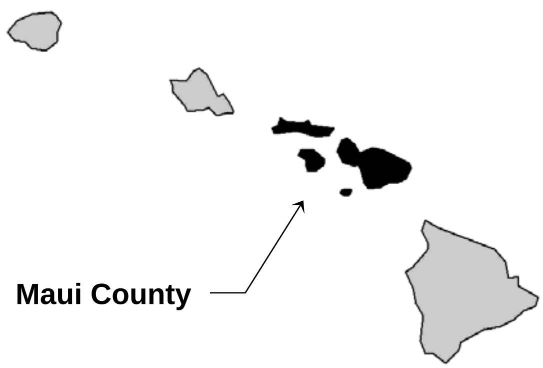
FLOOD INSURANCE STUDY

VOLUME 1 OF 2

MAUI COUNTY, HAWAII



Community Name	Community Number
MAUI COUNTY	150003

PRELIMINARY

AUG 08, 2014

REVISED
MONTH XX, 20XX

Federal Emergency Management Agency
FLOOD INSURANCE STUDY NUMBER
150003V002D

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components.

Initial FIS Effective Date: June 1, 1981

Revised FIS Dates:

September 6, 1989 – To change base flood elevations, to change special flood hazard areas, and to include the effects of wave action.

March 16, 1995 – To add base flood elevations, to change special flood hazard areas, and to include previously issued letters of map revision.

September 17, 1997 – To change base flood elevations, to change special flood hazard areas, to change zone designations, to add roads and road names, to incorporate previously issued letters of map revision, and to change floodway.

August 3, 1998 – To change special flood hazard areas, to reflect updated topographic information, and to incorporate previously issued letters of map revision.

May 15, 2002 – To change special flood hazard areas, to reflect updated topographic information, and to incorporate previously issued letters of map revision.

September 25, 2009 – To add special flood hazard areas, to add base flood elevations, to add floodway, to reflect updated topographic information, and to incorporate previously issued Letters of Map Revision.

September 19, 2012 – To change the special flood hazard areas, to change base flood elevations, and to incorporate previously issued letters of map revision.

[month day, 2015] – To change special flood hazard areas, to change base flood elevations, to add floodway, de-accredit Kaunakakai Stream levees, and to reflect updated topographic information.

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FLOOD INSURANCE STUDY
MAUI COUNTY, HAWAII

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and updates information on the existence and severity of flood hazards in the geographic area of Maui County, Hawaii. This FIS aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the county that will be used to establish actuarial flood insurance rates. This information will also be used by Maui County to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and will also be used by local and regional planners to further promote sound land use and floodplain development. Minimum floodplain management requirements for participation in the NFIP are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses for the original study were prepared by the U.S. Army Corps of Engineers (USACE), Pacific Ocean Division, for the Federal Insurance Administration (FIA), under Interagency Agreement Nos. IAA-H-7-76 and IAA-H-10-77, Project Order Nos. 29 and 4, respectively. This work, which was completed in June 1978, covered all significant flooding sources in Maui County. The hydraulic analyses for the Islands of Maui and Molokai were conducted by the R. M. Towill Corporation and by Sam Hirota, Inc., respectively, under subcontract to the USACE, while the USACE prepared the hydrologic analyses.

Updated hydrologic and hydraulic analyses, which were completed in December 1984, for the Kamiloloa and Kaunakakai areas on the Island of Molokai and the Wailuku, Kihei, and Kahului areas on the Island of Maui, were prepared by the USACE, Pacific Ocean Division, under Interagency Agreement No. EMW-84-E-1506, Project Order No. 1, Amendment No. 2.

This study was revised on March 16, 1995, to incorporate the results of new detailed flooding information along Kailua Gulch and shallow flooding in the Town of Wailuku. The data for this restudy were prepared by Sam O. Hirota, Inc. (SHI), under Contract No. EMW-89-C-2842.

The study was revised on September 17, 1997, to change base flood elevations, to change special flood hazard areas, to change zone designations, to add roads and road names, to incorporate previously issued letters of map revision, and to change floodway.

The study was revised on August 3, 1998, to incorporate the results of new detailed flood-hazard information along the coast of the Pacific Ocean in the vicinity of Lahaina Town on the northwestern end of the Island of Maui. The data was prepared by the USACE, Pacific Ocean Division, for FEMA, under Interagency Agreement No. EMW-95-E-4756. This restudy was completed in April 1997.

This study was revised on May 15, 2002, to incorporate the results of new detailed riverine and tsunami coastal flooding for an unnamed stream at Kuau Point, east of Lower Paia, located along the northern side of the Island of Maui. The data for this restudy were prepared by the USACE, Honolulu District, under Inter-Agency Agreement No. EMW-97-IA-0154, Project Order No. 7.

A new detailed coastal hurricane storm surge and wave height analysis was performed by Dewberry and Exponent as subcontractors to RMTC/URS, a Joint Venture, under FEMA contract number EMW-2003-CO-0046. Dewberry conducted the storm surge, wave height analyses, and hazard mapping and Exponent performed the hurricane selection, generation of storm meteorological data, and stillwater frequency analysis. This work was completed in August 2008.

The hydrologic and hydraulic analyses for Kamaole and Kaluaihakoko Gulches were performed by RMTC/URS for FEMA, under contract Task Order 2 of EMF-2003-CO-0046 to prepare a flood study for two streams on the Island of Maui. That work was completed in March 2005.

The September 25, 2009, study was conducted for FEMA to develop new flood hazard information for Waikapu Stream. This project was carried out under contract Task Order 14 of EM-2003-CO-0046 by Tetra Tech Incorporated and completed in November 2006 for the County of Maui Department of Planning.

A tsunami risk study of the Island of Lanai in Maui County, Hawaii was conducted in September 2009 by RMTC/URS for the Department of Homeland Security's Federal Emergency Management Agency (FEMA) to determine the 1% annual chance tsunami runup elevations and risk zones along the coastline. This project was carried out for FEMA under contract Task Order 22 of EMF-2003-RP-0001.

In 2010, this FIS was updated by FEMA study contractor BakerAECOM, LLC, to incorporate information from the 2009 tsunami risk study of the Island of Lanai, and the 2008 hurricane study on the Islands of Maui and Lanai. The 2008 hurricane study included the Island of Molokai however, Molokai was not incorporated into this revision. This project was carried out for FEMA under contract Task Order HSFE09-09-J-0001 of HSFEHQ-09-D-0368.

In 2014, this Flood Insurance Study (FIS) was updated by FEMA study contractor BakerAECOM to incorporate information from the 2008 hurricane study for the Island of Molokai and the de-accredited levees along Kaunakakai Stream. The study also incorporated revisions to Waikapu Stream as well as new detailed study for Kihei Gulch. Keokea Gulch and an approximate study for Waimahaihai Gulch. The revisions to Waikapu Stream included updating the November 2006 Waikapu Stream study hydrology prepared for the County of Maui Department of Planning by Tetra Tech by calibrating to available gauge data. This project was carried out for FEMA under contract Task Orders HSFE09-09-J-0001 and HSFE09-09-J-0002 of HSFEHQ-09-D-0368.

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held the community described in this countywide FIS. An initial CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to explain the nature and purpose of a FIS and to identify the streams to be studied by detailed methods. A final CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to review the results of the study.

Information on existing and planned flood-control projects was obtained from the Maui County Department of Public Works, Hawaii Department of Land and Natural Resources, and U.S. Geological Survey (USGS).

Tsunami characteristics and methods of studying tsunamis for the original report were discussed at a conference on February 25, 1977, attended by coastal engineering and tsunami experts from the University of Hawaii, National Oceanic and Atmospheric Administration (NOAA), Oahu Civil Defense Agency, and the FIA.

A final CCO meeting for the September 6, 1989, revised analysis was held on August 24, 1988, to present the results to the community. The meeting was attended by representatives of the Federal Emergency Management Agency (FEMA) and the study contractor, county officials, and interested members of the community.

The results of the March 16, 1995, study were reviewed at the final consultation coordination meeting held on November 15, 1993, and attended by representatives of Maui County and FEMA.

For the August 3, 1998, study, an initial CCO meeting was held on May 4, 1994, and attended by representatives of FEMA, the USACE, and Maui County. The results of this restudy were reviewed at the final CCO meeting held on August 5, 1997, and attended by representatives of FEMA, Maui County, and the study contractor. All problems raised at that meeting have been addressed in this restudy.

For the May 15, 2002, study, an initial CCO meeting was held on August 5, 1997, and attended by representatives of FEMA, the USACE and the County of Maui. The results of the restudy were reviewed at the intermediate CCO meeting held on September 23, 1999, and attended by representatives of FEMA, the USACE, and the County of Maui.

An initial CCO meeting was held on August 24, 2004, and attended by representatives of FEMA, the USACE, and the County of Maui. The final CCO meeting for the September 25, 2009 restudy was held on June 12, 2008, and attended by representatives of FEMA, the USACE, and the County of Maui.

An initial CCO meeting was held on January 27, 2010 in Wailuku, Hawaii and attended by representatives of FEMA, the study contractor, and the County of Maui. The final CCO meeting for the September 19, 2012 restudy was held on August 23, 2010, and attended by representatives of FEMA, the study contractor, USACE, Hawaii Department of Land and Natural Resources (DLNR) and the County of Maui.

An initial CCO meeting was held on August 19, 2010 in Wailuku, Hawaii and attended by representatives of FEMA, Hawaii Department of Natural Resources, the USACE, the study contractor, and the County of Maui.

The final CCO meeting for the [insert effective date] restudy was held on [August 11, 2014], and attended by representatives of FEMA, the study contractor, and the County of Maui.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the Islands of Maui and Molokai, which together with the Islands of Lanai and Kahoolawe are incorporated as Maui County. The Island of Lanai is privately owned and the Island of Kahoolawe is used by the U.S. Navy as a target area. All forest reserves, national parks, wildlife refuges, and other government property of the Islands of Kahoolawe, Lanai, Maui, and Molokai have been included in this study.

The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

On the Island of Maui, all or portions of the following streams were studied by detailed methods:

Hahakea Gulch
Honokahua Stream
Honokeana Bay Gulch
Honokowai Stream
Iao Stream
Kahana Stream
Kahoma Stream
Kahului Harbor
Kailua Gulch
Kalepa Gulch
Kalialinui Gulch
Kaluaihakoko Stream
Kamaole Gulch
Kaopala Gulch
Kauaula Stream
Keahaiwai Gulch
Keokea Gulch
Kihei Gulch 1
Kihei Gulch 2
Kihei Gulch 3
Kihei Gulch 4
Kope Gulch
Kulanihakoi Gulch
Liilioholo Gulch
Mahinahina Gulch
Napili Gulch 2
Napili Gulch 3
Napili Gulch 4
Napili Gulch 5
Olowalu Gulch 2
Olowalu Stream
Spreckel's Ditch (Wailuku Town Area)
Unnamed Stream at Kuau Point
Waiakoa Gulch
Waiakoa/Keahaiwai Split Flow
Waiehu Stream
Waihee River
Waikapu Stream
Waikapu Honoapaiilani Highway Overflow
Waipuilani Gulch

The following streams were studied by detailed methods on the Island of Molokai:

Kahananui Gulch
Kamalo Gulch
Kamiloloa Gulch
Kaunakakai Stream
Kawela Gulch
Keawanui Gulch
Manawai Gulch
Mile 84 Stream
Ohia Gulch
Pukoo Gulch
Unnamed Gulch
Waialua Stream

The entire coastlines of the Islands of Maui and Molokai were studied by detailed methods in order to establish tsunami inundation limits. In 2009, approximately 80% of the coastline of the Island of Lanai was studied to determine 1% annual chance tsunami risk zones. The Lanai tsunami study includes the coastline from Kaumalapau Harbor on the west coast clockwise around to Manele Bay on the south shore with a total shoreline length of approximately 40 miles.

The following sections of coast were studied in whole for the hurricane storm surge and wave height hazard using detailed methods:

- On the Island of Lanai, the southwestern and southern coastline from Kaumalapau to Manele.

- On the Island of Maui the western, southern, and eastern facing coasts from Honokahua to Kulepeamoa Point.

- On the Island of Molokai, the coastline south and east of Ilio Point to Cape Halawa.

Approximate methods were used to study the following areas on the Island of Maui:

Elialii Gulch
Haneoo Gulch
Hawelewele Gulch
Honanana Gulch
Honokohau Gulch
Honomaele Gulch
Kahakuloa Gulch
Kailua Gulch
Kailua Gulch 2
Kalepa Gulch
Kanemoeala Gulch
Kapia Stream
Kawaipapa Gulch
Kuiaha Gulch
Lelekea Stream
Maliko Gulch at Makawao
Mikimiki Gulch
Nuanualoa Gulch
Opelu Gulch
Pahihi Gulch
Papaahawhowa Gulch
Ponding in Kealia Ponding Area
Ponding at Kihei
Ponding on Maui Airport Road
Ponding at SR 30 and Waiale Road
Maliko Gulch
Ponding near Waihee River
Punaha Gulch
Waimahaihai Gulch
Waiokamilo Stream
Several unnamed gulches

Approximate methods were used to study the following areas on the Island of Molokai:

Ahaino Gulch
Aikoolua Gulch
Ekahahui Gulch
Halawa Stream
Halena Gulch
Honomuni Gulch
Honouliwai Stream
Kahinawai Gulch
Kainalu Gulch
Kalona Gulch
Kaluaaha Gulch
Kaluapeelua Gulch
Kapuaokoolau Gulch
Kawaikapu Gulch
Puniuohuanui Gulch
Several unnamed gulches
Keanakiole Gulch
Kiinohu Gulch
Kuakea Gulch
Kukuku Gulch
Kupeke Gulch
Manawainui Gulch
Maunaoluolu Gulch
Moanui Stream
Mokuolua Gulch
Naninanikukui Gulch
Oneohilo Gulch
Pahukauila Gulch
Papohaku Gulch
Punakou Gulch
Waiakane Gulch

The streams below were studied by approximate methods and were found to pose minimal flood hazards; therefore, no floodplain boundaries were delineated.

Alele Stream	Maalo Gulch
Kukuiula Stream	Mokupea Gulch
Lahaina Gulch 2	Moomooiki Gulch
Lahaina Gulch 3	Pohakupule Gulch
Launiupoko Stream	Ukumehame Gulch 2

Approximate analyses were used to study those areas having low development potential or minimal flood hazards as identified at the initiation of the study. The scope and methods of study were proposed to and agreed upon by FEMA and Maui County.

This FIS also incorporates the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision [LOMR], Letter of Map Revision - based on Fill [LOMR-F], and Letter of Map Amendment [LOMA], as shown in Table 1, "Letters of Map Change."

This <date> revision of the FIS incorporates one LOMR. Case 10-09-3595P, "Kope Gulch," was effective February 24, 2011 for Maui County. This LOMR has been fully incorporated into the FIS Report, and has been incorporated on FIRM panel 1500030381F, but has not been incorporated on FIRM panel 1500030383E, since the portion of the LOMR affecting FIRM panel 1500030383E is outside this PMR extent. The portions of LOMR remain effective on panel 1500030383E.

Case 12-09-2563P, "Self Help Housing-Hana LOMR," was effective July 8, 2013 for Maui County. This LOMR is not incorporated in this PMR since it is outside the panels affected by this PMR. This unincorporated LOMR remains effective.

TABLE 1: LETTERS OF MAP CHANGE

Community	Flooding Source(s)/Project Identifier	Date Issued	Type
Maui County	Kope Gulch	February 24, 2011	LOMR
Maui County	Schloemer Property	January 18, 2011	LOMR
Maui County	Waiakoa Gulch	March 25, 2008	LOMR
Maui County	Makena Surf Property	February 29, 2008	LOMR
Maui County	Hahakea Gulch	May 24, 2007	LOMR
Maui County	Tahmoush Property, Papohaku Beach	May 10, 2006	LOMR
Maui County	Alii Village Subdivision & Drainage Improvements	February 25, 2005	LOMR
Maui County	Maui Nui Park	July 1, 2004	LOMR
Maui County	Puu-Kahana Subdivision	June 13, 2003	LOMR
Maui County	Ka' Ono' Ulu Estates- Phase IV	May 8, 2003	LOMR
Maui County	Makena Beach Lots, Lot A-2 and Lot B	May 6, 2003	LOMR
Maui County	Mahinahina Gulch	February 22, 1999	LOMR
Maui County	Kai Ala Subdivision – Pailolo Channel	July 13, 1998	LOMR
Maui County	Kalepa Bridge Replacement	October 22, 1997	LOMR
Maui County	Makena Surf Subdivision	July 18, 1997	LOMR
Maui County	Kahului Airport Tsunami Flood Study	July 23, 1996	LOMR
Maui County	Owa Subdivision	August 22, 1994	LOMR

2.2 Community Description

The State of Hawaii legally consists of 132 islands with a total land area of 6,425 square miles, 99.9 percent of which is in eight major islands. Hawaii is unique in that it has only two levels of government: state and county. There are no smaller municipalities under the county level and no school districts.

Maui County is the second largest of the four Hawaiian counties, comprising a total area of approximately 1,173 square miles. The Island of Maui covers an area of approximately 728 square miles; the Island of Molokai, approximately 261 square miles; Island of Lanai, approximately 139 square miles; and the Island of Kahoolawe, approximately 45 square miles.

In recent years, tourism has become the major industry in the county, surpassing the pineapple and sugar cane industries. Maui County attracts more tourists than any other county in the state. The tourist industry is expected to grow with continued resort development.

The Town of Wailuku is the county seat. Wailuku and the adjoining Town of Kahului form the business hub of the county. Kahului has a deep-draft harbor and an airport that serve the entire island.

Two principal types of circulation account for precipitation on the islands: the clockwise flow from the stable high-pressure cell northeast of Hawaii that initiates orographic rainfall (caused by the presence of mountains), and the counterclockwise flow of cyclonic storms that produce generally distributed rainfall (amounting to 20 to 30 inches per year). Orographic rainfall is restricted to mountain areas where uplifting of the moist air exceeds 2,000 feet; these are the parts of the state with the highest rainfall.

The predominant northeasterly trade winds directly influence the climate of the islands. Generally, leeward locations are markedly drier and sunnier than the windward slopes. The wet winter season extends from October through April on Maui and from December through March on Molokai. The dry summer season extends from May through September on Maui and from June through August on Molokai.

Rainfall varies considerably from one part of each island to another. The windward areas of Maui generally get heavier rainfall than the leeward side. The zones of highest rainfall on the windward side of Haleakala, a 10,023-foot high volcano lie between the 2,000- and 4,000-foot elevations, where the median annual rainfall is 200 to 300 inches. On the western side of the island, the median annual rainfall near the summit of Puu Kukui is approximately 400 inches. In contrast, leeward locations in central Maui, such as Kihei, have a mean annual rainfall of approximately 10 inches. The climatic situation is much the same on the Island of Molokai, where the windward side of the island gets heavier rainfall. The average annual rainfall for the island ranges from approximately 12 inches to over 150 inches. This great disparity in annual rainfall on the two islands arises from the fact that the Hawaiian Islands extend over a latitudinal belt that is a zone of desiccation throughout the world except where marine air masses are forced to rise over mountain barriers. Orographic rainfall results from the cooling of the uplifted airmasses, creating extremely high rainfall under the ideal conditions of mountain elevation and trend, and wind direction and velocity.

Throughout Hawaii, the temperature is generally warm and pleasant. Variations in temperature depend more on location than season. On Maui and Molokai, the climate ranges from warm and dry in the coastal areas to semitropical on the windward mountain slopes. The average annual temperature is 72 degrees Fahrenheit (°F). At the summit of Haleakala, the temperature occasionally drops below 32°F during the winter and snow covers the peak for short periods of time.

ISLAND OF MAUI

The Island of Maui has an extreme length and width of 48 and 26 miles, respectively. Approximately 29 miles of coastline are made up of cliffs over 100 feet high. Thirty-eight and one-half percent of the land area has a slope of less than 10 percent, 25.5 percent has a 10- to 19-percent slope, and 36 percent has a slope of 20 percent or greater (University of Hawaii, 1973).

The two volcanic cones of Haleakala, on East Maui, and Puu Kukui, on West Maui, form the island. Another well-known geological feature is the Needle, a rock pinnacle located in the Iao Valley on West Maui. The two cones are joined by a relatively flat isthmus, formed of sand blown inland when the sea was somewhat lower during the late Pleistocene Period. East Maui is geologically younger than West Maui, as evidenced by the absence of deeply incised canyons and extensive areas of volcanic lava and cinders on the leeward slopes of Haleakala. Volcanic rocks, cinders, and ash are the basic material from which the in situ soils developed. The lands more suitable for agriculture, including the gentle slopes of central Maui and the tablelands of West Maui, resulted from alluvial deposits and the decomposition of basaltic materials (USACE, 1971).

Descriptions of the streams studied by detailed methods on Maui follow.

Hahakea Gulch

The portion of Hahakea Gulch studied in detail extends from its mouth to 4,000 feet upstream; the average slope in the study area is approximately 3.2 percent. There are three stream crossings within the study area, one located downstream of the old Honoapiilani Highway, the second at the new highway, the third at a culvert at a cane haul road approximately 2,100 feet upstream of its mouth. Ground cover along the study area varies from sugarcane upstream of the cane haul road to low grass at the Kaanapali Golf Course downstream of the cane haul road.

Honokahua Stream

Napili Gulch 2-3 was studied for approximately 2,000 feet. The studied portion has an average slope of approximately 2 percent. Below Honoapiilani Highway, most land development is hotels and apartment buildings. The shoreline is a white sand beach which extends to the southwest approximately 1,000 feet. The land upstream of the highway is used to grow pineapples.

Honokeana Bay Gulch

The average slope of Honokeana Bay Gulch within the limits of the 2,700-foot-long study area is 3 percent. The upper portion of the area is planted in pineapple crops. Residential and hotel developments are located along the lower part of the gulch.

Honokowai Stream

Honokowai Stream was studied for approximately 3,000 feet upstream of its mouth. Its slope averages approximately 1 percent. Three bridges cross the stream within the limits of the study area; the first is located at the existing Honoapiilani Highway, the second at the new Honoapiilani Highway, and the last at a cane haul road approximately 2,500 feet of the mouth. The ground cover along the stream below the old highway is primarily low brush on the south bank of the stream. Single-family dwellings, apartment buildings, and hotels line the stream’s north bank. The area above the old highway is predominantly sugarcane fields with some residential-commercial development north of the stream.

Iao Stream

Iao Stream is on the eastern slope of the West Maui Mountains, near the north end of the "saddle" that connects East and West Maui. Iao Stream was studied for a distance of 13,600 feet. There is fairly heavy commercial, agricultural, and residential development along the study reach.

Kahana Stream

Kahana Stream was studied for 1,600 feet. The only major stream crossing is located 400 feet upstream from the mouth at the old Honoapiilani Highway Bridge. The average slope of the stream is approximately 1.5 percent. Below Honoapiilani Highway and immediately above it, there are scattered residential homes and apartment buildings. Above these homes, to the upper limits of the study area, are sugarcane fields.

Kahoma Stream

The study area of Kahoma Stream extends approximately 5,000 feet upstream from its mouth. Its slope is approximately 2 percent. Starting from its mouth near the existing Mala Wharf, the studied portion extends upstream under a bridge at Front Street and along a stand of eucalyptus trees to a bridge under Honoapiilani Highway, the second at the new Honoapiilani Highway, and the last bridge at a cane haul road approximately 2,500 feet upstream from the mouth. The ground cover along the stream below the old highway is primarily low brush on the south bank of the stream. Single-family dwellings, apartment buildings, and hotels line the stream's north bank. The area above the old highway is predominantly sugarcane fields with some residential-commercial development north of the stream.

Kahului Harbor

Kahului Harbor, located in Kahului Bay, is the only deep-draft harbor serving the Island of Maui. The harbor is approximately 94 miles southwest of Honolulu and is centrally located on the northern shore of the island. The port handles transpacific and interisland cargos, including containerized and generalized cargos, cement, fertilizer products, bulk sugar, and molasses.

Kahului Harbor is exposed to prevailing winds and waves from the north and northeast quadrants. Northeast trade waves are present 80 to 90 percent of the time during May through September and 60 to 70 percent of the time during the remainder of the year. Typically, these deepwater waves have periods ranging from 6 to 10 seconds and heights of 4 to 12 feet. The northern swell is generated in the northern Pacific Ocean by intense winter storms. These waves typically have periods of 12 to 18 seconds and deep water heights of 5 to 25 feet. These waves generally occur during October through March and are among the largest waves that reach the Hawaiian Islands.

Kalepa Gulch

Kalepa Gulch was studied for approximately 3,900 feet. The portion studied has an average slope of 3.5 percent. Ground cover in the study area varies from sandy shoreline to thick brush with some trees and cultivated sugarcane fields below Kahekili Highway. Near Kahekili Highway, Kalepa Gulch runs through the north end of the Town of Waihee. Waihee Elementary School is on the north bank at the highway. Above the town, Kalepa Gulch flows through sugarcane fields.

Kalialinui Gulch

Kalialinui Gulch is located east of Kahului, near Kahului Airport. Flowing along Sunnyside Road, Kalialinui Stream passes through the industrial area adjacent to the airport. The drainage area covers approximately 19.2 square miles; the average slope is approximately 0.6 percent. Above the intersection of Sunnyside and Dairy Roads, the gulch is covered with grass and brush. Downstream of the intersection, the channel area is clear of vegetation. A portion of the channel near the airport access road is concrete lined.

Kamaole Gulch

Kamaole Gulch has an average slope within the 1,500-foot long study area of approximately 2 percent. The gulch runs through pastureland above Kihei Road and between several houses below Kihei Road.

Kaopala Gulch

Kaopala Gulch was studied 1,500 feet from Honoapiilani Highway. Its slope is approximately 3 percent. The overbank terrain has nearly the same slope as the gulch. Apartment buildings and hotels have been constructed between the highway and the shoreline; above the highway, there are residential dwellings, in a strip that varies from 100 to 200 feet wide. Upland from the residential dwellings are sugarcane fields to the south of the gulch and pineapple fields to the north.

Kauaula Stream

The Kauaula drainage basin contains 3.9 square miles of agricultural, forest, and residential lands. The study area extends approximately 2,600 feet upstream of its mouth, and the average slope of the stream is approximately 3.9 percent. There are four major stream crossings within the study area. Kauaula Stream flows in an improved concrete-lined channel between the mouth and a bridge at the Honoapiilani Highway. The channel is also concrete-lined between the highway and another stream crossing approximately 50 feet upstream from the highway at a cane haul road. The upper portion of the reach above the first cane haul crossing about 2,500 feet above the mouth at another cane haul road. The upper portion of the reach above the first cane haul bridge is unlined.

Keahaiwai Gulch

The length of Keahaiwai Gulch is approximately 3,000 feet and the average slope of the gulch is 0.6 percent. The gulch runs through sugarcane and corn fields above Mokulele Highway. At the highway, the stream passes through a box culvert and makes its way to Kealia Pond, which has an outlet to the sea near the northern end of the pond.

Keokea Gulch

Keokea Gulch is a fairly well-defined watercourse above Piilani Highway. However, its channel becomes undefined once it passes the electrical substation upon entering Kihei Regional Park (located between Piilani Highway, South Kihei Road, East Welakahao Road and Halekuai Street). The study area covers 9.15 square miles; its slope varies from approximately 2 percent in the upper reach down to a slope of nearly 0.0 percent at Kihei Regional Park.

Kihei Gulch 1

The Kihei Gulch 1 watercourse is not well defined. The average slope of this gulch is approximately 0.4 percent over the study length of 1,500 feet, measured upstream from the mouth. The average slope from approximately 1,500 feet to just upstream of Piilani Highway is approximately 3.3 percent.

Kihei Gulch 2

Kihei Gulch 2 lies to the north of the Inter-Continental Hotel, and was studied for a distance of 1,500 feet above its mouth. Its slope averages 5 percent.

Kihei Gulch 3

Kihei Gulch 3 is located north of and adjacent to the Intercontinental Hotel. Its average slope in the study area is approximately 5.5 percent. Kihei Gulch 3 was studied for a distance of 1,500 feet upstream of the mouth. Kihei Road separates the hotel grounds from the Wailea Golf Course, and the gulch below Kihei Road is approximately 20 feet deep. Its cross sections vary considerably from very steep below Kihei Road, and this type of moderate slope is predominant throughout the golf course areas on Kihei Gulch 3.

Kihei Gulch 4

Kihei Gulch 4 is located to the southeast of Wailea between Wailea and Makena in the vicinity of the Wailea Golf Course. Kihei Road runs parallel to the lower portion of the gulch until it crosses the gulch at the shoreline. The average slope is approximately 5 percent. The study area on the gulch extends approximately 1,500 feet upstream from the mouth at the shoreline.

Kope Gulch

The study area on Kope Gulch extends 4,400 feet upstream of its mouth; the gulch has an average slope of approximately 7 percent. The upper limit of the study area is approximately 3,000 feet above Kahekili Highway. Kope Gulch is located to the south of the Town of Waihee and flows within the cultivated sugarcane fields above and below Kahekili Highway.

Kulanihakoi Gulch

The Kulanihakoi Gulch study area covers 14.97 square miles, and the stream has a 0.4-percent average slope. Kulanihakoi Gulch has characteristics similar to that of neighboring Waipuilani Stream. The upper one-half of the gulch is covered with Keawe trees and brush. Downstream, there are some scattered trees along the coastline.

Liilioholo Gulch

Liilioholo Gulch has an average of approximately 3 percent within the 2,000 feet of study area extending from its mouth upstream. The present channel is very shallow, ranging from 3 to approximately 6 feet deep. It is also very narrow, from 5 to 10 feet across. In the upper reach of the study area, the alignment of the channel is nearly perpendicular to the shoreline; but, as it nears Kihei Road, the gulch runs northward and intersects Kihei Road.

Mahinahina Gulch

The study area along Mahinahina Gulch extends 1,200 feet upstream from its mouth. The stream slopes at an average of approximately 2.5 percent. Two bridges cross the stream; the first is at the old Honoapiilani Highway, and the second is at the new Honoapiilani Highway, approximately 600 feet above the old one. Development along the banks of the gulch between the shoreline and the area immediately above the old Honoapiilani Highway is primarily residential. Sugarcane fields are the predominant ground cover above the residential area.

Napili Gulch 2-3

Napili Gulch 2-3 was studied for approximately 2,000 feet. The studied portion has an average slope of approximately 2 percent. Below Honoapiilani Highway, most land development is hotels and apartment buildings. The shoreline is a white sand beach which extends to the southwest approximately 1,000 feet. The land above the highway is used to grow pineapples.

