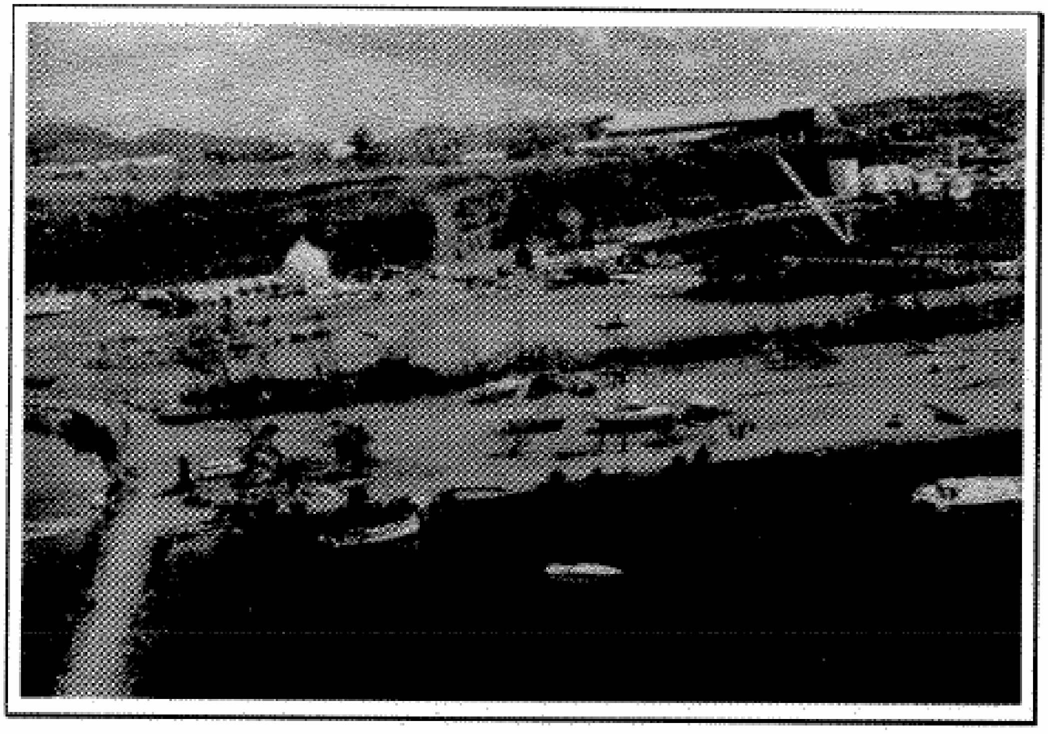
COASTAL HAZARD MITIGATION STUDY FOR ENERGY AND LIFELINE FACILITIES

STATE OF HAWAII



PREPARED FOR
STATE OF HAWAII
DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT
AND TOURISM

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U.S. ARMY CORPS
OF ENGINEERS
HONOLULU ENGINEER DISTRICT

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Cover Photograph:

Aerial photograph of fuel storage facilities in Nawiliwili Harbor on the island of Kauai after Hurricane Iniki struck the island on September 11, 1992. Wave action inside the harbor caused damages to several boats and mooring facilities and although no fuel storage facilities sustained any damages from coastal flooding, the photograph illustrates how a facility might be vulnerable to coastal flooding.

EXECUTIVE SUMMARY

This study was prepared under the authority of a Memorandum of Agreement dated 21 November 1994 between the U.S. Army Corps of Engineers, Honolulu Engineer District and the State of Hawaii, Department of Business, Economic Development and Tourism.

The study identifies potential flooding of energy systems and lifeline facilities in the State of Hawaii, identifies possible flood mitigation alternatives to reduce the vulnerability of those systems from coastal flooding associated with hurricanes and tsunamis, and proposes additional work to develop and implement those alternatives.

The Hawaiian energy systems evaluated include electrical utilities and the petroleum and gas industry. This study also focuses on protecting critical lifeline systems, such as telecommunications services, emergency services (fire, police and medical), wastewater and water utilities, and food distribution, which are heavily dependent on the energy systems.

Each of the facilities identified above can be afforded a certain level of protection from flooding damages. Consistent with National Flood Insurance Program objectives, all structural and non-structural impro'vement alternatives to protect vulnerable facilities would be evaluated for a 100-year level of protection. A short discussion of some of the possible protective measures is included in this study. Possible project alternatives will not be exactly the same for each facility; each facility will require detailed study based on facility location, flood elevation, base floor elevations, and specific operation impacts. Only then will flood wall or revetment heights, or other mitigation measures such as floodproofing be determined.

The key to successfully reducing risks of future damage to persons and property is mitigation. Although it may not be economically feasible to implement all of the recommendations from future studies, the proposals in this report should be used as a framework for opportunities to reduce the energy and critical lifeline facilities' vulnerability to the risks associated with flooding hazards. The following proposals are more fully discussed in the body of the report and should be implemented as soon as possible:

- **Provide hurricane coastal inundation maps for the entire State of Hawaii to identify flood prone areas for energy and critical facilities.**

- **Provide detailed plans for mitigating coastal flooding for energy and critical facilities in flood prone areas for the State of Hawaii.**

- **Repair the Kaumalapau Harbor Breakwater to improve fuel delivery to Lanai.**

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1 INTRODUCTION

1.1 Study Authority

This study was prepared under the authority of a Memorandum of Agreement dated 21 November 1994 between the U.S. Army Corps of Engineers, Honolulu Engineer District and the State of Hawaii, Department of Business, Economic Development and Tourism.

1.2 Purpose and Scope of Study

The purpose of this study is to identify potential flooding of energy systems and lifeline facilities in the State of Hawaii and to propose possible flood mitigation alternatives to reduce the vulnerability of those systems from coastal flooding associated with hurricanes and tsunamis.

The Hawaiian energy systems evaluated include electrical utilities and the petroleum and gas industry. This study also focuses on protecting critical lifeline systems, such as telecommunications services, emergency services (fire, police and medical), wastewater and water utilities, and food distribution, which are heavily dependent on the energy systems.

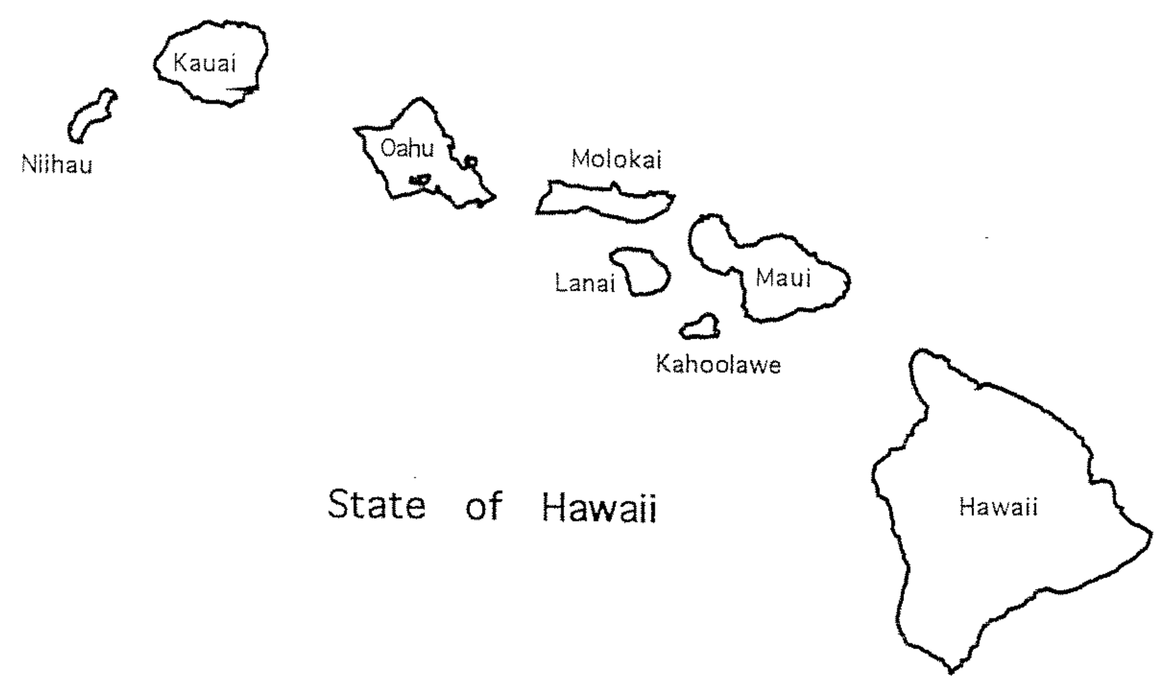
Under a separately funded study, the U.S. Department of Energy (DOE) developed hazard mitigation recommendations associated with natural disasters such as hurricanes (wind damage), earthquakes, and volcanic activity as well as all lifeline facilities.

1.3 Study Area

The Hawaiian Islands extend over 1,500 miles across the North Central Pacific Ocean and are part of a volcanic mountain range, most of which are submerged. The highest part of the range along the southeastern end of the chain forms the major populated islands of the State of Hawaii. The eight principal islands (Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niihau) encompass 6,425 square miles which accounts for more than 99 percent of the total land area of the State of Hawaii (Figure 1).

The population, economic, and government center of the State of Hawaii is located in the City of Honolulu on the island of Oahu.

The study area was limited to the six main inhabited Hawaiian Islands of Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai.



Hazard Mitigation Study
State of Hawaii

Figure 1
State of Hawaii

U.S. Army Corps of Engineers
Honolulu District

2 SELECTED NATURAL DISASTERS AFFECTING THE HAWAIIAN ISLANDS

2.1 Hurricanes

Hurricanes are infrequent sources of powerful winds and destructive waves which annually threaten and occasionally directly impact the Hawaiian Islands. The hurricane season in the northern hemisphere runs from June through November each year. While many hurricanes approach the islands annually, their paths (normally southeast to northwest) usually take them to the south of the island chain resulting in little more than high surf and heavy rainfall. The most damaging hurricanes to impact the Hawaiian Islands within the past four decades were Hurricane Dot in August 1959, Hurricane Iwa in November 1982, and Hurricane Iniki in September 1992. Hurricane Iwa and Iniki caused widespread flooding in coastal areas on the island of Kauai due to high water levels and high surf.

2.2 Tsunamis

The Hawaiian Islands have a long history of falling victim to destructive tsunamis. The earliest recording of a severe tsunami in the Hawaiian Islands was in 1837 when a tsunami with an elevation of 20 feet generated by an earthquake in Chile came ashore in the town of Hilo on the island of Hawaii killing 46 people. Since 1837, 16 tsunamis have reached the islands, many resulting in loss of life and significant property damage.

Most of the destructive tsunamis in the Hawaiian Islands have been generated along the coast of South America, the Aleutian Islands, and the Kamchatkan Peninsula. Approximately one fourth of all the tsunamis recorded in the Hawaiian Islands have originated along the coast of South America, while more than one half have originated in the Kuril-Kamchatka-Aleutian region of the north and northwest Pacific. The remaining tsunamis originated along the Philippine, New Hebrides, and Tonga-Kermadec arcs, or in seas adjacent to the Pacific Ocean. The most devastating tsunami in terms of loss of life and property was the Great Aleutian Tsunami of 1946, whose fifty-five foot waves killed 173 people and caused approximately $26 million in property damage in Hilo. The most recent tsunami in Hawaiian history occurred on November 29, 1975, when waves generated by an earthquake with an epicenter on the South Puna coast reached elevations as great as perhaps 26 feet along the southeastern coast.

Tsunamis generated by local seismic events have caused high wave runups in the islands, especially on the southeast coast of the island of Hawaii. The 1868 tsunami produced the largest waves of record in the Hawaiian Islands with 60-foot waves reported on the South Puna coast of the island of Hawaii .

3 HAWAIIAN ENERGY SYSTEMS INFRASTRUCTURE

The electrical utility, petroleum and gas industry, and lifeline systems are described in detail in the DOE Hazard Mitigation Study, and are briefly summarized below. The criteria used in selecting facilities for evaluation was their location with respect to the designated 100-year tsunami floodplain on the Flood Insurance Rate Map (FIRM) for all the islands. For Oahu and portions of Kauai, an additional criterion for selecting facilities for evaluation was their location with respect to hurricane evacuation zones derived from potential hurricane floodplains identified in recent Hurricane Vulnerability Studies. This additional step was incorporated because hurricane floodplains may extend beyond the tsunami floodplain. The Corps of Engineers prepared Hurricane Vulnerability Studies and identified hurricane floodplains and evacuation zones for the following areas:

Honolulu and Vicinity in 1985;
Windward Oahu in 1991;
Leeward Oahu in 1994;
Waimea and Kekaha, Kauai, 1986;
and Poipu and Vicinity, Kauai in 1986 and 1993.

In determining the coastal inundation limits for southern Oahu from Barbers Point to Koko Head, the general characteristics of four scenario hurricanes were used. The inundation limits determined in this study using hypothetical hurricanes were incorporated into the FIRM in September of 1987 for southern Oahu and labeled Zone A (Areas inundated by the 100-year flood; base flood elevations and flood hazard factors not determined). There is no frequency assigned to these hypothetical hurricanes. The tsunami flood events on the other hand, have been numerically derived based on historical records and are considered reasonable 100-year events. For this study, there was no comparison overlay made of the coastal inundation from hurricanes and the FIRM.

A follow-on to this Inundation Study was the "Enumeration of Dwelling Units, Population, Critical Facilities and Life lines Within the Coastal Inundation Limits For Southern Oahu" which was used to determine which critical facilities and lifelines are subject to non-function during a hurricane. The Windward and Leeward Coastal Inundation Limits Study used two scenario hurricanes--the worst model and the worst case-- to determine the most conservative/restrictive inundation limit. These lines were overlaid and compared with the FIRM. The Enumeration Study for the respective districts were used to provide an estimate of the number of dwelling units, population, critical facilities and lifelines which are located within the coastal floodplain of the study areas. Evacuation maps derived by the City and County of Honolulu were created using named streets and/or landmarks to the greatest extent possible to define flooding boundaries. These boundaries do not necessarily conform exactly to the FIRM or hurricane study boundaries. The critical facilities and lifelines located within the coastal inundation limits could become nonfunctional during a hurricane.

3.1 Electrical Utility System

The electrical utility systems on each of the Hawaiian Islands generate and distribute their own power requirements. There are no interconnections between islands, therefore, electrical systems on each island operate independently from each other.

The Hawaiian Electric Company, Inc. (HECO) is a subsidiary of Hawaiian Electric Industries, Inc. (HEI), a holding company. HECO operates the electrical system on the island of Oahu and has subsidiary utilities, the Hawaii Electric Light Company (HELCO) on the island of Hawaii, and the Maui Electric Company (MECO) on the island of Maui. MECO operates the Lanai Division on the island of Lanai, and the Molokai Division on Molokai. Citizens Utilities, Kauai Division, is the electrical company operating on the Island of Kauai. Citizen Utilities is a holding company headquartered in Connecticut, with divisions in Arizona, Idaho, Vermont, and Hawaii.

Many of the electrical system facilities are located along the coastal areas of the islands and are subject to damages from coastal flooding caused by hurricanes and tsunamis. The electrical facilities located within the proximity to the coastline were evaluated for potential flooding from the high water levels and large waves generated by hurricanes and tsunamis. Table 1 provides a list of the electrical facilities located within the coastal floodplain. Appendix A provides the locations and, where available, the associated 100-year coastal flood elevations for the electrical facilities within the coastal floodplain. The FIRM depicts the 100-year tsunami event except for southern Oahu and portions of Kauai. The lines are based on the hurricane coastal inundation limits based on hypothetical storms with no frequency assigned for southern Oahu. On Kauai, Hurricanes Iwa and Iniki data were used to employ the "joint probability method" which combined hurricane and tsunami data.

Table 1
Electrical Facilities Within Coastal Inundation Zone

Electrical Power Plants	**Location**
H-POWER Power Plant	Oahu
AES Coal Generation Plant	Oahu
Kahului Power Plant	Maui
Waiakea Power Plant	Hawaii
Electrical Substations	**Location**
Hawaiian Cement Substation	Oahu
AES Generator Transformer Substation	Oahu
Kakaako Substation	Oahu
Kewalo Substation	Oahu
Makaloa Substation	Oahu
McCully Substation	Oahu
Ena Substation	Oahu
Kuhio Substation	Oahu

3.2 Petroleum and Gas Industry Systems

Petroleum is the primary source of energy for the Hawaiian Islands. There are no natural resources of petroleum on any of the Hawaiian Islands, therefore, crude and refined oil product are imported. Crude oil is refined at two refineries, Chevron USA refinery and Tesoro refinery, both located at the Campbell Industrial Park on the island of Oahu. The refined oil products are piped to various users including the electrical utilities, the military, Honolulu International Airport, and Honolulu Harbor Terminal facilities. From those points, the products are stored, locally consumed, transshipped to the neighbor islands, or exported.

The majority of the storage terminals are located within the commercial harbor areas of all islands. The larger storage terminals are located in Honolulu Harbor, Honolulu International Airport, and Campbell Industrial Park areas on the island of Oahu. The Honolulu Harbor Terminals pass approximately 90-percent of the refined petroleum products within the State. Almost all of the deliveries of refined petroleum products to the neighbor island are off-loaded to barges at the Honolulu Harbor Terminals.

Although the terminals on the neighbor islands are relatively small, they play a vital role in the petroleum supply chain. Most of the neighbor islands have only one commercial harbor with terminal facilities except for the island of Hawaii and Kauai. Hawaii has two harbor and terminal facilities located at Hilo and Kawaihae. However, product is currently trucked across the island from Hilo rather than off-loaded at Kawaihae due to inadequate facilities. Kauai also has two harbor and terminal facilities located at Nawiliwili and Port Allen.

Kaumalapau Harbor, owned by the Lanai Company, is the only harbor on Lanai with petroleum off-loading and storage facilities. Although the terminal facilities are not subject to flooding from hurricanes or tsunamis, it should be noted that storm damage to the breakwater allows waves to enter the harbor during both storm and non-storm conditions and those conditions prevent the fuel barge from entering the harbor to off-load product. A separate study was initiated to investigate possible solutions to reducing the harbor surge and other efforts are underway to identify alternate delivery and off-loading procedures to ensure adequate fuel supply.

There are no natural gas sources nor natural gas production facilities in the Hawaiian Islands. However, the Chevron refinery and The Gas Company produce synthetic natural gas (SNG) and liquefied petroleum gases (LPG) on Oahu. SNG and LPG are also imported. SNG is mainly distributed by underground utility pipelines for residential and commercial customers for hot water and cooking. LPG is distributed to the neighbor islands by barge and mainly distributed on Oahu by trucks to pressure tanks. On the neighbor islands, LPG is primarily distributed by truck to stationary tanks at residences, however some residential customers are served by pipeline. Some of the gas storage facilities are collocated with the petroleum facilities within the harbor areas.

Like the electrical facilities, the petroleum and gas facilities are located along the coastal areas and are subject to coastal flooding from hurricanes and tsunamis. Table 2 provides the petroleum and gas facilities located within the coastal 100-year tsunami floodplain for all islands and the hurricane floodplain (Oahu and Kauai only). Appendix B provides the locations and, where available, associated 100-year coastal flood elevations for the petroleum and gas facilities within the coastal floodplain. Again, the FIRM depicts the 100-year tsunami event except for southern Oahu and portions of Kauai. The lines are based on the hurricane coastal inundation limits based on hypothetical storms with no frequency assigned for southern Oahu. On Kauai, Hurricanes Iwa and Iniki data were used to employ the "joint probability method" which combined hurricane and tsunami data.

