Quail and pheasants were being released by DLNR personnel in the early 1960's and it is doubtful that quail now occur at the station.

Sanderling (<u>Calidris alba</u>)
Sanderlings are generally confined to pond edge and tidal flats. Counts of this species have generally increased since 1977, like tattlers (Table A2-3). Peak winter counts have been in the high 20's and low 30's, whereas no more than 6 birds have been found in summer (Table A2-3).

Scaup, Greater (<u>Aythia maritima</u>)
A lone male was identified 15 and 23 January 1979 ('E 40-15), the only record for the station.

Scaup, Lesser (Aythia affinis)
This scaup has been seen three times at Nu'upia Ponds; 26 December 1966 (CC), possibly the same bird 14 January 1977 (DLNR) and another individual in January 1977 (DLNR).

Shama (Copsychus malabaricus)
This songbird has been seen once on a Christmas Count or a DLNR census in 1985 and it has been occasionally observed in shrub forests on the Station (R. J. Shallenberger, pers. comm.).

Shearwater, Wedge-tailed (Puffinus pacificus chlororhynchus)
One individual was found caught in the wire fence around the Ulupa'u WWA and many were flying seen over the ocean around the WMA in the evening in May 1991. They nest on islands in Kailua Bay, on Moko Manu and could possibly nest on the outer cliffs of Ulupa'u Crater. Each year many juveniles have become disoriented and crash into lights on station. They are picked up by Game Wardens and transferred to Sea Life Park for rehabilitation and subsequent release. In 1990, 14 shearwaters were turned in.

Shoveler, Northern (Anas cylpeata)
The highest counts of shovelers at Nu'upia ponds occurred during the winter of 1947-1948 (Table A2-1) when pintail populations were also high. The species was not recorded again until 1963, and it has periodically occurred since in small numbers only.

Silverbill, Warbling (Lonchura malabarica (cantans))
This bird is known to be common on Hawaii and Maui and has been reported to occur at MCBH on Oahu.

Skylark (Alauda arvensis)
On 26 December 1952 (CC), two birds were seen on the Station, the only records for the area. This introduced species has declined on Oahu in the past 20 years.

Snipe, Common (Capella gallinago)
A single bird seen 26 December 1966 (CC) at Nu'upia Ponds is the only record for the station of this rare bird.

Sparrow, House (Passer domesticus)
Up to 108 sparrows have been counted at the Station, although the species was not found on several counts (Table A2-6). The average is 57 birds per count.

Sparrow, Java (Padda oryzivora)
This species is increasing on 0ahu and eight were first seen on Station on the 1986 Count. Since then, they have been every year and in 1991, 51 were recorded.

Stilt, Black-Necked (Himantopus mexicanus knudseni)
The Hawaiian Stilt is an endemic race found on all the main islands of Hawaii. It is also a federally listed endangered species. The Nu'upia ponds at MCBH are known to provide a major nesting habitat for these endangered species. This is another of the endangered waterbirds of Hawaii that are protected by special management plans at the MCBH to ensure proper maintenance of their habitats and nesting requirements.

Tattler, Wandering (Heteroscelus incanum)
Tattlers are found near Nu'upia Ponds, at the wastewater treatment plant, and on rocky shores of Mokapu Peninsula. The species is usually solitary or in pairs, but occasionally more than two are seen together especially just prior to and following migration periods (similar to golden plover). Although tattlers normally breed in the arctic and sub-arctic, a few non-breeders remain in Hawaii in summer. From 1941 to 1976 counts of tattlers at the station averaged 5 birds with a range of 0 to 9 birds per count. Since 1976 winter counts have averaged 13 birds with a high of 21 tattlers on 19 January 1977 (Table A2-3). It is unknown whether there has been a real increase in populations or if counts have been more complete in later years.

Teal, Green-winged (Anas crecca)
This teal is an uncommon winter visitor to Hawaii like the wigeon (Pyle 1977), and it has been reported three times at Nu'upia, all single birds; 16 December 1979 (CC), 7 January 1980 (DLNR), and 14 November 1982 (G.V. Byrd pers. comm.).

Tern, Caspian (Sterna caspia)
A single Caspian tern was seen from late summer 1979 through the winter until May 1980 at Nu'upia Ponds ('E 41:7, CC). Another sighting was recorded there in late December 1981 ('E 43:12, CC), and up to 2 birds were present in January 1983 (T. Burr pers. comm.).

Tern, Great Crested (Sterna bergii)
The first record of this bird in Hawaii was made at Nu'upia Eholu on 21 October 1988. This individual remained on Station for two Christmas counts and was last seen in December 1989. The nearest colony is on Motu Tabu at Christmas Island, Kiribati, Central Pacific Ocean, about 1800 miles south.