Napili Gulch 4-5

Napili Gulch 4-5 has an average slope of approximately 3.5 percent, and the length of the area studied is approximately 3,400 feet. There is one bridge at Honoapiilani Highway and a culvert on a cane haul road approximately 2,600 feet upstream from the highway. Ground cover above the highway consists of fairly thick trees and pineapple fields. The shoreline at the stream mouth is a sandy beach.

Olowalu Gulch 2

The mouth of Olowalu Gulch 2 is east of Hekili Point. The study area extends approximately 2,000 feet upstream of its mouth, and the average slope of the stream is approximately 0.9 percent.

Olowalu Stream

The length of the study area is approximately 2,800 feet, and the stream has an average slope of approximately 2.5 percent. Olowalu Stream is one of the largest streams in the area. Ground cover, consisting of thick brush, is found along the banks and in sections of the stream bed. Sugarcane fields lie outside the crest of its banks. Two bridges cross Olowalu Stream, one at the existing Honoapiilani Highway and one at the cane haul road immediately upstream of the highway.

Spreckel’s Ditch (Wailuku Town Area)

Spreckels Ditch is on the eastern slope of the West Maui Mountains, near the north end of the “saddle” that connects East and West Maui. The study area covers 2.07 square miles. Spreckels Ditch passes through the Town of Wailuku where it flows into Waiale Reservoir, to the south. There is fairly heavy commercial, agricultural, and residential development along the study reach.

Waiakoa Gulch

The study area extends 4,000 feet upstream of its mouth, and Waiakoa Gulch has an average slope of approximately 1.4 percent. The ground cover above Kihei Road consists of thick Keawe trees and brush. Seaward of Kihei Road, condominiums and apartment buildings occupy both banks.

Waiehu Stream

The studied portion for Waiehu Stream starts at its mouth below Kahekili Highway and extends upstream a distance of 3,000 feet. Within the study reach, the average slope of the stream is approximately 0.1 percent. There are three major crossings along the stream reach: a bridge located 650 feet above the mouth of the stream, a second bridge located 600 feet below Kahekili Highway, and two 10-foot diameter culverts on Kahekili Highway, near its intersection with the Waihu Beach Road. Ground cover along the watercourse is primarily thick brush and trees below Kahekili Highway, with the exception of a sand dune area to the south of the stream, below Waiehu Beach Road. Above Kahekili Highway, there are cultivated sugarcane fields along the stream.

Waihee River

The Waihee River study area extends 6,000 feet upstream from its mouth, and the river has a slope of approximately 0.3 percent. The elevation change within the study area is 185 feet. A multispan bridge structure at Kahekili Highway crosses the river approximately 3,000 feet upstream of its mouth. Ground cover in the area is primarily thick brush and tree growth, except near the shoreline where the trees thin out and eventually give way to low brush and a rocky shore.

Waikapu Stream

The study of Waikapu Stream was conducted for a 6.00-mile stretch in Maui County, extending from approximately 0.8 miles upstream of the Honopiilani Highway to its termination at the Kealia Pond on the southern coast of Maui Island. The Waikapu stream passes through the central lowlands of Maui Island originating from Maui's western mountains. The boundaries along the southern portion of the Waikapu stream tie in with existing floodplain boundaries.

Waipuilani Gulch

The Waipuilani study area covers approximately 14.54 square miles. The gulch has a 1-percent slope in the upper course of the study area and a very mild, 0.5-percent slope in the lower portion. Thick Keawe trees are brush cover the upper reach of the stream. The lower stream area varies from moderately thick brush to open beach.

ISLAND OF MOLOKAI

On the Island of Molokai, pineapple, livestock, vegetables, and corn seed are the major products. The State built a large-scale irrigation project, which enlarged the role of diversified agriculture. In recent years, tourism has also become important in the economy of the island. Development of resorts on the west coast will further expand the tourism industry. Maunaloa and Kaunakakai are the major settlements on Molokai.

Topography in the area ranges from a relatively flat coastal plain with an average elevation of 3.5 feet to the slopes of the East Molokai Mountains of 3,000 feet. The coastal plains are characterized by low, marshy ground with terrestrial and calcareous soils extending approximately 700 feet inland from the ocean. Grass and brush predominantly cover the coastal plain area. Keawe trees grow in the area above the coastal plain.

The climate on the Island of Molokai is typically characterized by that of the Hawaiian Islands in general. The island experiences a two-season year (winter/summer), mild and uniform temperatures, marked geographical differences in rainfall, generally humid conditions, and a general dominance of northeasterly tradewinds. Temperatures obtained from the temperature recording station at Kualapuu, located approximately 5 miles from Kaunakakai, are applicable to the Kaunakakai area, with only few degrees variation. The mean average temperature ranges from 69°F in January to 76°F in August.

Descriptions of the streams studied by detailed methods on Molokai follow.

Kamiloloa Gulch

The Kamiloloa Gulch drainage basin is approximately 0.5 mile east of the Kaunakakai Basin. The shoreline area near the mouth of the Kamiloloa Stream is lightly populated. Lying just within the drainage area is the Kapaakea residential development. The drainage basin covers an area of approximately 3.7 square miles.

Kaunakakai Stream

The Kaunakakai Stream drainage basin is located on the south-central coast of Molokai. The Town of Kaunakakai, the urban and commercial center of the island, lies within the drainage area, along the coastal plain. The basin covers an area of 6.0 square miles, ranging from a developed coastal area to the forest of the East Molokai Mountains.

Unnamed Gulch

Approximately 0.75 mile west of Kaunakakai Stream is an unnamed gulch. A mangrove thicket extends approximately 800 feet from the shoreline at the mouth of the gulch. A portion of Kalanianaole Colony residential development lies within the drainage boundary. The basin has an area of approximately 4.2 square miles.

The remaining areas on the Island of Maui where detailed stream analyses were performed are composed of several small tributaries which originate in the Molokai Forest Reserve. They are on the leeward, or southern, side of the eastern one-half of the island and flow generally southerly to the Pacific Ocean. Most of the gulches are dry much of the time. Waialua Stream is the only perennial watercourse on the leeward side of Molokai (USACE, 1966).

Residences are built mainly along the coastal highway. Land use consists of scattered residences, truck farming, taro farming, and grazing on both sides of the coastal highway in the floodplains.

ISLAND OF LANAI

Lanai is the least populated and smallest of the main Hawaiian Islands. The island is relatively dry, except for the central mountain area. The islands highest point, Lanaihale, reaches about 3,370 feet. The only significant population center is Lanai City; which is located near the center of the island at an elevation of about 1,700 feet. The approximately 47 miles of coastline vary widely in character. The north and east coast of the island is generally a gently sloping rocky coastal area, with narrow sand and gravel beaches, and some extents of relatively wide and long white sand beach. Along the southeast to south coast the nearshore terrain steepens, and along the south and west coasts the shoreline consists of 500-foot high sea cliffs.

The climate on the Island of Lanai is typically characterized by that of the Hawaiian Islands in general, with mild and uniform temperatures, marked geographical differences in rainfall, and a general dominance of northeasterly tradewinds.

2.3 Principal Flood Problems

Flood problems in the county are related primarily to channel overflow, overland flow, and standing water in poorly drained areas. Stream channel overflow is mainly due to the high frequency of intense rainfall typical of the Hawaiian Islands. Sandbars, which often form at the mouths of rivers and streams, may cause some backwater problems until washed out by large discharges.

In addition to riverine flooding, unusual surf conditions, tsunamis, and hurricanes cause considerable damage in beach and low-lying coastal areas. In some areas along the coast, all three types of flooding may occur. Tsunamis, which are a series of waves generated by submarine earth movements, travel at high velocities and have had a devastating effect on the developed areas within the County of Maui.

The Hawaiian Islands have a long history of tsunami occurrences. The extent of the coastal areas affected by these waves depends on the wave velocity and height at the shoreline and upon the steepness and roughness of the coast. Not only are inland areas inundated, but the tremendous force of the wave is capable of destroying everything within its path. Usually, beach and coastal erosion is extensive. Flooding from ocean water, with its high salt content, can also damage vegetation and farm crops.

Most of the destructive tsunamis affecting the Hawaiian Islands have been generated along the coasts of South America, the Aleutian Islands, the Kamchatka Peninsula, or Japan. The number of locally generated tsunamis is very small. The most destructive tsunami to hit the county occurred on April 1, 1946. This tsunami reportedly claimed nine lives, demolished 37 homes, and damaged 335 other buildings. Other recent tsunamis affecting Maui County occurred in 1952, 1957, 1960, and 1964. In the past 146 years, approximately 43 tsunamis have battered the Islands of Maui and Molokai. Within the Hawaiian Islands, the City of Hilo on Hawaii has been most severely damaged from Tsunami impacts. Based on 1970 figures, Hilo had suffered losses of $62 million over the past 50 years.

Although historical records show that the occurrence of hurricane landfall is infrequent, hurricane-induced storm surge and waves also pose a flooding threat to the island. Review of hurricane storm-tracks from 1949 to 2008 indicate that only 14 storms Category 1 or higher have come within a 200 nautical mile radius of the Hawaiian Islands. The islands within the County of Maui have significant exposure to hurricane induced storm surge, with extensive low-lying areas located on the south shore. Despite the fact that Lanai, Maui, or Molokai Islands have not experienced direct hurricane landfall in recent history, the islands have been impacted from hurricane-generated wind and waves. Three hurricanes have made landfall or had notable impacts to the Hawaiian archipelago, these are reviewed below.

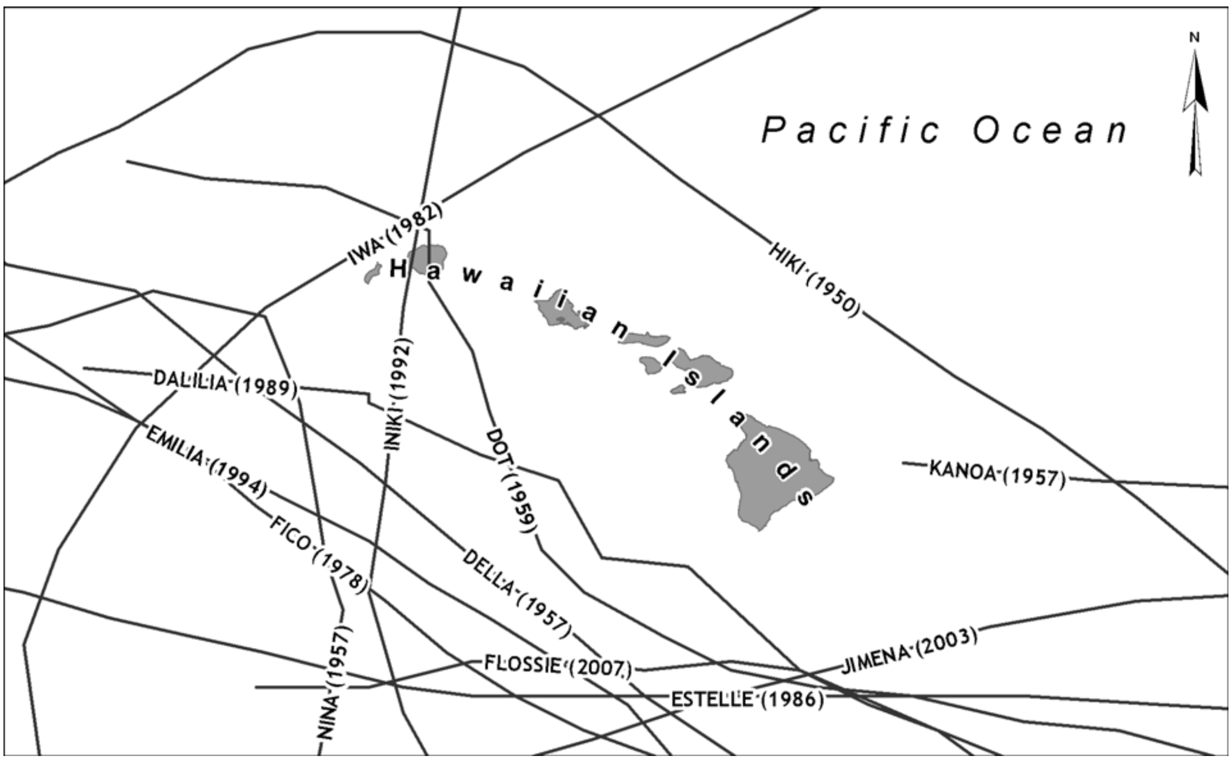


Figure 1. Hurricane tracklines within a 200 nautical mile radius of the Hawaiian Islands (1949-2008).

Hurricane Dot made landfall on the Island of Kauai on August 6, 1959, as a Category 3 storm. Wind gusts of 103 mph, with sustained winds of 81 mph were recorded at Kilauea Light, and damaged vegetation indicated that winds may have exceeded 125 mph in some locations (National Weather Service, 1959). A peak storm surge of 2.6 ft was recorded in Nawiliwili Harbor on the island of Kauai. On the Island of Oahu, damage was limited to rain-induced flooding and localized wind damage. The island of Hawaii experienced local flooding related to torrential rainfall in addition to minor wave damage near South Point and along the Kona Coast (National Weather Service, 1959).

Although it did not make direct landfall on any of the Hawaiian Islands, Hurricane Iwa caused severe wind damage to the Island of Kauai and notable wave damages to the southwest facing coasts of all islands. Hurricane Iwa passed to the north of the Island of Kauai as a Category 1 hurricane on November 11, 1982. The south shore of the Island of Kauai and the Waianae coast of the Island of Oahu experienced severe wave damage. Total damages from the storm were estimated at $250 million, in 1982 dollars (National Weather Service, 1982).

The storm-of-record for the Hawaiian Islands is Hurricane Iniki. Hurricane Iniki made landfall on the Island of Kauai on September 11, 1992, as a Category 4 storm with maximum sustained winds over land at 140 mph with gusts as high as 175 mph. Extensive wind, wave and surge damage occurred along the south coast of the Island of Kauai, damaging or destroying 14,350 homes (National Weather Service 1992). A peak surge of 4.1 ft LTD was observed by a water level station in Nawiliwili Harbor on the island of Kauai.

While the specific cause of tsunami and hurricane related flooding can be attributed to a single factor, the cause of flooding as a result of stream overflow may be due to various reasons. Possible flood causes include: debris-clogged streams, flash floods, and undefined streamflow patterns, isolated depressions in topography, inadequate drainage facilities, and changed drainage conditions because of development.

Flooding in Maui County is attributable to fast-moving surface runoff from steep mountain slopes discharging onto low, flat, coastal plains. This condition causes stormwater from the highlands to overtop lowland streams and flood areas adjacent to the streams. Most flood problems on the island occur in the low-lying areas, which have largely been developed with inadequate or nonexistent flood-control measures and storm drainage systems.

Excessive surface water from overland flow frequently causes flooding in poorly drained areas. Many of these problems are found in developed areas where the natural drainage patterns have been altered during development. Other factors which contribute to this type of flooding are insufficient or excessive land slopes and poor soil conditions.

The most recent flooding that followed with a Federal Disaster Declaration occurred in December 2007. A low pressure system moved southeast over Hawaii on December 3, 2007. The atmospheric instability combined with warm moist conditions ahead of a cold front led to high gusts and extremely heavy rains across the state. Maui and the Big Island received the heaviest rains between the sixth and the eighth of December. Rainfall caused flooding, flash flooding, mudslides and collapse of previously solid ground around gulches and usually dry streambeds. Gusts generated very rough and turbulent ocean conditions along the south and west facing leeward beaches. High surf combined with heavy runoff and mudslides, turning coastal water muddy brown and causing severe beach erosion in many areas.

Widespread flooding was common across portions of upcountry and central Maui. A home was washed off its foundations in Keokea. Gulches in the upper elevations in the Kula Forest Reserve were filled by heavy flows, leading to flash flooding in residential areas in Waiohuli below. Haleakala National Park was closed due to flooding and rock and mudslides across access roads and power outages. Seven inches of heavy rain in Kihei caused major flooding of low-lying streets and torrents of mud and soil up to three inches deep. South Kihei Road was closed due to standing water and flash floods. Beaches in many areas near Kihei were closed after the storm due to dangerous conditions and damage to lifeguard towers. Power outages from the storm caused water shortages for many communities because power is required to pump water to storage tanks. Emergency water tankers were stationed around the area. The State estimated total damages from the storm to be about $5 million. On February 6, 2008, a federal disaster was declared for the State of Hawaii (FEMA-1743-DR) to make Public Assistance available for emergency work and repair or replacement of facilities damaged during this event. This information was obtained from the Pacific Disaster Center's "Maui County Most Affected as Storm Pounds State of Hawaii" article. Detailed descriptions of the Islands of Maui and Molokai are provided below:

Flood problems for those areas that have been studied by detailed methods are described below.

ISLAND OF MAUI

Hahakea Gulch

No record of riverine flooding has been found for this gulch. Wave heights for tsunamis observed in this area have varied between 10 feet in 1960 and 12 feet in 1946 (University of Hawaii, 1976).

Honokahua Stream

Honokahua has had flooding problems in the downstream area near the existing Honapiihani Highway. Flooding damage has been limited to homes near the mouth of this stream. No estimates of damage are available for past floods.

Honokeana Bay Gulch

In October and November 1961, storm flooding from Honokeana Bay Gulch and gulches in the surrounding area damaged property and caused road washouts and highway bridge failures.

Honokowai Stream

Honokowai Stream has frequently flooded the Honokowai Town area, usually in the form of sheetflow. Flooding to a depth of approximately 2 feet has been recorded (USACE, 1971). Waves of 14 feet were observed during the 1946 tsunami, which destroyed several homes (University of Hawaii, 1976).

Iao Stream

There have been numerous floods on this stream since the early 1900s, many of which have inflicted heavy damage in terms of loss of life and property destruction. The most significant floods occurred in January 1916, November 1930, January 1948, December 1950, November 1961, and January 1971. Records for the years prior to 1903 are unavailable.

The flood of 1916 was the worst flood to hit the area. Peak discharge was estimated to be 17,000 cfs at the Market Street bridge. Thirteen lives were lost, and 70 homes were demolished.

The storm of December 1950 dumped 5 inches of rain in a 2-hour period, causing the stream to rise and overflow very rapidly. The discharge was estimated to be 7,550 cfs. Residences, commercial properties, crops, and other private property were damaged. This flood resulted in the loss of one life and $130,000 worth of damage.

The flood of November 1961 resulted in an estimated $95,000 in damage to homes, sugarcane fields, and public and commercial properties. This flood occurred after the county had constructed flood-control structures near the Market Street bridge between 1951 and 1955.

In January 1971, heavy rains resulted in flooding along the stream’s right over bank. The discharge was estimated to be 5,280 cfs.

In addition to flooding in the immediate stream area, flooding from sheetflow is a problem. The areas near the intersection of Keanu Street and State Highway 30 and the Kahookele Street area across from Wailuku Elementary School are constant problems. Water is either pumped out or seeps into the ground.

In February 1965, the area bounded by Waiale Road, Kaahumanu Avenue, and Spreckels Ditch was flooded with several feet of water. Sheetflow through the downtown area and overflow from the ditch caused this flood.

Tsunami flooding occurred in May 1960, when waves of 15 feet were reported in this area, causing damage of nearly $750,000 (USACE, 1971; University of Hawaii, 1976; State of Hawaii, April 1973).

Kahana Stream

Kahana Stream has flooded the area near its mouth at the Honoapiilani Highway. During flood conditions, the existing highway becomes impassable. During the April 1946 tsunami, 24-foot high waves struck this coastal area, and the 1960 tsunami caused 10-foot waves (University of Hawaii, 1976).

Kahoma Stream

The area around Kahoma Stream, which flows through Lahaina, has been flooded frequently. The alignment of the existing channel and its limited capacity in the lower reaches, approximately 600 cubic feet per second (cfs), have greatly contributed to the flooding problem. The stream slope is relatively steep and velocities from floodwaters are very high. Thus, overbank flooding has resulted. The seawall along Front Street prevents floodwaters from out letting directly into the ocean.

Since 1879, the Lahaina area has been damaged by at least 19 floods; however, there are no records prior to 1960. The January 1916 flood was reported to have caused severe damage in this area. Lahaina was severely damaged by two major floods, one on May 13, 1960, and the other from October 31 to November 3, 1961. USGS reported peak discharges of 7,750 cfs and 3,400 cfs for the respective storms.

During the 1960 storm, Kahoma Stream had five peaks, each of which flooded the Front Street area of Lahaina. The Mala, Cannery, and Keawe Camp areas were flooded during the final peak of this storm, and 130 families were evacuated from their homes. Many of these homes were flooded to a depth of 5 feet. Damage from the 1961 storm was estimated to be in excess of $1.6 million (USACE, 1971; State of Hawaii, 1973).

During the tsunami of May 23, 1960, waves of 9 to 10 feet in height battered the coastline between Maalaea and Lahaina. Damage was estimated to be in the vicinity of $59,000 (State of Hawaii, 1973). A tsunami with waves up to 12 feet high hit the Lahaina area on April 1, 1946, damaging or destroying numerous homes. Estimates of damage are unavailable (USACE, 1971).

Kahului Area

The Kahului area is subject to inundation from both tsunamis and sheetflow. The overflow of Kalialinui Gulch contributes to flooding in the industrial area adjacent to Kahului Airport.

The coastline area fronting Kahului town is subject to tsunami inundation. The tsunamis of April 1946 and May 1960 caused extensive damage to the communities of Kahului, Spreckelsville, and Paia, along the north shore of the island, destroying several homes. The most devastating tsunami to hit the Kahului area occurred in May 1960, causing an estimated $763,000 worth of damage (University of Hawaii, 1973).

Kalepa Gulch

Flooding from Kalepa Gulch has inundated Waihee Village and Waiehu Golf Course Road.

Kamaole Gulch

Kamaole Gulch has flooded its banks on several occasions. The most recent storm event on record was the storm of 2007. The December 2007 rainstorm caused major flooding in low-lying streets. Beaches near Kihei were closed after the storm due to dangerous conditions and damage to lifeguard towers and power outages caused water shortages for many communities. The 1971 storm caused damage totaling approximately $95,000 in the Kihei area (USACE, 1977). The storm of March 1968 inflicted heavy damage on Kihei Road and water mains. Floodwater from Kamaole Gulch topped Kihei Road, and the lawn of nearby Kamaole Beach Park was completely washed away.

Kaopola Gulch

There is no record of riverine flooding in this area.

Kauaula Stream

As recently as January 1971, Kauaula Stream overflowed and inundated developments near the stream (USACE, 1971). However, channel improvements have been made since the 1971 storm, and no flooding has been recorded since.

Keahaiwai Gulch

Historical data for this gulch are very limited because its floodwaters merge with the floodwaters of Waiaka Stream. Therefore, flood damage attributed to overflow from this gulch cannot be ascertained. Damage from flooding on this gulch in the Kihei area would be the same as stated for Waiakoa Gulch.

Keanue, Wailua, and Hana

Flooding has occurred in Keanae and Wailua, though damage has not been severe. At Hana, sheetflow runoff has caused damage to the hotel, most notably in April 1968.

Damage to the coast during the April 1946 tsunami was extensive. At Maliko Bay, 28-foot-high waves swept over 1,300 feet inland. The entire end of the Keanae Peninsula was inundated by 16-foot-high waves. Several buildings were damaged and two persons were killed. Several homes along the north side of Hana Bay were damaged by 13-foot-high waves. At Hamoa, waves of up to 23 feet in height destroyed homes and killed several people (USACE, 1971).

Kihei Gulch 1

During past rainstorms, Kihei Gulch 1 has contributed to the flooding of the Kalama Park area. The most recent recorded flooding was in February 1971, when the Kalama Park area was inundated. Due to their close proximity, Keokea Gulch and Kihei Gulch 1 drain into one floodplain during rainstorm flooding of

Kalama Park and the surrounding area. During the storm of March 1968, the walls of a house near an outlet channel, which drains ponded overflow from the gulch, were undermined. Other properties in the same area were inundated by the floodwater.

Kihei Gulches 2, 3, 4

The December 2007 rainstorm caused major flooding in low-lying streets. Beaches near the Kiehi areas were closed after the storm due to dangerous conditions and damage to lifeguard towers and power outages caused water shortages for many communities.

Kope Gulch

Kope Gulch has flooded the community of Waiehu on various occasions. Storm runoff flows through the sugarcane fields, depositing mud and debris on Kahekilo Highway. Ponded water eventually seeps into the ground or is pumped into nearby low-lying areas. No estimates of storm damage are available. Historical occurrences of flooding from Waiehu Stream coincide with those on Kalepa Gulch because the two are so close together. Businesses, homes, and public facilities have been damaged; however, no estimate of these damages is available. Tsunami records in this area show wave heights of 14 feet during the May 1960 tsunami and damage amounting to $74,000 (USACE, 1971).

Kulanihakoi Gulch

Kulanihakoi Gulch, like many of the streams in the Kihei area, overtops its banks during heavy rainstorms because of the inability of the existing channel to carry storm discharges. A sand dune at the mouth of the stream intensifies the drainage problem by producing a ponding effect. Kulanihakoi Gulch overtopped its banks during the storms of 1967, January 1971 and December 2007. The December 2007 rainstorm caused major flooding in low-lying streets. Beaches were closed after the storm due to dangerous conditions and damage to lifeguard towers and power outages caused water shortages for many communities. Damage during the January 1971 storm was estimated at $95,000 in the Kihei area, including Kamaole Beach Park. The Kihei floodplain was inundated to depths of 6 feet (USACE, 1971). During the storm of March 1967, floodwater overtopped Kihei Road and washed out a portion of the U.S. Bureau of Standards property. Other damage included ruined agricultural crops, torn pavement, and eroded shoulders along Kihei Road and several secondary streets. Damage to the Kihei area was estimated at $71,300 (USACE, 1970).

The tsunami of May 23, 1960, caused approximately $23,000 in damage to the Kihei area. Inundation in the floodplain areas damaged homes, roads, and utilities. High surf conditions at Kihei during January 1959 and January 1963 flooded areas along the coast. Although flooding was not significant, substantial amounts of sand were washed away by the eroding action of the waves (USACE, 1971).

Liilioholo Gulch

Liilioholo Gulch is flooded by both tsunami activity and stormwater runoff from a drainage basin of 4.1 square miles. The gulch flooded during the storm of March 1967 and washed out some roads and water mains (U.S. Department of the Interior, 1968).

Mahinahina Gulch

Mahinahina Gulch and the surrounding area have flooded in the past, mostly in the form of sheetflow. During the May 1946 tsunami, 14- to 20-foot waves battered the coastline in this area (University of Hawaii, 1976). No estimate of damage is available.

Napili Gulch 2-3

On Napili Bay, the area has been severely damaged by flooding on several occasions. During the storm of March 17, 1967, a break in a large earth fill road embankment approximately 0.6 mile northeast of the bay released water in the gulch and flooded the hotel area. Damage to the hotel was estimated to be approximately $50,000. In addition, private property owners in the area sustained substantial damage (USACE, 1971). On March 24, 1967, minor damage was caused in the same area from heavy rains. In November 1967, some hotels in the area were damaged by excessive runoff from the gulch. Records prior to 1967 are unavailable (USACE, 1971).

Napili Gulch 4-5

There are no records of flood damage from this gulch, which is located southwest of Napili Gulch 2-3.

Olowalu Gulch 2

Olowalu Gulch 2 has virtually no history of flooding because its drainage basin is fairly small. Observed storm action in this area has resulted primarily in shallow flooding. However, facts about the extent of flooding have not been recorded.

Olowalu Stream

Olowalu Stream has little record of flooding. During the March 1967 storm, damage to property was minimal-one home was flooded and mud and debris were spilled onto Honoapiilani Highway (U.S. Department of the Interior, 1968). Debris lodged in culverts and bridges caused floodwaters to back up and overtop the banks of the stream. During the April 1, 1946, tsunami, waves of up to 10 feet hit this area, causing minor damage and inundation of the low coastal areas (USACE, 1971). During the tsunamis of 1957 and 1960, wave heights reached 8 and 11 feet, respectively (State of Hawaii, 1974).

Southern Coast of Maui

Except for the April 1968 storm, flood damage information in the area is lacking. Many bridges and road sections were either washed out or covered by landslides. Streams between Kipahulu and Nuu are known to have flooded numerous times, especially near the mouths.

The tsunami of April 1946 caused minor damage in this area. Wave heights varied from 21 feet at Kaupo to 10 feet at Nuu. No other information is available for this area.

Spreckel's Ditch (Wailuku Town Area)

Due to the close proximity of this area to Iao Stream, the record of flooding is very similar. Since the early 1900s, there have been numerous accounts of flooding along Iao Stream and its tributaries. Records for the years rior to 1903 are unavailable; however, the most significant recorded incidences of flooding occurred in January 1916, November 1930, January 1948, December 1950, November 1961, and January 1971 (University of Hawaii, 1973).

In addition to flooding in the immediate stream area, flooding from sheetflow is a problem. The areas near the intersection of Kaenu Street area across from Wailuku Elementary School are commonly affected. In February 1965, the area bounded by Waiale Road, Kaahumanu Avenue and Spreckels Ditch was flooded with several feet of water. Sheetflow through the downtown area and overflow from the ditch caused this flood.

Waiakoa Gulch

Waiakoa Gulch has overflowed during almost every heavy rainstorm in the area. The gulch becomes very shallow near the intersection of Mokulele Highway and Kihei Road, and during rainstorms it overflows its banks and floods the surrounding area. Persistent accumulation of sand deposits at the mouth of the gulch plays a major role in preventing free flow of water to the ocean, and in recent years development along the gulch, especially between Kihei Road and the shoreline, has intensified the drainage problem. Past floods include those in January 1916, February 1951, April 1956, March 1967, and January 1971 (USACE, 1971; U.S. Department of the Interior, 1968; USACE, 1970). Although the January 1916 flood was not recorded in Kihei, it is believed to be the "worst flood in history." Heavy damage was inflicted all over the island. The flood of February 1951 is considered the greatest flood in the Kihei area. Damage to public and private property was estimated to be $75,000.

Waihee River

Flooding in the Waihee River study area has occurred in the form of runoff, which spread through the fields and flows toward the highway. However, no record of flooding by the river is available. Flooding due to a tsunami occurred in 1946, when 23-foot high waves were reported (University of Hawaii, 1976). Because the study area is used primarily as pastureland, estimates of damage are unavailable.

Waikapu Stream

There are two stream gages along Waikapu Stream; USGS Gage No. 16650500 is a crest-stage recorder with 34 years of annual peak flow data from 1963 to 1997, and USGS Gage No. 1650200 is a crest-stage recorder with 8 years of annual peak flow data from 2002 to 2009. There are no significant historical flood losses recorded for this stream.

Waipuilani Gulch

Waipuilani Gulch floods the surrounding area because of its small capacity. Flooding is further aggravated by the damming caused by sand berms located along the coastline, which restricts the drainage of floodwaters into the sea.