Table 2
Petroleum and Gas Facilities Within Coastal Inundation Zone

Refinery	**Location**
Chevron USA Refinery	Oahu
Petroleum Storage and Terminal Facilities	
Hawaiian Electric Fuel Storage Facility	Oahu
Campbell Industrial Park Texaco Terminal	Oahu
Honolulu Airport Jet Fuel Storage Terminal	Oahu
Kahului Tesoro Terminal	Maui
Kahului Power Plant Fuel Storage Tanks	Maui
Kahului Chevron Terminal	Maui
Molokai Harbor Petroleum Storage Tanks	Molokai

3.3 Lifeline Systems

The lifeline systems were briefly investigated because of its importance to the services provided following a natural disaster, as well as being heavily dependent on the energy systems. The following lifeline facilities were evaluated for potential coastal flooding from hurricanes and tsunamis: telecommunications services, emergency services (fire, police and medical), wastewater and water utilities, and food distribution.

The lifeline facilities subject to coastal flooding from hurricanes and tsunamis are provided in Table 3. These facilities were determined to be within the coastal 100-year tsunami floodplain for all islands and the hurricane floodplain for Oahu and Kauai. Appendix C provides the locations and, where available, associated 100-year coastal flood elevations for the lifeline facilities within the coastal floodplain. Again, it should be noted the FIRM depicts the 100-year tsunami event except for southern Oahu and portions of Kauai. The lines are based on the hurricane coastal inundation limits based on hypothetical storms with no frequency assigned for southern Oahu. On Kauai, Hurricanes Iwa and Iniki data were used to employ the "joint probability method" which combined hurricane and tsunami data.

Table 3
Lifeline Facilities Within Coastal Inundation Zone

Communication Facilities	Location
Ewa Beach Hawaiian Telephone Office	Oahu
Waikiki Hawaiian Telephone Office	Oahu
Aina Haina Hawaiian Telephone Office	Oahu
Sunset Beach Hawaiian Telephone Office	Oahu
Waialua Hawaiian Telephone Office	Oahu
Fire and Police Stations	
Ewa Beach Fire Station	Oahu
Ala Moana Fire Station	Oahu
Kapahulu Fire Station	Oahu
Wailupe Fire Station	Oahu
Kaaawa Fire Station	Oahu
Hauula Fire Station	Oahu
Sunset Beach Fire Station	Oahu
Waialua Fire Station	Oahu
Waianae Fire Station	Oahu
Waianae Police Station	Oahu
Kihei Fire Station	Maui
Wastewater Facilities	
Iroquois Point Wastewater Treatment Plant	Oahu
Fort Kamehameha Wastewater Treatment Plant	Oahu
Sand Island Wastewater Treatment Plant	Oahu
Fort Armstrong Wastewater Pump Station	Oahu
Ala Moana Wastewater Pump Station	Oahu
Fort DeRussy Wastewater Pump Station	Oahu
Beach Walk Wastewater Pump Station	Oahu
Public Bath Wastewater Pump Station	Oahu
Waialae Kahala Wastewater Pump Station	Oahu
Niu Valley Wastewater Pump Station	Oahu
Kuliouou Wastewater Pump Station	Oahu
Heeia Wastewater Pump Station	Oahu
Kahanahou Wastewater Pump Station	Oahu
Waikalua Wastewater Pump Station	Oahu
Kaneohe Wastewater Treatment Plant	Oahu
Kaneohe Bay Wastewater Pump Station #2	Oahu

Table 3
Lifeline Facilities Within Coastal Inundation Zone
-continued-

Wastewater Facilities	**Location**
Kaneohe Bay Wastewater Pump Station #3	Oahu
Kaneohe Bay Wastewater Pump Station #4	Oahu
Waianae Wastewater Treatment Plant	Oahu
Hilo Wastewater Pump Station	Hawaii
Banyan Drive Wastewater Pump Station	Hawaii
Pua Wastewater Pump Station	Hawaii
Onekahakaha Wastewater Pump Station	Hawaii
Kolea Wastewater Pump Station	Hawaii
King Kamehameha Wastewater Pump Station	Hawaii
Emma Wastewater Pump Station	Hawaii
Kahaluu Wastewater Pump Station	Hawaii
Water Supply Facilities	
Wailupe Water Pump Station	Oahu
Punaluu Well I	Oahu
Pupukea Water Pump Station	Oahu
Lualualei Water Pump Station	Oahu
Nanakuli Water Pump Station	Oahu

4 GROUPING FACILITIES WITHIN THE COASTAL FLOODPLAIN

4.1 Facility Groupings

The neighbor island energy facilities located within the tsunami coastal flood inundation zone were identified using the most current Flood Insurance Rate Map (FIRM) published by the Federal Emergency Management Agency. The "model" hurricane used in the Hurricane Vulnerability Study prepared by the Corps of Engineers for the State of Hawaii (Honolulu and Vicinity, 1985; Windward Oahu, 1991; and Leeward Oahu, 1994) is assumed to be representative of a hurricane most likely to strike the Oahu facilities located within the hurricane inundation zone. For evaluation purposes, facilities were grouped by specific facility type based on proximity to the shoreline and whether the facilities would be subject to coastal velocity hazard. No distinction was made among the hurricane and tsunami floodplains in this regard since hurricane inundation exceeds tsunami inundation for some instances, especially along southern Oahu where most of the facilities are located. Using the methodology described above, projected flood heights associated with the 100-year tsunami and the "model" hurricane, coastal runups were calculated. Facility groupings for hurricane and tsunami evaluation to include flood height elevations in feet above mean sea level (msl) are provided in Table 4.

The energy systems were divided into eight groups based on facility type. These groups include electrical power plants, electrical substations, refineries, petroleum and gas terminals/storage, communication services, fire and police stations, wastewater and water pump stations, and wastewater treatment plants. Within each grouping, the facilities were subdivided based on proximity to the shoreline. The facilities were grouped into either VE or AE Zones. Facilities within the VE zone are subject to coastal flooding with velocity hazard and the base flood elevation determined within the special flood hazard areas inundated by the 100-year flood. Facilities within the AE zone are subject to flooding with base flood elevations determined within the special hazard inundated by the 100-year flood. The VE and AE zones were estimated for the facilities on the island of Oahu from the hurricane inundation maps. Table 4 provides the facility groupings.

Table 4
Energy Facility Groupings

Energy Facility	FEMA 100-Year Flood Elev (ft above msl)	Flood Zone Designation
Electrical Power Plants		
H-POWER Power Plant	7.6	AE
AES Coal Generation Plant	7.6	AE
Kahului Power Plant	19.0*	AE
Waiakea Power Plant	17.0	AE
Electrical Substations		
Hawaiian Cement Substation	7.6	AE
AES Generator Transformer Substation	7.6	AE
Kakaako Substation	4.5	AE
Kewalo Substation	6.7	AE
Makaloa Substation	7.4	AE
McCully Substation	7.2	AE
Ena Substation	7.2	AE
Kuhio Substation	6.7	AE
Refinery		
Chevron USA Refinery	8.7	VE

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Table 4
Energy Facility Groupings
-continued-

Petroleum and Gas Terminal/Storage	**FEMA 100-Year Flood Elev (ft above msl)**	**Flood Zone Designation**
Hawaiian Electric Fuel Storage Facility	8.7	AE
Campbell Industrial Park Texaco Terminal	7.6	AE
Honolulu Airport Jet Fuel Storage Terminal	5.5	AE
Kahului Tesoro Terminal	18.0	AE
Kahului Power Plant Fuel Storage Tanks	19.0	AE
Kahului Chevron Terminal	13.0	AE
Molokai Harbor Petroleum Storage Tanks	3.0	VE
Communication Facility		
Ewa Beach Hawaiian Telephone Office	5.7	AE
Waikiki Hawaiian Telephone Office	7.8	AE
Aina Haina Hawaiian Telephone Office	6.3	AE
Sunset Beach Hawaiian Telephone Office	16.0	AE
Waialua Hawaiian Telephone Office	12.0	AE
Fire and Police Station		
Ewa Beach Fire Station	5.7	AE
Ala Moana Fire Station	7.4	AE
Kapahulu Fire Station	7.7	AE
Wailupe Fire Station	7.3	AE
Kaaawa Fire Station	10.0	VE
Hauula Fire Station	10.0	VE
Sunset Beach Fire Station	18.0	AE
Waialua Fire Station	12.0	VE
Waianae Fire Station	9.2	AE
Waianae Police Station	12.0	VE
Kihei Fire Station	7.0	AE
Wastewater and Water Pump Station		
Fort Armstrong Wastewater Pump Station	6.7	AE
Ala Moana Wastewater Pump Station	7.4	AE
Fort DeRussy Wastewater Pump Station	6.9	AE
Beach Walk Wastewater Pump Station	6.7	AE
Public Bath Wastewater Pump Station	10.0	AE
Waialae Kahala Wastewater Pump Station	7.0	AE

Table 4
Energy Facility Groupings
-continued-

Wastewater and Water Pump Station	FEMA 100-Year Flood Elev (ft above msl)	Flood Zone Designation
Niu Valley Wastewater Pump Station	6.0	AE
Kuliouou Wastewater Pump Station	7.5	AE
Heeia Wastewater Pump Station	9.6	AE
Kahanahou Wastewater Pump Station	6.3	AE
Waikalua Wastewater Pump Station	8.0	AE
Kaneohe Wastewater Treatment Plant	8.0	AE
Kaneohe Bay Wastewater Pump Station #2	5.6	AE
Kaneohe Bay Wastewater Pump Station #3	5.6	AE
Kaneohe Bay Wastewater Pump Station #4	5.6	AE
Hilo Wastewater Pump Station	16.0	AE
Banyan Drive Wastewater Pump Station	11.0	AE
Pua Wastewater Pump Station	19.0	AE
Onekahakaha Wastewater Pump Station	14.0	AE
Kolea Wastewater Pump Station	20.0	AE
King Kamehameha Wastewater Pump Station	10.0	AE
Emma Wastewater Pump Station	9.0	AE
Kahaluu Wastewater Pump Station	12.0	AE
Wailupe Water Pump Station	8.3	AE
Punaluu Well I	7.4	AE
Pupukea Water Pump Station	18.0	AE
Lualualei Water Pump Station	14.0	VE
Nanakuli Water Pump Station	12.7	AE
Wastewater Treatment Plant		
Iroquois Point Wastewater Treatment Plant	5.2	AE
Fort Kamehameha Wastewater Treatment Plant	4.5	VE
Sand Island Wastewater Treatment Plant	5.9	AE
Waianae Wastewater Treatment Plant	14.0	AE

5 ALTERNATIVE HAZARD MITIGATION MEASURES

Each of the facilities identified above can be afforded a certain level of protection from flooding damages. Consistent with National Flood Insurance Program objectives, all structural and non-structural improvement alternatives would be evaluated for a 100-year level of protection. In the case of the relocation alternative this involves moving energy facilities outside of the base floodplain. Project alternatives will not be exactly the same for each facility; each facility will require detailed study based on facility location, flood elevation, base floor elevations, and specific operation impacts. Only then will flood wall or revetment heights, or other mitigation measures such as floodproofing be determined.

5.1 Structural Alternatives

The structural mitigation alternatives evaluated for VE zones facilities, those subject to a coastal velocity hazard, are provided below:

5.1.1 Rubblemound Revetment

A rubblemound revetment is flexible facing of quarrystone armor and underlayers placed on a sloping shoreline to provide protection to the shoreline and adjacent areas against scour by wave currents and waves by dissipating wave energy on and through the rough quarrystone armor and underlayers. Revetments provide protection for the land immediately behind them and offer no protection to the adjacent areas up or down coast or to the beach fronting the structure. In areas where the beach is used for recreational activities, rubblemound revetments may not be aesthetically desirable and may occupy valuable beach area as well as making access to the beach difficult.

5.1.2 Concrete Armor Unit Revetment System

A concrete armor unit revetment system consists of performed concrete armor units placed on a sloping shoreline to provide protection to the shoreline and adjacent areas against scour by wave currents and waves by dissipating wave energy through the armor unit layers. Like rubblemound revetments, these revetment systems are designed to protect the land immediately behind them and offer no protection to the adjacent areas up or down coast or to the land fronting the structure.

5.1.3 Seawall

Seawalls are impervious self supporting structures used to protect the backshore area against wave action. Seawalls are primarily designed to withstand and deflect wave energy. Most seawalls are constructed with a vertical or near vertical face which tends to reflect wave energy causing increased erosion and scour to the area fronting the structure. However, potential erosion and scour can possibly be mitigated by toe protection placed in front of the structure.

5.1.4 Beach Fill

A protective beach, created by placing clean beach sand along the shore, would dissipate wave energy impinging on the shoreline and protect the backshore area. The beach fill would have to extend sufficiently seaward of existing shorelines with a berm elevation sufficiently high to prevent wave overtopping and damage of the backshore area.

A newly created beach is considered sacrificial as it functions as an eroding buffer zone while providing flood protection. The useful life of a protective beach depends on how quickly it erodes under normal conditions. Because a newly created beach is subject to continued erosion, it must be maintained though a periodic sand nourishment program. New fill must be added at a rate equal to the natural losses caused by erosion to maintain sufficient width and berm elevation for continued protection. The need for renourishment is determined by the long-term shoreline retreat or littoral transport rates. The year to year erosion rates can vary greatly from the long-term average erosion rates and may be significantly influenced by the occurrence of major storms. A rapid succession of severe storms can completely eliminate the replenished beach in a short period of time. Therefore, while an average nourishment interval can be estimated, the actual required interval will vary depending on beach conditions and climatic conditions.

To adequately design the beach fill using current criteria requires further detailed study of currents, offshore bathymetry, and littoral transport processes. Other studies required would include determining the characteristics of the existing beach material or native sand, locating a sand source, evaluating the borrow material, determining the existing beach berm elevation and width, and determining existing beach profiles.

5.2 Nonstructural Alternatives

A number of hazard mitigation options are included in this nonstructural floodproofing proposal not reduce or eliminate the occurrence of floods, but are intended to minimize loss of life and damages when floods occur through the implementation of various programs discussed below.

5.2.1 Floodplain Management and Regulations

Floodplain zoning may be regarded as a response to long-range flood warning. The regulatory floodplain is usually an area that is expected to be flooded on the average of once in 100 years. On the basis of this expectation, zoning regulations discourage construction within the regulated area. In this manner, zoning reduces the growth of future damages where it is effectively enforced, but does not affect existing floodplain development.

Flood insurance, by itself, does not reduce flood damages. In fact, when subsidized as it is now by the Federal government, it could encourage greater flood damages by spreading the financial burden over a large segment of the population, just as disaster relief does. The National Flood Insurance Program (NFIP), however, has been coupled with a (virtually) mandatory program directed at achieving nationwide local floodplain zoning according to national standards. The Program thus has two goals: (a) to compensate flood victims for their monetary losses in the short term and (b) to encourage floodplain zoning for the longer-term reduction in flood damages.

5.2.2 Improved Flood Warning and Temporary Evacuation

Flood warning over the years by the National Weather Service has proved invaluable in saving lives and giving people in danger areas an opportunity to remove or protect some of their possessions. Improvements to the system to increase warning times or accuracy will likely be beneficial and cost effective. Flood warning systems can be separated into predicting hurricanes and tsunamis and communicating the predictions. Communication has received the same attention that predictions has, with reliance placed generally on the mass media and or sirens. Recently, weather radios have been introduced that automatically sound an alarm when a warning signal is transmitted. The radio is then turned on to listen to the official forecast from the Nation Weather Service. Currently, these radios are keyed to warn about hurricanes and severe thunderstorms. Purchase is optional with each person, however, in hazardous floodplains, such radios could be supplied, by various means, to all dwellings and/or business establishments and keyed to response to tsunami warnings as well.

5.2.3 Permanent Evacuation and Relocation

Floodplain evacuation reduces flood damages by removing improvements from the floodplain. Its effectiveness for this single purpose seems beyond question. However, as currently implemented, it severely limits future use of the evacuated floodplain land for economically productive activities.

Most project plans evaluated for floodplain evacuations have envisaged future uses of the land for open space, greenbelts, interruptible recreational purposes, and wildlife. These plans have particular appeal and benefits for those concerned with environmental issues. However, on reflection it is clear that, almost by definition, easily interruptible uses of any area provide little economic return. As such, net economic efficiency of the future use of the Nation's floodplains seems clearly negative under current programs.

Flood proofing and floodplain evacuation are essentially the only nonstructural alternatives potentially implementable and capable of relieving or reducing current flooding problems.

5.2.4 Flood Proofing

Flood proofing (raising buildings above flood levels, elevating utilities, raising access roads, etc.), like floodplain evacuation, can reduce existing flood damages. In economic terms, however, it is much more practical when applied to new construction as opposed to modifications within existing floodplain developments. Minimum standards of design and construction for flood proofing of buildings and structures is contained in Engineering Pamphlet (EP) 1165-2-314 (Flood Proofing Regulations) dated 15 December 1995. Some of the available flood proofing techniques include the following:

(1) Continuous wall or block foundation
(2) Fill
(3) Elevating on piles or columns
(4) Levees, ringwalls, floodwalls (individual)
(5) Closures and sealants
(6) Wet flood proofing
(7) Floatable structure

6 RECOMMENDED ECONOMIC ANALYSIS METHODOLOGY FOR FUTURE STUDY

Economic analysis in future studies should focus on quantifying the annualized net benefits accruing to each proposed floodproofing alternative at selected energy facilities. These benefits should be divided by the annualized implementation cost of each floodproofing measure to determine the ratio between the two. A recommendation for project implementation would result from a benefit-cost ratio of unity or greater (annualized benefits equal or exceed annualized costs.

Annualized net benefits (or savings in potential damages) are defined as the difference in damages projected to occur at a given facility for with- and without-project conditions. Based on responses to a mail survey of those Hawaiian energy industry facilities located within the hurricane and tsunami floodplains, there were no historical damages to the facilities. Approximately 40 percent of the facilities surveyed responded. Employing study assumptions and methodologies consistent with past DOE mitigation studies, it bears mentioning that by basing damages purely on historical record, storms with probabilities of occurrence lower than those on historical record are not accounted for. The recommendations for each facility therefore are only as good as the largest storm event to impact that facility.

To quantify damages, detailed structure and inventory values should be acquired for each affected facility as well as site specific ground elevations. Damages are then based on projected flood heights associated with storm event probabilities up to a one percent event for conditions with and without floodproofing improvements. The net of the two are the damages avoided (or net benefits) associated with project implementation. Other benefits associated with a project such as impacts to the local economy, lifeline services, etc. can also be quantified on an annualized basis using present worth values and capital recovery factors (at an interest rate to be determined) over the expected life of a project. Project costs should be annualized using the same capital recovery factor as that used in the benefit analysis.

7 STUDY CONCLUSION AND RECOMMENDATIONS

The key to successfully reducing risks of future damage to persons and property is mitigation. Although it may not be economically feasible to implement all of the recommendations from future studies, the recommendations in this report should be used as a framework for opportunities to reduce the energy and critical lifeline facilities' vulnerability to the risks associated with flooding hazards. The following proposals should be implemented:

HURRICANE INUNDATION STUDIES FOR HAWAIIAN ISLANDS PROPOSAL

Provide hurricane coastal inundation maps for the entire State of Hawaii to identify flood prone areas for energy and critical facilities.

Description: Coastal flooding from hurricanes is a major concern and poses a constant threat for the State of Hawaii. Both Hurricanes Iniki (1992) and Iwa (1982) affected the islands of Kauai and Oahu and underscore the fact that the Hawaiian Islands are vulnerable to severe coastal flooding from hurricanes regardless of intensity or strength. Under FEMA's National Flood Insurance Program, flood insurance rate maps have been developed for the State of Hawaii showing base flood elevations for the 100-year and in some instances, the 500-year event for major riverine and tsunami (seismic sea wave) floods. However detailed risk-based hurricane flood studies have never been conducted for the entire State of Hawaii.