Tern, Least (Sterna albifrons)
First seen 27 December 1953 (CC) at the Station, the species was not recorded again until the 1970's; up to 4 birds 8 May to at least late, July 1973 ('E 35:18, DLNR), and 1 bird seen 10 September 1978 ('E 40:29).

Tern, Sooty (Sterna fuscata)
This species nests in large numbers on Mokumanu, and individuals are occasionally seen in flight over the station land around Ulupa'u Head.

Tern, White (Gygis alba)
This native seabird has become more common on Oahu in recent years, but few records for the station exist. One is a bird seen 26 July 1972 ('E 33:28-29) another white tern was seen flying over the ponds in April 1991.

Tropicbird, Red-tailed (Phaethon rubricauda)
This species nests only very locally in the main Hawaiian Islands (Shallenberger 1981) so occasional observations of this tropicbird at Ulupa'u Head (1 bird 24 December 1974, Christmas Bird Count-hereafter CC-; 3 birds 10 July 1976, 'Elepaio-hereafter 'E-37:45; and

one bird 11 June and three more 29 July 1978, 'E 39:61) are particularly interesting. On 27 April 1991, one was observed exploring the cliff face and landing. At least three were seen in courtship display repeated during April and May 1991. It is possible that the species nests in rock crevices on the sea slopes of Ulupa'u Head, at least in some years.

Tropicbird, White-tailed (<u>Phaethon lepturus</u>)
Two birds seen 16 December 1964 (CC) and one bird flying over Ulupa'u Head on 19 April 1991 are the only records of this species at the station.

Turnstone, Ruddy (<u>Arenaria interpres</u>)
Unlike tattlers, ruddy turnstones usually occur in flocks. They may be found on exposed tidal flats, at pond edges, on short-grass areas, along rocky shores and at the waste water treatment plant. Since turnstones occur in flocks and move around frequently, counts vary considerably (Table A2-3). Winter counts are highest, as only non-breeders remain in summer. The high winter count exceeded 250 birds, while the high summer count was nearly 60 birds (Table, A2-3).

Whimbrel (<u>Numenius phaeopus</u>)
A pale-rumped whimbrel, the characteristic of the asiatic subspecies N.p. variegatus, was observed on 14 November 1982 and 19 January 1983 near the AAV-created ponds north of Nu'upia 'Ekolu Pond (G.V. Byrd and R. J. Shallenberger pers. comm.).

White-eye, Japanese (<u>Zosterops japonicus</u>)
Counts of this species have exceeded 20 birds seven times, but less than 5 white-eyes were found 21 times. The recent (1983-91) average is 5.7 birds per count, much less than the average for previous years (25 birds per count). The apparent decrease may be a combination of less thorough coverage and a population decrease.

Wigeon, American (<u>Anas americana</u>)
This species is an uncommon winter visitor to Hawaii (Pyle 1977). Wigeons have been recorded at Nu'upia Ponds in 4 winters; 5 birds on 4 January 1956 (CC), 1 bird on 14 January 1967 (DLNR), up to 2 birds 31 December 1967 (CC) to 8 January 1968 (DLNR), and a lone bird 8 January 1968 (DLNR). A very unusual mid-summer record occurred in 1977 (DLNR).

Willet (<u>Catoptrophorus semipalmatus</u>)
The Willet present at Nu'upia Ponds 24 December 1974 was one of very few records of this species for Hawai'i.

Yellowlegs, Greater (<u>Totanus melanoleucus</u>)
A single record of this rare migrant from North America exists for the Station; a lone bird seen 22 December 1957 (CC).

Yellowlegs, Lesser (<u>Totanus flavipes</u>)
Two birds were seen at Nu'upia Ponds on 17 December 1978, the only record for the station.

APPENDIX C

WAYSIDE EXHIBIT FABRICATORS

National Association for Interpretation
Beaumont, Texas
1997

-Wayside Exhibit Fabricators-

Digital Printing

(as of September 1999)