ISLAND OF MOLOKAI

Little flood information is available for this island, although flooding is known to have occurred. In east Molokai, the storms of February 4 and April 13, 1965, are believed to be the worst storms to hit the area. Other storms, on April 12, 1948, and November 10, 1955, appeared to have caused considerable flooding. Most flooding has been confined to the coastal and lowland areas. Flooding in west Molokai is known to have occurred, but as with east Molokai, information is scanty. Some flooding occurred in October 1961 and November 1965.

The tsunami of 1946 is the only well-documented storm to hit Molokai. The northern coast of the island reportedly received the brunt of the wave. On east Molokai, minor inundation did little damage to residences and private property. Wave heights of 6 feet were reported along the Pukoo-Kupeke coast. Little or no damage was reported on east Molokai during the tsunamis of 1957 and 1960. In west Molokai, wave heights of 20, 36, and 39 feet were reported for the 1946 tsunami (USACE, 1966; State of Hawaii, Map FP-21, April 1973).

ISLAND OF LANAI

Reported historical tsunami runup data are scarce for the island of Lanai. Tsunami Wave Runup Heights in Hawaii (1976) presents tsunami runup data for tsunamis in 1949, 1952, 1957, 1960 and 1964. For the island of Lanai, data is available only for the 1949 tsunami; runup of 7 feet above mean lower low water was reported at both Kaumalapau Harbor and Manele Bay.

2.4 Flood Protection Measures

On the Island of Maui, flood protection measures were completed for Iao Stream and 12 other streams.

The USACE studied the Kihei area for flood-control and related purposes. The USACE prepared a report in 1964 that included a design for a system of lateral interceptor ditches approximately 0.6 mile inland to collect sheetflow and convey it into four lined channels (USACE, 1977). This proposal could not be economically justified, but these structures may form the basis of the new flood-control program.

Maui County developed an interior drainage system for Kihei that utilizes three of the four proposed channelized streams. The system consists of approximately 32,000 feet of drain lines, box culverts, and pipe culverts with 320 feet of open channel. Stormwater from the Kihei area is collected by the interior drainage system and discharged into the lined Kulanihakoi, Waipuilani, or Keokea Gulches. Installation of the system was accomplished in phases over a period of several years. The environmental impact statement was prepared. (Maui County Department of Public Works, 1977)

The U.S. Soil Conservation Service has studied a watershed protection and flood prevention project for the Honolua watershed aimed at reducing erosion, preventing floodwater and sediment damage in the floodplain, and reducing sediment pollution of coastal waters (U.S. Department of Agriculture, 1976). Project measures included de-silting basins located on Honokowai Stream, Mahinahina Gulch, Pahakukaanapali Gulch, Kahana Stream, Kaopala Gulch, Honokeana Bay Gulch, Napili Gulch 4-5, and Napili Gulch 2-3; approximately 0.8 mile of floodwater diversions; 0.7 mile of floodwater channels; land treatment measures on 24,000 acres; construction of four bridges; relocation of three water mains; and controlled use of floodplain areas. All structural measures were designed for a 1% annual chance life. In addition, all structures were designed to carry runoff from the 1-percent annual chance flood. A total of 44.4 acres were committed to structural measures, including 36.4 acres in gulches and 8 acres now in sugarcane production. Installation committed 6.8 acres for dam sites, 4.6 acres for channels, and 1.5 acres for diversions. The remaining 31.5 acres committed were required for sediment basins, which will remain dry except during storms.

Kahoma Stream was studied by the USACE for flood-control and related purposes (USACE, August 1973), which consist of a debris basin, a concrete trapezoidal channel, and a revetted outlet and appurtenances that provide flood protection to the Town of Lahaina.

The Iao Stream Flood Control Project was constructed by the USACE (USACE, April 1975). The project provides flood control through the construction of channels and levees and the utilization of nonstructural considerations in combination with the levee improvements. The flood-control improvements extend along the Iao Stream floodplain for a distance of approximately 2.5 miles upstream of the mouth. The principal project features consist of a debris basin, channel improvements, stream realignment with channelization and a program of levee and floodplain management.

On the Island of Molokai, Kaunakakai Stream has been improved by the USACE. In 1950, earth levees were constructed to prevent flooding in the Kaunakakai homestead area. These levees were designed for a capacity of 5,000 cfs, plus a 3-foot freeboard. Flood-control measures include the enlargement of the stream channel with earth levees. The levee structures constructed on Kaunakakai Stream by the USACE have been de-accredited as flood protection structures, and as such they do not show protection on the effective FIRM. The USACE has also planned similar flood-control improvements for Kamiloloa Stream in the vicinity of the Kapaakea Homestead area, located to the east of Kaunakakai.

The Ohia Gulch channel has been improved from its mouth to approximately 500 feet upstream. This should help prevent flooding from flows smaller than the 1-percent annual chance flood discharge.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the county, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1-percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this FIS. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for the flooding sources studied in detail affecting the county.

For areas subject to riverine flooding on the Island of Maui, a regional flood-frequency analysis of all streamflow data on the island was utilized to determine selected discharges at ungaged locations. The multiple regression technique was used to develop the relationship between pertinent characteristics of the station flood-frequency curves and basin and climatological characteristics. The method used on this island is that recommended by U.S. Water Resources Council Bulletin 17 (U.S. Water Resources Council, 1976). Data from 50 stream gaging stations were used in the regional analysis. The records ranged in length from 11 to 60 years, with 25 stations having a length of record of 25 years or more.

From the station flood-frequency curves, discharges for the selected recurrence intervals were determined. Each set of discharges was then correlated to various basin and climatological characteristics, using a regression equation. The multiple-regression analysis was made using the records for the entire island, separating the records into windward and leeward stations, and into the northeast stations of the island and the remaining stations. The most consistent relationships were developed by using the records for the entire island. Regression constants were computed by the method of least squares.

Basin and climatological characteristics that had little or no significance were eliminated. The drainage area and the 2-year, 24-hour precipitation were found to be the most significant characteristics. Discharges were then computed using the equations that were determined by this analysis.

For the Island of Molokai, a regional flood-frequency analysis was undertaken to compute discharges for the selected recurrence intervals at ungaged sites on the island. Station flood-frequency curves were determined using the procedures outlined in Bulletin 17 (U.S. Water Resources Council, 1976). Data from 13 gaged stations were utilized, and a generated skew coefficient of -0.05 was used.

A multiple-regression technique was used to develop the relationship between peak discharge and physiographic and meteorological characteristics to the drainage basin characteristics. Therefore, a regional analysis of discharge versus drainage area was conducted. The 50-, 10-, 2-, 1-, and 0.2-percent annual chance flood flows were plotted against the respective drainage areas, and a smooth curve was constructed through these points. These curves were used to select the 10-, 2-, 1-, and 0.2-percent annual chance flood discharges for the ungaged locations.

The riverine flood boundaries caused by an unnamed stream flowing through the residential development of Kuau were determined using the USACE HEC-RAS hydraulic computer program (USACE, September 1998) and the detailed topographic maps referenced above. The 10-, 2-, 1-, and 0.2-percent annual chance discharges were estimated using updated multiple regression equations developed by the USGS during the early 1980s and used in the June 1, 1981, FIS. For the September 25, 2009, restudy, the additional years of stream gage records did not substantially change the computed discharges from the June 1, 1981, study.

Flow values were calculated independently using HEC-HMS by Tetra Tech, Inc., and is summarized in a report prepared for the County of Maui Department of Planning dated November 2006 (Tetra Tech, 2006).

Hydrologic analyses were carried out to establish the peak discharges of 1-percent annual chance floods for approximately 536 miles of streamlines in the islands of Maui, Molokai, and Lanai. The main topographic information used in this restudy of Maui, Molokai, and Lanai are USGS DEM (digital elevation models) in 30-foot grid size and LiDAR (Light Detection and Ranging) in the Local Tidal

Datum (LTD). Drainage areas were delineated using TIN (triangulated irregular network) and 10-foot contours generated from these digital topographic data.

A regression equation, developed by USCOE in 1981 for the island of Maui, was used to estimate peak discharges of streams on all three islands. The equation can be expressed as:

$$Q_{100} = 142*(DA^{0.89})*(P_{2\text{-}24}{}^{1.24})$$

where
Q_{100} = 1% annual chance discharge in cubic feet per second
DA = drainage area in squared mile
$P_{2\text{-}24}$ = mean 2-year 24-year rainfall depth in inches

The mean rainfall depth of 2-year 24-hour event was computed for each contributing drainage area based on the rainfall isopluvial map obtained from the Technical Paper 51 of NOAA's National Weather Services.

Regression equation is an empirical formula to estimate instantaneous stream peak flows based on basin and rainfall characteristics. Details of flood hydrograph cannot be obtained from using this approach. Thus, as a conservative approach, peak discharges were simply added at stream junction where two or more tributaries combine.

Topographic information used in the hydrologic and hydraulic analysis is based on LiDAR terrain data collected for the September 25, 2009, study. Hydrologic flow values for each stream were determined through the use of regression equations developed by the USACE, and rely upon the drainage area and the 2-year, 24 hour duration rainfall depths. The 2-year, 24 hour rainfall depths used in the regression equations were interpolated from isohyetal charts developed by the U.S. Department of Commerce, Weather Bureau. Drainage areas at various points along the streams were determined using Digital Elevation Model (DEM) based on LiDAR data collected. The total drainage areas of the Kaluaihakoko Stream and Kamaole Gulch were to be 0.656 sq. miles and 5.209 sq. miles, respectively. For the 1-percent annual chance flood, the Kaluaihakoko Stream and Kamaole Gulch are associated with a peak discharge of 461 cfs and 3,765 cfs, respectively.

The 2014 update included revised hydrology for Kihei Gulch 1 and Waikapu Stream in Maui County. Discharges for these streams were computed for the 10-, 2-, 1-, and 0.2-percent-annual-chance storm events using the USACE HEC-HMS version 3.4 software package (Reference 5). Basin hydrographs were generated using the NRCS TR-55 methodology for Kihei Gulch 1 while Waikapu Stream used the modified time of concentration calculation developed for the Hawaiian Islands in 1973 by USACE. All models used the Muskingum-Cunge method for routing flows downstream. Land use and soil data was based on several sources. The land use and soil data for the Kihei Gulch 1 model (developed by R.M. Towill Corp. for the County of Maui Department of Public Works in the April 2009 draft report for the *Kihei Drainage Master Plan Waiakoa Gulch to Kilohana*

Drive Existing Conditions) were based on NOAA Coastal Change Analysis Program (C-CAP) website (imagery collected in 2005 and published in 2008) and the NRCS website (Soil Survey Geographic Database, SSURGO), respectively. The R.M. Towill hydrographs were used in the Keokea Gulch revision and the peak discharges of the hydrographs were used in revising Waimahaihai Gulch. The R.M. Towill study included the effects of a diversion structure that diverts flows from Waimahaihai Gulch to Keokea Gulch. This diversion structure substantially reduces the 1-percent flows previously conveyed by Waimahaihai Gulch. The Waikapu Stream model (developed by Tetra Tech in 2006 for the County of Maui Department of Planning in a report titled *Maui County Hydrologic Analysis for Waihee Stream, Waiehu Stream, Waikapu Stream, Kope Gulch, Kalepa Gulch and Unnamed Channels*) used field surveys, area maps, aerial photographs and GIS coverages to base its land use. Basin WK1 soil data was collected from the NRCS website (Soil Survey Geographic Database, SSURGO). Precipitation data for all streams was obtained from the National Oceanographic and Atmospheric Administration (NOAA) Atlas 14 Volume 4: Hawaiian Islands precipitation frequency estimates.

Final flow rates for Waikapu Stream were revised and calibrated to available gage data in the 2011 restudy of the Waikapu Stream model (developed by Tetra Tech in 2006 for the County of Maui Department of Planning in a report titled *Maui County Hydrologic Analysis for Waihee Stream, Waiehu Stream, Waikapu Stream, Kope Gulch, Kalepa Gulch and Unnamed Channels*). Sub-Basin areas and routing reaches were kept from the previous study, and other hydrologic parameters were adjusted to calibrate the model to the observed gage data.

A summary of the drainage area - peak discharge relationships for all the streams studied by detailed methods is shown in Table 2, "Summary of Discharges."

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
ISLAND OF MAUI					
HAHAKEA GULCH					
At mouth	4.0	1,800	3,600	4,600	7,500
HONOKAHUA STREAM					
At mouth	3.8	1,670	3,360	4,300	7,020
HONOKEANA BAY GULCH					
At mouth	0.6	350	670	830	1,300
HONOKOWAI STREAM					
At mouth	6.0	2,000	4,000	5,200	8,200

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
IAO STREAM					
At mouth	10.1	6,100	11,000	13,800	20,600
ISLAND OF MAUI - continued					
KAHANA STREAM					
At mouth	4.6	2,000	4,000	5,100	8,400
KAHOMA STREAM					
At mouth	5.3	2,600	5,100	6,400	10,200
KAILUA GULCH					
At mouth	9.3	2,700	6,000	8,000	13,800
KALEPA GULCH					
At mouth	1.6	522	887	1,114	1,402
KALIALINUI GULCH					
At mouth	19.2	2,700	7,300	10,300	20,800
At Sunnyside and Airport Roads	18.5	2,605	7,045	9,975	20,090
KALUAIHAKOKO STREAM					
At mouth	0.7	129	332	461	897
KAMAOLE GULCH					
At mouth	5.2	1,132	2,756	3,765	7,044
KAOPALA GULCH					
At mouth	0.95	550	1,100	1,300	2,100
KAUAULA STREAM					
At mouth	3.9	1,400	3,000	4,000	6,700
KEAHAIWAI GULCH					

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
At mouth	N/A	N/A	N/A	8,950	N/A
Approximately 400 feet upstream of Mokulele Highway	N/A	N/A	N/A	7,600	N/A
KEOKEA GULCH					
At mouth	9.0	N/A	N/A	8,066	N/A
ISLAND OF MAUI - continued					
KIHEI GULCH 1					
At mouth	1.1	421	813	1,007	1,515
At Alaloa Road	0.9	309	580	712	1,056
At Piilani Highway	0.6	223	421	518	765
KIHEI GULCH 2					
At mouth	3.9	930	2,200	3,000	5,500
KIHEI GULCH 3					
At mouth	3.6	870	2,060	2,790	5,130
KIHEI GULCH 4					
At mouth	2.3	590	1,400	1,900	3,400
KOPE GULCH					
At mouth	2.0	1,047	1,737	2,216	2,787
KULANIHAKOI GULCH					
At mouth					
Subarea 7	14.6	3,017	7,362	10,061	18,830
Subarea 8	0.4	79	197	271	516
Subarea 9	0.2	N/A	259	303	N/A
LIILIOHOLO GULCH					
At mouth	4.1	920	2,200	3,000	5,700
MAHINAHINA GULCH					
At mouth	1.9	930	1,800	2,300	3,700
NAPALI GULCH 2-3					
At mouth	0.8	420	810	1,020	1,600

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
NAPALI GULCH 4-5					
At mouth	0.9	540	1,000	1,300	2,000
OLOWALU STREAM					
At mouth	5.1	1,600	3,600	4,700	8,100
ISLAND OF MAUI - continued					
SPRECKELS DITCH (WAILUKU TOWN AREA)					
At mouth	2.7	870	1,785	2,295	3,805
UNNAMED STREAM AT KUAU POINT					
At mouth	3.1	690	1,830	2,540	5,000
WAIAKOA GULCH					
At mouth					
At Piilani Highway	N/A	N/A	N/A	6,800	N/A
Subarea 5	N/A	N/A	N/A	5,450	N/A
WAIEHU STREAM					
At mouth	4.8	3,700	6,300	7,770	11,200
At Kehekili Highway	4.5	2,697	4,383	5,550	6,960
WAIHEE RIVER					
At mouth	6.8	7,450	10,837	12,844	15,784
WAIKAPU STREAM					
Just upstream of confluence with Kolaloa Gulch	7.4	1,244	1,966	2,242	3,470
Approximately 4,200 feet downstream of Kuihelani Highway	5.9	1,180	1,900	2,173	2,981
At Kuihelani Highway	4.8	1,135	1,799	2,011	2,563
At Honoapiilani Highway	4.3	1,111	1,765	1,955	2,403

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
WAIPUILANI GULCH					
At mouth					
Subarea 9	12.4	2,913	6,868	9,275	16,941
Subarea 10	0.6	116	293	406	779
Subarea 11	0.3	66	162	222	422
Subarea 12	0.8	205	494	672	1,251
Subarea 13	0.1	28	58	78	141
Subarea 14	0.2	26	71	102	209
Subarea 15	0.3	38	106	152	313
ISLAND OF MOLOKAI					
KAHANANUI GULCH					
At mouth	1.0	1,700	3,700	5,000	8,600
KAMALO GULCH					
At mouth	4.0	4,300	9,600	12,600	22,100
KAMILOLOA STREAM					
At mouth	3.7	2,525	6,000	8,200	15,655
KAUNAKAKAI STREAM					
At mouth	6.0	5,636	11,400	15,000	28,390
KAWELA GULCH					
At mouth	5.7	5,800	13,000	17,000	30,000
KEAWANUI GULCH					
At mouth	0.8	1,400	3,100	4,100	7,400
MANAWAI GULCH					
At mouth	0.7	1,300	3,000	3,900	7,000
MILE 84 STREAM					
At mouth	3.7	2,525	6,000	8,200	15,655
OHIA GULCH					
At mouth	1.3	2,100	4,500	6,000	10,600
PUKOO GULCH					
At mouth	0.5	960	2,320	2,900	5,200
WAIALUA STREAM					

TABLE 2: SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. miles)	Peak Discharges (cubic feet per second)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
At mouth	2.6	3,500	7,700	10,200	18,000

Tsunami wave elevations for the coastal areas of the Islands of Maui and Molokai were calculated using a report prepared by the USACE Waterways Experiment Station (USACE, August 1977). A hybrid finite element numerical model was developed to supplement historical data in determining the 10 largest tsunami elevations for the Island of Maui, and the 2 largest tsunami elevations for the Island of Molokai, from 1837 to 1979, used in the frequency analysis. The model provides an accurate and representative response of the islands to tsunami activity due to rapid bathymetric and/or wave height variations. The numerical model was adjusted and verified by comparing the calculated results of the model with tide gage recordings of the 1960 and 1964 tsunamis.

In the August 3, 1998, revision, the updated tsunami runup analysis was prepared using the TSU2 computer program and an aerial topographic map entitled "Topographic Survey of Lahaina Town Coastline," at a scale of 1:200, with a contour interval of 2 feet, prepared by the USACE, and dated January 3, 1996.

In the May 15, 2002, restudy, the tsunami runup analysis was prepared using the USACE's TSU2 computer program and detailed topographic maps (USACE, 1998). Use of the model yields starting tsunami elevations for various flood frequencies at a point 200 feet inland of the shoreline. The water-surface elevations for a 1-percent annual chance tsunami at that location along the coastlines of Maui and Molokai are shown on the Tsunami Coastline Profiles (Exhibit 2).

Tsunami wave elevations were also developed for the Island of Lanai in a September 2009 study, extending along about 40 miles of shoreline, encompassing approximately 80% of the island's coastline. The 1% annual chance tsunami runup elevations and risk zones for the study area were developed using USACE methodology contained in the Manual for Determining Tsunami Runup Profiles On Coastal Areas of Hawaii (1978). Topographic LiDAR data obtained in 2004-2006 and ortho-rectified aerial photography are the primary data sources used in the study. The study methodology involved determining representative shoreline transect profiles, and then determining for each transect the runup coefficients, and ground surface friction factors. The 1% annual chance tsunami runup reference elevation is then calculated at each transect and the tsunami runup profile is calculated.

In 2008 a hurricane storm surge study was completed. The Advanced Circulation model for Coastal Ocean Hydrodynamics (ADCIRC), (Luettich, 1992), developed by the USACE was selected to develop the stillwater elevations or storm surge for the State of Hawaii. ADCIRC is a two-dimensional depth integrated, finite element, hydrodynamic model that solves the equations of motion for a moving fluid on a rotating earth. Water surface elevations are obtained from the solution of the depth-integrated continuity equation in the generalized wave continuity equation form, whereas velocities are obtained from the solution of the two-dimensional momentum equations. The model has the capability to simulate tidal circulation and storm surge propagation over large domains and is able to provide highly detailed resolution along the shoreline and other areas of interest. The Empirical Simulation Technique (EST), also developed by the USACE Scheffner et al. (1999), was used to develop the stillwater frequency curves for the 10-, 2-, 1-, and 0.2-percent annual chance stillwater elevations.

The ADCIRC grid was sourced from an existing grid developed by the USACE. The USACE grid was used for offshore areas, whereas new higher resolution nearshore and topographic coverage was added around the islands of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii. The greater part of the bathymetric data set was comprised of 255 individual National Oceanographic and Atmospheric Administration (NOAA) National Ocean Service (NOS) hydrographic surveys, collected from 1900 to 2005. The USACE Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) provided bathymetric LiDAR collected in 1999 and 2000. This dataset provided high-resolution coverage of the nearshore bathymetry, where available. The USACE Honolulu District provided a 2004 hydrographic survey of Honolulu Harbor. A 2004 multibeam survey of Pearl Harbor conducted by the U.S. Navy was provided by the NOAA National Geophysical Data Center. All soundings were converted to the Local Tidal Datum using relationships developed from NOAA gages. Finally, all datasets were merged and overlapping data were removed to produce the best possible data.

The topographic portion of the ADCIRC grid was populated with LiDAR data collected for the project along the southern coasts of the four islands, including Maui County's Kahoolawe, Lanai, Maui, and Molokai Islands, included in the study. The LiDAR data were collected in Fall 2006, post-processed to bare earth and quality controlled to meet FEMA mapping standards. To facilitate use with ADCIRC, elevations were converted to meters. LiDAR elevations were delivered in LTD; therefore no vertical datum conversion was necessary.

Wind and pressure fields were required for input. A model called the Planetary Boundary Layer model (PBL), developed by V.J. Cardone (Cardone, 1992) was used for this study. The PBL model uses the parameters from a hurricane or tropical storm to simulate the event and develop wind and pressure fields. The PBL model simulates hurricane-induced wind and pressure fields by applying the vertically integrated equations of motion.

The storms applied in this study, shown in Table 3, "Summary of Historical Storm Events Selected for Development of Storm Surge Elevations," were selected to represent the range of different storm magnitudes impacting the study area. Storm selection was limited to events passing within 200 nautical miles of at least two islands in the study area. Eleven hurricane and tropical storm events were selected for storm surge modeling. Due to the low number of historical storms identified in the storm selection, the historical storm events were duplicated and shifted laterally by one radius to maximum winds, in order to represent the potential range of tracks that future storms may take. In total, 100 storms were generated for developing stillwater elevations within the study area using this method.

TABLE 3: SUMMARY OF HISTORICAL STORM EVENTS SELECTED FOR DEVELOPMENT OF STORM SURGE ELEVATIONS

Name of Storm	HURDAT Identification Number	Storm Event
Hiki	10	August 12-21, 1950
Della	65	September 1-11, 1957
Nina	74	November 29-December 6, 1957
Dot	93	August 1-8, 1959
Maggie	222	August 20-26, 1970
Diana	250	August 11-19, 1972
Iwa	411	November 19-24, 1982
Gil	418	July 23-August 4, 1983
Dalilia	532	July 11-21, 1989
Iniki	598	September 5-13, 1992
Daniel	707	July 23-August 5, 2000

The ADCIRC model was calibrated by simulating tidal cycles, and then validated by performing storm hindcasts. The tidal calibration is conducted by forcing tides at the open ocean boundaries of the model using known values (Le Provost, 1998), and comparing the simulated water levels to observations over a specific time period or a tidal signal re-synthesized from known tidal constituents. Storm hindcasts are performed upon successful completion of tidal calibrations to evaluate the ability of the model to replicate historical storm events. A wind and pressure field representing a historical storm event is input into the model then resulting water elevations are compared to observed water levels and records. Model validation was performed against Hurricanes Dot and Iniki for this study. Simulated water levels for each event were compared to observed water levels at the NOAA tidal gauge in Nawiliwili Harbor which represented the best available data. Results from both events showed good agreement with observed storm hydrographs.

The EST model was used for the stage-frequency analysis. The EST generates a large population of life-cycle databases that are processed to compute mean value frequencies. Input vectors describe the characteristics of each storm such as central pressure and maximum winds. Input vectors for EST analysis included: tidal phase, minimum distance from eye to station, central pressure deficit, maximum winds in hurricane, forward speed of eye of hurricane, and radius to maximum winds. The input response vector was the maximum surge elevation recorded at each station for each storm simulated with ADCIRC. The output is a stage-frequency curve for each station in the study area. The EST model performed a hundred simulations at each station, for a simulated period of 500 years. The mean value was selected from the entire EST simulation population at each station, and the return period elevation is the final resultant value.

Stillwater elevations for Maui County, obtained using the ADCIRC and EST models, are summarized in Table 4, "Summary of Coastal Stillwater Elevations." Locations of the surge stations are shown in Figure 2, "Stillwater Station Location Map." Please note that the station numbers for surge stations do not coincide with the transect numbers.

TABLE 4: SUMMARY OF COASTAL STILLWATER ELEVATIONS†

ISLAND OF LANAI

Flooding Source and Location			Elevation (ft ltd)			
Station	Longitude	Latitude	10-Percent	2-Percent	1-Percent	0.2-Percent
	(NAD83)					
Pacific Ocean						
257	-156.99446	20.78514	0.66	0.84	1.04	2.13
258	-156.98807	20.76859	0.66	0.85	1.05	2.16
259	-156.98160	20.75044	0.66	0.83	1.02	2.07
260	-156.97007	20.73939	0.66	0.85	1.06	2.14
261	-156.95589	20.73205	0.66	0.86	1.08	2.08
262	-156.94517	20.73183	0.66	0.87	1.08	2.18
263	-156.92446	20.73364	0.66	0.87	1.09	2.15
264	-156.91180	20.73443	0.66	0.87	1.10	2.16
265	-156.89892	20.73886	0.66	0.86	1.10	2.17
266	-156.89550	20.73754	0.66	0.86	1.09	2.14
267	-156.89108	20.73347	0.66	0.81	1.03	1.90
268	-156.88635	20.73770	0.66	0.88	1.12	2.19
269	-156.88620	20.74277	0.66	0.90	1.16	2.34
270	-156.88186	20.74179	0.66	0.88	1.12	2.21
271	-156.87389	20.74381	0.66	0.87	1.11	2.13
272	-156.86128	20.75172	0.66	0.88	1.13	2.19
273	-156.85042	20.75609	0.66	0.88	1.13	2.19
274	-156.62328	21.02501	0.66	0.85	1.06	2.07
275	-156.63981	21.02682	0.66	0.80	1.00	1.96
276	-156.65125	21.00769	0.66	0.85	1.08	2.07
277	-156.66837	21.00719	0.66	0.80	1.00	1.93
278	-156.66964	20.99767	0.66	0.83	1.05	1.98
279	-156.67624	20.98443	0.66	0.83	1.06	1.97
280	-156.68539	20.96512	0.66	0.83	1.07	1.96
281	-156.69391	20.94770	0.66	0.82	1.03	1.97
282	-156.69384	20.93816	0.66	0.84	1.07	2.12
283	-156.69810	20.92839	0.66	0.84	1.05	2.08
284	-156.69804	20.92090	0.66	0.83	1.04	2.01
285	-156.69407	20.91166	0.66	0.83	1.05	2.06
286	-156.68726	20.90281	0.66	0.86	1.11	2.21
287	-156.68720	20.89260	0.66	0.85	1.08	2.14
288	-156.68930	20.88186	0.66	0.80	0.97	1.89
289	-156.68009	20.87231	0.66	0.87	1.13	2.26

†These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

TABLE 4: SUMMARY OF COASTAL STILLWATER ELEVATIONS[†]

ISLAND OF MAUI

Flooding Source and Location			Elevation (ft ltd)			
Station	**Longitude**	**Latitude**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
	(NAD83)					
Pacific Ocean						
290	-156.66588	20.85435	0.66	0.89	1.16	2.29
291	-156.65298	20.84009	0.66	0.87	1.13	2.23
292	-156.64834	20.83342	0.66	0.86	1.10	2.18
293	-156.63398	20.82408	0.66	0.89	1.17	2.30
294	-156.62413	20.80861	0.66	0.85	1.08	2.09
295	-156.60842	20.80705	0.66	0.92	1.22	2.49
296	-156.59812	20.80164	0.66	0.90	1.19	2.36
297	-156.58406	20.79238	0.66	0.86	1.11	2.15
298	-156.55973	20.78687	0.66	0.89	1.18	2.32
299	-156.54668	20.77953	0.66	0.88	1.15	2.24
300	-156.53357	20.77284	0.66	0.88	1.14	2.17
301	-156.51998	20.77847	0.66	0.90	1.19	2.37
302	-156.51023	20.79025	0.66	0.95	1.30	2.68
303	-156.49919	20.79479	0.66	0.96	1.29	2.75
304	-156.47767	20.79007	0.66	0.95	1.26	2.60
305	-156.46159	20.77427	0.66	0.94	1.25	2.49
306	-156.46137	20.75527	0.66	0.90	1.17	2.27
307	-156.45693	20.73232	0.66	0.86	1.10	2.14
308	-156.45008	20.71830	0.66	0.89	1.17	2.30
309	-156.44818	20.70184	0.66	0.88	1.13	2.20
310	-156.44695	20.68040	0.66	0.86	1.08	2.10
311	-156.44421	20.66242	0.66	0.88	1.11	2.14
312	-156.44554	20.65499	0.66	0.87	1.09	2.07
313	-156.44439	20.64738	0.66	0.88	1.11	2.15
314	-156.45410	20.63912	0.66	0.85	1.05	1.97
315	-156.44898	20.63002	0.66	0.87	1.09	2.07
316	-156.44142	20.61991	0.66	0.87	1.11	2.06
317	-156.43969	20.61376	0.66	0.87	1.10	2.06
318	-156.44326	20.60400	0.66	0.85	1.05	1.91
319	-156.43966	20.60146	0.66	0.86	1.06	1.94
320	-156.43236	20.59428	0.66	0.86	1.06	2.00
321	-156.42685	20.59237	0.66	0.87	1.09	2.04
322	-156.41880	20.59568	0.66	0.88	1.12	2.08

[†]These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

TABLE 4: SUMMARY OF COASTAL STILLWATER ELEVATIONS†

ISLAND OF MAUI (continued)