Background: Frequency analysis of coastal inundation caused by hurricanes affecting the State of Hawaii, has never been conducted due primarily to the limited amount of data from actual hurricane strikes. The threat however remains ever present during any given hurricane season which lasts from June to November. During the period from 1950 to 1997 for example, the annual number of tropical cyclones (hurricanes and tropical storms) entering or originating in the Central Pacific has varied from zero to a high of 11 as recent as 1992 and 1994.

The State of Hawaii has recognized the potential hazards of flooding from tropical cyclones and hence has completed Hurricane Evacuation Studies (HES) for the island of Oahu and is currently preparing evacuation studies for the island of Kauai. These studies are funded jointly by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency for the State of Hawaii Department of Defense and local Civil Defense Agencies. These evacuation studies contain inundation maps for "typical" and "worst" case scenario hurricanes but do not associate any hurricane risk factors. Due to the priority of island historical hurricane exposures and from the limited annual funding for these studies, the Counties of Maui and Hawaii do not have any completed technical hurricane evacuation studies although the potential risk is still present. Recent efforts of the National Emergency Management Association/Federal Emergency Management Agency Hurricane Task Force have elevated the priority of funding for the Counties of Maui and Hawaii through the year 2001.

An on-going effort is currently being conducted by the Corps of Engineers Pacific Ocean Division and the Coastal Engineering Research Center at the Waterways Experiment Station, to conduct a hurricane frequency study for the Territory of American Samoa which like the State of Hawaii, has limited hurricane data of recent times. This study is funded by FEMA and employs a statistical analysis technique for determining frequency of occurrence relationships for storm induced parameters. The results from the frequency analysis of this study would appear to yield best available base flood elevations once finalized in June 1998.

Recommendation: **It is recommended that additional coastal inundation maps under the HES program or risk-based flood insurance studies be conducted for remaining islands of Hawaii that lack detailed analysis. State Civil Defense strongly supports these efforts. These studies should be expedited to identify coastal flood prone areas. Mitigation of hurricane coastal flooding for energy and critical facilities can not be adequately addressed until inundation studies have been completed and underlying flood problems identified.**

Lead Agencies: FEMA, U.S. Army Corps of Engineers, State of Hawaii Department of Defense, and the Department of Land and Natural Resources

Funding: FEMA

Schedule: As soon as possible.

DETAILED FLOOD MITIGATION STUDIES PROPOSAL

Provide detailed plans for mitigating coastal flooding for energy and critical facilities in flood prone areas for the State of Hawaii.

Description: Coastal flooding of energy and critical facilities is a major concern for the State of Hawaii since most of those facilities are situated in low-lying areas and vulnerable to flooding. Hazard mitigation measures can reduce the vulnerability of these systems to water inundation due to coastal flooding caused by hurricanes and tsunamis.

Background: Both Hurricanes Iniki (1992) and Iwa (1982) affected the islands of Kauai and Oahu and underscore the fact that the Hawaiian Islands are vulnerable to severe coastal flooding from hurricanes regardless of intensity or strength, and history shows numerous tsunamis have struck the State and are capable of causing severe property damage.

Mitigation alternatives available are wide and varied and can include both structural and nonstructural measures. Revetments provide protection to the shoreline and adjacent areas against overtopping and scour by wave currents and waves by dissipating wave energy on and through the rough quarrystone armor and underlayers. Seawalls are vertical, impervious, self supporting structures primarily designed to withstand and deflect wave energy.

Floodproofing building and structures is another means of reducing flood damage. Raising buildings above flood levels, elevating utilities, raising access roads, using continuous wall or block foundations, levees, ringwalls, individual floodwalls, closures and sealants, wet flood proofing, and floatable structures are all methods of floodproofing.

Although nonstructural floodproofing proposal do not reduce or eliminate the occurrence of floods, they are intended to minimize loss of life and damages when floods occur through the implementation of various programs. Floodplain zoning discourages construction within regulated areas and reduces the growth of future damages where it is effectively enforced, but does not affect existing floodplain development.

Flood warning over the years by the National Weather Service has proved invaluable in saving lives and giving people in danger areas an opportunity to remove or protect some of their possessions. Improvements to the system to increase warning times or accuracy will likely be beneficial and cost effective.

Floodplain evacuation reduces flood damages by removing improvements from the floodplain. However, as currently implemented, it severely limits future use of the evacuated floodplain land for economically productive activities.

Recommendation: **Develop specific mitigation measures for the facilities identified in this study using additional coastal inundation maps completed under the HES program or risk-based flood insurance studies. Mitigation of hurricane coastal flooding for energy and critical facilities can not be adequately addressed until inundation studies have been completed and underlying flood problems identified. The specific measures for each of the facilities identified should be consistent with National Flood Insurance Program objectives, all structural and non-structural improvement alternatives would be evaluated for a 100-year level of protection. Project alternatives will not be exactly the same for each facility; each facility will require detailed study based on facility location, flood elevation, base floor elevations, and specific operation impacts. Only then will flood wall or revetment heights, or other mitigation measures such as floodproofing be determined. For those facilities with mitigation measures in place, those existing measures or plans should be reviewed for completeness and sufficiency.**

Lead Agencies: For completing the coastal inundation studies: FEMA, U.S. Army Corps of Engineers, State of Hawaii Department of Defense, and the Department of Land and Natural Resources

For developing the specific mitigation measures for public facilities and review of existing measures: FEMA, and State of Hawaii Department of Defense.

For developing the specific mitigation measures for private facilities: Affected companies.

Funding: FEMA for public facilities.
Applicable company for private facilities.

Schedule: As soon as possible.

REPAIR BREAKWATER AT KAUMALAPAU HARBOR PROPOSAL

Repair the Kaumalapau Harbor Breakwater to improve fuel delivery to Lanai.

Description: Kaumalapau Harbor is protected by a rubble-mound breakwater originally 400 feet in length which has since eroded from storm surges generated by Hurricane Iniki and subsequent storms to a present length of approximately 200 feet. This deterioration of the breakwater has resulted in increased wave energy within the harbor and frequent delays for it's users.

Background: Kaumalapau Harbor, owned by the Lanai Company, is a small barge harbor located on the southwest coast of the island of Lanai. As the only commercial harbor serving the Lanai's estimated 2,426 residents (1990 census) and visitors, the harbor is the island's sustenance and economic lifeline.

The harbor is used for off-loading petroleum products to storage tanks and terminal facility located adjacent to the harbor. Although the storage tanks and terminal facility are not subject to flooding from hurricanes or tsunamis, it should be noted that storm damage to the breakwater allows waves to enter the harbor during both storm and non-storm conditions and those conditions prevent the fuel barge from entering the harbor to off-load product. During prolonged storm conditions when the barge can't off-load product, the lifeline systems could become in danger of inadequate fuel supply.

A separate study conducted by the US Army Corps of Engineers investigated possible solutions to reducing the harbor surge. The solutions recommended by the study were determined economically infeasible. The Lanai Oil Company recently acquired a new 4,000 barrel capacity fuel barge in an attempt to ensure adequate fuel supply.

Without improvements to the breakwater, barge service to Lanai will continue to be inconvenienced and jeopardized and the possibility of inadequate fuel supplies could severely interrupt the lifeline systems and additional damage to the breakwater will exist.

Recommendation: **It is recommended that for system reliability to the lifeline systems the breakwater at Kaumalapau Harbor be repaired to prevent storm surges within the harbor to freely allow harbor usage.**

Lead Agencies: State of Hawaii Department of Transportation and Lanai Company.

Funding: Expenditures would be made by the Lanai Company and recovered through user fees.

Schedule: As soon as possible.

APPENDIX A

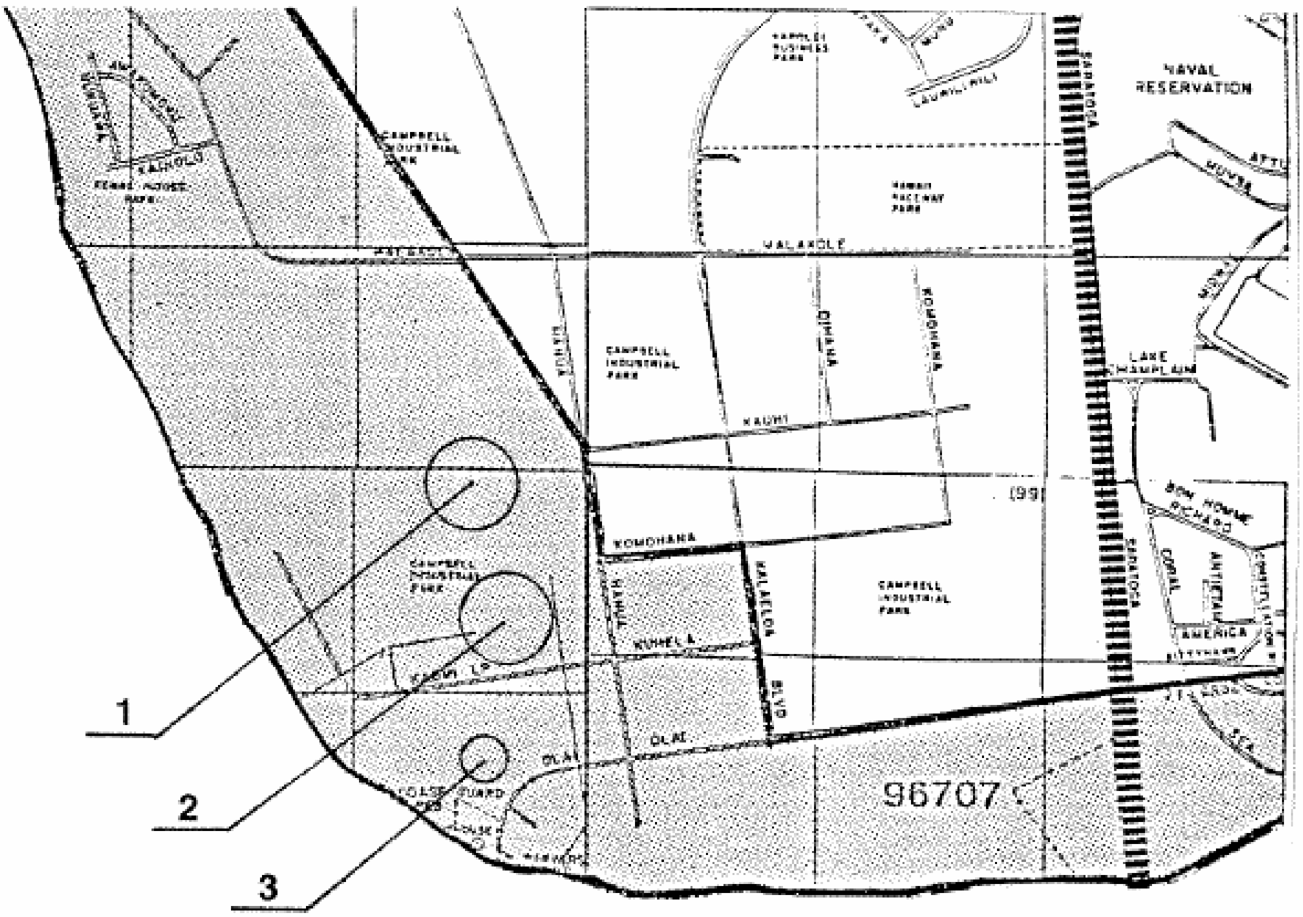
Electrical Facilities

Within

Hurricane Inundation Zone
Island of Oahu

Tsunamis Inundation Zone
Island of Hawaii

CAMPBELL INDUSTRIAL PARK AREA



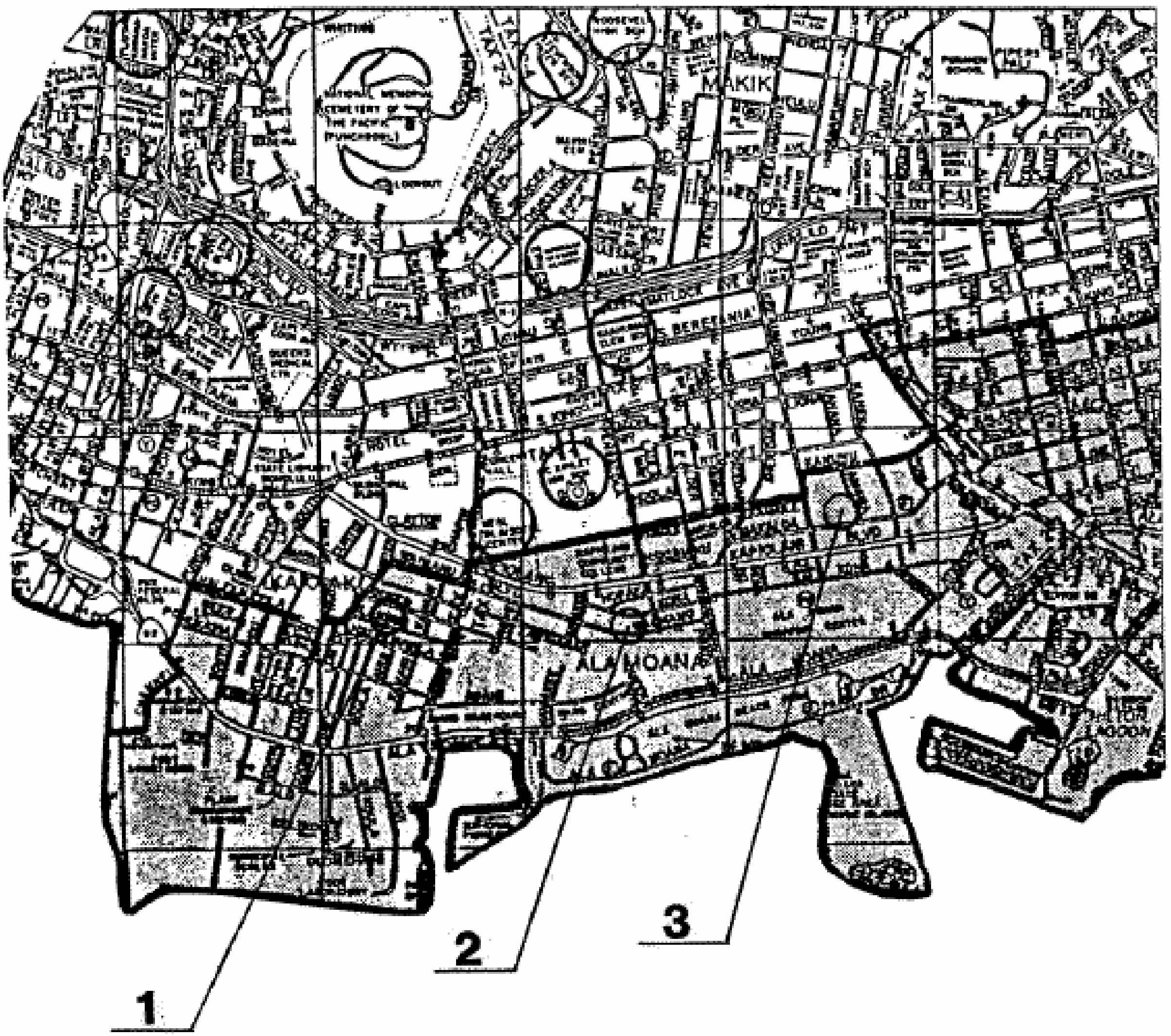
Electrical Facility	Flood Elev (msl)
1) H-POWER Power Plant	7.6
2) AES Coal Generation Plant and Generator Transformer Substation	7.6
3) Hawaiian Cement Substation	7.6

Hazard Mitigation Study
Island of Oahu

Electrical Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAKAAKO-ALA MOANA AREA



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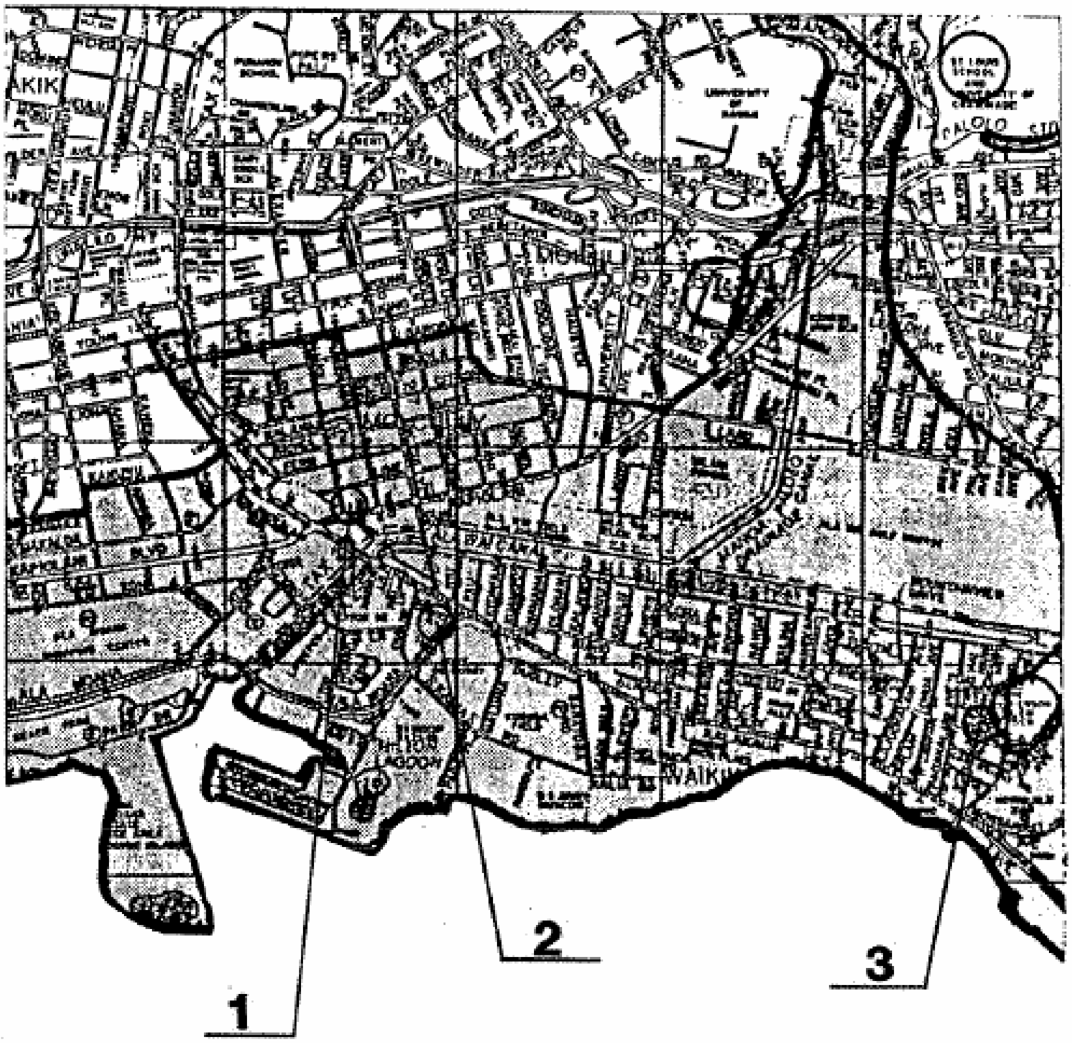
Electrical Facility	Flood Elev (msl)
1) Kakaako Substation	4.5
2) Kewalo Substation	6.7
3) Makaloa Substation	7.4