VENDOR	SPECIFICATIONS	COSTS	COLOR PROOFS	WARRANTY	COMMENTS	RESISTANCE TO VANDALISM
Pannier Graphics Division 345 Oak Road Gibsonia, PA 15044-9805 800-544-8428 contact: Robin Heddaeus	• digitally printed fiberglass embedment (DIGI-FEG) panel • printer = inkjet	•average $35/sq foot •estimate **$300** for a 2' x 3' panel setup & fabrication	full-layout proof 50% of original size. first proof no charge. charge for additional proofs or changes to original layout.	5 years against fading (pro-rated replacement). 10 years against delaminating, chipping, & crazing.	pre-press layout & prep = $50/hr $150 minimal order also make custom order frames.	moderate
RhinoCore USA sales rep: Nancy Bedard 514-878-1320	• high pressure laminate resin panel • printer = inkjet	•average $46-48/sq foot •estimate **$383** for a 2' x 3' panel setup & fabrication	15" x 15" color panel proof @ $25 each.	5 years against fading, delaminating, discoloration, blistering, staining, cracking, or any other manufacturing degradation.	pre-press layout, typeset, scanning, etc. = $76/hr	moderate
Grand Visuals 7332 South Alton Way Bldg. #13, Ste. F Englewood, CO 80112 303-221-3860 contact: Tom Hicks	• fused PVC digital prints with UV inhibitor • printer = electrostatic	•average $37-49/sq foot •estimate **$558** for a 2' x 3' panel setup & fabrication	full-size color proof (cost included in the pre-press cost)	3 years against fading & delamination (25% reduction for fabrication of replacement panel) (this product has been field tested for 3 years. as it continues to hold up in the field, the warranty will be extended.)	pre-press layout, typeset, scanning, full-size color proof, etc. = average $300/panel	low

Technical data provided by the manufacturers
Tests completed in 1999 by:National Park Service, Long Distance Trails Group Office
<Contact: Andrea Sharon - met at Syracuse NIW99>
P.O Box 728, Santa Fe, NM 87504
505-988-6842; Andrea_Sharon@nps.gov

Interpretive Panel Media Comparisons

Four alternatives are compared for fabricating interpretive panels. All alternatives can be prepared from a digital file, provide potentially colorful output, and are warranted for at least 3 years against fading and manufacturer defects. The following comparison describes fiberglass embedment, fused PVC, porcelainized enamel, and Folia, analyzes their strengths and weaknesses, and ends with a summary.

Characteristic	Fiberglass Embedment	Fused PVC*	Porcelainized Enamel	Folia
Manufacture Process	A digital print (400 dpi) is made on special paper that is embeded between two fiberglass sheets providing weatherproof protection.	A 400 dpi digital print is made on an electrostatic carrier, inks are fused into a PVC sheet and the carrier removed. Panel is then covered with Lustex.	Special glass is mixed with colors and fused to sheet steel at high temperatures. Accepts color and b&w prints up to 200 dpi.	300 dpi digital ouput is bonded to weatherproof laminate and covered with a UV and graffiti protectant.
Fade Resistance	Some fade of browns and reds, some yellowing. Overall sun resistance is good. Fiberglass "sheds" over time and may cloud where impacted by blowing sand.	Less than 1% fade on all colors with UV exposure at 9,000 feet elevation. Surface does not appear to be affected by blowing sand.	No appreciable fade. Surface may be etched by blowing sand.	No appreciable fade (manufacturer's claim--not yet field-tested). Not yet tested in blowing sand.
Graffiti Removal	All paints and markers partially removed by appropriate solvents; however, clouding or coloring of surface likely to occur.	All paints and markers removed by appropriate solvents.	All paints and markers removed by appropriate solvents.	All paints and markers removed with alcohol.
Impact Resistance	May crack or shatter with heavy blows.	Accepts 100# hammer blow without cracking or shattering. Sharp object may crack unbacked panel in extreme cold, however, panel has been shot at .50• F without cracking or shattering.	Durable but enamel can crack and break away with heavy blows leaving metal to rust.	Accepts 100# hammer blow with minor dent in surface.
Gunshot Impact	Gunshort likely to crack or shatter and do damage to embedded artwork. Repair is difficult to conceal.	Gunshot will make hole that can be refilled with PTEX plastic and artwork touched up.	Gunshot will make bullet hole and expose metal to rust.	Gunshot will make bullet hole that can be refilled with plastic wood and artwork touched up. Not a permanent fix.
Cuts and Scratches	Highly visible but can be touched up with resin.	Difficult to detect. Repair generally not needed.	Difficult to scratch. Hardiness of glass, but can scratch with diamond ring.	Durable but can scratch through digital surface into laminate
Warranty	Three year warranty on fading and deterioration. Full replacement on manufacturer defects.	Three year warranty on fading and deterioration. Full replacement on manufacturer defects.	Three year warranty on fading and deterioration. Full replacement on manufacturer defects.	Ten-year warranty on fading and deterioration. Full replacement on manufacturer defects.
Cost	Comparable to fused PVC (but only if digitized image is used rather than silkscreened image).	Comparable to fiberglass embedment.	Four to eight times higher than others.	Comparable to fiberglass embedment.
Summary	Less vandal resistant, slow turnaround.	Low cost, more vandal resistant, quick turnaround.	Most vandal resistant, slow turnaround, expensive.	Durable, low cost, cross-border shipment from Canada, long warranty.

*Fused PVC as provided by Grand Visuals' of Denver was tested for this summary--other fabricators have used materials and fabrication processes that sometimes give less desirable end products, though they may still call it fused PVC.