Flooding Source and Location			Elevation (ft ltd)			
Station	**Longitude**	**Latitude**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
	(NAD83)					
Pacific Ocean						
323	-156.41553	20.59076	0.66	0.87	1.10	2.03
324	-156.41360	20.58238	0.66	0.83	1.03	1.81
325	-156.40255	20.57617	0.66	0.86	1.08	1.99
326	-156.39027	20.57530	0.66	0.86	1.09	2.01
327	-156.36285	20.57320	0.66	0.87	1.09	2.06
328	-156.33674	20.57888	0.66	0.86	1.07	1.91
329	-156.30172	20.58098	0.66	0.85	1.07	1.95
330	-156.27243	20.59302	0.66	0.88	1.11	2.17
331	-156.24433	20.60488	0.66	0.85	1.07	2.06
332	-156.22549	20.61346	0.66	0.88	1.10	2.15
333	-156.20520	20.62272	0.66	0.87	1.11	2.17
334	-156.18188	20.62284	0.66	0.86	1.09	2.17
335	-156.16811	20.62118	0.66	0.86	1.08	2.08
336	-156.15107	20.62352	0.66	0.86	1.10	2.15
337	-156.13785	20.61489	0.66	0.84	1.06	2.09
338	-156.12507	20.62503	0.66	0.88	1.10	2.20
339	-156.10980	20.63192	0.66	0.86	1.08	2.14
340	-156.08693	20.64272	0.66	0.87	1.08	2.12
341	-156.07597	20.64784	0.66	0.87	1.10	2.15
342	-156.06373	20.64511	0.66	0.83	1.05	1.97
343	-156.05048	20.64872	0.66	0.84	1.05	2.00
344	-156.03823	20.65933	0.66	0.85	1.07	1.97
345	-156.03239	20.67187	0.66	0.87	1.11	2.10
346	-156.02308	20.67883	0.66	0.87	1.11	2.06
347	-156.00586	20.68551	0.66	0.87	1.10	2.03
348	-157.25840	21.22136	0.66	0.79	1.00	1.82
349	-157.25453	21.20889	0.66	0.84	1.10	2.15
350	-157.25073	21.19972	0.66	0.84	1.11	2.18
351	-157.25384	21.18916	0.66	0.84	1.11	2.19
352	-157.26373	21.17210	0.66	0.85	1.12	2.22
353	-157.27651	21.16216	0.66	0.85	1.10	2.15
354	-157.28650	21.15300	0.66	0.84	1.09	2.11
355	-157.29398	21.14218	0.66	0.83	1.06	2.09
356	-157.30007	21.13279	0.66	0.83	1.06	2.08
357	-157.30344	21.11802	0.66	0.84	1.06	2.14
358	-157.31266	21.10340	0.66	0.82	1.02	2.01
359	-157.30123	21.08876	0.66	0.85	1.09	2.13
360	-157.28975	21.09075	0.66	0.88	1.16	2.28

†These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

TABLE 4: SUMMARY OF COASTAL STILLWATER ELEVATIONS†

ISLAND OF MOLOKAI

Flooding Source and Location			Elevation (ft ltd)			
Station	**Longitude**	**Latitude**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
	(NAD83)					
Pacific Ocean						
361	-157.26882	21.08774	0.66	0.88	1.16	2.31
362	-157.26095	21.08352	0.66	0.87	1.14	2.25
363	-157.24396	21.08159	0.66	0.87	1.15	2.27
364	-157.22677	21.08617	0.66	0.91	1.22	2.45
365	-157.19697	21.08521	0.66	0.90	1.19	2.45
366	-157.18401	21.08817	0.66	0.89	1.17	2.43
367	-157.16561	21.08947	0.66	0.91	1.21	2.53
368	-157.14709	21.08769	0.66	0.88	1.17	2.40
369	-157.12131	21.09375	0.66	0.94	1.29	2.76
370	-157.10626	21.09742	0.66	0.99	1.41	3.08
371	-157.09474	21.09793	0.66	0.99	1.43	3.09
372	-157.07223	21.09577	0.66	0.98	1.39	3.02
373	-157.05246	21.09214	0.66	0.96	1.34	2.88
374	-157.03768	21.09060	0.66	0.97	1.40	3.00
375	-157.02802	21.08513	0.66	0.91	1.23	2.59
376	-157.01148	21.07783	0.66	0.93	1.25	2.69
377	-156.98953	21.07233	0.66	0.92	1.22	2.65
378	-156.96518	21.06581	0.66	0.90	1.18	2.58
379	-156.94220	21.06029	0.66	0.91	1.19	2.68
380	-156.92165	21.05706	0.66	0.92	1.24	2.86
381	-156.90700	21.05389	0.66	0.90	1.21	2.82
382	-156.89435	21.04906	0.66	0.89	1.16	2.62
383	-156.87540	21.04486	0.66	0.87	1.14	2.56
384	-156.85537	21.05380	0.66	0.93	1.22	2.80
385	-156.85145	21.04924	0.66	0.90	1.17	2.55
386	-156.84405	21.05156	0.66	0.95	1.26	2.94
387	-156.83128	21.05661	0.66	0.97	1.31	3.08
388	-156.82002	21.06296	0.66	1.00	1.35	3.29
389	-156.81391	21.06288	0.66	0.93	1.24	2.91
390	-156.79319	21.06976	0.66	0.89	1.19	2.62
392	-156.75377	21.09567	0.66	0.89	1.17	2.34
391	-156.77035	21.08428	0.66	0.92	1.22	2.51
393	-156.74267	21.10823	0.66	0.90	1.20	2.40
394	-156.73277	21.11681	0.66	0.87	1.12	2.16
395	-156.72585	21.12373	0.66	0.87	1.13	2.21
396	-156.71401	21.13713	0.66	0.86	1.09	2.10
397	-156.70853	21.15977	0.66	0.80	1.00	1.94
398	-156.73240	21.16266	0.66	0.84	1.09	2.08

†These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

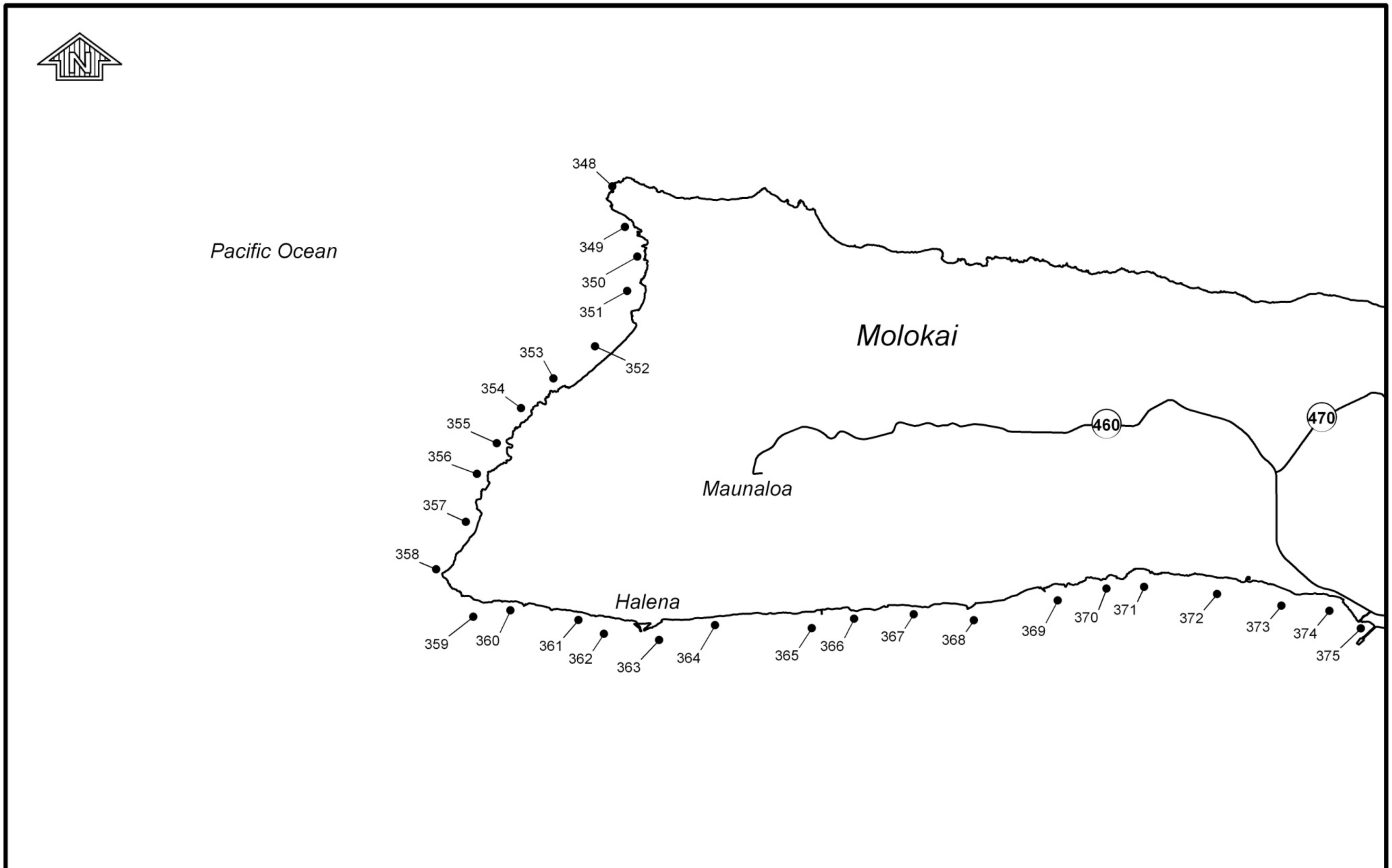


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MOLOKAI

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 1

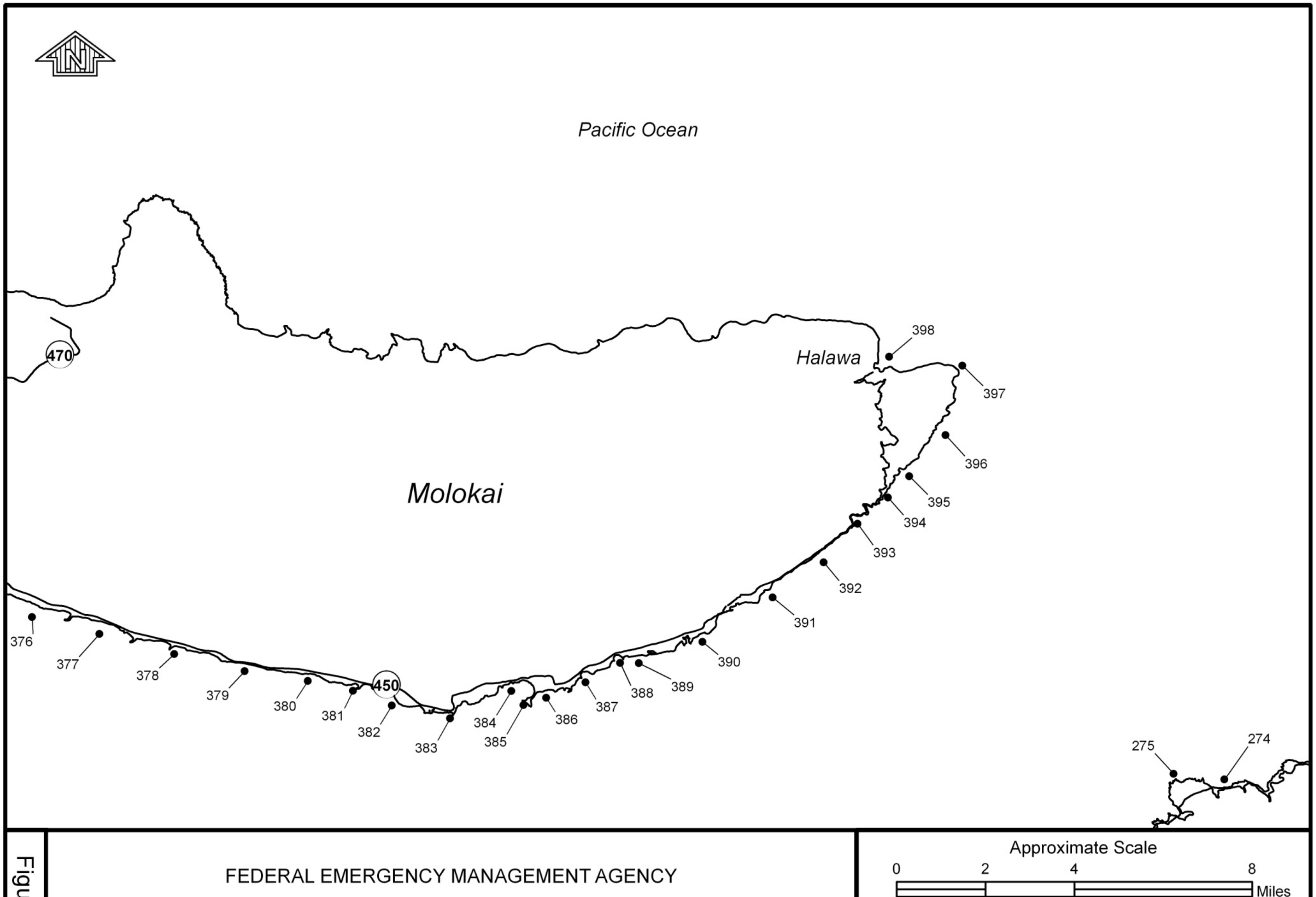


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MOLOKAI

STILLWATER STATION LOCATION MAP 2

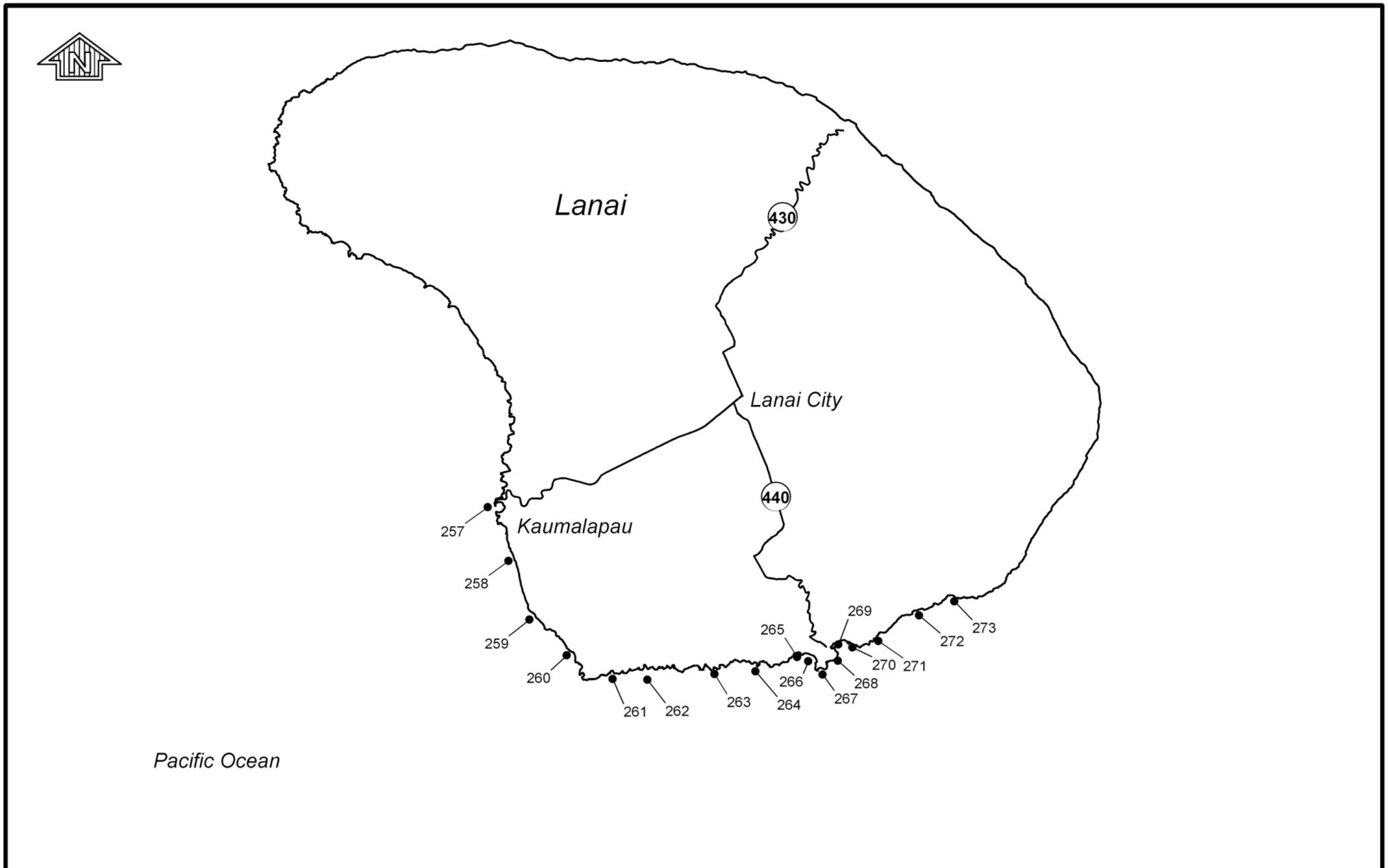


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF LANAI

STILLWATER STATION LOCATION MAP 3

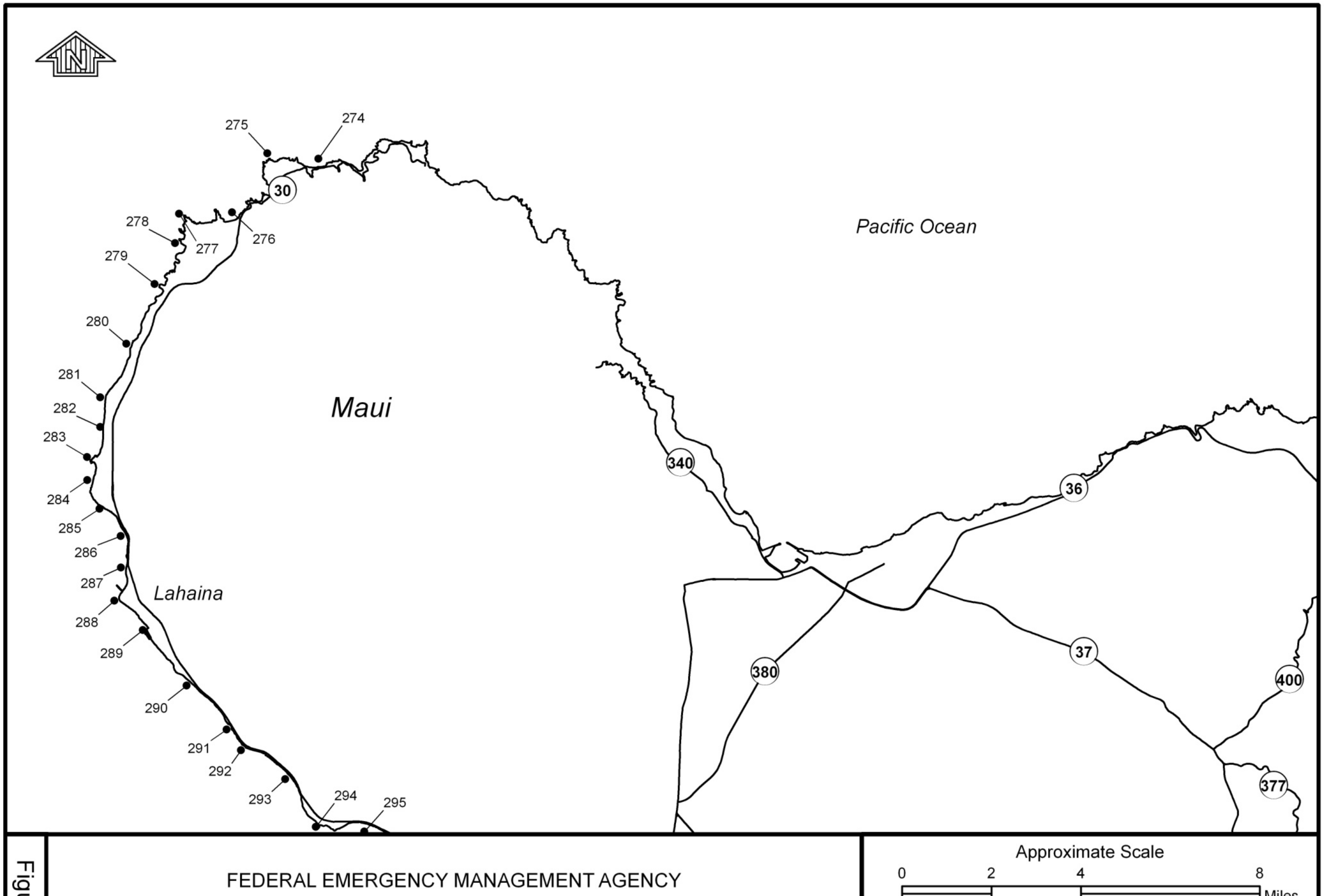


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

STILLWATER STATION LOCATION MAP 4

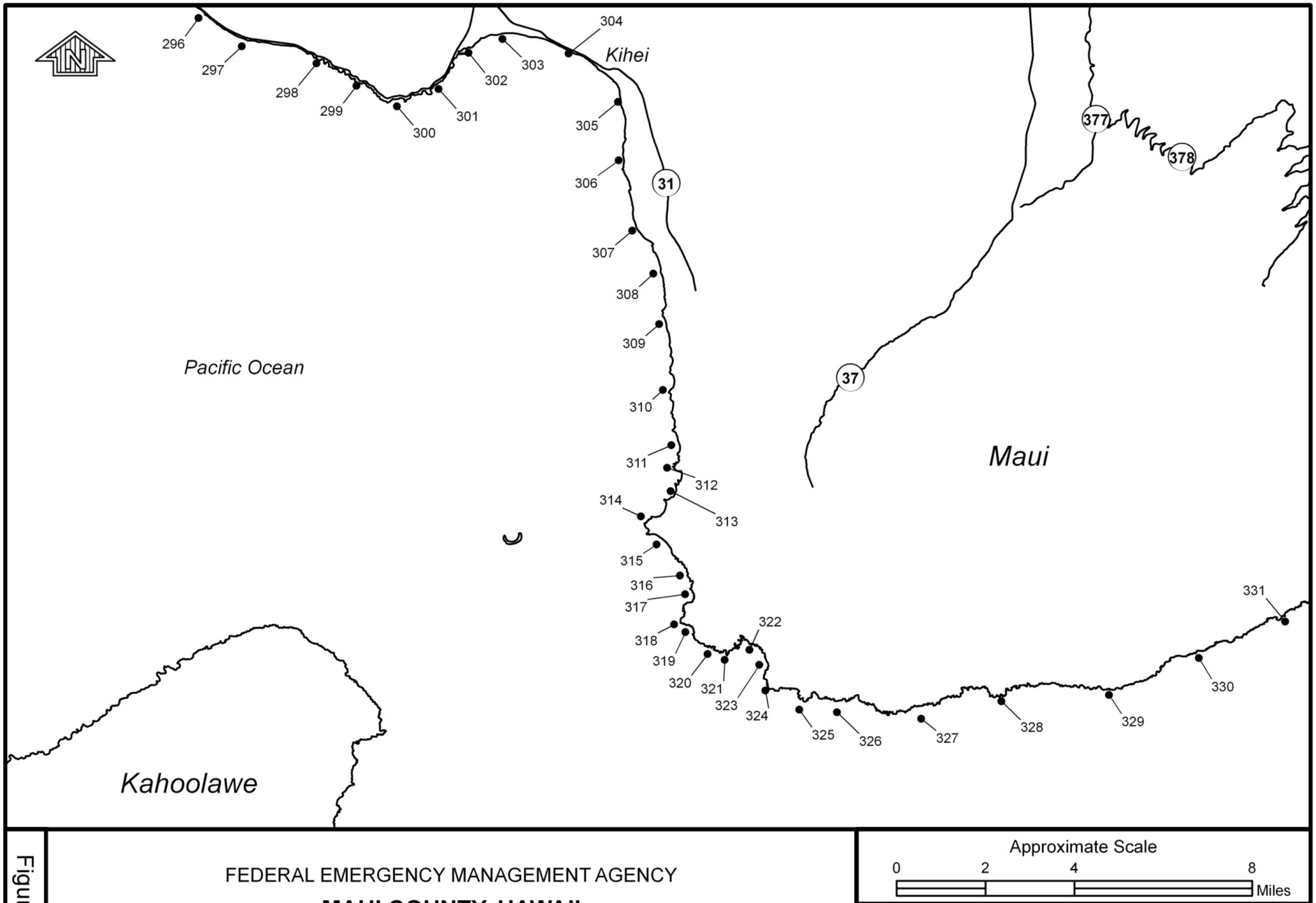


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

STILLWATER STATION LOCATION MAP 5

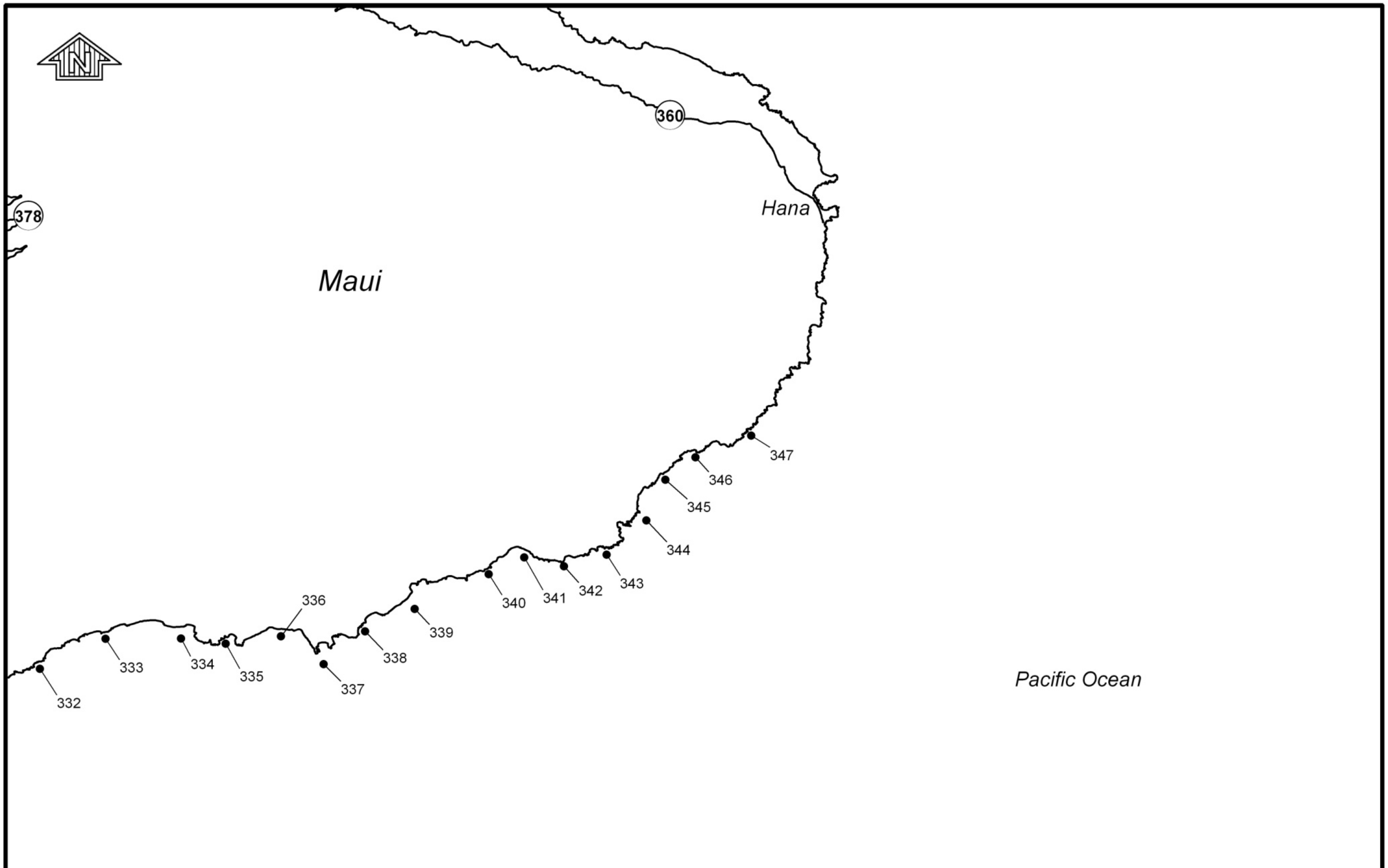


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

STILLWATER STATION LOCATION MAP 6

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the source studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. For construction and/or floodplain management purposes, users are encouraged to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Water-surface profiles for floods of the selected recurrence intervals for the streams studied by detailed methods were computed through use of the USACE HEC-2 step-backwater computer program (USACE, October 1973). For streams outletting into the ocean, starting water-surface elevations on the Islands of Maui and Molokai were determined using normal depth analysis.

Cross sections for the backwater analyses of the streams studied by detailed methods were obtained from topographic maps (USACE, Topographic Maps, Contour Interval 5 feet, 1976; USACE, Topographic Maps, Contour Interval 2 feet; USACE, 1977; USACE, Topographic Maps, Contour Interval 5 feet, August 1973; USACE, Topographic Maps, Contour Interval 10 feet, January 1977; USACE, January 1975; USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977; USACE, 1984; USACE, Topographic Maps, Kahului Area, January 1977; USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976) and field surveys of the floodplain areas. Bridges, culverts, and stream channel cross sections, including below-water sections, were field surveyed. Cross sections were located at close intervals above and below bridges, culverts, and other hydraulic structures in order to compute the significant backwater effects from these structures. Some bridges over streams studied by detailed methods were determined to wash out by floodwater and were not restrictive to flow; therefore, they were not included in the hydraulic analyses of the streams.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM (Exhibit 3).

Shallow flooding information in the Town of Wailuku was taken from a report entitled "Wailuku Flood Study, Zone AO – FIRM Panel 190, Wailuku, Maui, Hawaii," prepared by SHI, dated September 25, 1992. Manning's formula was used to determine 1-percent annual chance flood depths, velocities, and widths for the study area, which extends south of Kaohu Road for a distance of approximately 2,400 feet, west of Spreckels Ditch and Waiale Drive, and east of Honoapiilani Highway. The results of the study determined an average 1-percent annual chance flood depth of 1 foot.

Kaluaihakoko Stream, Kamaole Gulch, and Waikapu Stream were restudied in 2009 using detailed methods.

Kaluaihakoko Stream & Kamaole Gulch

Hydraulic analysis for Kaluaihakoko Stream and Kamaole Gulch was conducted using HEC-RAS 3.1.1. Manning's "n" values used in the model were chosen from the USGS Water-Supply Paper 2339 by engineering judgment and field inspection of the floodplain areas. The hydraulic analysis results were used to delineate the 1- and 0.2-percent floodplains. Encroachment stations were used to determine floodway boundaries associated with a maximum floodway increase of 1 foot.