Hazard Mitigation Study
Island of Oahu

Electrical Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

WAIKIKI AREA



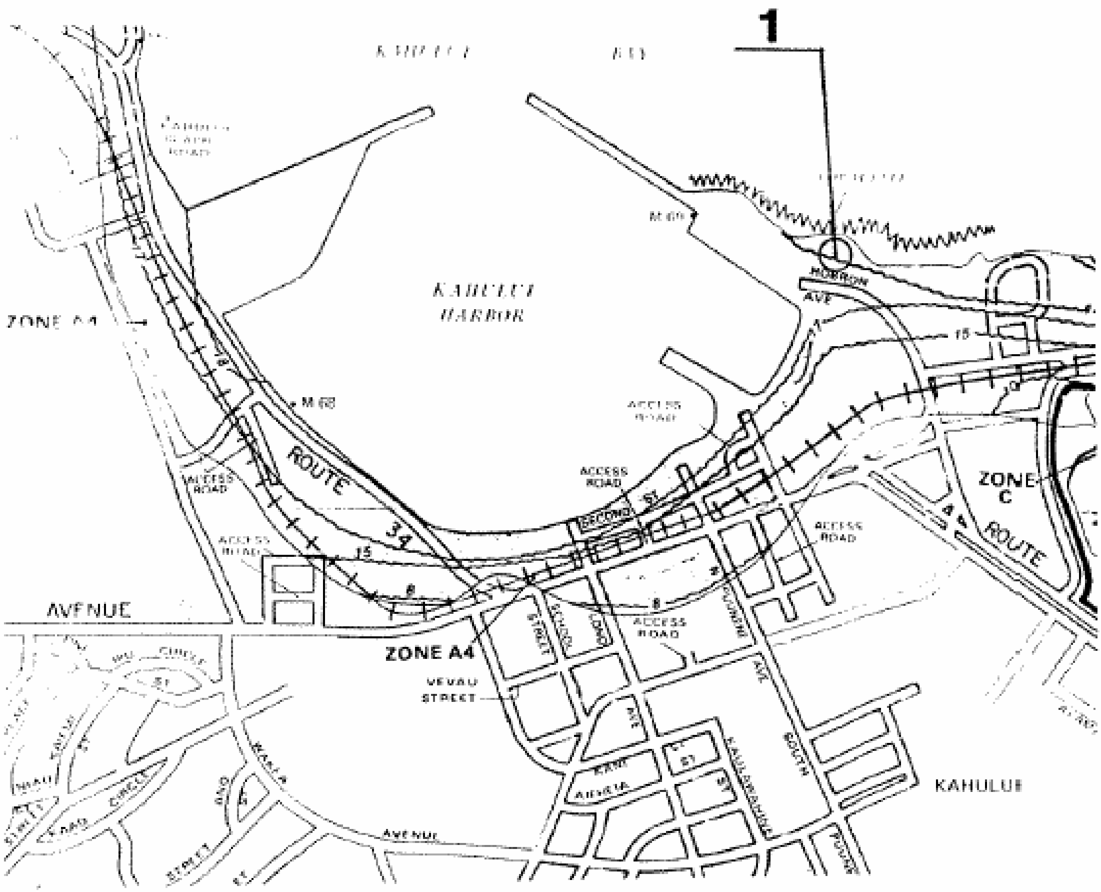
Electrical Facility	Flood Elev (msl)
1) McCully Substation	7.2
2) Ena Substation	7.2
3) Kuhio Substation	6.7

Hazard Mitigation Study
Island of Oahu

Electrical Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAHULUI AREA



Electrical Facility	Flood Elev (msl)
1) Kahului Power Plant	19.0

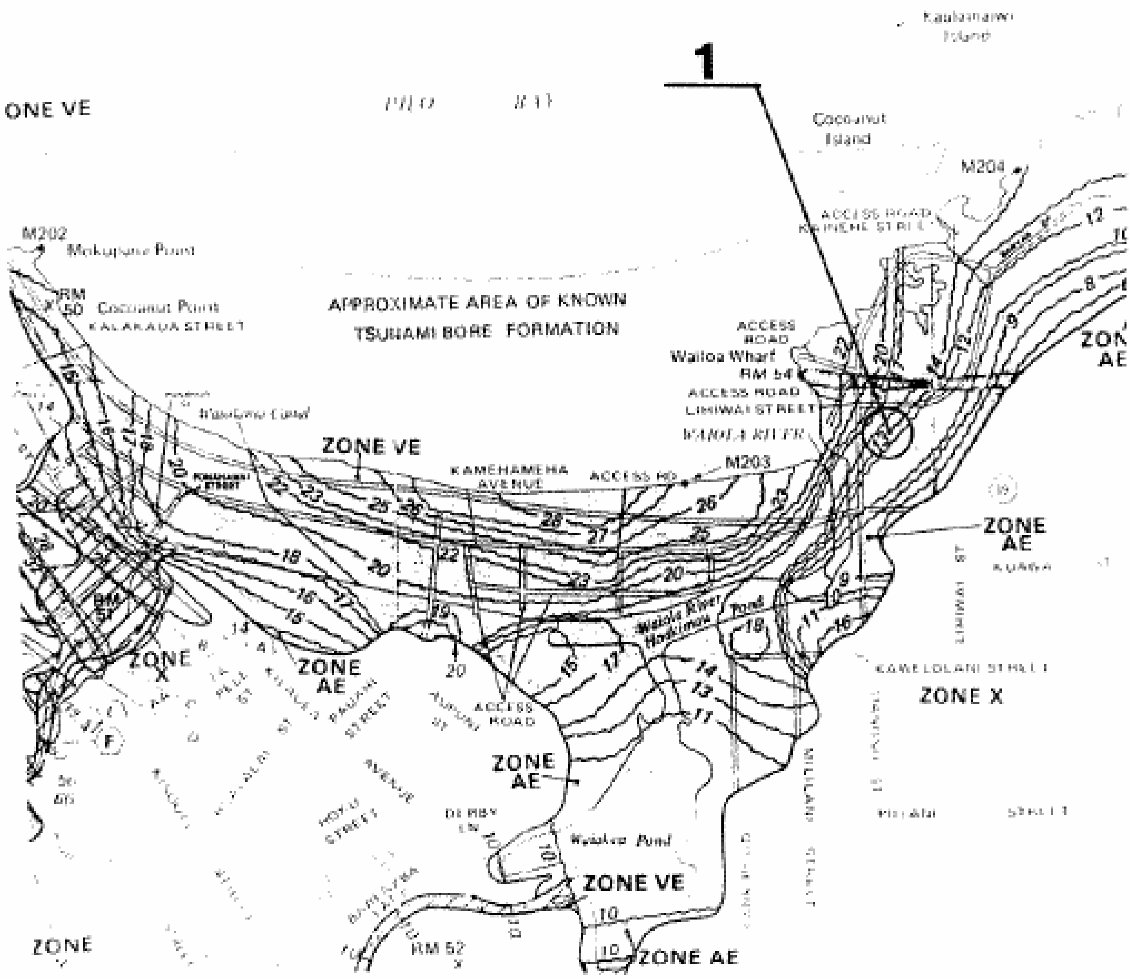
Hazard Mitigation Study
Island of Maui

**Electrical Facilities
Within
Tsunamis Inundation Zone**

U.S. Army Corps of Engineers
Honolulu District

Revised: May 2005

HILO AREA



Electrical Facility	Flood Elev (msl)
1) Waiakea Power Plant	17.0

Hazard Mitigation Study
Island of Hawaii

Electrical Facilities Within Tsunamis Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

APPENDIX B

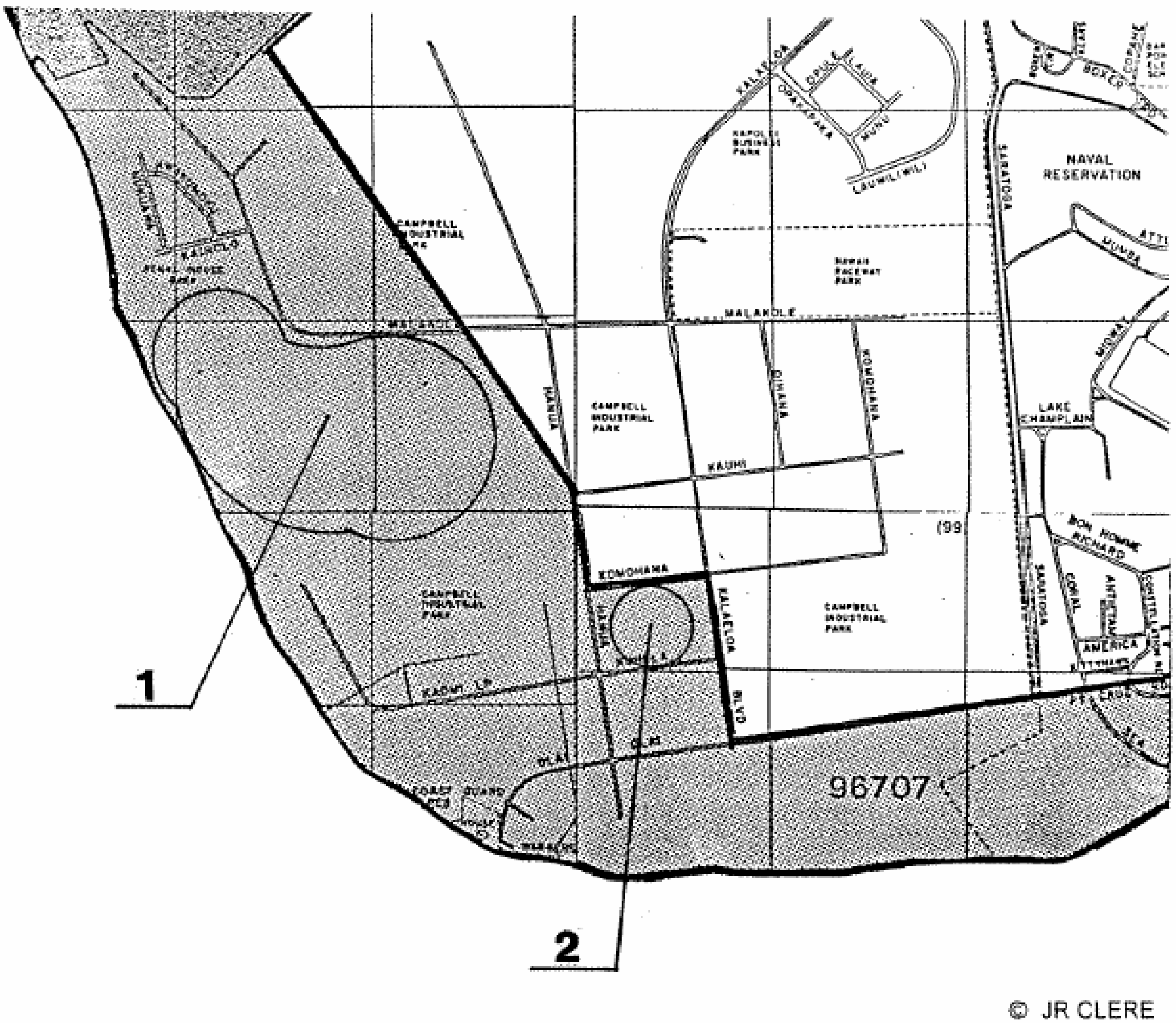
Petroleum and Gas Facilities

Within

Hurricane Inundation Zone
Island of Oahu

Tsunamis Inundation Zone
Island of Maui
Island of Molokai

CAMPBELL INDUSTRIAL PARK AREA



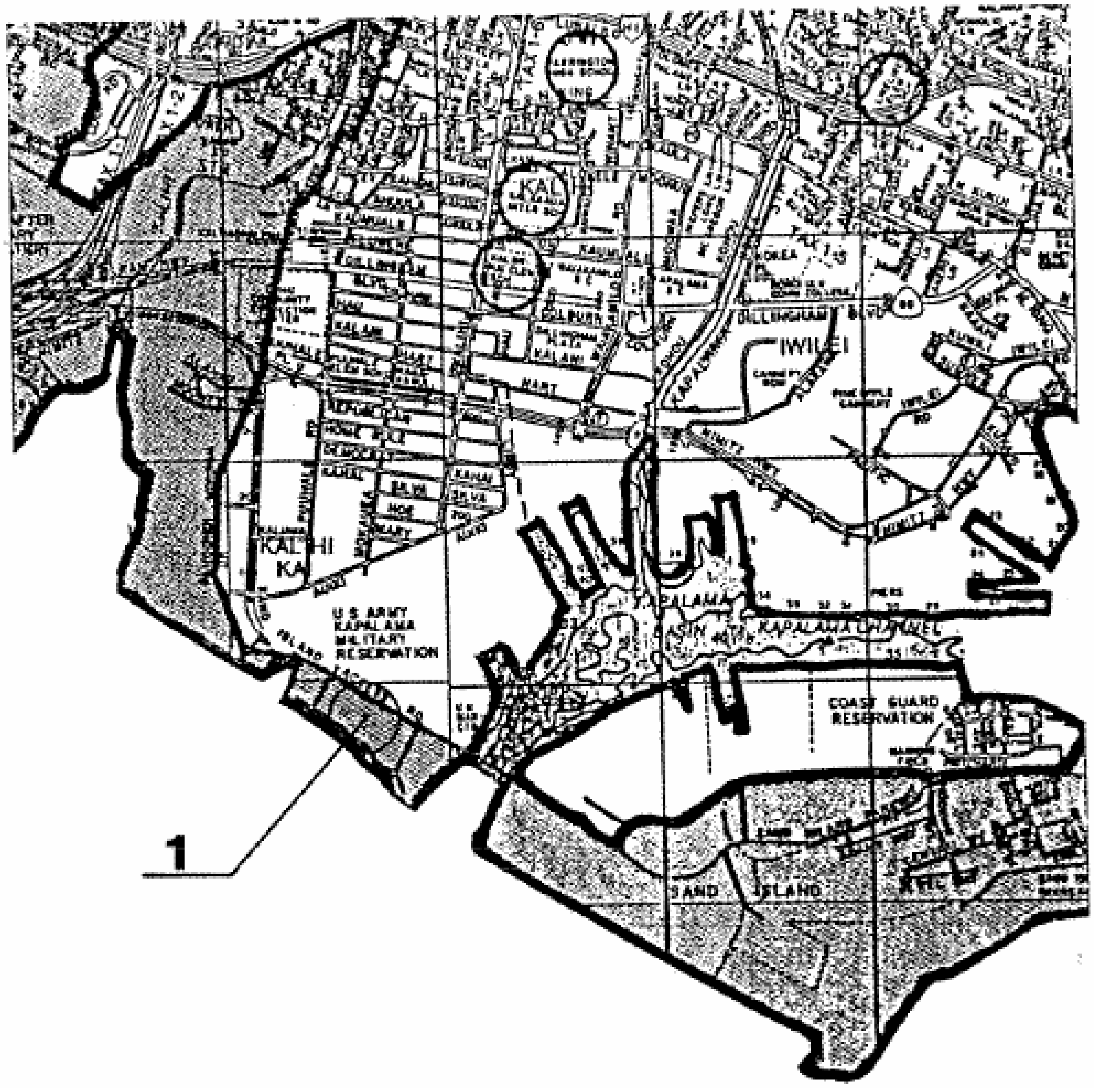
Petroleum and Gas Facility	Flood Elev (msl)
1) Chevron USA Refinery/ Hawaiian Electric Storage Facility	8.7
2) Texaco Terminal	7.6

Hazard Mitigation Study
Island of Oahu

Petroleum and Gas Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

MAPUNAPUNA-SAND ISLAND AREA



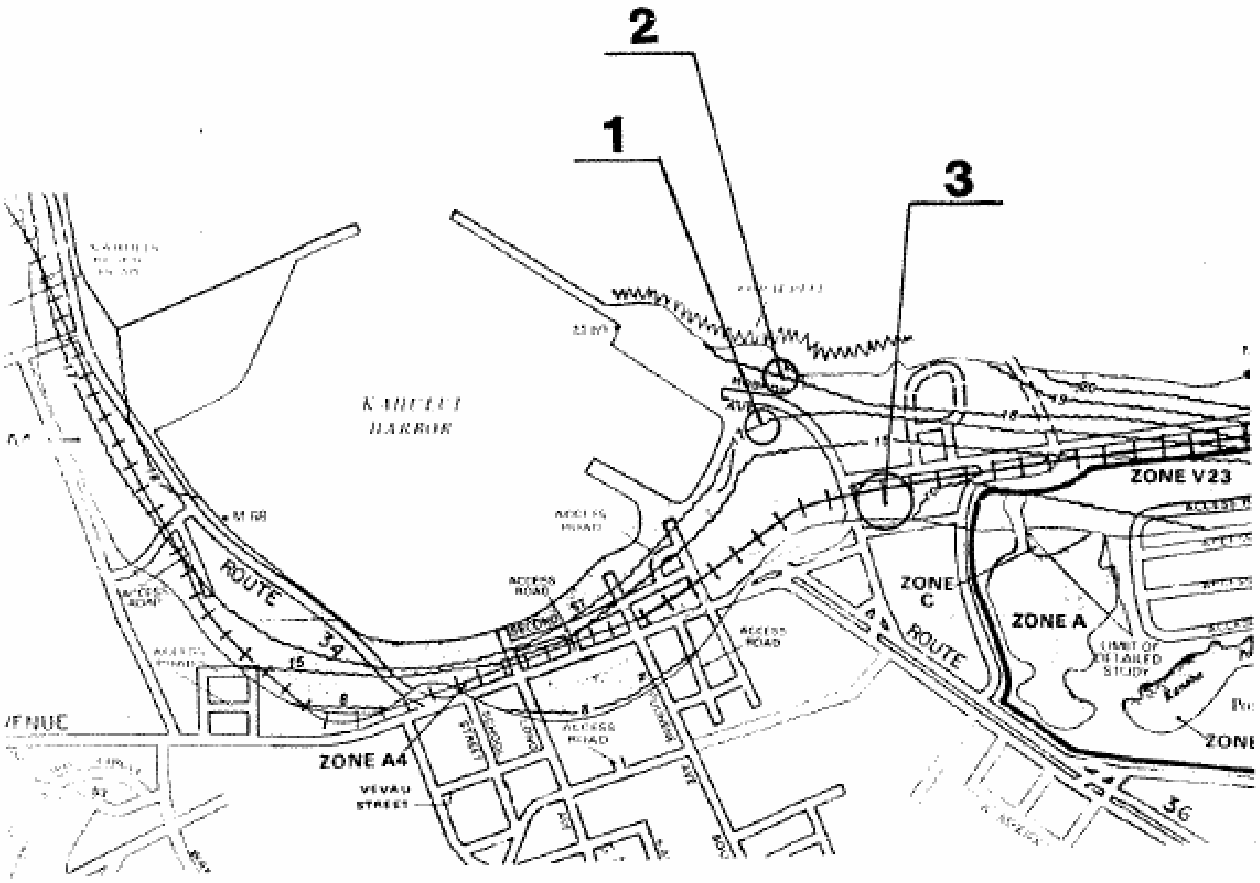
Petroleum and Gas Facility	Flood Elev (msl)
1) Airport Jet Fuel Storage Terminal	5.5

Hazard Mitigation Study
Island of Oahu

Petroleum and Gas Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAHULUI HARBOR AREA