Waikapu Stream

Waikapu Stream was studied by detailed methods in 2009 for the County of Maui Department of Planning.

The Waikapu hydraulic model calculations were conducted using HEC-RAS Version 3.1.3 (United States Army Corps of Engineers, May 2005); while HEC-GeoRAS version 4.2.92 and ArcGIS 9.2 was used to generate the geometry file and map the results. The delineation of the streamline was accomplished by using contours derived from the TIN and the aerial imagery for Maui County.

Hydraulic cross sections were developed from the TIN for the HEC-RAS hydraulic models. The data for the TIN was obtained from Maui County. Elevation data was provided in the LTD, and all cross section profiles used in the HEC-RAS model were generated from the county DEM data, with the exception of the upstream and downstream cross sections before and after each bridge. In the case of bridge cross sections, elevation data was obtained from a combination of DEM values for the outer portions of the cross section and elevation data obtained from as-built data for each bridge locations.

Manning's "n" values used in the model in the September 25, 2009, restudy were determined using the guidelines specified in the USGS Guide to Selecting Manning's Roughness Coefficients (USGS, 1989).

The stream crossings at Honoapiilani Highway and Kuihelani Highway were modeled. The as-built information for the crossings at these locations was utilized in the hydraulic analysis.

Contraction and expansion coefficients selected for the HEC-RAS model were based on standard guidance provided in the River Analysis System Hydraulic Reference Manual (USACE Hydrologic Engineering Center, 2002). Typically, contraction and expansion coefficients of 0.1 and 0.3, respectively, were used for all natural valley cross sections. Following the HEC-RAS modeling guidance for bridges, typical contraction and expansion coefficients of 0.3 and 0.5, respectively, were used for the two cross sections upstream of the bridge and for the one downstream of bridge.

Critical depth was used as the boundary condition for the Waikapu Stream given the flat area and Kealia Pond associated with the downstream end of the Waikapu Stream.

The 0.2-percent flow is not totally contained resulting in an overflow which appears to flow down East Waiko Road towards the southeast. This overflow for the 0.2-percent annual chance event diverges from the Waikapu Stream. Modeling this divergent flow was beyond the scope of this study, and therefore delineating the floodplain boundary along East Waiko Road was not attempted.

Likewise, at Honoapiilani Highway the 1-percent annual chance flow is not contained by the cross section and an overflow to the southwest occurs. The overflow leaving Waikapu Stream will flow along Honoapiilani Highway before turning westward and flowing overland. A limit of detailed study line was placed at the southern overbank, and flooding at this location was not incorporated into the floodplain boundary map.

In the 2014 restudy, the hydrology for Waikapu Stream was revised and the hydraulic modeling was updated to reflect new peak flow information. This restudy used the existing hydraulic model geometry upstream of cross-section 18,983 and added additional field survey information and new TIN cross-sections downstream of that location. Hydraulic model calculations were conducted using the computer program HEC-RAS Version 4.1.0 (United States Army Corps of Engineers, May 2005).

The hydraulic analyses for this FIS were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

All elevations are referenced to the Local Tidal Datum. Benchmarks used in this study, and their descriptions, are shown on the FIRM. Benchmarks shown on the FIRM represent those used during the preparation of this and previous FISs. The elevations associated with each benchmark were obtained and/or developed during FIS production to establish vertical control for determination of flood elevations and floodplain boundaries shown on the FIRM. Users should be aware that these benchmark elevations may have changed since the publication of this FIS. To obtain up-to-date elevation information on National Geodetic Survey (NGS) benchmarks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov. Map users should seek verification of non-NGS benchmark monument elevations when using these elevations for construction or floodplain management purposes.

Roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment and were based on field observations of the streams and floodplain areas. Roughness factors for all streams studied by detailed methods are shown in Table 5, "Manning's "n" Values."

TABLE 5: MANNING'S "n" VALUES

Stream	Channel "n"	Overbank "n"
<u>ISLAND OF MAUI</u>		
Hahakea Gulch	0.040	0.040
Honokahua Stream	0.030-0.040	0.040
Honokeana Bay Gulch	0.040-0.045	0.035-0.045
Honokowai Stream	0.013-0.030	0.015-0.030
Iao Stream	0.014-0.041	0.120-0.088
Kahana Stream	0.030	0.040
Kahoma Stream	0.040	0.040
Kalepa Gulch	0.040-0.050	0.030-0.045
Kalialinui Gulch	0.022-0.038	0.050-0.060
Kaluaihakoko Stream	0.043	0.013-0.053
Kamaole Gulch	0.040	0.040
Kaopala Gulch	0.025-0.035	0.030-0.035
Kauaula Stream	0.018-0.040	0.020-0.040
Keokea Gulch	0.020 – 0.048	0.012 – 0.080
Kihei Area	0.050	0.050
Kihei Gulch 1	0.04-0.08	0.03-0.1
Kihei Gulch 2	0.055	0.055
Kihei Gulch 3	0.020-0.050	0.035-0.040
Kihei Gulch 4	0.045	0.045
Kope Gulch	0.060	0.060
Liiliholo Gulch	0.040	0.040
Mahinahina Gulch	0.020-0.045	0.024-0.045
Napili Gulch 2-3	0.030-0.050	0.035-0.050
Napili Gulch 4-5	0.025-0.030	0.035-0.040
Olowalu Stream	0.040-0.080	0.040
Spreckels Ditch	0.040	0.040
Unnamed Stream at Kuau Point	0.030-0.150	0.030-0.150
Waiehu Stream	0.020-0.045	0.030-0.045
Waihee River	0.050	0.050
Waikapu Stream	0.035-0.065	0.035-0.13
<u>ISLAND OF MOLOKAI</u>		
Kamalo Gulch	0.025-0.06	0.03-0.07

TABLE 5: MANNING'S "n" VALUES

Stream	Channel "n"	Overbank "n"
Kailua Gulch	0.015-0.030	0.045
Kahananui Gulch	0.050	0.060-0.080
Kamiloloa Gulch	0.018-0.036	0.040
Keawanui Gulch	0.060-0.120	0.080-0.120
Kawela Gulch	0.045	0.060
Kaunakakai Stream	0.030-0.048	0.030 – 0.080
Manawai Gulch	0.050	0.080
Waialua Stream	0.040-0.050	0.060-0.080
Ohia Gulch	0.040-0.030	0.050-0.080
Pukoo Gulch	0.030-0.050	0.040-0.070
Mile 84 Stream	0.018-0.038	0.040

The topographic maps (USACE, Topographic Maps, Contour Interval 5 feet, 1976; USACE, Topographic Maps, Contour Interval 2 feet; USACE, 1977; USACE, Topographic Maps, Contour Interval 5 feet, August 1973; USACE, Topographic Maps, Contour Interval 10 feet, January 1977; USACE, January 1975; USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977; USACE, 1984; USACE, Topographic Maps, Kahului Area, January 1977; USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976) mentioned previously, and any conditions which differ from those described above, are summarized below.

ISLAND OF MAUI

Hahakea Gulch, Honokowai Stream, Mahinahina Gulch, Kahana Stream, and Kaopala Gulch

Topographic data were supplied by the USACE and are dated January 1975. Topographic maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, January 1975).

Honokahua Stream

Topographic data of the study area were obtained from the USACE. The maps, dated January 1975, were prepared at a scale of 1:4,800, with a contour interval of 5 feet (USACE, January 1975).

Honokeana Bay Gulch, Napili Gulch 4-5, and Napili Gulch 2-3

Topographic data of the study area were supplied by the USACE and are the same as those used for the above-mentioned streams (USACE, January 1975). However, because this area is heavily overgrown and contour lines are inaccurate, the given maps were adjusted according to data obtained during the field survey. Stream cross sections were taken from the adjusted maps and were used in the hydraulic computations.

Iao Stream

All data used in the hydraulic computations, including topographic data, stream channel cross sections, and bridge and culvert dimensions were based on data used in the design of the flood-control project for this stream (USACE, April 1975). Portions of this stream exhibit high velocities and a supercritical flow condition.

Kahoma Stream

Topographic data for the stream are the same as those used for Kauaula Stream (USACE, Topographic Maps, Contour Interval 10 feet, January 1977). Supercritical flow occurs in the upper reach of the stream. In the lower reach of the stream, sheetflow occurs. Shallow flooding extends from 4,200 feet from the shoreline to 300 feet above the mouth. The width of the 1-percent annual chance floodplain at Front Street is approximately 1,600 feet; at Honoapiilani, it is 3,500 feet wide; and at the upstream limit, the width is 230 feet.

Kamaole Gulch

Aerial photographs are those referenced above for the study area (USACE, Topographic Maps, Contour Interval 2 feet, December 1976). Velocities in the channel are as high as 19 feet per second, indicating supercritical flow condition.

Kailua Gulch

The 1-percent annual chance discharge for Kailua Gulch was obtained from a 1977 report prepared by SHI, for the USACE. The hydraulic analysis for Kailua Gulch was prepared using the USACE HEC-2 hydraulic computer model and an aerial topographic map entitled “Work Map for Flood Insurance Study, Kailua Gulch,” scale 1"=400', contour interval 10 feet, analysis added detailed flooding information, including a floodway, to the study reach of Kailua Gulch, which extended from its mouth for a reach of about 3,725 feet.

Kauala Stream

Aerial photographs of the study area were taken in January 1977. Photogrammetric maps were prepared at a scale of 1:4,800, with a contour interval of 10 feet (USACE, Topographic Maps, Contour Interval 10 feet, January 1977). High channel velocities and a supercritical flow condition exist on the stream.

Kihei Gulch 1 and Keokea Gulch

Topographic data were obtained from LiDAR information provided by Airborne1 in June, 2004. A Digital Elevation Model was created from this data with an accuracy of 2 feet. Keokea Gulch was studied using an unsteady flow HEC-RAS hydraulic model. An unsteady flow regime was selected for primarily two reasons: it would facilitate a 2-dimensional hydraulic model for the Kihei Regional Park area and it would enable a more dynamic solution for the upstream portion of the hydraulic model where supercritical flows are occurring during the 1-percent-annual-chance flood event. Supercritical flow and high channel velocities exist in the upper reaches of Keokea Gulch. As the channel gradient lessens toward the coastal areas and the floodplain widens, velocities tend to decrease and the flow becomes subcritical. The downstream portion of Keokea Gulch was studied using FLO-2D, an unsteady 2-dimensional hydraulic model. A 2-dimensional hydraulic model was used due to the poorly defined channel and flow paths once the floodwaters originating in the upper Keokea Gulch watershed reach the electrical substation opposite the East Welakahao Road. The primary means by which floodwaters leave the regional park is via overtopping South Kihei Road or through the culverts under Halekuai Street to the north.

Kihei Gulch 2

Aerial photographs of the area were flown at the same time as those for Kihei Gulch 3 (USACE, Topographic Maps, Contour Interval 2 feet, December 1976). Supercritical flow occurs because of a steep channel gradient and high velocities.

Kihei Gulch 3

Aerial photographs were taken of the study area in December 1976. Photogrammetric maps were prepared at a scale of 1:1,200, with a contour interval of 2 feet (USACE, Topographic Maps, Contour Interval 2 feet, December 1976). High channel velocities indicate that a supercritical flow condition exists.

Kihei Gulch 4

Aerial photographs were taken in December 1976. Photogrammetric maps were prepared at a scale of 1:2,400 with a contour interval of 5 feet (USACE, Topographic Maps, Contour Interval 5 feet, December 1976). Because of the steep channel slope, a supercritical flow condition exists for this stream.

Liilioholo Gulch

Aerial photographs are the same as referenced for Kihei Gulch 3 and Kihei Gulch 2 (USACE, Topographic Maps, Contour Interval 2 feet, December 1976). The hydraulic analysis indicates that the existing culvert cannot adequately convey the 1-percent annual chance flood. Overtopping of the channel banks will result, and stormwater will flow over the roadway and into Kamaole Beach Park No. 2. High channel velocities occur on this stream also, resulting in a supercritical flow condition.

Olowalu Gulch 2

Topographic maps of the study area were supplied by the USACE and are dated August 1973. These maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, Topographic Maps, Contour Interval 5 feet, August 1973). The 1-percent annual chance flood will overtop the west bank of the gulch approximately 2,500 feet upstream of Honoapiilani Highway and result in a shallow flooding condition. The width of the 1-percent annual chance floodplain at Honoapiilani Highway is approximately 1,000 feet.

Olowalu Stream

Topographic Maps are the same as those used for Olowalu Gulch 2 (USACE, Topographic Maps, Contour Interval 5 feet, August 1973). However, at approximately 1,400 feet upstream from the mouth, the flow breaks out and results in sheetflow. Shallow flooding extends from approximately 1,400 feet upstream to 350 feet above the mouth. The width of the 1-percent annual chance floodplain at the highway is approximately 1,900 feet and is centered along the stream.

Waiakoa and Keahaiwai Gulches

Aerial photographs were taken in January 1977. Photogrammetric maps were prepared at a scale of 1:4,800, with a contour interval of 10 feet (USACE, 1977). Hydraulic computations conducted separately for the two gulches show that the gulches will overflow during the 1-percent annual chance flood and merge. Shallow flooding will occur in the overbank areas. This area of shallow flooding extends approximately 2,300 feet north along Mokulele Highway from Keahaiwai Gulch to Uwapo Road and approximately 4,000 feet from the shoreline along Waiakoa Gulch.

Waihee River, Kalepa Gulch, Waiehu Stream

Aerial photographs of the study area were taken in January 1977. Photogrammetric maps were prepared at a scale of 1:4,800, with a contour interval of 10 feet (USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977).

Waikapu Stream

Topographic data were obtained from LiDAR information provided by Airborne1 in April, 2005. A Digital Elevation Model was created from this data with an accuracy of 2 feet.

Hydrology flow values were determined in a hydrologic study conducted by the Tetra Tech in November 2006; while topography data was obtained from Maui County. Hydraulics were calculated in HEC-RAS Version 3.1.3 and used as the basis for determining floodplain and floodway extents.

This study was revised in August, 2011 with updated hydrology and additional field survey. HEC-RAS geometry was selectively reused from the previous effective model to create a model with the best available data in all locations. Hydraulics calculations were performed in HEC-RAS Version 4.1.0 and floodway extents were revised.

Waipuilani and Kulanihakoi Gulches

Topographic data were obtained from the above-referenced photogrammetric maps (USACE, Topographic Maps, Contour Interval 2 feet, December 1976). The hydraulic analysis for the gulches indicated that they would overflow their banks. Further study showed that overflow from the gulches would merge. This analysis was performed by extending cross sections across both gulches. The 1-percent annual chance floodplain extends from Hoonani Street to Kenolio Street and approximately 2,500 feet inland along Kulanihakoi Gulch.

An updated tsunami runup analysis was prepared using the TSU2 computer program and an aerial topographic map entitled “Topographic Survey of Lahaina Town Coastline,” at a scale of 1:200, with a contour interval of 2 feet, prepared by the USACE, and dated January 3, 1996.

ISLAND OF MOLOKAI

For all streams studied by detailed methods on the island, December 1976 topographic maps were obtained from the USACE. The maps were prepared at a scale of 1:4,800, with a contour interval of 10 feet (USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976).

The hydraulic analysis of Wawaia Gulch indicated that sheet flow extends from 3,000 feet upstream of the mouth to 500 feet upstream of the mouth. The width of the 1-percent annual chance floodplain is 1,300 feet at Kamehameha V Highway.

Supercritical flow and high channel velocities exist in the upper reaches of the streams. As the channel gradient lessens toward the coastal areas and the floodplain widens, velocities tend to decrease and the flow becomes subcritical. This situation occurs on Kawela Gulch, Kamalo Gulch, Keawanui Gulch, Ohia

Gulch, Kahananui Gulch, and Waialua Stream. Manawi Gulch exhibits supercritical flow characteristics throughout its study length.

The determination of the hydraulic characteristics for areas of approximate study was calculated by various methods and are grouped into the general categories listed below:

1. Hydraulic characteristics were determined by methods described for detailed-study areas, with the exception that stream cross sections were not field surveyed, and bridges and culverts were not considered. However, there were field inspections of the floodplain areas.

2. A normal-depth computer program was utilized based on the topographic maps used in the detailed-study areas and on field inspections of the floodplains.

3. Hydraulic characteristics were extracted from prior studies or were taken from prior mapping of various locations on the islands.

The determination of maximum runup elevations for the Islands of Maui and Molokai was made using a study entitled Tsunami Inundation Prediction (Charles L. Bretschneider, 1976). This study developed formulas for predicting tsunami runup profiles and compared the calculated results with the recorded inundation data of the 1946 and 1960 tsunami on the Islands of Maui and Hawaii. Good to excellent correlations were obtained between the observed and calculated inundation profiles.

Runup elevations are dependent on starting tsunami elevations, inland ground elevations, roughness factors (Manning's "n" values), and expected type of wave behavior (bore or nonbore formation). The derivation of tsunami elevations is discussed in Section 3.1. USGS topographic maps (U.S. Department of the Interior, 1957, et cetera) were used for the tsunami hydraulic analyses.

Overland roughness factors used in the hydraulic computations were chosen by using engineering judgment and were based on field inspection by coastal areas. Most of the coastal areas of the county have experienced only the nonbore type of tsunami action.

For the 2009 Lanai tsunami study, determinations of the maximum runup elevations were made by calculating runup profiles for transects placed approximately 4,000 to 5,000 feet apart along the study area shoreline using LiDAR data (2004-2006). Locations of the transects for the study are shown in Figure 4. The study used the procedures described in the Manual For Determining Tsunami Runup Profiles On Coastal Areas of Hawaii (1978).

Friction factors for the Lanai tsunami study were determined using Manual For Determining Tsunami Runup Profiles On Coastal Areas of Hawaii (1978) and the report Roughness of Typical Hawaiian Terrain for Tsunami Run-up Calculations, A Users Manual (1986). Field inspection was done at each transect to determine the appropriate friction factors.

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to establish water-surface elevations and approximate inundation limit of the Zone A floodplains during the 1-percent annual chance flood. Steady-flow HEC-RAS version 3.1.3 and GeoRAS version 4.0 for ArcGIS version 9.2 were utilized. TIN and 10-foot contours provided topographic background for the analysis.

Streamlines and flow paths for the hydraulic analysis were developed using streamlines established from the hydrologic analyses. Cross-section geometrical data was computed from TIN and 10-foot contours. Bridges and culvert crossings were not incorporated into the hydraulic modeling.

Due to the unavailability of land-use data, roughness coefficients used in the hydraulic analysis on all streams were manually estimated by engineering judgments from aerial images. It was assumed that all streams have the same Manning’s “n” values of 0.045 and 0.040 for channels and overbanks, respectively.

Coastal Hydraulic Analysis

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The USACE has established the 3.0 ft. breaking wave as the criterion for identifying the limit of coastal high hazard zones (USACE, 1975). The 3.0 ft. wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame and brick veneer structures.

Figure 3, “Transect Schematic,” illustrates a profile for a typical transect along with the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Figure 3 also illustrates the relationship between the local still water elevation, the ground profile and the location of the Zone V/Zone A boundary. This inland limit of the coastal high hazard area is delineated to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this coastal high hazard area.

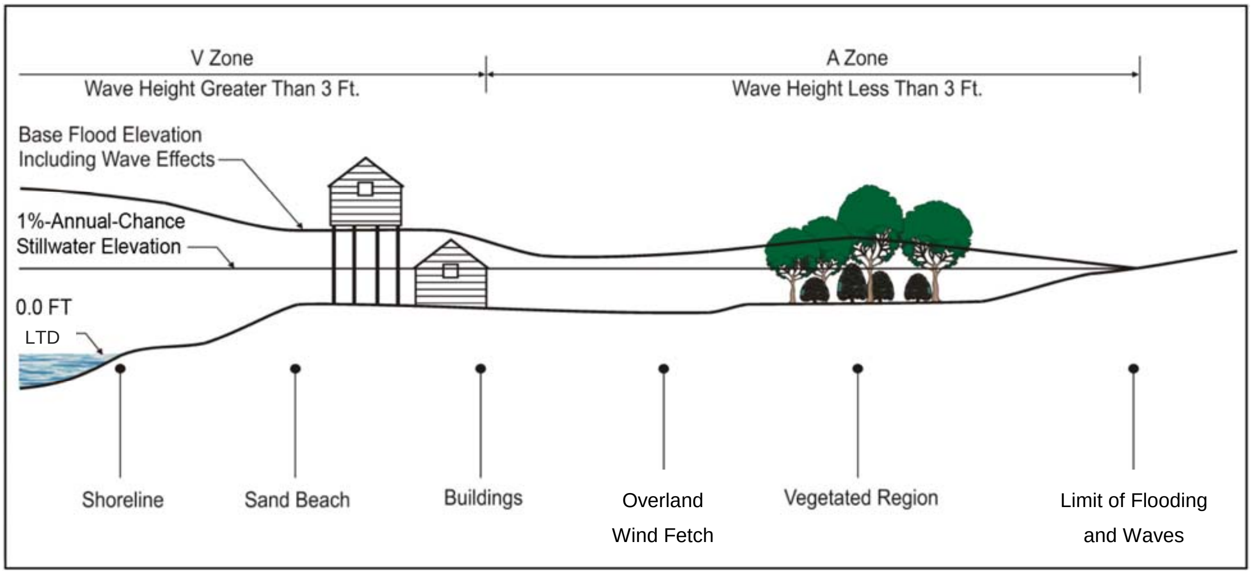


Figure 3. Transect Schematic

Deepwater wave characteristics associated to the 1-percent annual chance storm were developed using the hurricane prediction technique for slowly moving hurricanes as described in the Shore Protection Manual (USACE, 1984). The wave conditions are calculated based on hurricane parameters, such as central pressure deficit, forward translation speed, radius to maximum winds and maximum sustained speed. In particular for the Hawaiian Islands, Hurricane Iniki's parameters from the HURDAT database (1992) were utilized for the application of the prediction technique. FEMA guidelines for Zone V mapping define H_s as the significant wave height or the average over the highest one third of waves and T_s as the significant wave period associated with the significant wave height. Mean wave conditions are described as:

$$\overline{H} = H_s \times 0.626$$
$$\overline{T} = T_s \times 0.85$$

where $\overline{H}$ is the average wave height of all waves and $\overline{T}$ is the average wave period.

The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, the transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects. Transects are shown on FIRM panels with detailed coastal flooding.

The transect profiles were obtained using bathymetric and topographic data from various sources. The greater part of the bathymetric data set was comprised of 255 individual surveys NOAA NOS hydrographic surveys, collected from 1900 to 2005. Soundings were originally in the mean lower low water (MLLW) or mean low water (MLW) datums. Relative datum differences were retrieved for NOS water level gages in the Hawaiian Islands, and an average conversion factor was determined for each datum (0.08 meter (m) decrease from MLW to MLLW, and 0.8 m increase in depth from MLLW to LTD). The USACE Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) provided bathymetric LiDAR for the six islands, including Maui County's Kahoolawe, Lanai, Maui, and Molokai Islands. This dataset was collected in 1999 and 2000, and provided high-resolution coverage of the nearshore bathymetry surrounding the islands. Depths were adjusted from the MLLW datum to LTD and merged with the NOAA dataset. The USACE Honolulu District provided a 2004 hydrographic survey of Honolulu Harbor. Depths were adjusted from MLLW to LTD and merged into the comprehensive dataset. A 2004 multibeam survey of Pearl Harbor conducted by the U.S. Navy was provided by the NOAA National Geophysical Data Center. Depths were converted from MLLW to LTD and merged into the dataset. Once all datasets were assembled, overlapping data was removed to leave the best possible data in the nearshore areas of the islands. The topographic portion of the transect profiles was populated from LiDAR. These data were collected for floodplain mapping along the southern coasts of the six islands, including Maui County's Kahoolawe, Lanai, Maui, and Molokai Islands, included in the study and extends from the shoreline to the approximate 10 meter contour. The LiDAR data were collected in Fall of 2006, post-processed to bare earth and quality controlled to meet FEMA mapping standards. LiDAR elevations were delivered in LTD, therefore no conversion was necessary.

Beach erosion was applied as per standard FEMA (2003) and FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners methodology and VE Zones were mapped up to the extent of the Primary Frontal Dune (PFD).

Nearshore wave-induced processes, such as wave setup and wave runup, constitute a greater part of the combined wave envelope than storm surge due to the islands' high cliffs and location exposed to ocean waves. For this particular environment, the Direct Integrated Method (FEMA, 2007) was used to determine wave setup along the coastline.

Offshore coral reefs surround Hawaii, producing localized variation in wave setup values. A modified wave setup approach was applied in locations where reefs extend above the breaking depth of the incident wave height. The criterion applied was based upon the methodology outlined by Gourlay (1996).

Wave height calculation used in this study follows the methodology described in the FEMA (2003) and the FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners.

RUNUP 2.0 was used to predict wave runup value on natural shore then adjusted to follow the FEMA (2005) “Procedure Memorandum No. 37” that recommends the use of the 2% wave runup for determining base flood elevations. For steep cliffs and in areas dominated by coral reefs, wave runup was determined using the Technical Advisory Committee for Water Retaining Structures (TAW) method (van der Meer, 2002). In presence of shore-protection structures, wave runup calculations were computed using the appropriate roughness coefficient for the structure. The Shore Protection Manual (SPM) Method was applied in cases of wave runup on vertical structures. For wave run-up at the crest of a slope that transitions to a plateau or downslope, run-up values were determined using the “Methodology for wave run-up on a hypothetical slope” as described in the FEMA (2003) and the FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners.

Figure 4, “Transect Location Map,” illustrates the location of each transect along which the coastal analysis have been performed within the hurricane study area boundaries. Along each transect, wave envelopes were computed considering the combined effects of changes in ground elevation, vegetation and physical features. Between transects, elevations were interpolated using topographic maps, land-use and land-cover data, and engineering judgment to determine the aerial extent of flooding. The results of the calculations are accurate until either local topography, vegetation, or cultural development within the community undergo major changes. For the 2009 Island of Lanai tsunami risk study (from Kaumalapau Harbor on the west coast clockwise around to Manele Bay), an additional Lanai Island transect location map shows both the tsunami transect runup analysis and respective tsunami coefficient locations.

The transect data for Lanai, Maui, & Molokai Islands are presented in Table 6, “Transect Descriptions,” which describes the location of each transect. In addition, Table 6 provides the 1-percent annual chance stillwater, wave setup and maximum wave crest elevations for each transect along the island coastline. In Table 7, “Transect Data,” the flood hazard zone and base flood elevations for each transect flooding source is provided, along with the 10-, 2-, 1-, and 0.2-percent annual chance stillwater elevations for the respective flooding source. For the 2009 Island of Lanai tsunami risk study, there are separate tsunami transect location information presented in Table 8, “Tsunami Transect Locations,” which provides the beginning and ending coordinates, and length of each transect profile used in the tsunami runup analyses. In Table 9, “Tsunami Transect Data,” the table provides a separate transect data summary of the results for the detailed tsunami runup analysis with maximum 1-percent annual chance runup elevations for each transect, along with transect tsunami coefficient values (A & B).

For Maui and Molokai Islands, previous mapping of the tsunami hazard was merged with the detailed hurricane coastal hazard study in this revision. This was accomplished by comparing the zone type, base flood elevation, and inland flooding extent of coincident tsunami and hurricane storm surge hazards. The higher of the two elevations was retained and presented on the Flood Insurance Rate Map. If in a tsunami hazard-dominated area, the inland limit of the hurricane storm surge flooding extends further landward than the tsunami hazard, the tsunami base flood elevation is shown and the flooding extent is extended to where the hurricane hazard is mapped. This is to reflect the increased hazard generated by the use of updated topographic data. The VE Zone was extended and mapped to the inland limit of the Primary Frontal Dune for both tsunami and hurricane hazards. In cases where elevations were similar, engineering judgment was applied to facilitate the most appropriate representation of the higher hazard.

Users of the FIRM should also be aware that coastal flood elevations are provided in Table 4, "Summary of Coastal Stillwater Elevations" in this report. If the elevation on the FIRM is higher than the elevation shown in this table, a wave height, wave runup, and/or wave setup component likely exists, in which case, the higher elevation should be used for construction and/or floodplain management purposes.

As defined in the July 1989 *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping*, the coastal high hazard area (Zone VE) is the area where wave action and/or high velocity water can cause structural damage (*Guidelines and Specifications for Wave Elevation Determination and V-Zone Mapping*, FEMA, 1989). It is designated on the FIRM as the most landward of the following three points:

1) The point where the 3.0 ft or greater wave height could occur;
2) The point where the eroded ground profile is 3.0 ft or more below the maximum runup elevation; and
3) The primary frontal dune as defined in the NFIP regulations.

These three points are used to locate the inland limit of the coastal high hazard area to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this area.