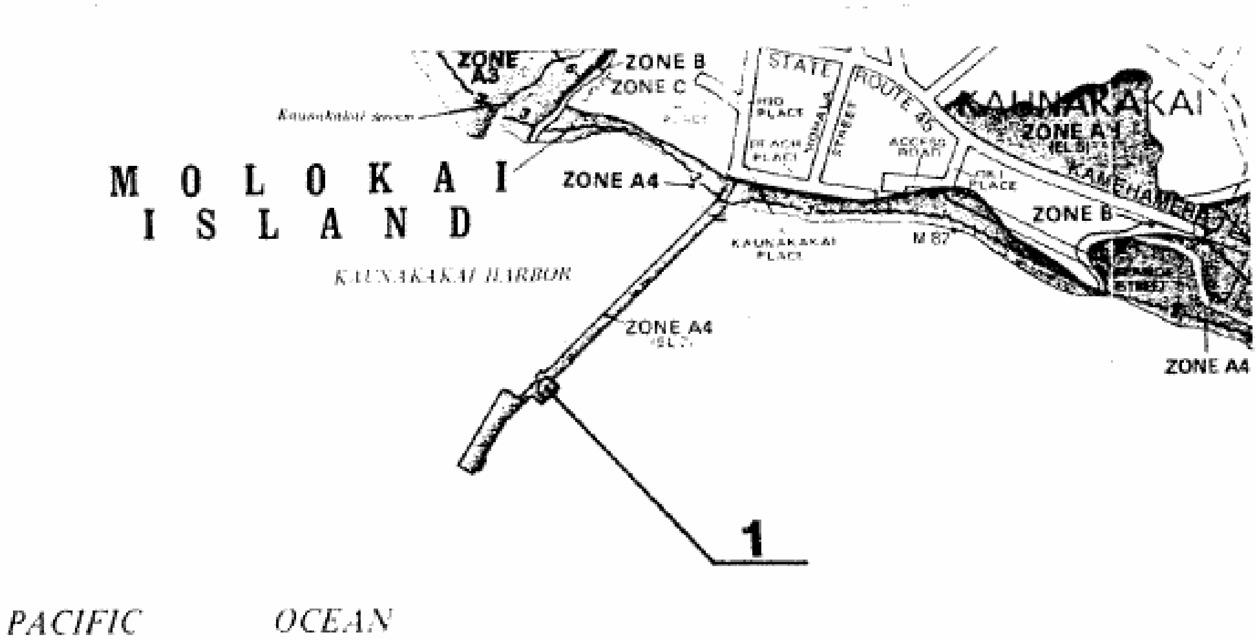
Petroleum and Gas Facility	Flood Elev (msl)
1) BHP Terminal	18.0
2) MECO Power Plant/Storage Tanks	19.0
3) Chevron Terminal	13.0

Hazard Mitigation Study
Island of Maui

Petroleum and Gas Facilities Within Tsunamis Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAUNAKAKAI HARBOR AREA



Petroleum and Gas Facility	Flood Elev (msl)
1) Molokai Petroleum Tanks (not in use)	3.0

Hazard Mitigation Study
Island of Molokai

Petroleum and Gas Facilities Within Tsunamis Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

APPENDIX C

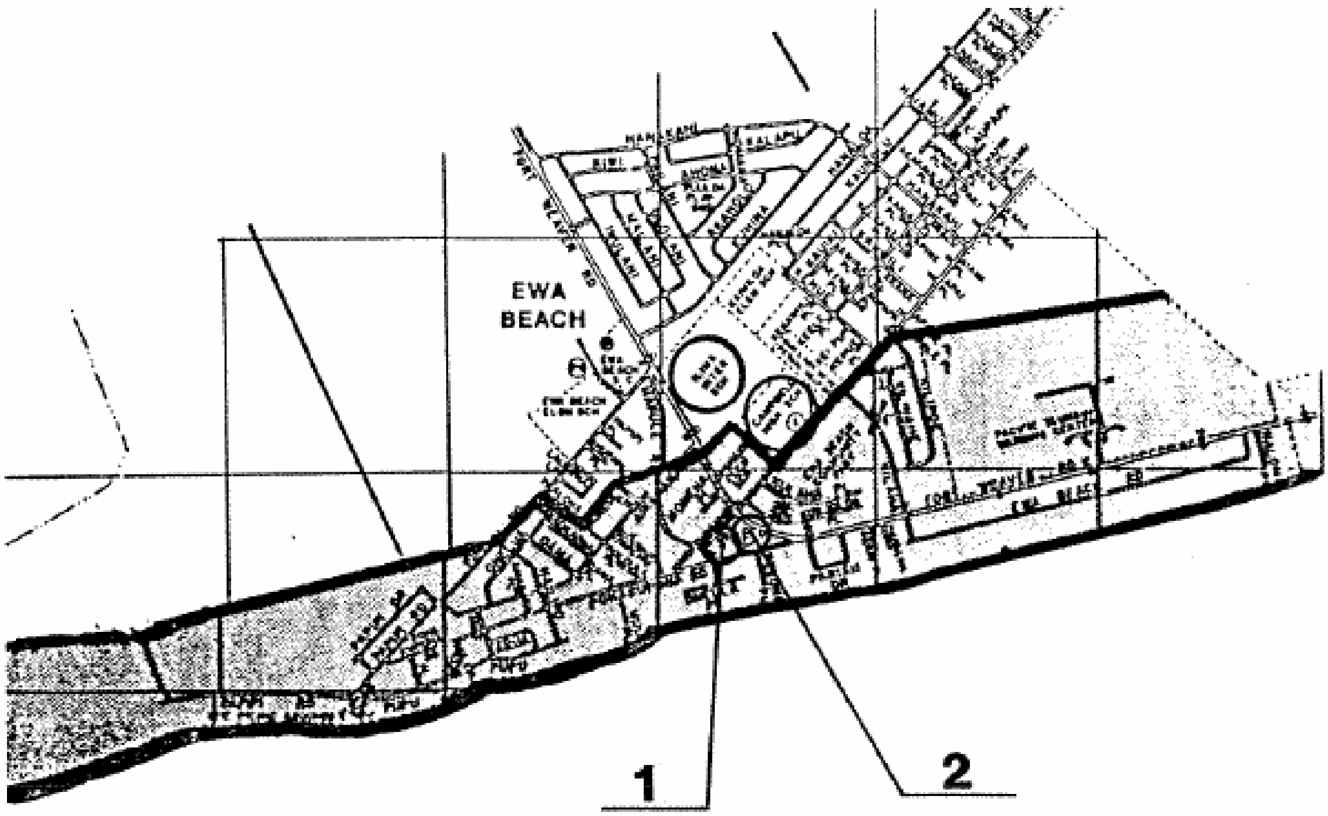
Lifeline Facilities

Within

Hurricane Inundation Zone
Island of Oahu

Tsunamis Inundation Zone
Island of Maui
Island of Hawaii

EWA BEACH AREA



Lifeline Facility	Flood Elev (msl)
1) Ewa Beach Hawtel Office	5.7
2) Ewa Beach Fire Station	5.7

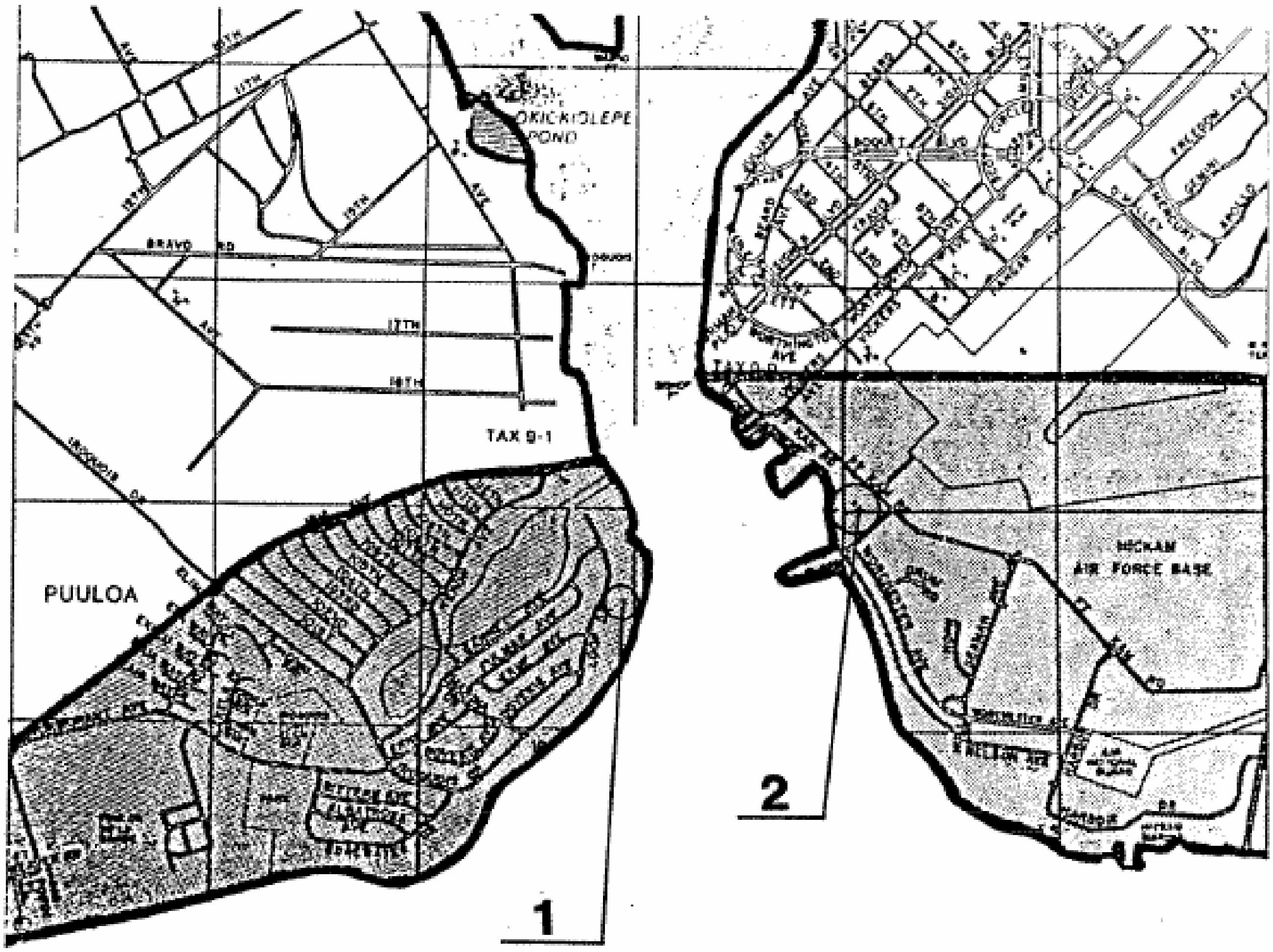
Hazard Mitigation Study
Island of Oahu

Lifeline Facilities
Within
Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

Revised: May 2005

IROQUOIS POINT - HICKAM AIR FORCE BASE AREA



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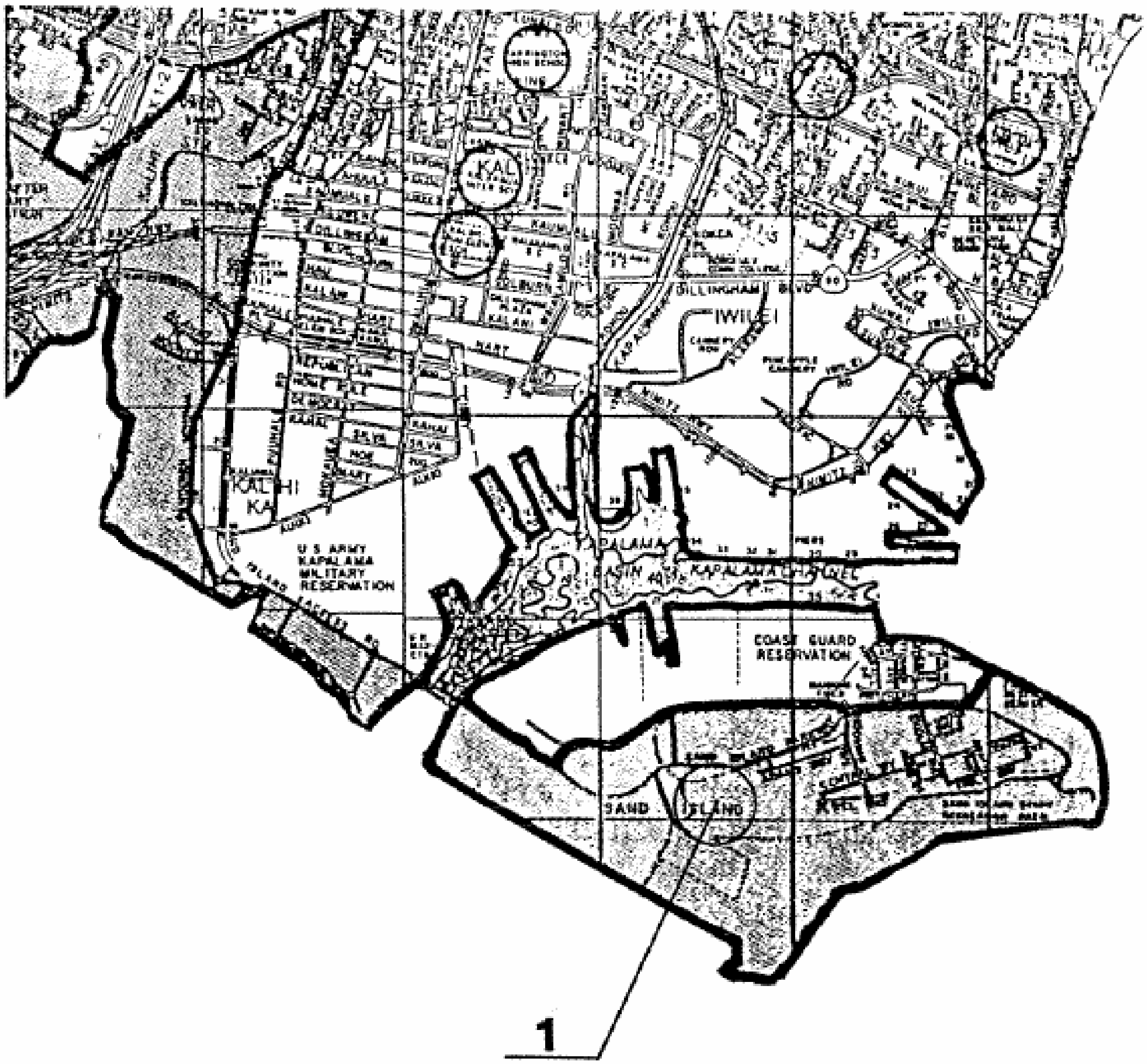
Lifeline Facility	Flood Elev (msl)
1) Iroquois Point WWTP	5.2
2) Fort Kam WWTP	4.5

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

SAND ISLAND AREA



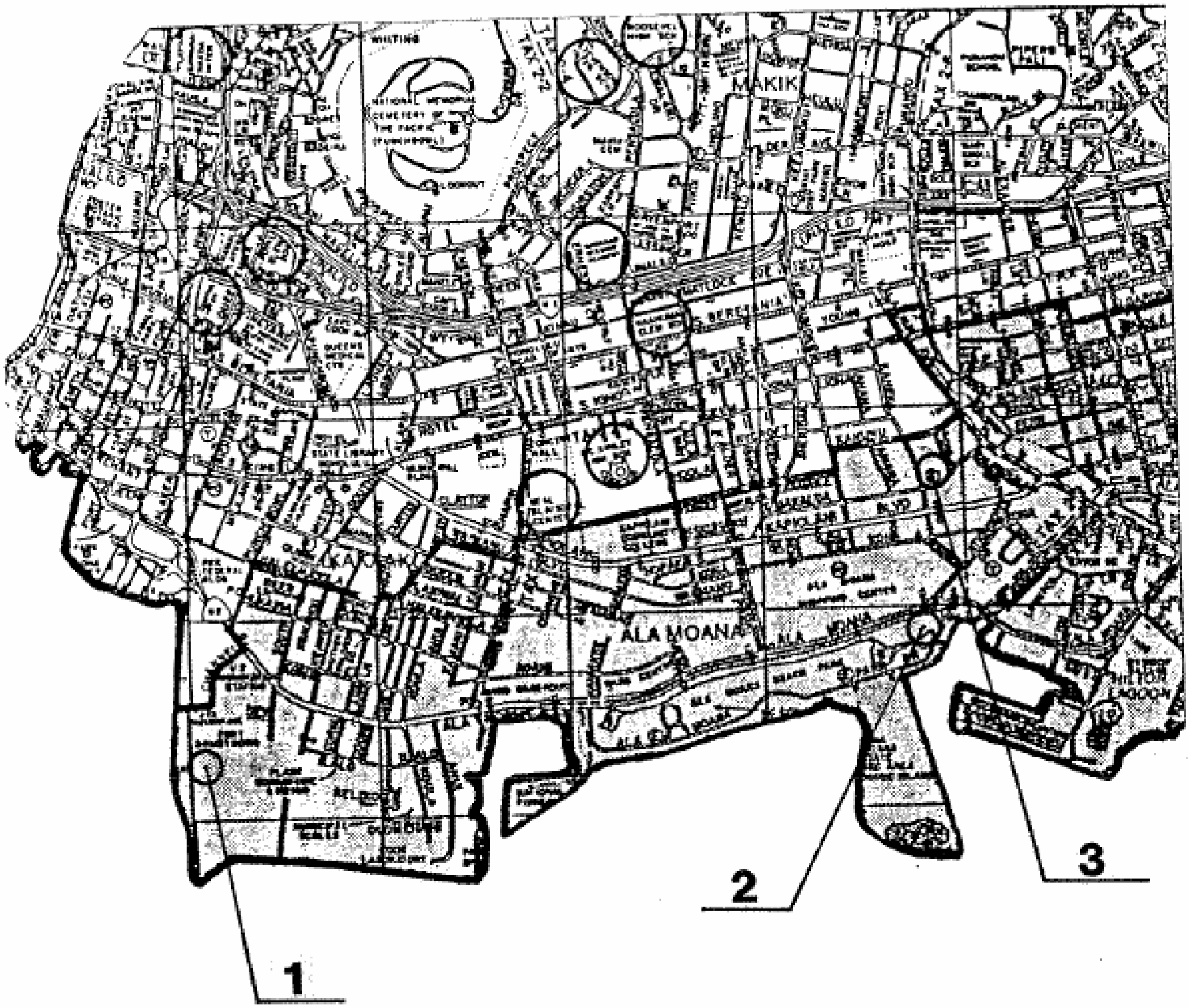
Lifeline Facility	Flood Elev (msl)
1) Sand Island WWTP	5.9

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAKAAKO - ALA MOANA AREA



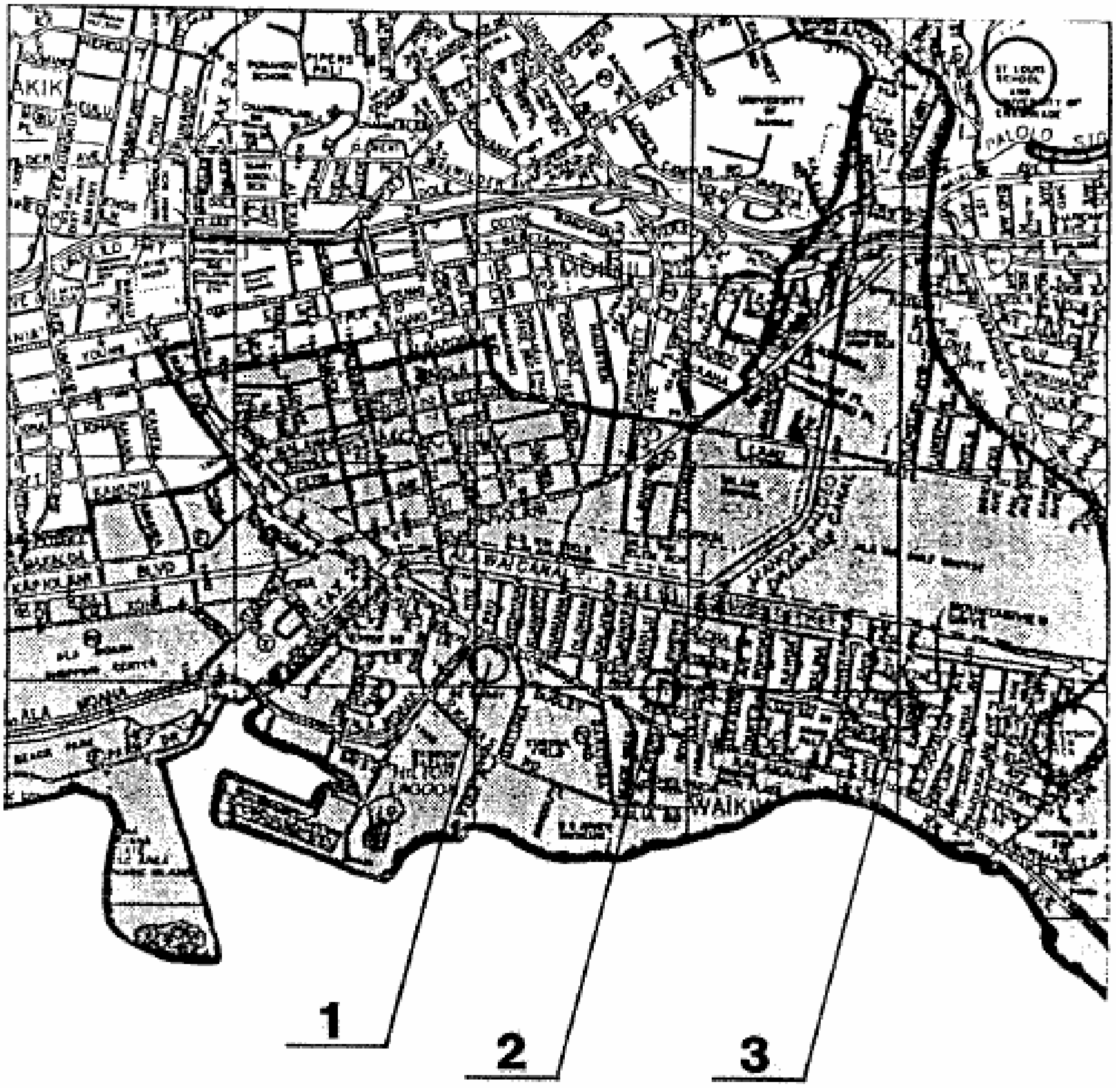
Lifeline Facility	Flood Elev (msl)
1) Fort Armstrong WWPS	6.7
2) Ala Moana WWPS	7.4
3) Ala Moana Fire Station	7.4

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

WAIKIKI AREA



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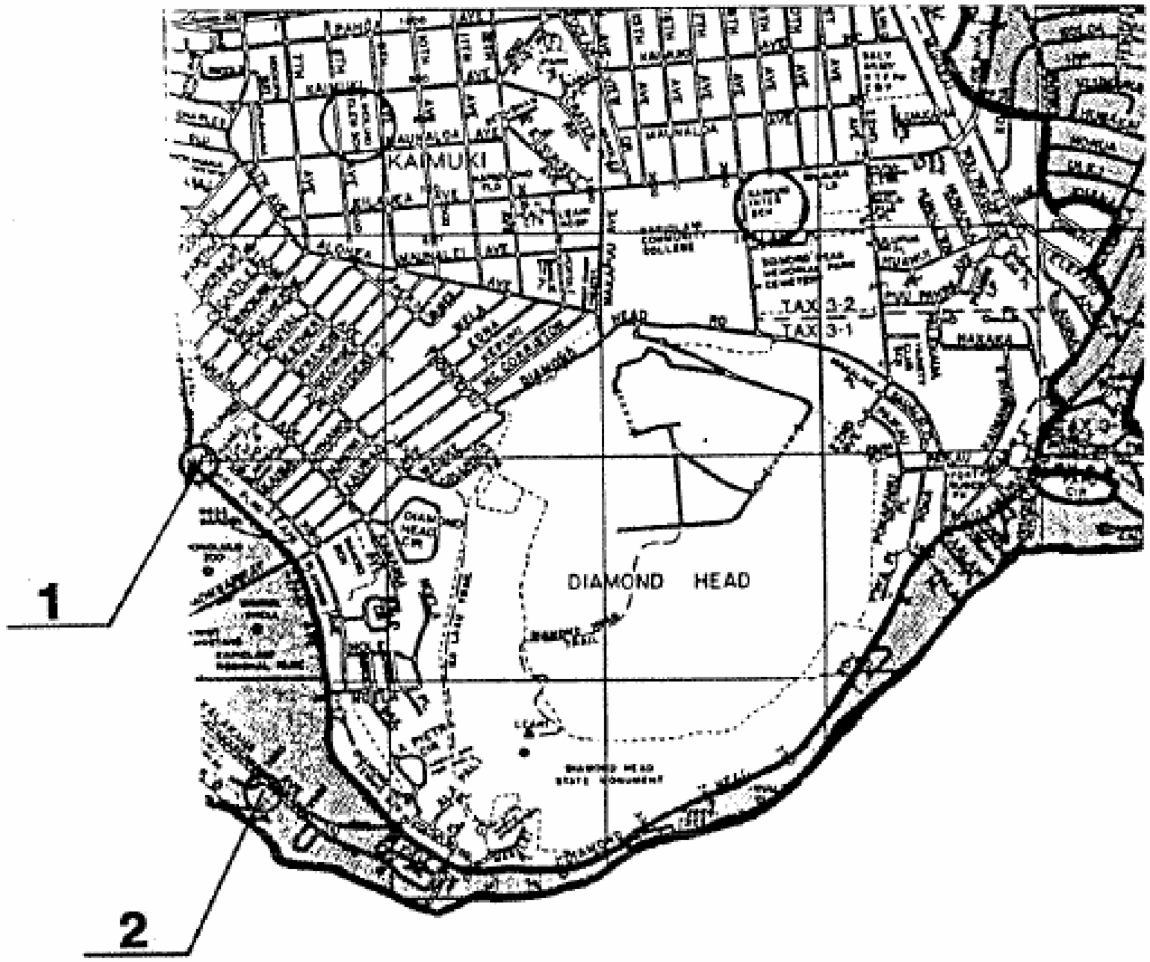
Lifeline Facility	Flood Elev (msl)
1) Fort DeRussy WWPS	6.9
2) Beach Walk WWPS	6.7
3) Waikiki Hawtel Office	7.8

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAPIOLANI PARK - DIAMOND HEAD AREA



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Lifeline Facility	Flood Elev (msl)
1) Kapahulu Fire Station	7.7
2) Public Bath WWPS	10.0*

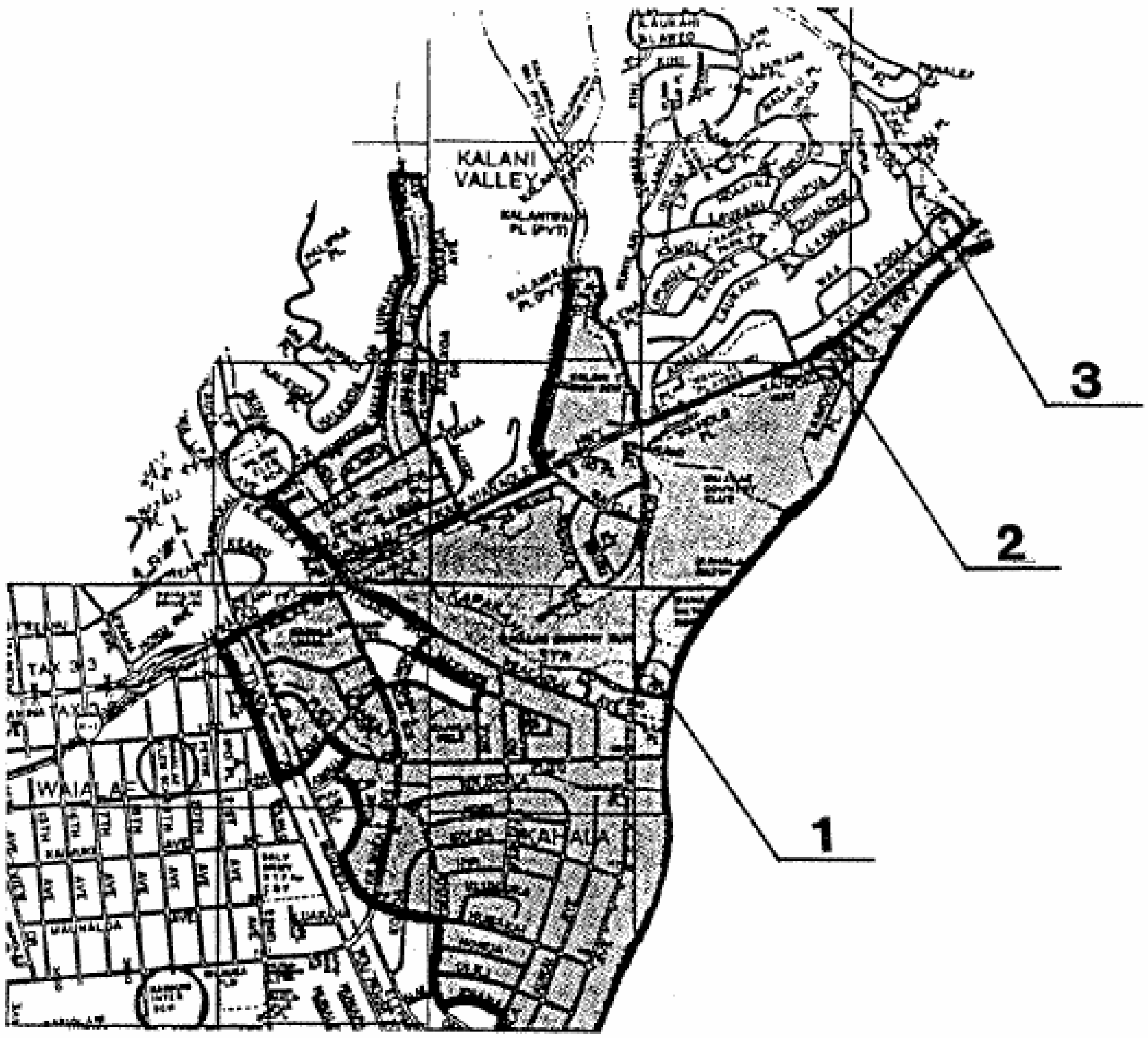
* Elevation is from the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAHALA AREA



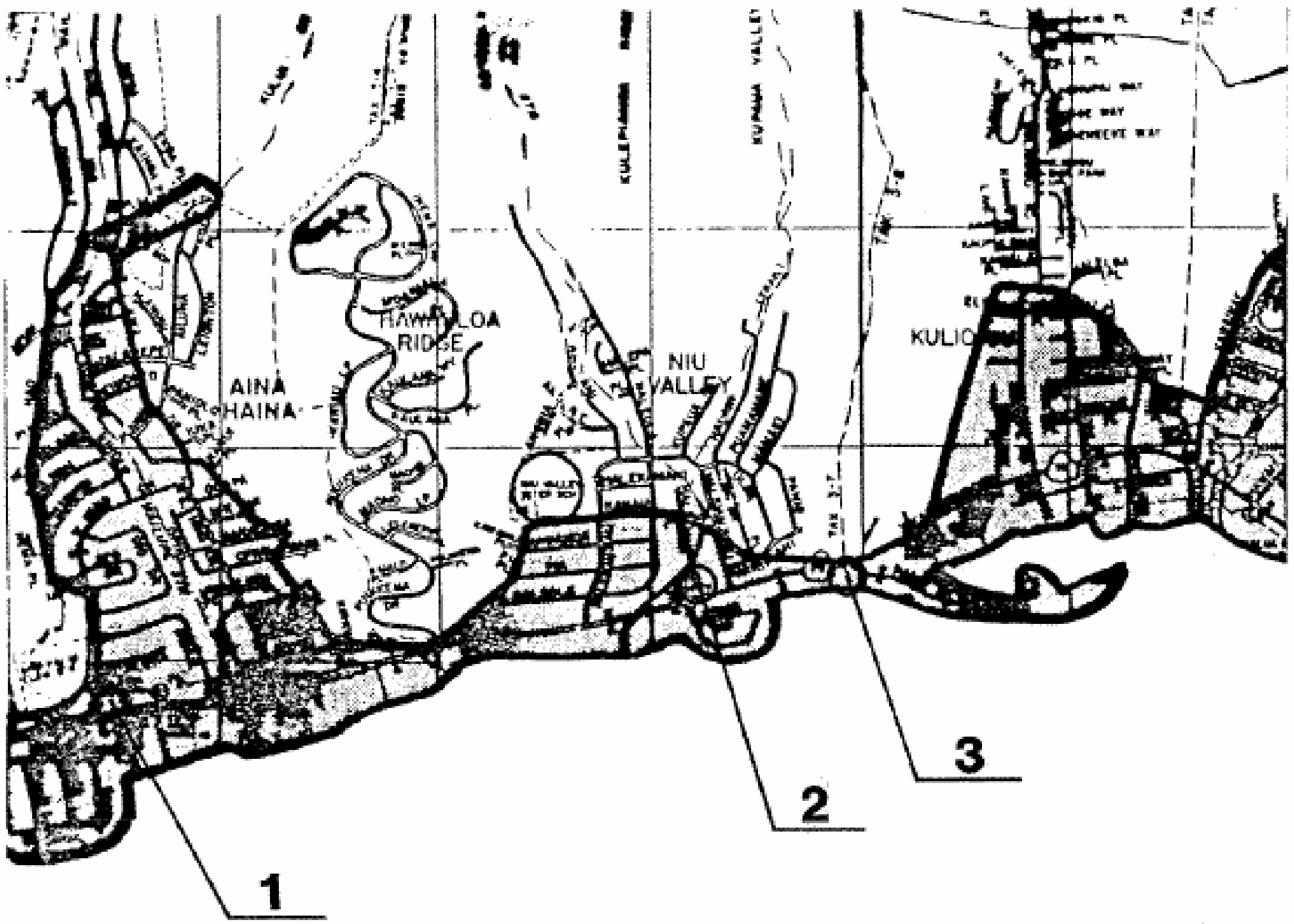
Lifeline Facility	Flood Elev (msl)
1) Waialae Kahala WWPS	7.0
2) Wailupe WPS	8.3
3) Wailupe Fire Station	7.3

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

AINA HAINA - KULIOUOU AREA



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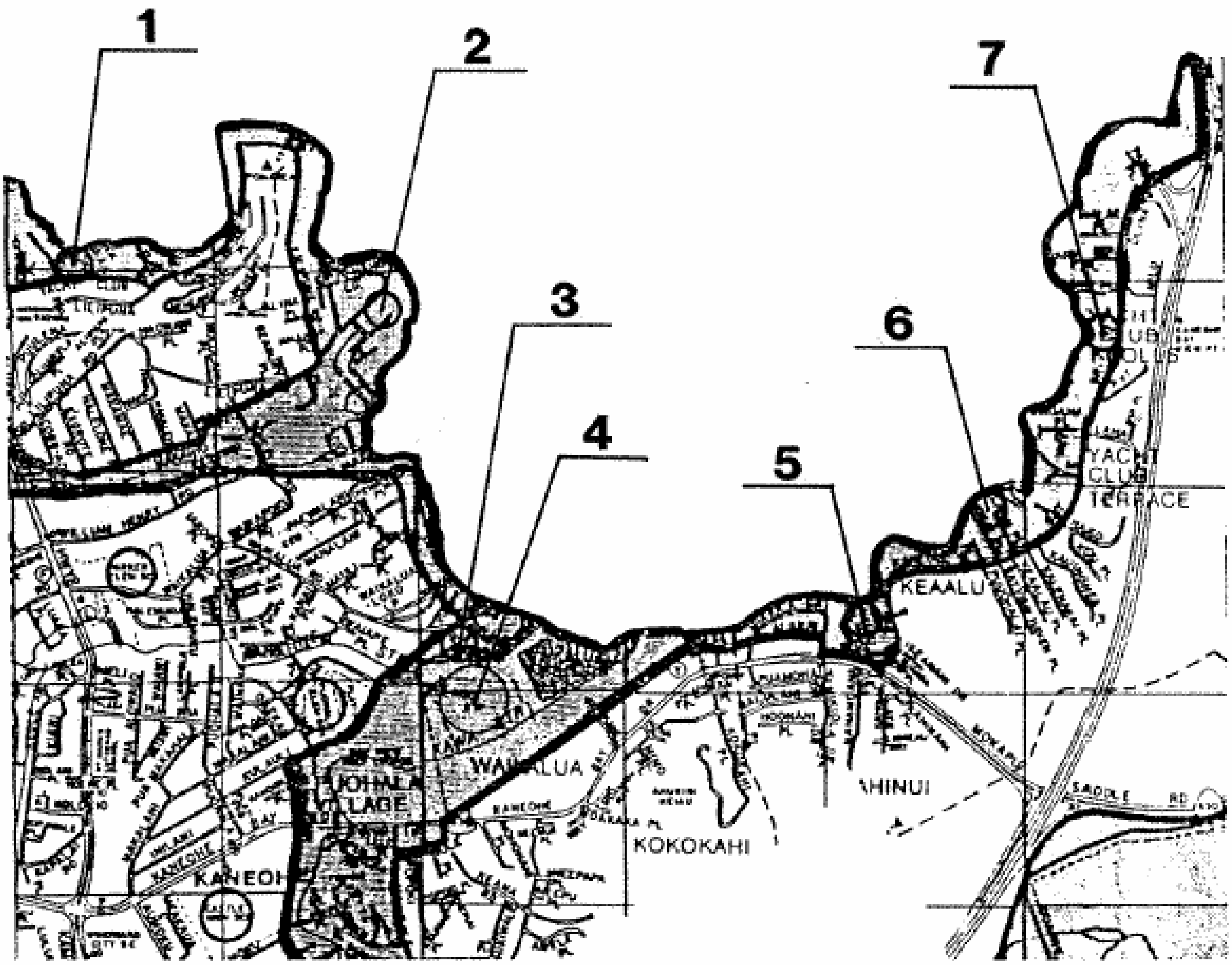
Lifeline Facility	Flood Elev (msl)
1) Aina Haina Hawtel Office	6.3
2) Niu Valley WWPS	6.0
3) Kuliouou WWPS	7.5

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KANEOHE AREA



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Lifeline Facility	Flood Elev (msl)
1) Heeia WWPS	9.6
2) Kahanahou WWPS	6.3
3) Waikalua WWPS	8.0*
4) Kaneohe WWTP	8.0*
5) Kaneohe Bay WWPS #2	5.6
6) Kaneohe Bay WWPS #3	5.6
7) Kaneohe Bay WWPS #4	5.6

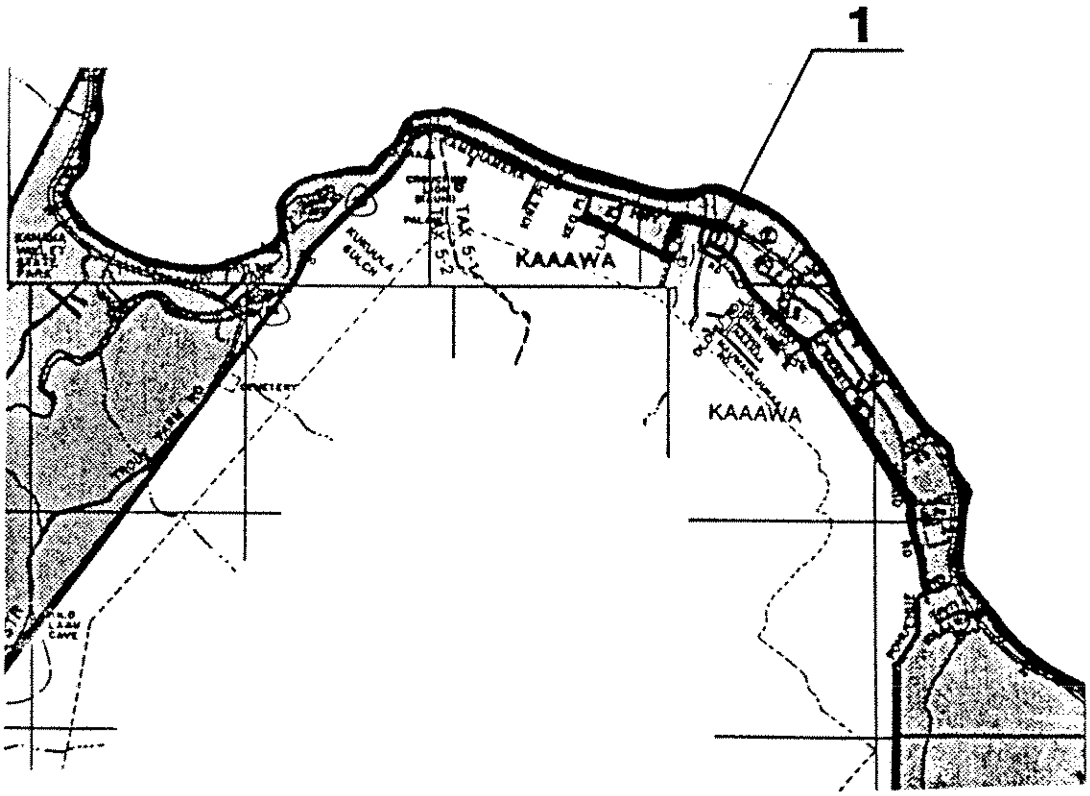
* Elevation is from the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