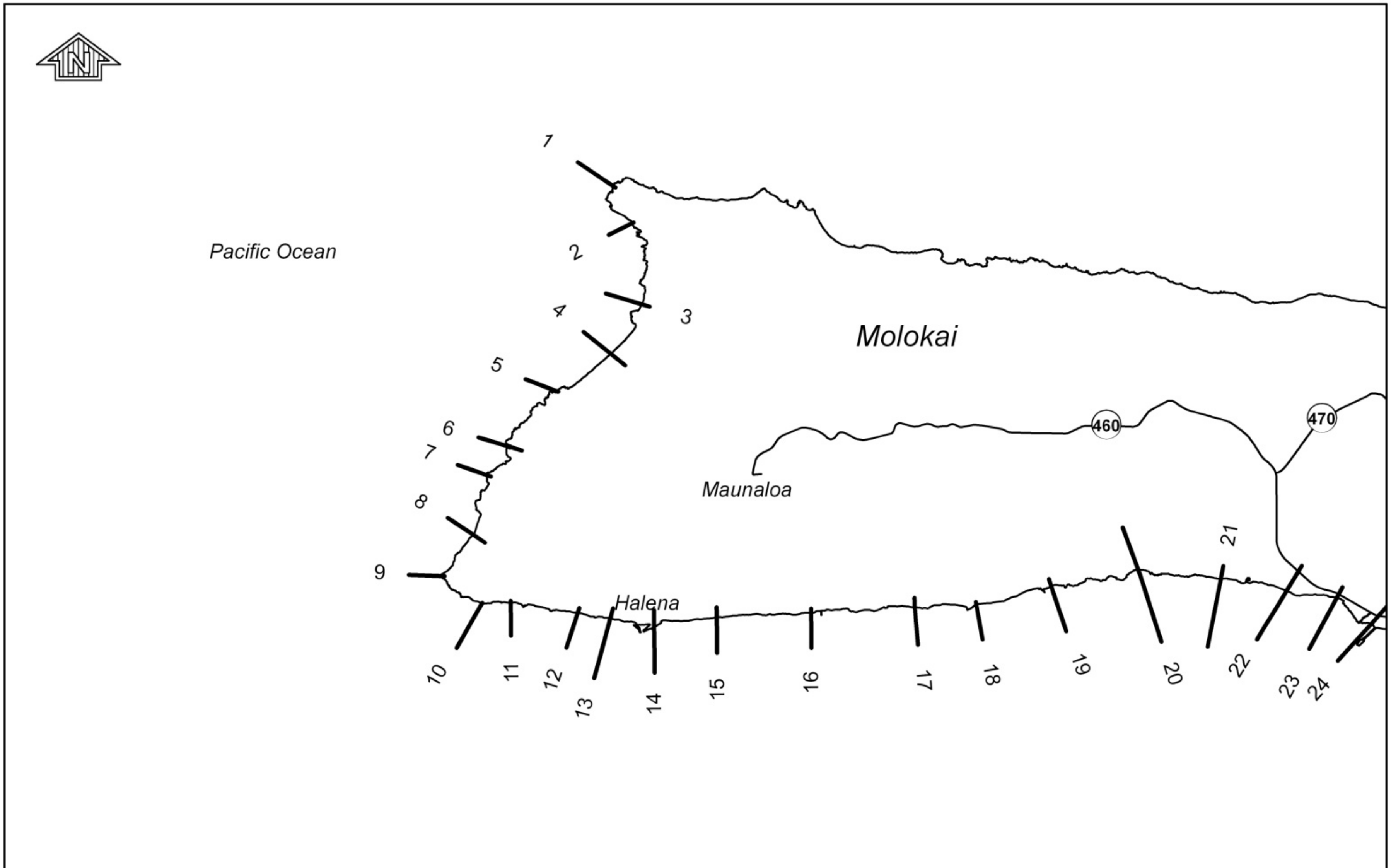


Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

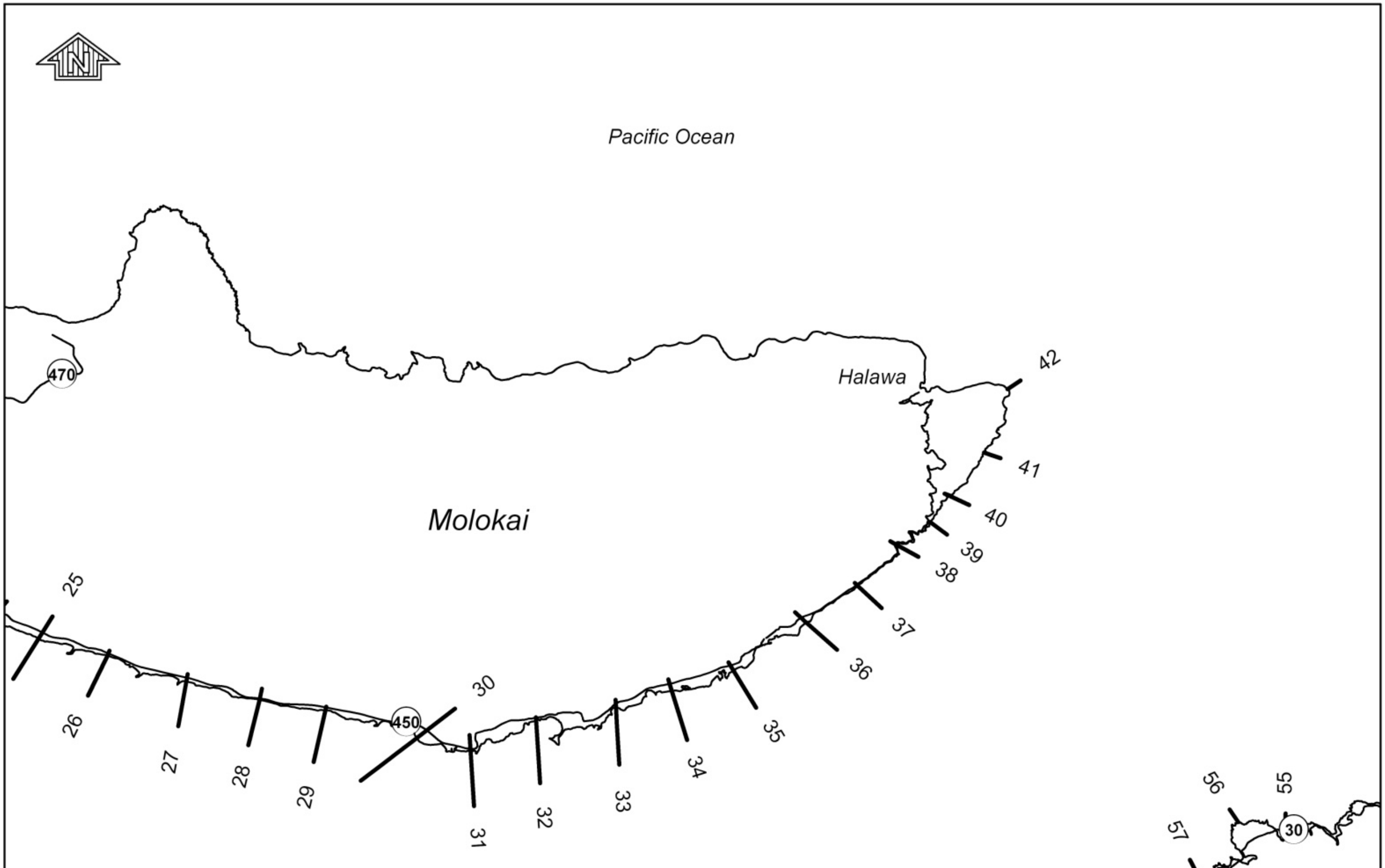
MAUI COUNTY, HAWAII

ISLAND OF MOLOKAI

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 1



FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MOLOKAI

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 2

Figure 4

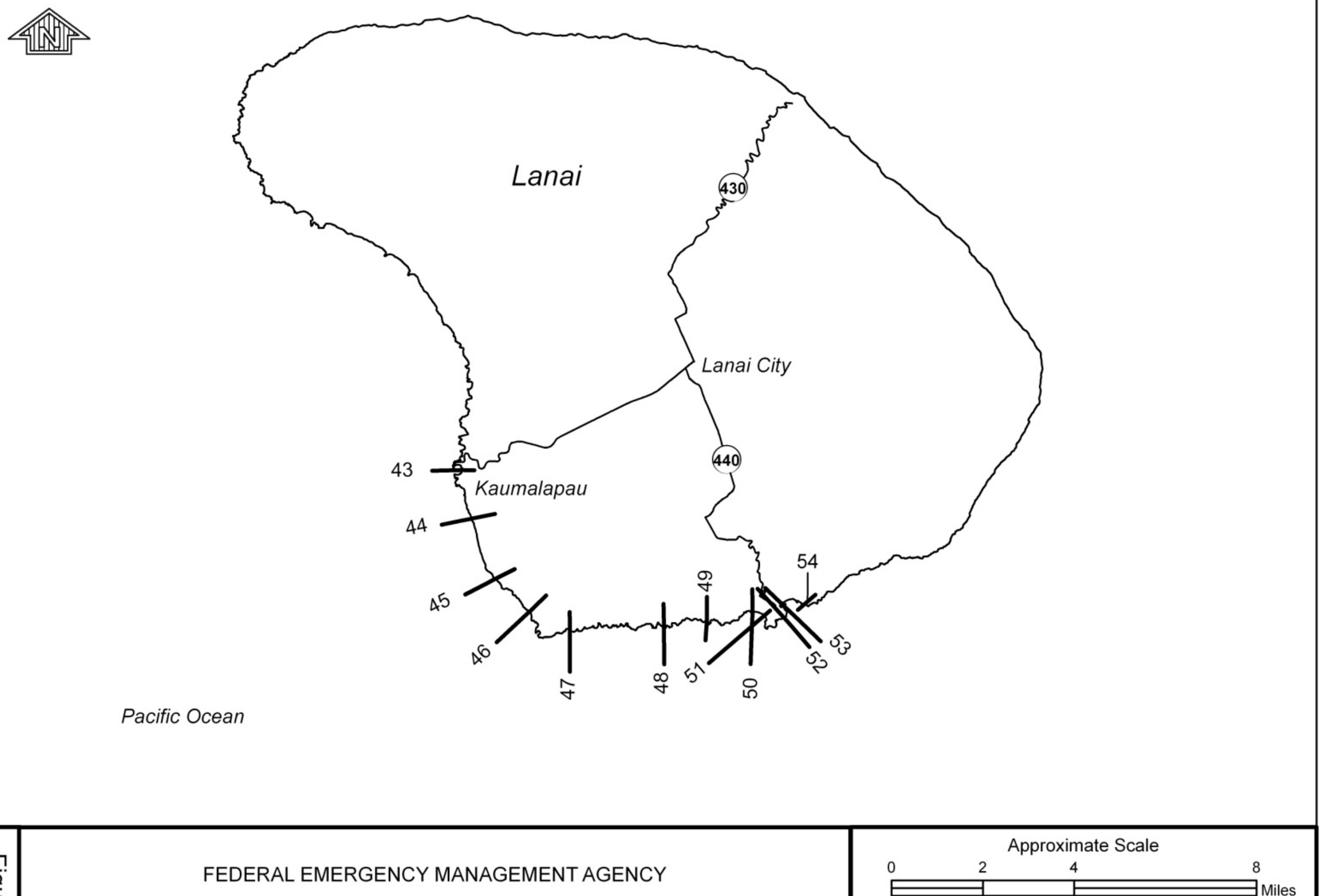


Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF LANAI

TRANSECT LOCATION MAP 3

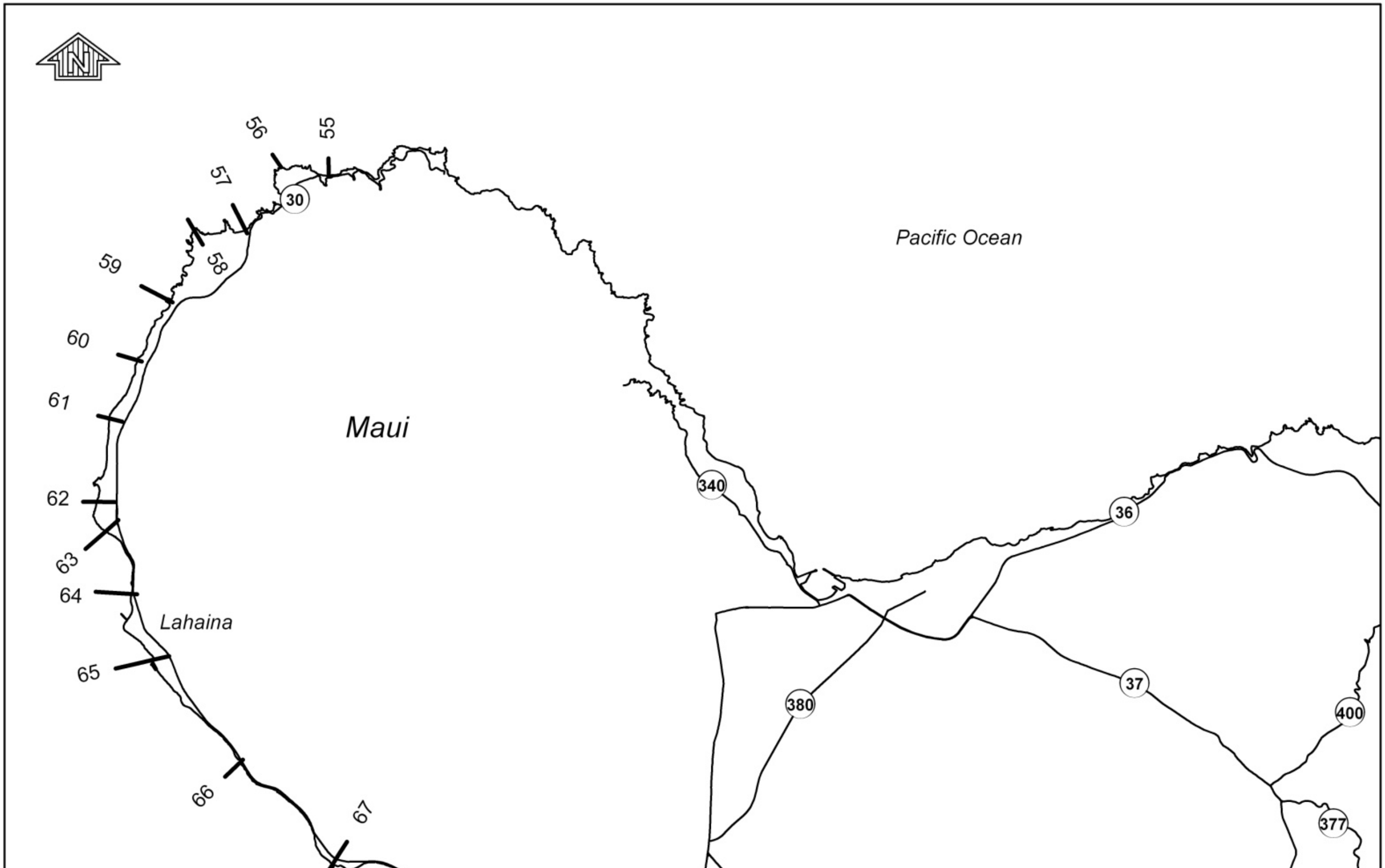


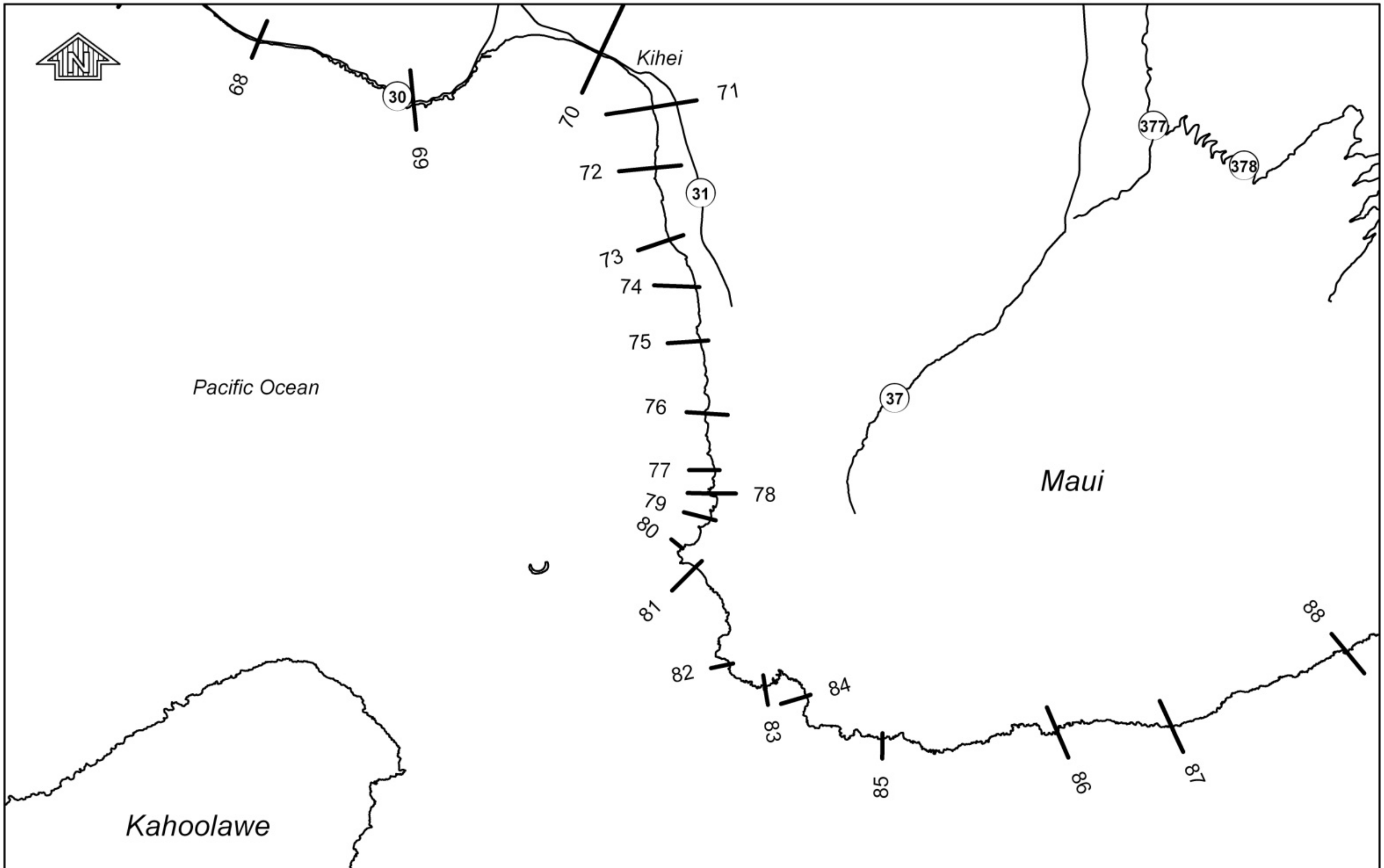
Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

TRANSECT LOCATION MAP 4



FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

TRANSECT LOCATION MAP 5

Figure 4

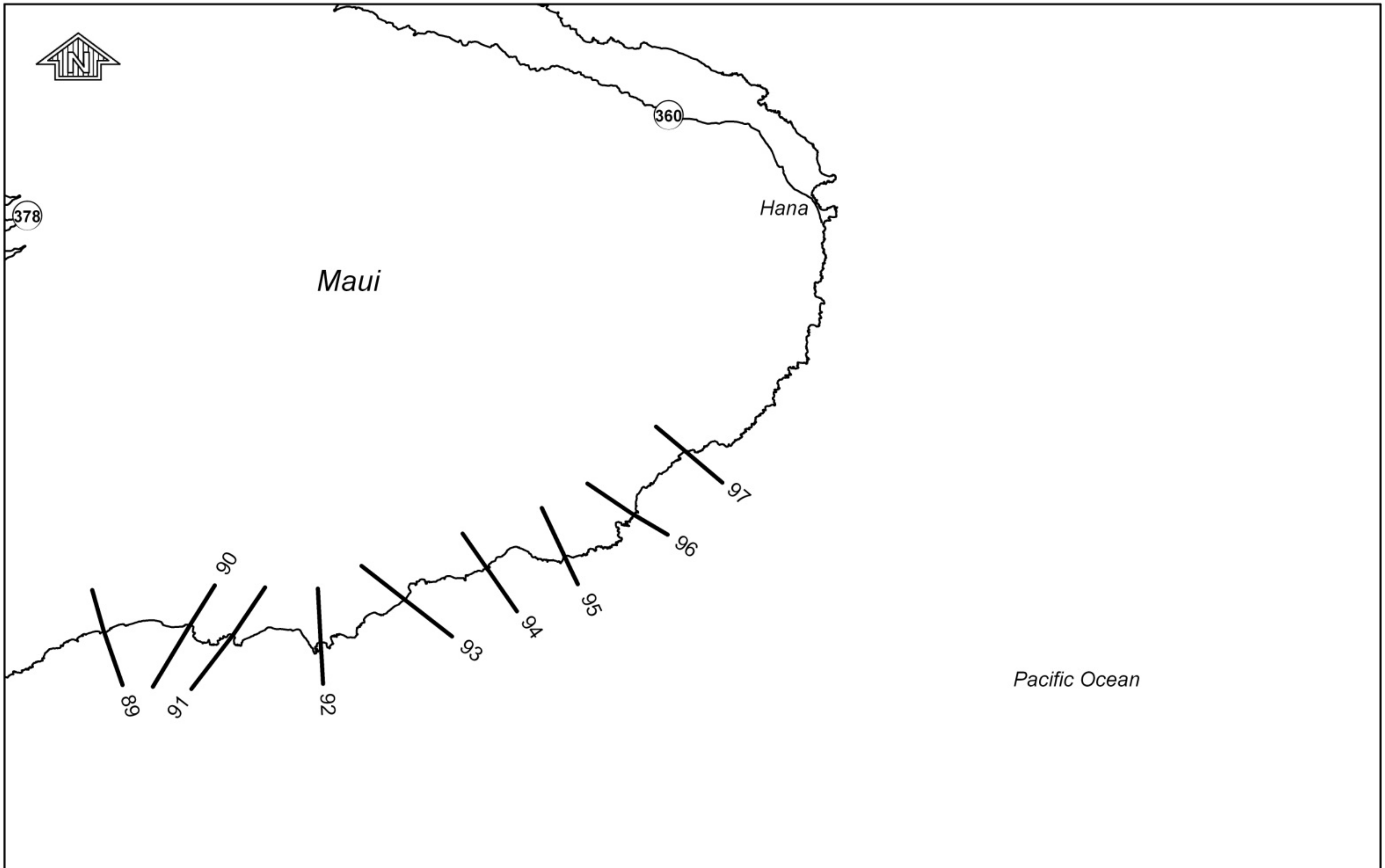


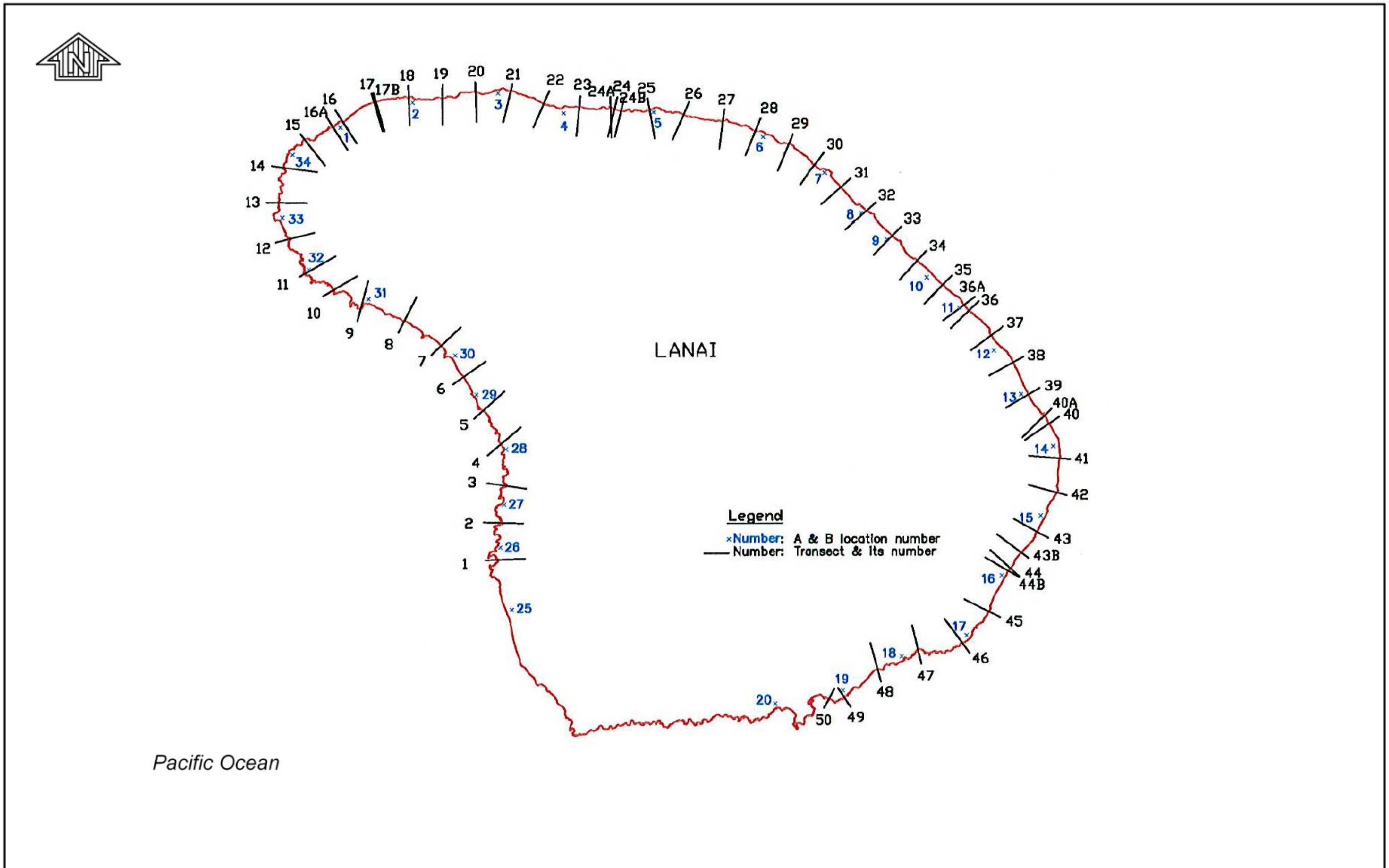
Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF MAUI

TRANSECT LOCATION MAP 6



FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

ISLAND OF LANAI

TRANSECT LOCATION MAP 7

Figure 4

TABLE 6: TRANSECT DESCRIPTIONS[†]

ISLAND OF MOLOKAI

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
1	On the Pacific Ocean coastline, on the northwest side of the island, approximately 2.36 miles north northwest of the intersection of Lio Place and Kakaako Road, located near Ilio Point, at N 21.221444°, W 157.257816°.	1.0	5.4	13.2[1]
2	On the Pacific Ocean coastline, on the NW side of the island, approximately 1.50 miles NNW of the intersection of Kalua Koi Road and Kakaako Road, located north of Kepuhi, at N 21.210367°, W 157.251945°.	1.1	4.4	10.8[1]
3	On the Pacific Ocean coastline, on the northwest side of the island, approximately 0.457 miles west of the intersection of Kalua Koi Road and Kaiaka Road, located in Kepuhi, at N 21.185218°, W 157.249111°.	1.1	4.3	8.8[1]
4	On the Pacific Ocean coastline, on the northwest side of the island, approximately 0.867 miles southwest of the intersection of Kalua Koi Road and Pa Loa Loop, located in Wahilauhue, at N 21.169693°, W 157.258378°.	1.1	4.5	10.5[1]
5	On the Pacific Ocean coastline, on the northwest side of the island, approximately 960 feet northwest of the intersection of Kulawai Place and Kaula Ili Wy, located near Puu Koai, at N 21.158324°, W 157.275103°.	1.1	4.7	8.9
6	On the Pacific Ocean coastline, on the northwest side of the island, approximately 0.426 miles southwest of the intersection of Pohakuloa Road and Kulawai Loop, located north of Kaunala Bay, at N 21.141195°, W 157.289022°.	1.1	4.5	8.5
7	On the Pacific Ocean coastline, on the northwest side of the island, approximately 1,810 feet northwest of Kaupoa (elevation 28 feet Local Tidal Datum), at N 21.132553°, W 157.296693°.	1.1	4.9	9.1
8	On the Pacific Ocean coastline, on the northwest side of the island, approximately 1.01 miles north northeast of Coast Guard Beacon near Laau point, located at Kamakaipo, at N 21.114312°, W 157.3009°.	1.1	4.3	8.2
9	On the Pacific Ocean coastline, on the west side of the island, approximately 0.390 miles northwest of a Coast Guard beacon, located at the Coast Guard Reservation at Laau Point, at N 21.101615°, W 157.310241°.	1.0	5.1	9.4

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MOLOKAI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest[1]
10	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.605 miles southeast of a Coast Guard beacon, located east of the Coast Guard Reservation at Laau Point, at N 21.093274°, W 157.298462°.	1.1	4.3	8.3
11	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.06 miles east southeast of a Coast Guard beacon, located east of the Coast Guard Reservation at Laau Point, at N 21.093654°, W 157.289535°.	1.2	4.1	8.0
12	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.14 miles west northwest of Haleolono Point, at N 21.090407°, W 157.268857°.	1.2	4.2	8.3
13	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.488 miles north northwest of Haleolono Point, at N 21.08869°, W 157.258842°.	1.1	5.2	9.8
14	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.389 miles southeast of the northernmost vertex in a heart-shaped assemblage of trails to the north of Lono Harbor, at N 21.086039°, W 157.245422°.	1.2	4.3	8.4
15	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,980 feet east southeast of a water tank, located in Halena, at N 21.089075°, W 157.226169°.	1.2	4.2	8.4
16	On the Pacific Ocean coastline, on the southwest side of the island, approximately 270 feet south southwest of the point where the stream of Onopalani Gulch crosses Lee Shore Road, at N 21.090472°, W 157.197173°.	1.2	4.2	8.3
17	On the Pacific Ocean coastline, on the southwest side of the island, approximately 680 feet south southeast of the point where the stream of Waiakane Gulch crosses Lee Shore Road, at N 21.092301°, W 157.165418°.	1.2	5.0	9.6
18	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,370 feet east of the point where the stream of Kukuku Gulch crosses Lee Shore Road, at N 21.093084°, W 157.146379°.	1.2	5.1	9.6

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MOLOKAI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest[1]
19	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.640 miles southwest of Puu Iloli (peak), located at Pakanaka Fishpond, at N 21.098024°, W 157.123246°.	1.3	5.1	9.8
20	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.996 miles south southwest of the pumping station near Palaau Homesteads, located in Palaau, at N 21.101731°, W 157.095925°.	1.4	5.1	10.0
21	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.37 miles southwest of the intersection of Maunaloa Highway (Highway 460) and Hoawa Road, located west of Umipaa, at N 21.0992°, W 157.071519°.	1.4	4.8	9.5
22	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,770 feet southwest of the intersection Hoawa Road and Kahanu Ave, located in Kalanianaole Colony, at N 21.097041°, W 157.050942°.	1.3	5.4	10.3
23	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,700 feet WNW of the intersection of Maunaloa Highway (Highway 460) and Manila Place, located in Kalanianaole Colony, at N 21.095195°, W 157.035438°.	1.4	5.0	9.8
24	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,120 feet southwest of the intersection of Maunaloa Highway (Highway 460) and Kaunakakai Place, located in Kaunakakai, at N 21.08716°, W 157.024761°.	1.2	5.0	9.6
25	On the Pacific Ocean coastline, on the southwest side of the island, approximately 660 feet southwest of the easternmost intersection of west Kamehameha V Highway and Kapaakea Loop, located in about midway between Kamioloa and Kaunakakai, at N 21.081838°, W 157.009441°.	1.2	6.6	12.0
26	On the Pacific Ocean coastline, on the southwest side of the island, approximately 270 feet south of the intersection of west Kamehameha V Highway and Pano Place, located in Kamiloloa, at N 21.076369°, W 156.988366°.	1.2	5.0	9.6

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MOLOKAI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest[1]
27	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.525 miles west northwest of the intersection of east Kamehameha V Highway and Uluanui, located in Kawela, at N 21.068412°, W 156.963955°.	1.2	5.5	10.2
28	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,100 feet east southeast of the intersection of east Kamehameha V Highway and Onioni Drive, located at Kakahaia National Wildlife Refuge, at N 21.062688°, W 156.941436°.	1.2	4.6	8.9
29	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.73 miles east southeast of the intersection of east Kamehameha V Highway and Onioni Drive, located at Panahaha Fishpond, at N 21.059505°, W 156.921158°.	1.2	4.6	9.0
30	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,940 feet southeast of the intersection of east Kamehameha V Highway and a trail that leads up Aikoolua Gulch, located at Kamahuehue Fishpond, at N 21.051527°, W 156.891901°.	1.2	5.2	9.7
31	On the Pacific Ocean coastline, on the south side of the island, approximately 210 feet southwest of the intersection of east Kamehameha V Highway and a road that runs thence north that one encounters just before the 90° bend inland as one travels east through Kamalo on the Highway, at N 21.046984°, W 156.876242°.	1.1	5.5	10.2
32	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1,670 feet southwest of a water tank 970 feet onshore from Keawanui Fishpond, located about midway between Ulapue and Kamalo, at N 21.056272°, W 156.85598°.	1.2	5.4	10.2
33	On the Pacific Ocean coastline, on the southeast side of the island, approximately 0.439 miles southwest of the point where Kaluaaha Bridge crosses a stream, located in Ualapue at Ualapue Fishpond, at N 21.060182°, W 156.831364°.	1.3	5.6	10.6

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MOLOKAI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest[1]
34	On the Pacific Ocean coastline, on the southeast side of the island, approximately 630 feet east northeast of the point where east Kamehameha V Highway crosses the stream that drains into Niaupala Fishpond, located in Kaluaaha, at N 21.067544°, W 156.814813°.	1.2	5.4	10.2
35	On the Pacific Ocean coastline, on the southeast side of the island, approximately 720 feet south southeast of the point where east Kamehameha V Highway crosses a stream, located in Pukoo, at N 21.0716°, W 156.794984°.	1.2	5.8	10.7
36	On the Pacific Ocean coastline, on the southeast side of the island, approximately 0.438 miles east northeast of Ionomuni Bridge, located in Pauwalu, at N 21.086754°, W 156.772939°.	1.2	4.8	9.2
37	On the Pacific Ocean coastline, on the southeast side of the island, approximately 280 feet southeast of a church, located in Walalua, at N 21.097871°, W 156.756661°.	1.2	5.0	9.5
38	On the Pacific Ocean coastline, on the southeast side of the island, approximately 660 feet south of a water tank, located about 1.5 miles northeast of Walalua, at N 21.110696°, W 156.745052°.	1.2	5.4	10.1
39	On the Pacific Ocean coastline, on the southeast side of the island, approximately 850 feet southeast of the point where east Kamehameha V Highway crosses a stream in a hairpin turn, located about 1,450 feet northeast of Kaipukaulua Gulch, at N 21.117449°, W 156.734199°.	1.1	4.7	8.9
40	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1,450 feet east southeast of a water tank inside a bend in east Kamehameha V Highway, located near Punolohi, at N 21.126107°, W 156.729463°.	1.1	4.3	8.4
41	On the Pacific Ocean coastline, on the southeast side of the island, approximately 0.873 miles, east northeast of the east end of the landing strip near Hoku, located near Puuloa, at N 21.138893°, W 156.717328°.	1.1	4.4	8.5
42	On the Pacific Ocean coastline, on the east side of the island, approximately 1.68 miles east of the northern end of east Kamehameha V Highway, located at Cape Halawa, at N 21.158627°, W 156.710309°.	1.0	4.7	9.4[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF LANAI

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest[1]
43	On the Pacific Ocean coastline, on the west side of the island, approximately 1,120 feet northeast of Kaumalapau Light (at a Coast Guard Reservation), located at Kaumalapau, at N 20.785079°, W 156.989242°.	1.0	5.0	21.0[1]
44	On the Pacific Ocean coastline, on the west side of the island, approximately 1.19 miles west northwest of a radio beacon (which is located 1 mile inland, midway between two Coast Guard Reservations), at N 20.769682°, W 156.98649°.	1.1	4.9	14.4[1]
45	On the Pacific Ocean coastline, on the west side of the island, approximately 1.16 miles south southwest of a radio beacon (which is located 1 mile inland, midway between two Coast Guard Reservations), at N 20.75051°, W 156.979048°.	1.0	5.1	12.9[1]
46	On the Pacific Ocean coastline, on the west side of the island, approximately 0.585 miles north northwest of the lighthouse at Palaoa Point (at the Coast Guard Reservation at the southwest corner of the island), located in Kaunolu, at N 20.740318°, W 156.967927°.	1.1	5.2	37.9[1]
47	On the Pacific Ocean coastline, on the south side of the island, approximately 0.639 miles east of the lighthouse at Palaoa Point (at the Coast Guard Reservation at the southwest corner of the island), located near Kaunolu, at N 20.733921°, W 156.955327°.	1.1	4.9	9.8[1]
48	On the Pacific Ocean coastline, on the south side of the island, approximately 2.34 miles west southwest of the intersection of Manele Road and Manele Harbor Road, located west of Po'opo'o (island), at N 20.734799°, W 156.925472°.	1.1	6.4	54.6[1]
49	On the Pacific Ocean coastline, on the south side of the island, approximately 1.44 miles west southwest of the intersection of Manele Road and Manele Harbor Road, located about 0.5 miles east of Huawai Bay, at N 20.737347°, W 156.911814°.	1.1	5.0	16.1[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF LANAI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
50	On the Pacific Ocean coastline, on the south side of the island, approximately 0.500 miles west southwest of the intersection of Manele Road and Manele Harbor Road, located between Kapiha Bay and Hulopoe Bay, at N 20.739493°, W 156.897349°.	1.1	5.0	20.9[1]
51	On the Pacific Ocean coastline, on the south side of the island, approximately 1,580 feet southwest of the intersection of Manele Road and Manele Harbor Road, located at Huloloe Bay, at N 20.738967°, W 156.893506°.	1.1	4.4	10.6[1]
52	On the Pacific Ocean coastline, on the south side of the island, approximately 1,800 feet southeast of the intersection of Manele Road and Manele Harbor Road, located near Leinohaunui Point, at N 20.737798°, W 156.88701°.	1.1	6.2	11.2
53	On the Pacific Ocean coastline, on the south side of the island, approximately 930 feet east of the intersection of Manele Road and Manele Harbor Road, located in Manele Bay, at N 20.742171°, W 156.88767°.	1.1	5.3	9.8
54	On the Pacific Ocean coastline, on the south side of the island, approximately 0.610 miles east northeast of the intersection of Manele Road and Manele Harbor Road, located in Manele Bay, at N 20.742626°, W 156.880641°.	1.1	5.1	11.8[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MAUI

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
55	On the Pacific Ocean coastline, on the north side of the island, approximately 1.1 miles northwest of intersection of Kahekili Highway and Honoapiilani Highway, located in Honolua, at N 21.02223°, W 156.624499°.	1.0	6.4	11.4
56	On the Pacific Ocean coastline, on the north side of the island, approximately 4,830 feet northeast of intersection of Honolua Place and Honoapiilani Highway, located in Honolua, at N 21.025168°, W 156.639386°.	1.0	6.9	24.7[1]
57	On the Pacific Ocean coastline, on the north side of the island, approximately 610 feet southwest of intersection of Lower Honoapiilani Road and Honoapiilani Highway, located in Honokahua, at N 21.005316°, W 156.650263°.	1.1	4.8	9.0
58	On the Pacific Ocean coastline, on the north side of the island, approximately 2,330 feet northwest of intersection of Lower Honoapiilani Road and Ridge Road, located in Kapalua, at N 21.006314°, W 156.666624°.	1.0	6.0	10.8
59	On the Pacific Ocean coastline, on the northwest side of the island, approximately 1,320 feet northwest of intersection of Lower Honoapiilani Road and Puamana Place, located in Kahana, at N 20.983988°, W 156.674479°.	1.1	4.5	16.4[1]
60	On the Pacific Ocean coastline, on the northwest side of the island, approximately 700 feet northwest of intersection of Lower Honoapiilani Road and Akahele Street, located in Kahana, at N 20.965155°, W 156.683247°.	1.1	4.5	8.6
61	On the Pacific Ocean coastline, on the west side of the island, approximately 1,480 feet southwest of intersection of Lower Honoapiilani Road and Kaanapali Shores Place, located in Honokowai, at N 20.947261°, W 156.692225°.	1.0	5.6	10.2
62	On the Pacific Ocean coastline, on the west side of the island, approximately 1,310 feet northwest of intersection of Nohea Kai Drive and Kaanapali Parkway, located in Kaanapali, at N 20.921425°, W 156.696081°.	1.0	4.5	9.8[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MAUI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
63	On the Pacific Ocean coastline, on the west side of the island, approximately 2,230 feet southeast of intersection of Nohea Kai Drive and Kaanapali Parkway, located in Kaanapali, at N 20.912504°, W 156.693085°.	1.1	4.5	8.9[1]
64	On the Pacific Ocean coastline, on the west side of the island, approximately 950 feet northwest of intersection of Olona Place and Front Street, located in Puunoa, at N 20.892971°, W 156.685357°.	1.1	4.5	9.6[1]
65	On the Pacific Ocean coastline, on the west side of the island, approximately 1,220 feet northwest of intersection of Prison Street and Luakini Street, located in Lanaina, at N 20.872684°, W 156.678847°.	1.1	6.8	12.1
66	On the Pacific Ocean coastline, on the southwest side of the island, approximately 2.6 miles southeast of intersection of Prison Street and Luakini Street, located in Launiupoko, at N 20.841311°, W 156.651544°.	1.1	6.5	11.7
67	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,000 feet southwest of intersection of Kapaki Place and Olowalu Village Road, located in Olowalu, at N 20.809499°, W 156.623306°.	1.1	6.2	11.1
68	On the Pacific Ocean coastline, on the southwest side of the island, approximately 2.9 miles southeast of intersection of Kapaki Place and Olowalu Village Road, located in Mopua, at N 20.79471°, W 156.582464°.	1.1	6.2	11.2
69	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.6 miles southwest of intersection of Honoapiilani Highway and Maalaea Boat Harbor Road, located in Maalaea, at N 20.775455°, W 156.534633°.	1.1	5.8	34.9[1]
70	On the Pacific Ocean coastline, on the southwest side of the island, approximately 4,710 feet northwest of intersection of North Kihei Road and South Kihei Road, located in Kihei, at N 20.790823°, W 156.476975°.	1.3	4.2	8.3

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MAUI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
71	On the Pacific Ocean coastline, on the southwest side of the island, approximately 970 feet southwest of intersection of Ohukai Street and Kenolio Road, located in Kihei, at N 20.774329°, W 156.460602°.	1.2	6.4	11.7
72	On the Pacific Ocean coastline, on the southwest side of the island, approximately 2,310 feet west of intersection of Hou Street and Eleu Place, located in Kihei, at N 20.755744°, W 156.459497°.	1.2	6.2	11.3
73	On the Pacific Ocean coastline, on the southwest side of the island, approximately 520 feet southwest of intersection of Waimahaihai Street and Halama Street, located in Keawakapu, at N 20.733404°, W 156.455428°.	1.1	6.5	11.6
74	On the Pacific Ocean coastline, on the southwest side of the island, approximately 2,540 feet northwest of intersection of Alaku Place and Omiko Place, located in Keawakapu, at N 20.718744°, W 156.448103°.	1.2	4.6	11.9[1]
75	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,280 feet southwest of intersection of Kilohana Drive and Waikai Street, located in Keawakapu, at N 20.702118°, W 156.44579°.	1.1	4.6	10.1[1]
76	On the Pacific Ocean coastline, on the southwest side of the island, approximately 2,740 feet northwest of intersection of Wailea Alanui Drive and Kaukahi Street, located in Makena, at N 20.679835°, W 156.445171°.	1.1	5.3	12.8[1]
77	On the Pacific Ocean coastline, on the southwest side of the island, approximately 3,690 feet northwest of intersection of Makena Road and Honoiki Street, located in Makena, at N 20.66221°, W 156.441541°.	1.1	4.6	12.1[1]
78	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,450 feet northwest of intersection of Makena Road and Honoiki Street, located in Makena, at N 20.654934°, W 156.443523°.	1.1	5.3	31.0[1]
79	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,980 feet southwest of intersection of Makena Road and Honoiki Street, located in Makena, at N 20.647025°, W 156.442771°.	1.1	4.5	8.5

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MAUI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
80	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.2 miles southwest of intersection of Makena Road and Honoiki Street, located in Makena, at N 20.638088°, W 156.451705°.	1.0	5.9	41.5[1]
81	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.5 miles southwest of intersection of Makena Road and Honoiki Street, located in Kanahena, at N 20.631996°, W 156.447726°.	1.1	4.6	10.2[1]
82	On the Pacific Ocean coastline, on the southwest side of the island, approximately 3.3 miles southwest of intersection of Ulupalakua Highway and Kalama Park Road, located in Kanahena, at N 20.602091°, W 156.43694°.	1.1	5.8	20.0[1]
83	On the Pacific Ocean coastline, on the south side of the island, approximately 3.1 miles southwest of intersection of Ulupalakua Highway and Kalama Park Road, located in Keoneoio, at N 20.594608°, W 156.426026°.	1.1	5.0	11.3[1]
84	On the Pacific Ocean coastline, on the south side of the island, approximately 2.7 miles southwest of intersection of Ulupalakua Highway and Kalama Park Road, located in Keoneoio, at N 20.592184°, W 156.413404°.	1.1	4.4	8.4
85	On the Pacific Ocean coastline, on the south side of the island, approximately 1.4 miles south of intersection of Ulupalakua Highway and Kalama Park Road, located in Keoneoio, at N 20.579482°, W 156.389688°.	1.1	4.9	10.6[1]
86	On the Pacific Ocean coastline, on the south side of the island, approximately 4.9 miles southeast of intersection of Ulupalakua Highway and Kalama Park Road, located in Keoneoio, at N 20.581076°, W 156.335626°.	1.1	5.8	26.0[1]
87	On the Pacific Ocean coastline, on the south side of the island, approximately 6.8 miles southeast of intersection of Ulupalakua Highway and Kalama Park Road, located in Nuu, at N 20.582458°, W 156.300304°.	1.1	5.5	13.0[1]
88	On the Pacific Ocean coastline, on the southeast side of the island, approximately 9.7 miles southeast of intersection of Ulupalakua Highway and Kalama Park Road, located in Nuu, at N 20.605455°, W 156.245885°.	1.1	5.8	33.5[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 6: TRANSECT DESCRIPTIONS†

ISLAND OF MAUI (continued)

Transect	Location	Elevation (feet Local Tidal Datum) 1-Percent Annual Chance Stillwater	Wave Setup	Maximum 1-Percent Annual Chance Wave Crest
89	On the Pacific Ocean coastline, on the southeast side of the island, approximately 12.2 miles east of intersection of Ulupalakua Highway and Kalama Park Road, located in Nuu, at N 20.624927°, W 156.205363°.	1.1	5.3	21.3[1]
90	On the Pacific Ocean coastline, on the southeast side of the island, approximately 12.3 miles southwest of intersection of South Hana Highway and Haou Road, located in Nuu, at N 20.626708°, W 156.179071°.	1.1	4.9	12.7[1]
91	On the Pacific Ocean coastline, on the southeast side of the island, approximately 11.6 miles southwest of intersection of South Hana Highway and Haou Road, located in Nuu, at N 20.623886°, W 156.165492°.	1.1	4.5	9.7[1]
92	On the Pacific Ocean coastline, on the southeast side of the island, approximately 10.0 miles southwest of intersection of South Hana Highway and Haou Road, located in Kaupo, at N 20.621802°, W 156.138506°.	1.1	4.6	10.6[1]
93	On the Pacific Ocean coastline, on the southeast side of the island, approximately 8.2 miles southwest of intersection of South Hana Highway and Haou Road, located in Mokulau, at N 20.634879°, W 156.112675°.	1.1	4.9	13.9[1]
94	On the Pacific Ocean coastline, on the southeast side of the island, approximately 6.4 miles southwest of intersection of South Hana Highway and Haou Road, located in Mokulau, at N 20.644745°, W 156.087326°.	1.1	5.5	49.4[1]
95	On the Pacific Ocean coastline, on the southeast side of the island, approximately 5.0 miles southwest of intersection of South Hana Highway and Haou Road, located in Kipahulu, at N 20.648078°, W 156.063019°.	1.0	4.8	17.5[1]
96	On the Pacific Ocean coastline, on the southeast side of the island, approximately 3.4 miles southwest of intersection of South Hana Highway and Haou Road, located in Kipahulu, at N 20.660964°, W 156.041547°.	1.1	5.6	24.1[1]
97	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1.7 miles southwest of intersection of South Hana Highway and Haou Road, located in Wailua, at N 20.680716°, W 156.025809°.	1.1	5.6	15.0[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 7: TRANSECT DATA†

ISLAND OF MOLOKAI

Flooding Source	Transect	Stillwater Elevation (feet LTD*)				Zone	Base Flood Elevation (feet LTD*)
		10-Percent	2-Percent	1-Percent	0.2-Percent		
Pacific Ocean	1	0.7	0.8	1.0	1.9	VE	13[2, 3]
						AE	13[2, 3]
Pacific Ocean	2	0.7	0.9	1.1	2.2	VE	11[2, 3]
						AE	11[2, 3]
Pacific Ocean	3	0.7	0.9	1.1	2.2	VE	9[2, 3]
						AE	9[2, 3]
Pacific Ocean	4	0.7	0.9	1.1	2.2	VE	11[2, 3]
						AE	11[2, 3]
Pacific Ocean	5	0.7	0.9	5.8[1]	2.1	VE	8-9[3]
						AE	6-8[3]
Pacific Ocean	6	0.7	0.8	5.6[1]	2.1	VE	8-9[3]
						AE	6-8[3]
Pacific Ocean	7	0.7	0.8	5.9[1]	2.1	VE	9[3]
		0.7	0.8	1.1	2.1	VE	8[2, 3]
						AE	8[2, 3]
Pacific Ocean	8	0.7	0.8	5.3[1]	2.1	VE	7-8[3]
						AE	5-7[3]
Pacific Ocean	9	0.7	0.8	6.1[1]	2.0	VE	9[3]
		0.7	0.8	1.0	2.0	VE	8[2, 3]
						AE	8[2, 3]
Pacific Ocean	10	0.7	0.9	5.4[1]	2.1	VE	8[3]
		0.7	0.9	1.1	2.1	VE	7[2, 3]
						AE	7[2, 3]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA†

ISLAND OF MOLOKAI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*) 10-Percent	2-Percent	1-Percent	0.2-Percent	Zone	Base Flood Elevation (feet LTD*)
Pacific Ocean	11	0.7	0.9	5.2[1]	2.3	VE	7-8
						AE	5-7
Pacific Ocean	12	0.7	0.9	5.4[1]	2.3	VE	8
		0.7	0.9	1.2	2.3	VE	7[2]
						AE	7[2]
Pacific Ocean	13	0.7	0.9	6.4[1]	2.2	VE	8-10
						AE	6-8
Pacific Ocean	14	0.7	0.9	5.4[1]	2.3	VE	8
						AE	5-8
Pacific Ocean	15	0.7	0.9	5.4[1]	2.4	VE	8
						AE	5-8
Pacific Ocean	16	0.7	0.9	5.4[1]	2.4	VE	8
						AE	5-8
Pacific Ocean	17	0.7	0.9	6.2[1]	2.5	VE	8-10
						AE	6-8
Pacific Ocean	18	0.7	0.9	6.2[1]	2.4	VE	8-10
						AE	6-8
Pacific Ocean	19	0.7	1.0	6.3[1]	2.8	VE	8-10
						AE	6-8
		0.7	1.0	4.9[1]	2.8	AE	5
Pacific Ocean	20	0.7	1.0	6.5[1]	3.1	VE	9-10
						AE	7-9
		0.7	1.0	2.6[1]	3.1	AE	3-6

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA†

ISLAND OF MOLOKAI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*) 10-Percent	2-Percent	1-Percent	0.2-Percent	Zone	Base Flood Elevation (feet LTD*)
Pacific Ocean	21	0.7	1.0	6.2[1]	3.0	VE	8-9
						AE	6-8
		0.7	1.0	2.9[1]	3.0	AE	3-5
Pacific Ocean	22	0.7	1.0	6.7[1]	2.9	VE	9-10
						AE	7-9
		0.7	1.0	6.0[1]	2.9	AE	6
		0.7	1.0	5.0[1]	2.9	AE	5
Pacific Ocean	23	0.7	1.0	6.4[1]	3.0	VE	8-10
						AE	6-8
Pacific Ocean	24	0.7	0.9	6.2[1]	2.6	VE	8-10
						AE	6-8
Pacific Ocean	25	0.7	0.9	7.8[1]	2.7	VE	10-12
						AE	8-10
Pacific Ocean	26	0.7	0.9	6.2[1]	2.6	VE	8-10
						AE	6-8
Pacific Ocean	27	0.7	0.9	6.6[1]	2.6	VE	9-10
						AE	7-9
Pacific Ocean	28	0.7	0.9	5.8[1]	2.7	VE	8-9
						AE	6-8
Pacific Ocean	29	0.7	0.9	5.9[1]	2.8	VE	8-9
						AE	6-8
Pacific Ocean	30	0.7	0.9	6.3[1]	2.6	VE	8-10
						AE	6-8
		0.7	0.9	4.5[1]	2.6	AE	5
Pacific Ocean	31	0.7	0.9	6.6[1]	2.6	VE	9-10
						AE	7-9
		0.7	0.9	5.6[1]	2.6	AE	6

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA[†]

ISLAND OF MOLOKAI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*)				Zone	Base Flood Elevation (feet LTD*)
		10-Percent	2-Percent	1-Percent	0.2-Percent		
Pacific Ocean	32	0.7	0.9	6.7[1]	2.8	VE	9-10
						AE	7-9
		0.7	0.9	6.3[1]	2.8	AE	6
Pacific Ocean	33	0.7	1.0	6.9[1]	3.1	VE	9-11
						AE	7-9
Pacific Ocean	34	0.7	0.9	6.7[1]	2.9	VE	9-10
						AE	7-9
Pacific Ocean	35	0.7	0.9	6.9[1]	2.6	VE	9-11[3]
						AE	7-9[3]
Pacific Ocean	36	0.7	0.9	6.0[1]	2.5	VE	8-9
						AE	6-8
Pacific Ocean	37	0.7	0.9	6.2[1]	2.3	VE	8-10
						AE	6-8
Pacific Ocean	38	0.7	0.9	6.6[1]	2.4	VE	9-10[3]
						AE	7-9[3]
Pacific Ocean	39	0.7	0.9	5.8[1]	2.2	VE	9
		0.7	0.9	1.1	2.2	VE	8[2]
						AE	8[2]
Pacific Ocean	40	0.7	0.9	5.4[1]	2.2	VE	8[3]
						AE	5-8[3]
Pacific Ocean	41	0.7	0.8	5.5[1]	2.1	VE	8[3]
		0.7	0.8	1.1	2.1	AE	8[2, 3]
Pacific Ocean	42	0.7	0.8	1.0	1.9	VE	9[2, 3]
						AE	9[2, 3]

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA[†]

ISLAND OF LANAI

Flooding Source	Transect	Stillwater Elevation (feet LTD*)				Zone	Base Flood Elevation (feet LTD*)
		10-Percent	2-Percent	1-Percent	0.2-Percent		
Pacific Ocean	43	0.7	0.8	1.0	2.1	VE	21[2]
						AE	21[2]
Pacific Ocean	44	0.7	0.8	1.1	2.1	VE	14[2]
						AE	14[2]
Pacific Ocean	45	0.7	0.8	1.0	2.1	VE	13[2]
						AE	13[2]
Pacific Ocean	46	0.7	0.9	1.1	2.1	VE	38[2]
						AE	38[2]
Pacific Ocean	47	0.7	0.9	1.1	2.1	VE	10[2]
						AE	10[2]
Pacific Ocean	48	0.7	0.9	1.1	2.1	VE	55[2]
						AE	55[2]
Pacific Ocean	49	0.7	0.9	1.1	2.2	VE	16[2]
						AE	16[2]
Pacific Ocean	50	0.7	0.9	1.1	2.2	VE	21[2]
						AE	21[2]
Pacific Ocean	51	0.7	0.8	1.1	2.1	VE	11[2]
						AE	11[2]
Pacific Ocean	52	0.7	0.9	7.3[1]	2.2	VE	9-11
						AE	7-9
Pacific Ocean	53	0.7	0.9	6.4[1]	2.3	VE	9-10
						AE	6-9
Pacific Ocean	54	0.7	0.9	1.1	2.2	VE	12[2]
						AE	12[2]

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA†
ISLAND OF MAUI

Flooding Source	Transect	Stillwater Elevation (feet LTD*) 10-Percent	2-Percent	1-Percent	0.2-Percent	Zone	Base Flood Elevation (feet LTD*)
Pacific Ocean	55	0.7	0.8	7.5[1]	2.0	VE	10-11[3]
						AE	9-10[3]
		0.7	0.8	1.0	2.0	AE	8[2, 3]
Pacific Ocean	56	0.7	0.8	1.0	2.0	VE	25[2]
						AE	25[2]
Pacific Ocean	57	0.7	0.8	5.9[1]	2.1	VE	8-9[3]
						AE	8[3]
		0.7	0.8	1.1	2.1	AE	7[2, 3]
Pacific Ocean	58	0.7	0.8	7.0[1]	1.9	VE	9-11[3]
						AE	7-9[3]
Pacific Ocean	59	0.7	0.8	1.1	2.0	VE	16[2, 3]
						AE	16[2, 3]
Pacific Ocean	60	0.7	0.8	5.6[1]	2.0	VE	8-9[3]
						AE	8[3]
		0.7	0.8	1.1	2.0	AE	7[2, 3]
Pacific Ocean	61	0.7	0.8	6.6[1]	2.0	VE	10
		0.7	0.8	1.0	2.0	AE	10[2]
Pacific Ocean	62	0.7	0.8	1.0	2.0	VE	10[2]
						AE	10[2]
Pacific Ocean	63	0.7	0.8	1.1	2.1	VE	9[2]
						AE	9[2]
Pacific Ocean	64	0.7	0.9	1.1	2.1	VE	10[2]
						AE	10[2]
Pacific Ocean	65	0.7	0.9	7.9[1]	2.3	VE	10-12
						AE	8-10

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA[†]

ISLAND OF MAUI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*) 10-Percent	2-Percent	1-Percent	0.2-Percent	Zone	Base Flood Elevation (feet LTD*)
Pacific Ocean	66	0.7	0.9	7.6[1]	2.2	VE	10-12
						AE	8-10
Pacific Ocean	67	0.7	0.9	7.2[1]	2.1	VE	9-11
						AE	7-9
Pacific Ocean	68	0.7	0.9	7.3[1]	2.2	VE	9-11
						AE	7-9
		0.7	0.9	5.5[1]	2.2	AE	6
Pacific Ocean	69	0.7	0.9	1.1	2.2	VE	35[2]
						AE	35[2]
Pacific Ocean	70	0.7	1.0	5.4[1]	2.6	VE	8[3]
		0.7	1.0	1.3	2.6	VE	7[2, 3]
						AE	7[2, 3]
Pacific Ocean	71	0.7	0.9	7.6[1]	2.5	VE	10-12
						AE	8-10
Pacific Ocean	72	0.7	0.9	7.4[1]	2.3	VE	9-11
						AE	7-9
Pacific Ocean	73	0.7	0.9	7.6[1]	2.1	VE	10-12
						AE	8-10
Pacific Ocean	74	0.7	0.9	1.2	2.3	VE	12[2]
						AE	12[2]
Pacific Ocean	75	0.7	0.9	1.1	2.2	VE	10[2]
						AE	10[2]
Pacific Ocean	76	0.7	0.9	1.1	2.1	VE	13[2]
						AE	13[2]

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA†

ISLAND OF MAUI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*) 10-Percent	2-Percent	1-Percent	0.2-Percent	Zone	Base Flood Elevation (feet LTD*)
Pacific Ocean	77	0.7	0.9	1.1	2.1	VE	12[2]
						AE	12[2]
Pacific Ocean	78	0.7	0.9	1.1	2.1	VE	31[2]
						AE	31[2]
Pacific Ocean	79	0.7	0.9	5.6[1]	2.1	VE	8-9
						AE	6-8
Pacific Ocean	80	0.7	0.9	1.0	2.0	VE	42[2]
						AE	42[2]
Pacific Ocean	81	0.7	0.9	1.1	2.1	VE	10[2]
						AE	10[2]
Pacific Ocean	82	0.7	0.9	1.1	1.9	VE	20[2]
						AE	20[2]
Pacific Ocean	83	0.7	0.9	1.1	2.0	VE	11[2, 3]
						AE	11[2, 3]
Pacific Ocean	84	0.7	0.8	5.4[1]	2.0	VE	8[3]
		0.7	0.8	1.1	2.0	AE	8[2, 3]
Pacific Ocean	85	0.7	0.9	1.1	2.0	VE	11[2]
						AE	11[2]
Pacific Ocean	86	0.7	0.9	1.1	1.9	VE	26[2]
						AE	26[2]
Pacific Ocean	87	0.7	0.9	1.1	2.0	VE	13[2]
						AE	13[2]
Pacific Ocean	88	0.7	0.9	1.1	2.1	VE	34[2]
						AE	34[2]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 7: TRANSECT DATA†

ISLAND OF MAUI (continued)

Flooding Source	Transect	Stillwater Elevation (feet LTD*)				Zone	Base Flood Elevation (feet LTD*)
		10-Percent	2-Percent	1-Percent	0.2-Percent		
Pacific Ocean	89	0.7	0.9	1.1	2.2	VE	21[2]
						AE	21[2]
Pacific Ocean	90	0.7	0.9	1.1	2.1	VE	13[2]
						AE	13[2]
						AO	Depth 2
						AE	11
Pacific Ocean	91	0.7	0.9	1.1	2.1	VE	10[2]
						AE	10[2]
Pacific Ocean	92	0.7	0.9	1.1	2.1	VE	11[2]
						AE	11[2]
Pacific Ocean	93	0.7	0.9	1.1	2.1	VE	14[2, 3]
						AE	14[2, 3]
Pacific Ocean	94	0.7	0.9	1.1	2.1	VE	49[2]
						AE	49[2]
Pacific Ocean	95	0.7	0.8	1.0	2.0	VE	18[2]
						AE	18[2]
Pacific Ocean	96	0.7	0.8	1.1	2.0	VE	24[2]
						AE	24[2]
Pacific Ocean	97	0.7	0.9	1.1	2.1	VE	15[2]
						AE	15[2]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
*Local Tidal Datum
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