KAAAWA AREA



Lifeline Facility	Flood Elev (msl)
1) Kaaawa Fire Station	10.0*

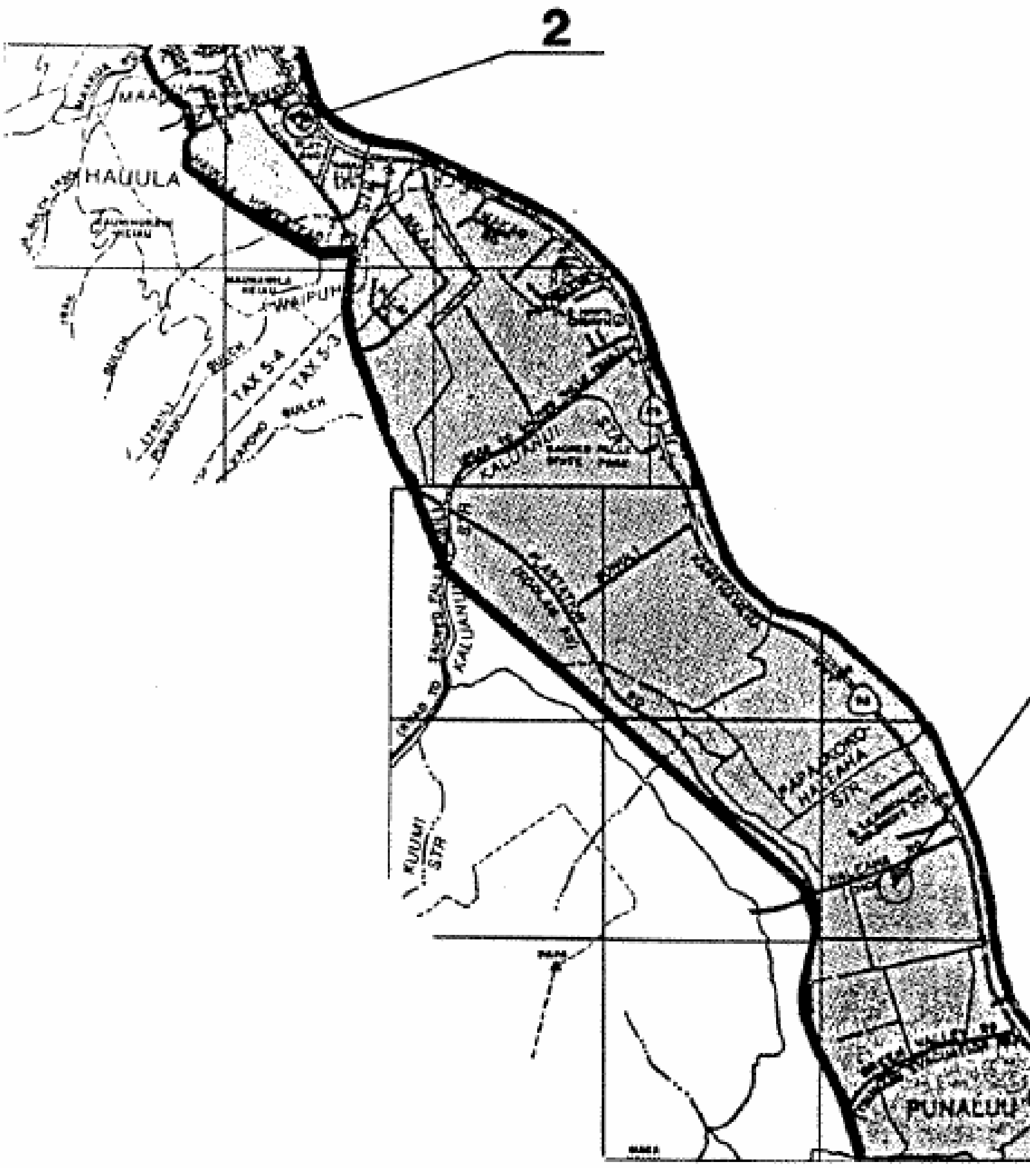
* Elevation is from the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities
Within
Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

PUNALULU - HAUULA AREA



Lifeline Facility	Flood Elev (msl)
1) Punaluu Well I	7.4
2) Hauula Fire Station	10.0*

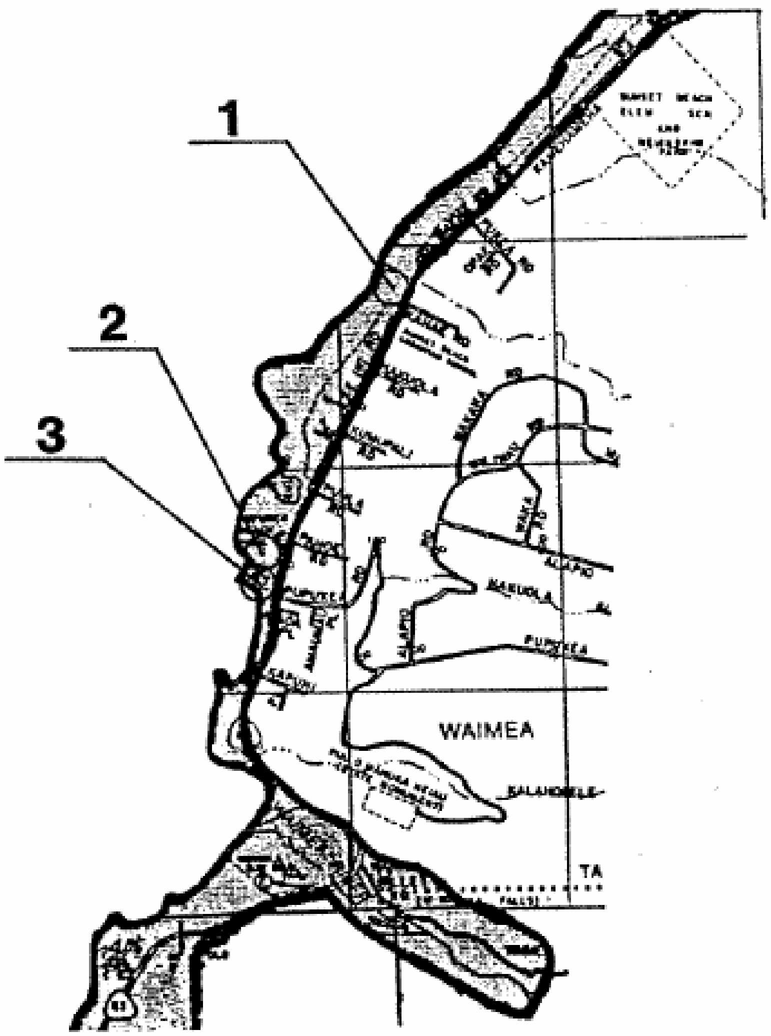
* Elevation is form the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

SUNSET BEACH - WAIMEA AREA



Lifeline Facility	Flood Elev (msl)
1) Sunset Beach Hawtel Office	16.0*
2) Pupukea WPS	18.0*
3) Sunset Beach Fire Station	18.0*

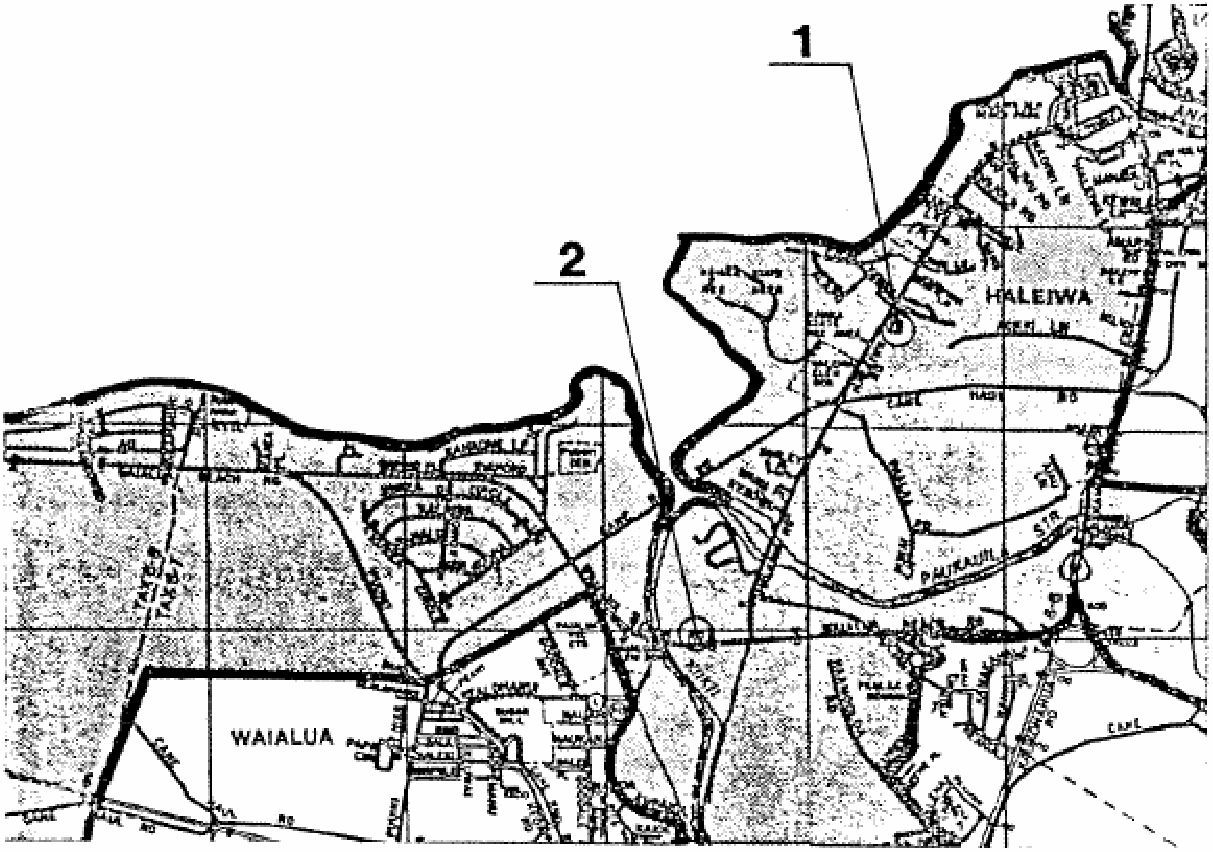
* Elevation is from the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities
Within
Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

HALEIWA - WAIALUA AREA



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Lifeline Facility	Flood Elev (msl)
1) Waialua Fire Station	12.0*
2) Waialua Hawtel Office	12.0*

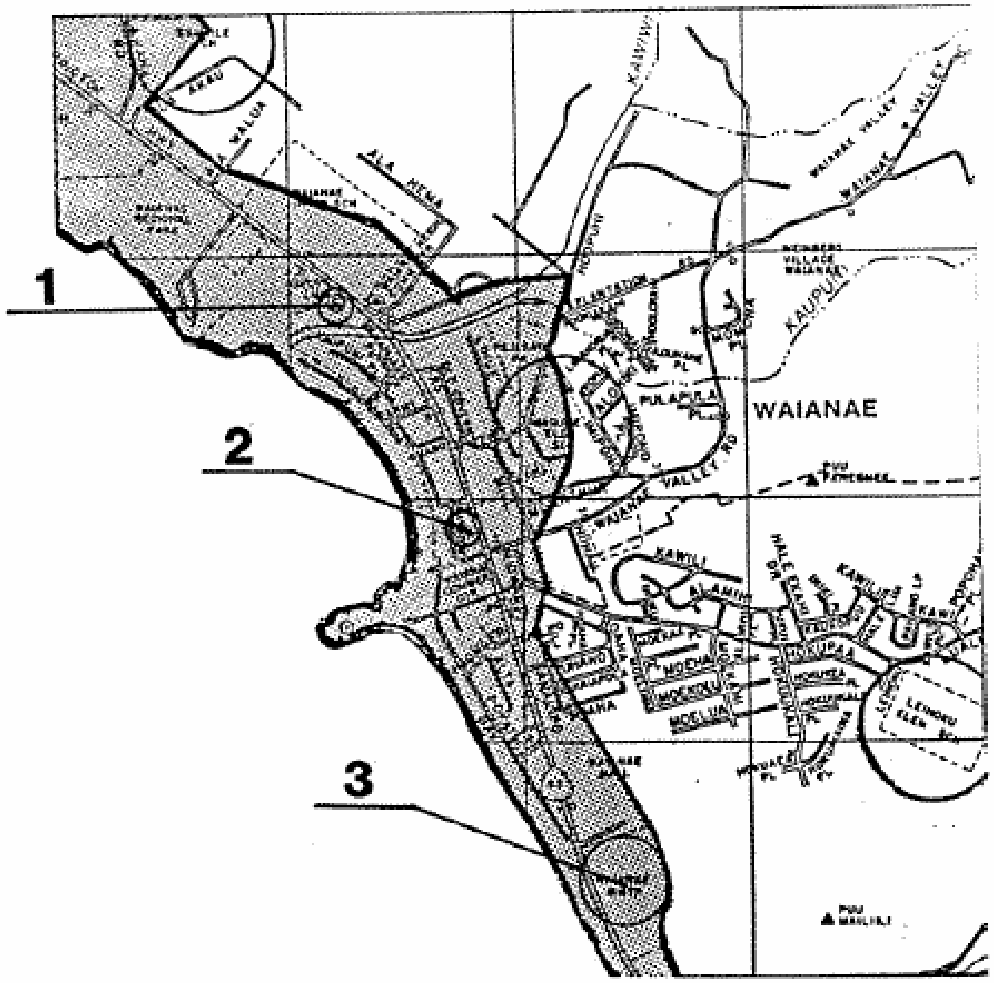
* Elevation is from the FIRM.

Hazard Mitigation Study
Island of Oahu

Lifeline Facilities Within Hurricane Inundation Zone

U.S. Army Corps of Engineers
Honolulu District

WAIANAE AREA



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Lifeline Facility	Flood Elev (msl)
1) Waianae Fire Station	9.2
2) Waianae Police Substation	12.0*
3) Waianae WWTP	14.0*

* Elevation is from the FIRM.

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Lifeline Facilities Within Hurricane Inundation Zone

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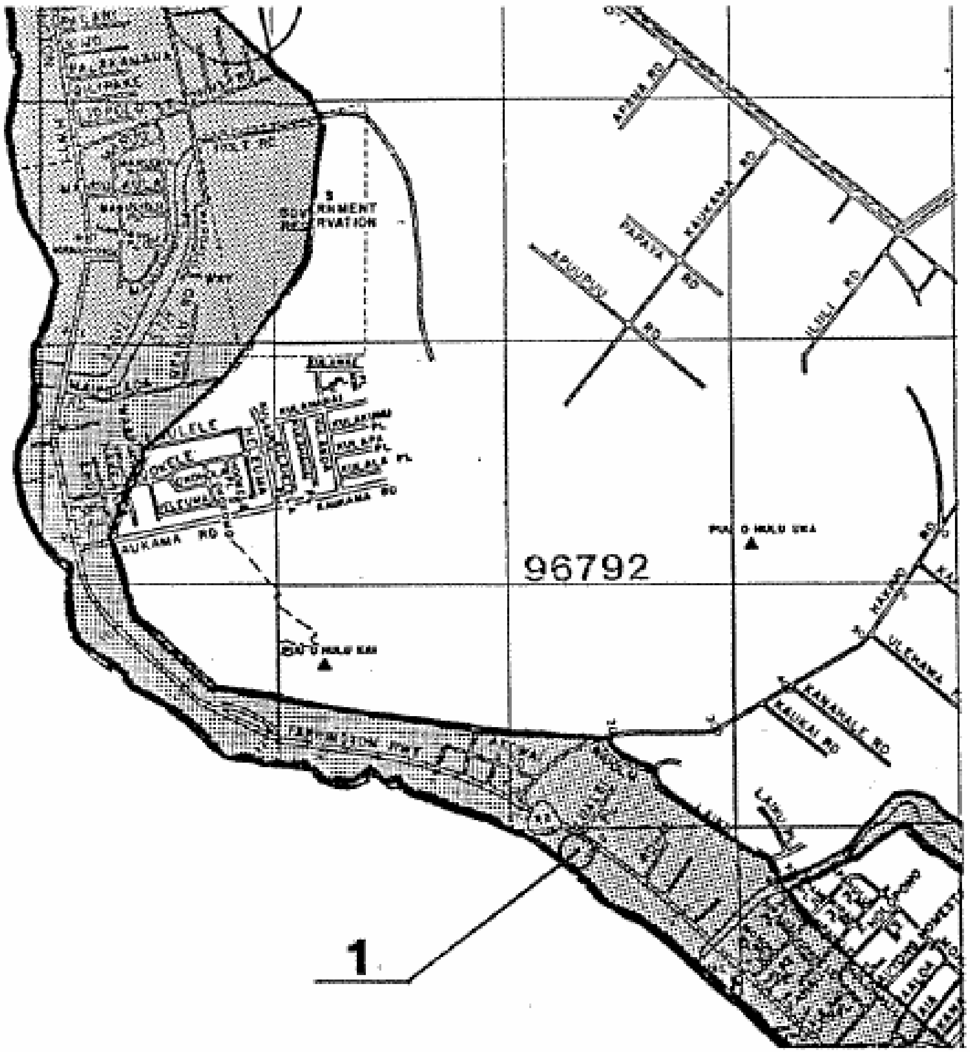
Honolulu District

NANAKULI AREA



Lifeline Facility
1) Lualualei WPS

Flood
Elev (msl)
14.0*

* Elevation is from the FIRM.

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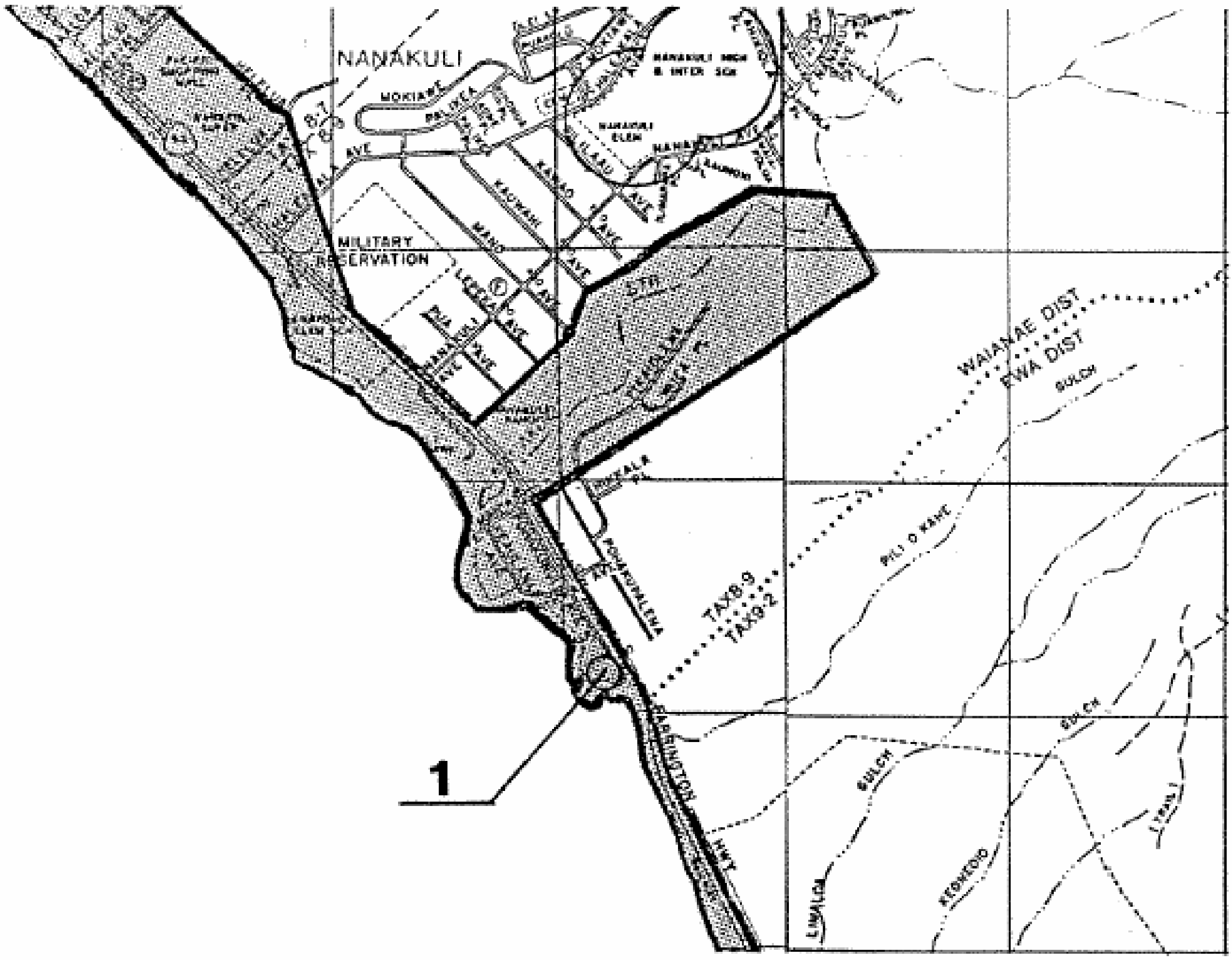
**Lifeline Facilities
Within
Hurricane Inundation Zone**

U.S. Army Corps of Engineers
Honolulu District

NANAKULI - KAHE AREA



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Lifeline Facility	Flood Elev (msl)
1) Nanakuli WPS	12.7

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Lifeline Facilities Within Hurricane Inundation Zone

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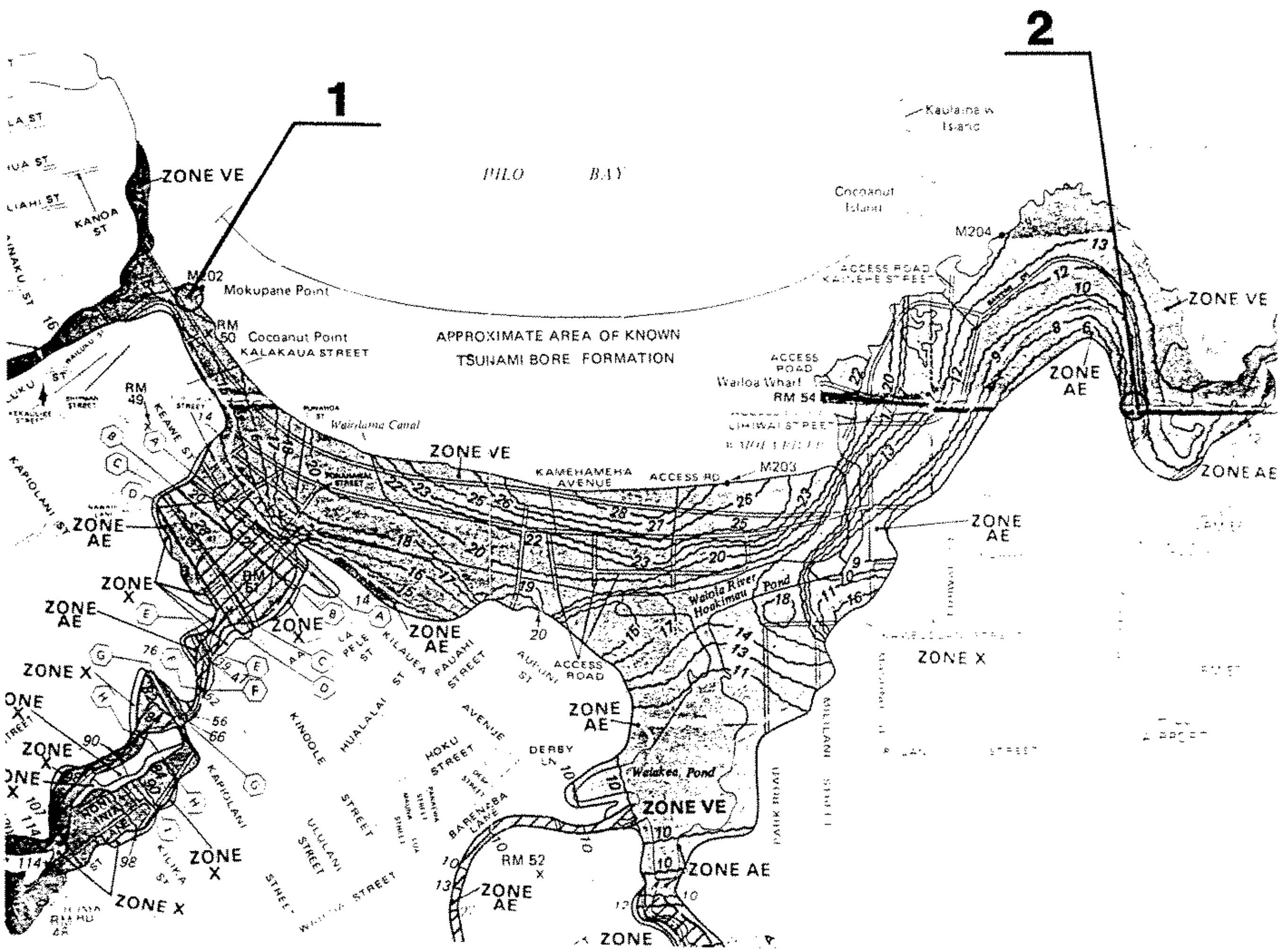
Honolulu District

HILO BAY AREA



Lifeline Facility	Flood Elev (msl)
1) Hilo WWPS	16.0
2) Banyan Drive WWPS	11.0

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Lifeline Facilities Within Tsunamis Inundation Zone

U.S. Army Corps of Engineers
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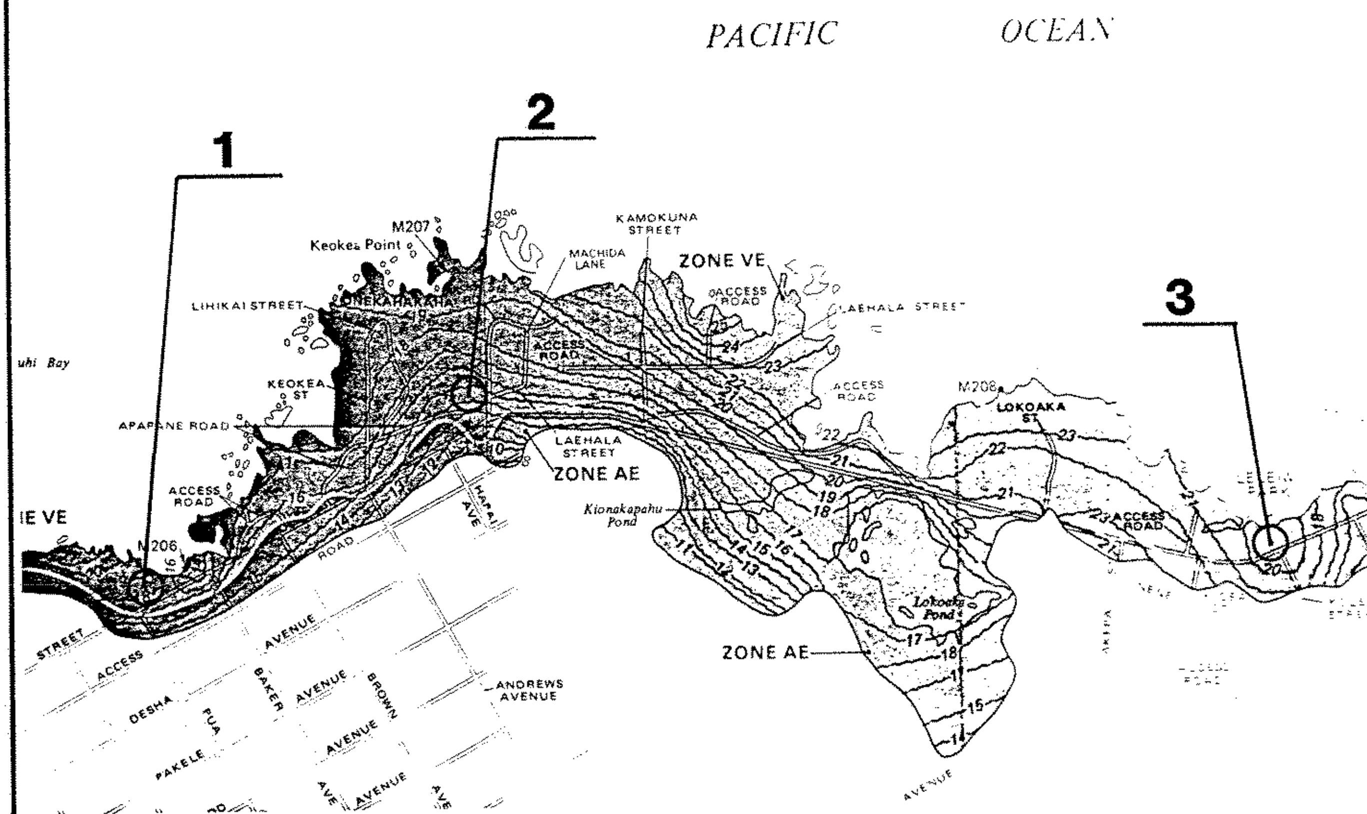
KEAKAHA AREA



Lifeline Facility	Flood Elev (msl)
1) Pua WWPS	19.0
2) Onekahakaha WWPS	14.0
3) Kolea WWPS	20.0

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Lifeline Facilities Within Tsunamis Inundation Zone

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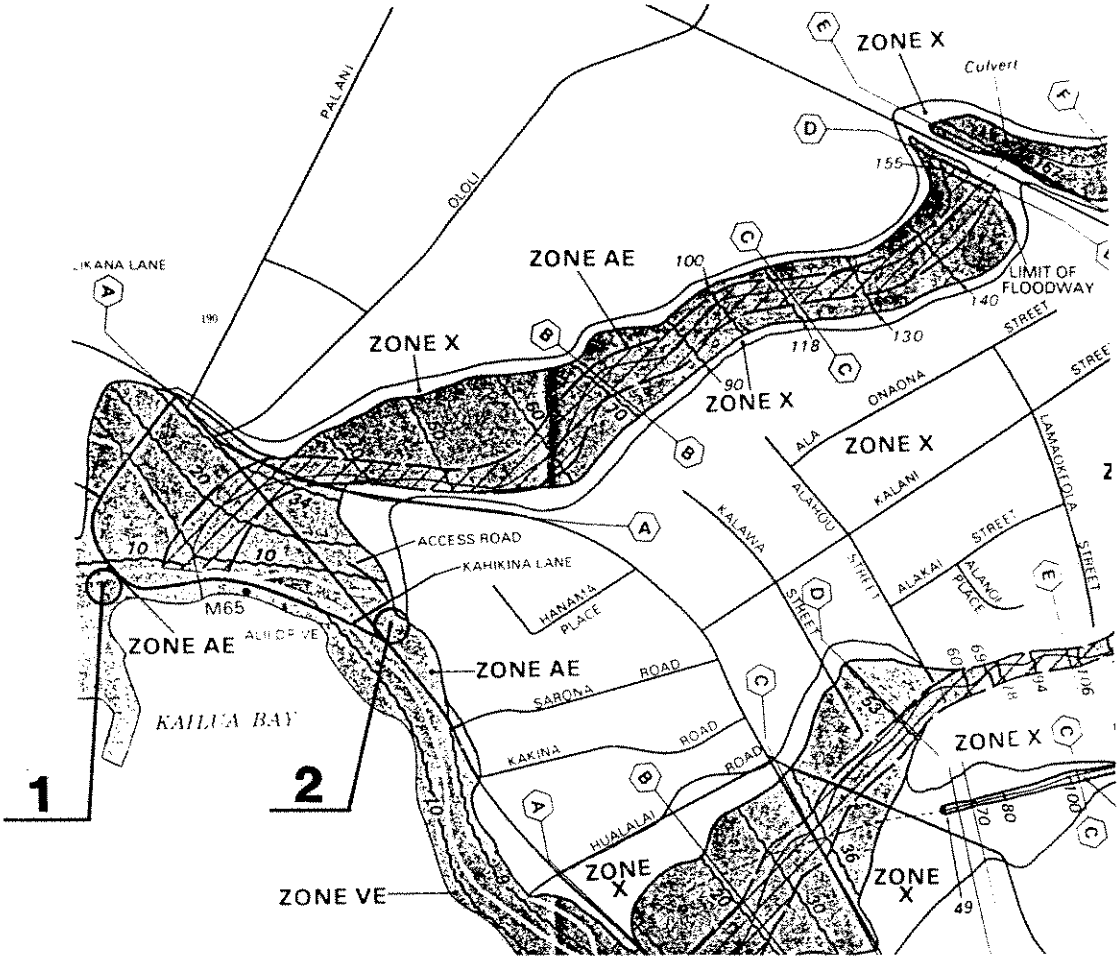
KAILUA BAY AREA



Lifeline Facility	Flood Elev (msl)
1) King Kam WWPS	10.0
2) Emma WWPS	9.0

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Lifeline Facilities Within Tsunamis Inundation Zone

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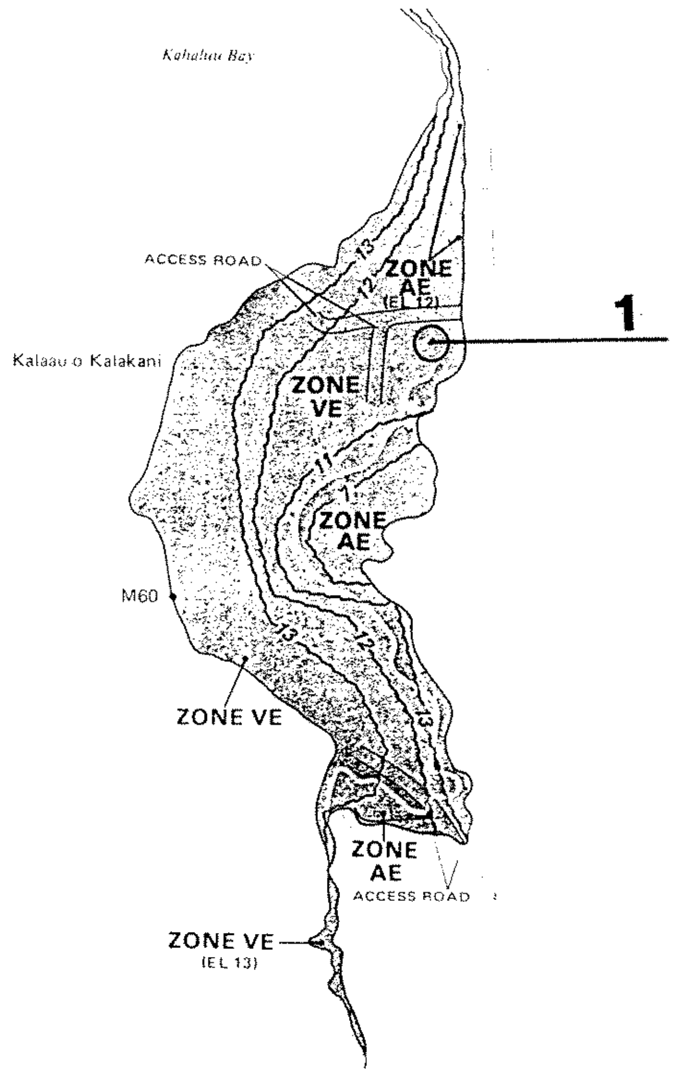
KAHALUU BAY AREA



Lifeline Facility	Flood Elev (msl)
1) Kahaluu WWPS	12.0

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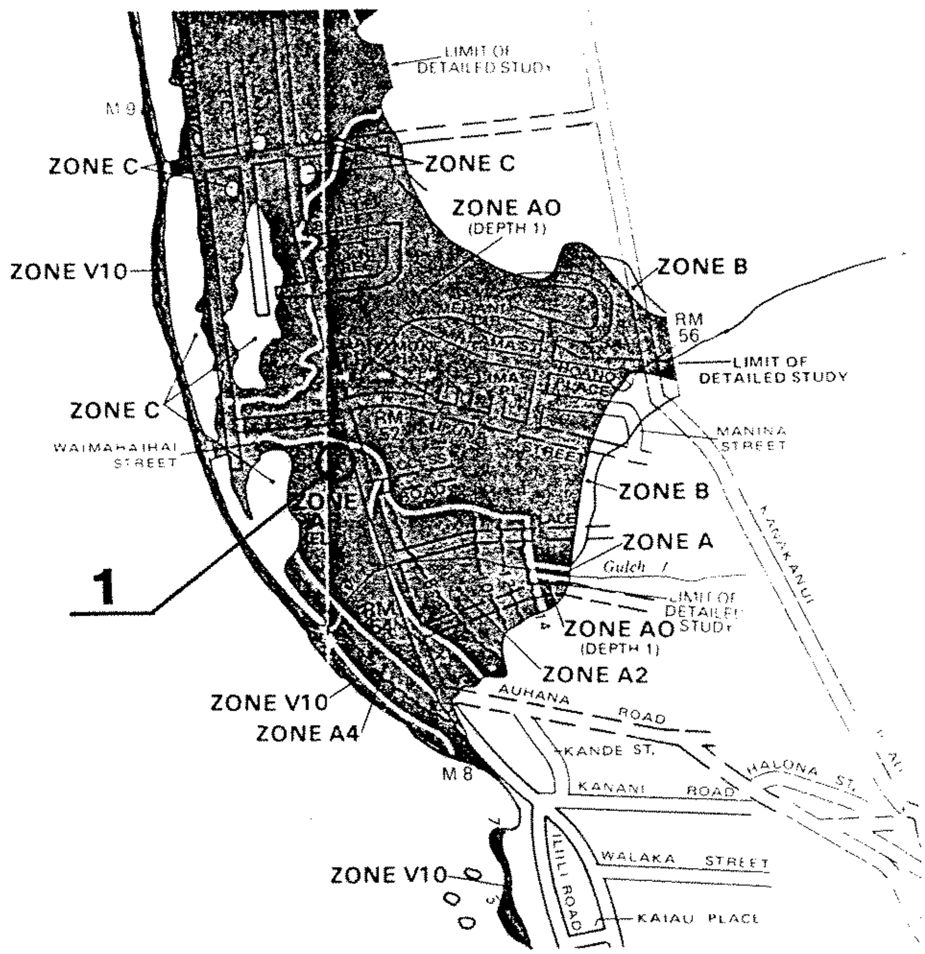
KIHEI AREA



Lifeline Facility	Flood Elev (msl)
1) Kihei Fire Station	7.0

Hazard Mitigation Study
Island of Maui

Lifeline Facilities Within Tsunamis Inundation Zone

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