TABLE 8: TSUNAMI TRANSECT LOCATIONS

ISLAND OF LANAI

Transect Number	Hawaii State Plane Zone 2, NAD83, U.S. Survey ft. First Transect Coordinates at MSL Shoreline (ft)		Last Transect Coordinates Inland (ft)		Transect Length (ft)
	East	North	East	North	
1	1530209.0	164296.4	1530345.5	164301.4	136.6
2	1530765.7	168381.8	1530983.8	168375.2	218.2
3	1531203.1	172483.0	1531611.8	172422.1	413.2
4	1530595.4	177147.0	1530723.7	177254.6	167.4
5	1528602.7	180840.9	1528644.6	180878.2	56.1
6	1526456.0	184567.4	1526498.3	184597.0	51.6
7	1523934.5	188017.1	1523984.5	188063.7	68.4
8	1519853.6	190814.7	1519877.3	190860.2	51.3
9	1515015.3	192171.8	1515040.7	192265.7	97.3
10	1511894.9	194185.4	1511953.1	194219.1	67.3
11	1508800.4	196048.2	1508877.8	196091.8	88.9
12	1507284.2	199961.7	1507742.1	200072.2	471.1
13	1506036.4	203954.6	1506352.4	203947.7	316.0
14	1506437.9	207855.8	1507199.7	207747.6	769.5
15	1508872.5	210922.2	1509147.6	210561.3	453.8
16A	1511966.9	212313.2	1512228.1	211907.0	483.0
16	1513043.2	212940.6	1513711.4	211901.0	1235.8
17	1516564.4	214996.7	1516859.2	213976.1	1062.3
17B	1516787.0	215022.0	1517008.0	214257.0	796.3
18	1520400.4	215490.9	1520414.3	215069.0	422.1
19	1524174.9	215515.3	1524169.3	214875.4	639.9
20	1527851.6	216234.5	1527876.1	215468.4	766.5
21	1531764.1	216351.6	1531487.3	215203.9	1180.6
22	1535387.9	214870.0	1534992.1	213967.9	985.1
23	1539319.3	214510.0	1539269.3	214031.7	480.9
24A	1542787.0	214524.9	1542812.1	213376.1	1149.1
24	1543239.2	214283.8	1543024.9	213399.4	910.0
24B	1543939.7	214024.6	1543775.4	213346.7	697.6
25	1547109.4	214152.0	1547152.1	213911.7	244.1
26	1550845.3	213606.2	1550576.6	213002.4	660.9
27	1555218.4	212878.4	1555044.5	211550.3	1339.4
28	1558818.8	211802.4	1558624.8	211330.4	510.3
29	1562509.5	210364.0	1562079.2	209333.0	1117.2
30	1565444.0	207984.8	1564516.2	206796.6	1507.5
31	1568414.4	205541.1	1567411.6	204679.5	1322.2

TABLE 8: TSUNAMI TRANSECT LOCATIONS

ISLAND OF LANAI

Transect Number	Hawaii State Plane Zone 2, NAD83, U.S. Survey ft. First Transect Coordinates at MSL Shoreline (ft)		Last Transect Coordinates Inland (ft)		Transect Length (ft)
	East	North	East	North	
32	1571306.5	202945.5	1570457.0	202220.2	1117.0
33	1574192.8	200223.3	1573258.5	199276.9	1329.9
34	1576981.7	197432.1	1575533.7	195899.0	2108.8
35	1579873.9	194771.8	1578561.5	193459.4	1856.0
36A	1582198.4	192500.4	1581179.4	191756.5	1261.6
36	1582786.9	191901.1	1581849.3	191020.9	1286.0
37	1585329.7	189169.6	1584120.5	188305.9	1486.0
38	1587763.9	186073.4	1586042.9	185142.4	1956.7
39	1589478.9	182508.0	1588990.3	182227.5	563.4
40A	1591244.1	180147.4	1589763.4	178702.1	2069.2
40	1591759.9	179272.9	1590882.6	178683.2	1057.1
41	1592998.1	175426.8	1591936.0	175515.4	1065.8
42	1592643.4	171635.5	1591036.1	172065.0	1663.7
43	1590416.5	167291.1	1589763.8	167649.4	744.6
43B	1588624.2	164991.2	1588076.3	165394.8	680.5
44	1587371.9	163284.9	1586697.6	163882.8	901.2
44B	1587143.4	162993.8	1586599.1	163299.0	624.0
45	1584945.1	158484.9	1584559.7	158673.5	429.0
46	1581909.2	155035.3	1581807.4	155172.1	170.5
47	1576978.8	154295.2	1576964.2	154355.8	62.3
48	1572430.3	152091.2	1572418.9	152132.6	42.9
49	1568633.9	149067.5	1568362.3	149459.2	476.6
50	1566899.4	148737.5	1566942.9	148812.8	87.0

TABLE 9: TSUNAMI TRANSECT DATA

ISLAND OF LANAI

Transect Number	Coefficient A	Coefficient B	Final 1% Annual Chance Tsunami Runup Elevation (ft. MSL)
1	4.5	4.1	4.9
2	4.5	4.4	4.6
3	4.5	4.4	4.6
4	4.5	4.3	4.7
5	4.5	4.3	4.7
6	4.5	4.3	4.7
7	4.5	4.3	4.7
8	4.5	4.4	4.6
9	4.6	4.4	4.8
10	4.6	4.4	4.8
11	4.6	4.4	4.8
12	4.6	4.4	4.8
13	4.9	4.8	5.0
14	5.7	5.8	5.6
15	6.7	6.9	6.5
16A	8.2	8.5	6.8
16	8.5	8.8	3.9
17	9.4	9.5	9.2
17B	9.5	9.5	8.2
18	10.3	10.2	10.4
19	11.0	11.0	11.0
20	12.2	12.0	12.4
21	12.7	12.4	13.0
22	13.2	12.7	13.7
23	13.4	13.0	13.8
24A	12.7	12.1	8.9
24	12.6	12.2	13.0
24B	12.5	11.9	11.8
25	11.8	10.9	12.7
26	10.7	9.2	12.0
27	9.4	7.4	11.4
28	7.0	6.3	7.7
29	6.6	5.5	7.7
30	6.2	5.0	7.4
31	6.0	4.6	7.4

TABLE 9: TSUNAMI TRANSECT DATA

ISLAND OF LANAI

Transect Number	Coefficient A	Coefficient B	Final 1% Annual Chance Tsunami Runup Elevation (ft. MSL)
32	6.0	4.7	7.3
33	7.6	6.3	8.9
34	8.5	7.3	8.1
35	9.1	8.0	7.4
36A	9.5	8.6	7.0
36	9.6	8.7	9.1
37	10.2	9.2	8.3
38	10.4	9.4	8.3
39	10.3	9.0	10.5
40A	9.3	8.1	7.2
40	9.0	7.9	9.6
41	8.0	7.0	9.0
42	7.5	6.4	7.9
43	6.7	6.0	5.9
43B	6.7	6.3	7.1
44	6.7	6.4	7.0
44B	6.7	6.5	6.9
45	6.0	5.9	6.1
46	5.4	5.3	5.5
47	5.1	4.6	5.6
48	4.7	4.4	5.0
49	4.7	4.4	5.0
50	4.7	4.2	5.2

Qualifying bench marks within a given jurisdiction that are cataloged by the National Geodetic Survey (NGS) and entered into the National Spatial Reference System (NSRS) as First or Second Order Vertical and have a vertical stability classification of A, B, or C are shown and labeled on the FIRM with their 6-character NSRS Permanent Identifier.

Bench marks cataloged by the NGS and Entered into the NSRS vary widely in vertical stability classification. NSRS vertical stability classifications are as follows:

- Stability A: Monuments of the most reliable nature, expected to hold position/elevation well (e.g., mounted in bedrock)

- Stability B: Monuments which generally hold their position/elevation well (e.g., concrete bridge abutment)
- Stability C: Monuments which may be affected by surface ground movements (e.g., concrete monument below frost line)
- Stability D: Mark of questionable or unknown vertical stability (e.g., concrete monument above frost line, or steel witness post)

In addition to NSRS bench marks, the FIRM may also show vertical control monuments established by a local jurisdiction; these monuments will be shown on the FIRM with the appropriate designations. Local monuments will only be placed on the FIRM if the community has requested that they be included, and if the monuments meet the aforementioned NSRS inclusion criteria.

To obtain current elevation, description, and/or location information for bench marks shown on the FIRM for this jurisdiction, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their Web site at www.ngs.noaa.gov.

It is important to note that temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with this FIS and FIRM. Interested individuals may contact FEMA to access this data.

Behind Levee Analysis

Some flood hazard information presented in prior FIRMs and in prior FIS reports for Maui County was based on flood protection provided by levees. Based on the information available and the mapping standards of the National Flood Insurance Program (NFIP) at the time that the prior FISs and FIRMs were prepared, FEMA accredited the levees as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year. For FEMA to continue to accredit the identified levees with providing protection from the base flood, the levees must meet the criteria of the Code of Federal Regulations, Title 44, Chapter I, Section 65.10 (44 CFR 65.10), titled “Mapping of Areas Protected by Levee Systems.”

On August 22, 2005, FEMA issued “Procedure Memorandum No. 34 – Interim Guidance for Studies Including Levees.” The purpose of the memorandum was to help clarify the responsibility of community officials or other parties seeking recognition of a levee by providing information identified during a study/mapping project. Often, documentation regarding levee design, accreditation, and the impacts on flood hazard mapping is outdated or missing altogether. To remedy this, Procedure Memorandum No. 34 provides interim guidance on procedures to minimize delays in near-term studies/mapping projects, to help our mapping partners properly assess how to handle levee mapping issues.

While documentation related to 44 CFR 65.10 is being compiled, the release of a more up-to-date FIRM for other parts of a community or county may be delayed. To minimize the impact of the levee recognition and certification process, FEMA issued "Procedure Memorandum No. 43 – Guidelines for Identifying Provisionally Accredited Levees" on March 16, 2007. These guidelines allow issuance of the FIS and FIRM while levee owners or communities compile full documentation required to show compliance with 44 CFR 65.10. The guidelines also explain that a FIRM can be issued while providing the communities and levee owners with a specified timeframe to correct any maintenance deficiencies associated with a levee and to show compliance with 44 CFR 65.10.

FEMA contacted Maui County to obtain data required under 44 CFR 65.10 to continue to show the levees as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year.

FEMA understood that it may take time to acquire and/or assemble the documentation necessary to fully comply with 44 CFR 65.10. Therefore, FEMA put forth a process to provide the communities with additional time to submit all the necessary documentation. For a community to avail itself of the additional time, it had to sign an agreement with FEMA. Levees for which such agreements were signed are shown on the final effective FIRM as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year and labeled as a Provisionally Accredited Levee (PAL). Communities have two years from the date of FEMA's initial coordination to submit to FEMA final accreditation data for all PALs. Following receipt of final accreditation data, FEMA will revise the FIS and FIRM as warranted.

FEMA coordinated with the local communities and other organizations to compile a list of levees based on information from the FIRM and community provided information.

Approximate analyses of "behind levee" flooding were conducted for all the levees and embankments in Maui County. The methodology used in these analyses is discussed below.

The Kaunakakai Stream levees have been de-accredited. A hydraulic analysis using HEC-RAS 4.1.0 was conducted evaluating the impacts of levees. The levee structures with inventory ID #6 & #31 were subjected to a Natural Valley Analysis. Four different scenarios were modeled: no right bank levee impacts on the floodwaters, no left bank levee impacts on the floodwaters, both levees having impact on the floodwaters, and neither levees impacting the floodwaters. The hydraulic analysis was conducted in accordance with the Levee Analysis and Mapping Plan that was created through FEMA and local community stakeholder co-ordination.

The embankment structure with inventory ID #5 is located on the Waialua Stream. Using the topographic information obtained by LiDAR engineering judgment, an approximate area of 1-percent annual chance flooding in the event of failure of the embankment was delineated.

The embankment structure with inventory ID #7 is located on the Kamilana Gulch. Using the topographic information obtained by LiDAR and engineering judgment, an approximate area of 1-percent annual chance flooding in the event of failure of the embankment was delineated.

The embankment structures with inventory IDs #8 and 24 are located on the Kahana Stream. Using the topographic information from 1/3 arc second USGS DEMs and engineering judgment, an approximate area of 1-percent annual chance flooding in the event of failure of the embankment was delineated.

The levee structure with inventory ID #11 is located on Iao Stream. Using the LiDAR topographic information, an approximate area of 1-percent annual chance flooding in the event of failure of the levees was determined by delineating the Iao Stream base flood elevations on the landward side of the levees.

The levee structure with inventory ID #27 is located on the Iao Stream. Using the topographic information from 1/3 arc second USGS DEMs, an approximate area of 1-percent annual chance flooding in the event of failure of the levees was determined by delineating the Iao Stream base flood elevations on the landward side of the levees.

The embankment structure with inventory ID #14 is located on the Kalialinui Stream. Using the topographic information from1/3 arc second USGS DEMs and engineering judgment an approximate area of 1-percent annual chance flooding in the event of failure of the embankment was delineated.

The embankment structure with inventory ID #20 is located on the Kihei Gulch 4. Using the LiDAR topographic information, an approximate area of 1-percent annual chance flooding in the event of failure of the embankments was determined by delineating the Kihei Gulch 4 base flood elevations on the landward side of the embankments.

The levee structure with inventory ID #30 is located on the Iao Stream. Using the topographic information from 1/3 arc second USGS DEMs and engineering judgment, a approximate area of 1-percent annual chance flooding in the event of failure of the levees was delineated.

3.3 Vertical Datum

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared.

All flood elevations shown in this FIS report and on the FIRM are referenced to Local Tidal Datum. Structure and ground elevations in the community must, therefore, be referenced to the Local Tidal Datum. For more information on Local Tidal Datum, see the National Oceanic and Atmospheric Administration's (NOAA) tidal information webpage at http://tidesandcurrents.noaa.gov/datum_options.html.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS provides 1-percent annual chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent annual chance flood elevations; delineations of the 1- and 0.2-percent annual chance floodplains; and 1-percent annual chance floodway. This information is presented on the FIRM and in many components of the FIS, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent annual chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent annual chance flood is employed to indicate additional areas of flood risk in the county. For the streams studied in detail, the 1- and 0.2-percent annual chance floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps at scales of 1:1,200, 1:2,400, and 1:4,800, with contour intervals of 2, 5, and 10 feet (USACE, Topographic Maps, Contour Interval 5 feet, 1976; USACE, Topographic Maps, Contour Interval 2 feet; USACE, 1977; USACE, Topographic Maps, Contour Interval 5 feet, August 1973; USACE, Topographic Maps, Contour Interval 10 feet, January 1977; USACE, January 1975; USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977; USACE, 1984; USACE, Topographic Maps, Kahului Area, January 1977; USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976).

For the flooding sources studied by approximate methods, the boundaries of the 1-percent annual chance floodplains were delineated using topographic maps taken from the previously printed FIS reports, FHBMs, and/or FIRMs for Maui County.

The 1- and 0.2-percent annual chance floodplain boundaries are shown on the FIRM (Exhibit 3). On this map, the 1-percent annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A and AE), and the 0.2-percent annual chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent annual chance floodplain boundaries are close together, only the 1-percent annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

The coastal high hazard area, the portion of the coast that is inundated by the 1-percent annual chance tsunami elevations and exhibits wave action, was determined utilizing tsunami elevations and runup elevations. The limit of runup is computed using runup elevations and known topographic characteristics and is based on a depth of flooding by the incoming tsunami of 0.0 foot. The 1-percent annual chance tsunami inundation boundaries were delineated using methods outlined in Tsunami Inundation Prediction (Charles L. Bretschneider, 1976) and topographic maps previously mentioned (USACE, Topographic Maps, Contour Interval 5 feet, 1976; USACE, Topographic Maps, Contour Interval 2 feet; USACE, 1977; USACE, Topographic Maps, Contour Interval 5 feet, August 1973; USACE, Topographic Maps, Contour Interval 10 feet, January 1977; USACE, January 1975; USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977; USACE, 1984; USACE, Topographic Maps, Kahului Area, January 1977; USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976; U.S. Department of the Interior, 1957, et cetera). Tsunami inundation boundaries were delineated for the Island of Lanai based on topographic LiDAR data obtained in 2004-2006 and orthorectified aerial photography.

The 1-percent annual chance floodplain boundaries for areas studied by approximate methods were determined by various methods and are grouped under three categories:

1. Approximate 1-percent annual chance boundaries determined by this study using the hydrologic and hydraulic methods described earlier for areas studied by approximate methods. Topographic maps (Charles L. Bretschneider, 1976) and topographic maps previously mentioned (USACE, Topographic Maps, Contour Interval 5 feet, 1976; USACE, Topographic Maps, Contour Interval 2 feet; USACE, 1977; USACE, Topographic Maps, Contour Interval 5 feet, August 1973; USACE, Topographic Maps, Contour Interval 10 feet, January 1977; USACE, January 1975; USACE, Topographic Maps, Haiku-Waihee Area, Island of Maui, January 1977; USACE, 1984; USACE, Topographic Maps, Kahului Area, January 1977; USACE, Topographic Maps, Hawala-Kamalo Area, Island of Molokai, December 1976; USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976; U.S. Department of the Interior, 1957, et cetera) are the same as those used for the areas studied by detailed methods.

2. Approximate 1-percent annual chance floodplain boundaries were extracted from prior studies that delineate flood-prone areas based on the flood history of the area (U.S. Department of the Interior, 1973, et cetera).

3. Approximate 1-percent annual chance floodplain boundaries were taken from the effective FIRM for Maui County.

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this FIS are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

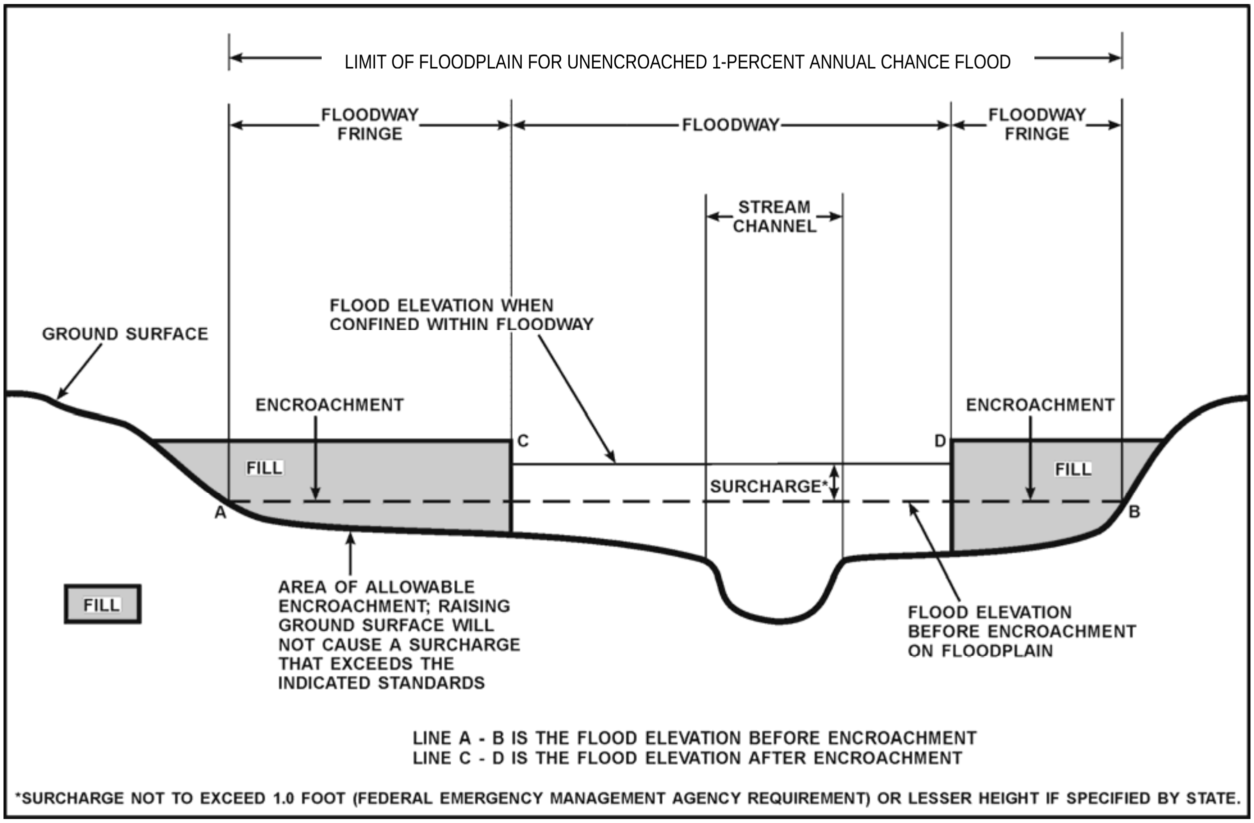
The floodways presented in this FIS were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain.

Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (Table 10). The computed floodways are shown on the FIRM (Exhibit 3). In cases where the floodway and 1-percent annual chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 10, "Floodway Data." In order to reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway. Floodwaters from those streams mentioned in Section 3.2 which exhibited supercritical flow were also found to have hazardous velocities. Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. To provide guidance for encroachment into these areas, a floodway is delineated for that part of the 1-percent annual chance floodplain that conveys flow.

Floodways were not deemed appropriate in the areas where shallow flooding conditions exist. For streams discharging into the ocean, the floodway boundaries were terminated at the coastal high hazard boundary. Additionally no floodway analysis was conducted on Keokea Gulch as encroaching upon the floodplain in the upper reaches of the study would create very high velocity hazards and the downstream reach where relatively safe encroachment on the floodplain would possible was within the Kihei Regional Park and in was studied by a 2-dimensional model, where floodway calculations are not practicable.

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water surface elevation of the 1-percent annual chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their



significance to floodplain development are shown in Figure 5, "Floodway Schematic".

Figure 5. Floodway Schematic

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
HAHAKEA GULCH								
A	650[1]	234	590	7.8	15.1	15.1	15.1	0.0
B	1,060[1]	331	700	9.3	35.2	35.2	35.2	0.0
C	2,010[1]	73	382	12.0	72.5	72.5	72.5	0.0
D	2,704[1]	70	941	4.9	115.4	115.4	116.3	0.9
E	3,426[1]	62	441	10.4	157.0	157.0	157.7	0.7
F	4,705[1]	25	314	14.7	226.7	226.7	227.2	0.5
HONOKAHUA STREAM								
A	1,460[2]	141	222	16.1	27.2	27.2	27.2	0.0
B	1,930[2]	159	326	8.6	40.1	40.1	40.1	0.0
HONOKEANA BAY GULCH								
A	360[2]	183	450	1.8	22.8	22.8	23.5	0.7
B	900[2]	78	118	7.0	33.0	33.0	33.0	0.0
C	1,900[2]	37	48	17.3	67.6	67.6	67.6	0.0
D	2,720[2]	43	75	17.4	112.5	112.5	112.5	0.0

[1] Stream distance in feet above confluence with Auau Channel
[2] Stream distance in feet above confluence with Honokeana Bay
[3] Stream distance in feet above confluence with Pacific Ocean

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

HAKAKEA GULCH – HONOKAHUA STREAM HONOKEANA BAY GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
IAO STREAM								
A	985	111	869	15.9	18.1	18.1	18.1	0.0
B	1,362	97	830	16.6	22.8	22.8	22.8	0.0
C	2,296	116	895	15.4	41.0	41.0	41.0	0.0
D	3,264	79	800	17.2	62.8	62.8	63.2	0.4
E	4,433	93	768	15.0	90.4	90.4	90.4	0.0
F	5,183	98	747	15.4	111.1	111.1	111.1	0.0
G	6,372	90	718	16.0	145.5	145.5	145.5	0.0
H	7,365	100	745	15.5	169.8	169.8	169.8	0.0
I	8,033	89	714	16.1	187.9	187.9	187.9	0.0
J	8,790	89	716	16.1	203.4	203.4	203.3	-0.1
K	10,005	109	1091	10.5	244.5	244.5	244.7	0.2
L	10,797	135	828	13.9	273.7	273.7	273.7	0.0
M	11,699	123	788	14.6	294.7	294.7	294.8	0.1
N	12,602	352	3,173	3.6	324.7	324.7	324.7	0.0
O	13,406	187	942	12.2	347.4	347.4	347.4	0.0

[1] Stream distance in feet above mouth

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

IAO STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KAHANA STREAM								
A	560**	*	*	*	15.6**	15.6**	*	*
B	631**	*	*	*	16.4**	16.4**	*	*
C	673**	*	*	*	17.5**	17.5**	*	*
D	772**	*	*	*	25.9**	25.9**	*	*
E	1,098**	*	*	*	26.1**	26.1**	*	*
F	1,195**	*	*	*	27.4**	27.4**	*	*
G	1,420**	*	*	*	29.3**	29.3**	*	*

[1] Stream distance in feet above mouth
*Data not available
** Distance and Water Surface Elevation values estimated from Flood Profile

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KAHANA STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KAHANANUI GULCH								
B	760[1]	171	846	10.5	15.2	15.2	16.2	1.0
KAILUA GULCH								
A	670[2]	795	1,362	5.9	17.2	17.2	17.2	0.0
B	1,220[2]	468	1,122	7.1	25.4	25.4	25.8	0.4
C	1,870[2]	462	982	8.1	41.2	41.2	42.1	0.9
D	2,330[2]	514	1,781	4.5	49.1	49.1	49.9	0.8
E	2,990[2]	141	707	11.3	66.1	66.1	66.7	0.6
F	3,320[2]	178	756	10.6	71.1	71.1	71.8	0.7
G	3,724[2]	127	671	11.9	82.8	82.8	83.1	0.3
KALEPA GULCH								
A	1,510[3]	130	255	8.0	54.9	54.9	54.9	0.0
B	3,160[3]	122	231	7.9	103.8	103.8	103.8	0.0
C	4,080[3]	237	307	5.5	163.0	163.0	163.0	0.0
D	4,860[3]	28	132	12.1	222.9	222.9	223.0	0.1
KALIALINUI GULCH								
A	1,400[3]	1,080	4,920	2.1	13.7	13.7	14.7	1.0
B	2,030[3]	900	3,024	3.4	14.7	14.7	15.5	0.8
C	3,135[3]	995	5,850	1.7	24.6	24.6	25.6	1.0
D	4,520[3]**	*	*	*	34.2**	34.2**	*	*

[1] Stream distance in feet above confluence with Pailolo Channel (Pacific Ocean)
[2] Stream distance in feet above mouth
[3] Stream distance in feet above confluence with Pacific Ocean

*Data not available
** Distance and Water Surface Elevation values estimated from Flood Profile

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KAHANANUI GULCH – KAILUA GULCH
KALEPA GULCH – KALIALINUI GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KALUAIHAKOKO STREAM								
A	177	19	49	9.5	13.4	13.4	13.4	0.0
B	214	26	57	8.1	16.0	16.0	16.2	0.2
C	383	24	69	7.2	18.3	18.3	18.6	0.3
D	521	78	192	2.2	22.2	22.2	22.2	0.0
E	560	29	67	6.4	22.2	22.2	22.3	0.1
F	773	31	80	5.4	28.1	28.1	28.2	0.1
G	1,013	25	52	8.2	33.0	33.0	33.0	0.0
H	1,050	31	66	6.5	33.7	33.7	34.0	0.3
I	1,129	25	52	8.3	36.1	36.1	36.1	0.0
J	1,259	42	75	5.7	40.7	40.7	40.8	0.1
K	1,622	25	54	8.4	54.9	54.9	54.9	0.0
L	1,668	35	161	2.6	57.9	57.9	58.2	0.3
M	1,734	27	67	6.2	58.8	58.8	59.0	0.2
N	1,777	23	50	8.4	62.1	62.1	62.1	0.0
O	1,853	23	106	3.9	65.5	65.5	65.7	0.2
P	1,914	23	61	6.9	65.6	65.6	65.8	0.2
Q	2,017	16	44	9.4	72.3	72.3	72.4	0.1
R	2,071	20	47	8.8	77.5	77.5	77.5	0.0
S	2,154	17	45	9.3	79.5	79.5	79.5	0.0
T	2,203	19	46	9.0	82.7	82.7	82.7	0.0
U	2,386	21	58	7.2	87.0	87.0	87.1	0.1
V	2,467	25	101	4.1	90.2	90.2	90.6	0.4
W	2,497	28	53	7.9	90.6	90.6	90.6	0.0
X	2,548	19	46	8.8	93.5	93.5	93.5	0.0
Y	2,596	17	44	9.3	94.7	94.7	94.7	0.0
Z	2,637	39	59	7.0	98.4	98.4	99.0	0.6
AA	2,765	50	117	7.8	102.5	102.5	103.0	0.5

[1] Stream distance in feet above confluence with Pacific Ocean

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KALUAIHAKOKO STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KALUAIHAKOKO STREAM (continued)								
AB	2,988[1]	38	84	4.8	106.2	106.2	106.3	0.1
AC	3,131[1]	46	81	4.9	108.5	108.5	108.5	0.0
AD	3,184[1]	21	47	8.5	118.7	118.7	118.7	0.0
AE	3,243[1]	24	49	8.2	122.3	122.3	122.3	0.0
AF	3,299[1]	19	63	6.4	123.1	123.1	123.5	0.4
AG	3,480[1]	27	51	7.8	131.6	131.6	131.7	0.1
AH	3,530[1]	43	170	2.4	135.5	135.5	135.6	0.1
KAMALO GULCH								
A	820[2]	487	1,179	10.7	7.8	7.8	8.8	1.0
KAMAOLE GULCH								
A	166[1]	420	715	5.3	11.2	11.2	12.1	0.9
B	302[1]	351	755	5.2	15.4	15.4	15.4	0.0
C	375[1]	255	850	5.0	16.8	16.8	17.8	1.0
D	514[1]	301	544	6.9	19.4	19.4	19.4	0.0
E	597[1]	260	616	6.1	23.6	23.6	23.8	0.2
F	813[1]	89	681	5.5	28.4	28.4	29.3	0.9
G	988[1]	83	424	8.9	29.2	29.2	30.2	1.0
H	1,196[1]	127	402	9.4	36.7	36.7	37.2	0.5
I	1,378[1]	52	284	13.2	40.4	40.4	40.4	0.0
J	1,684[1]	34	270	15.3	50.7	50.7	50.7	0.0

[1] Stream distance in feet above confluence with Pacific Ocean

[2] Stream distance in feet above confluence with Kalohi Channel (Pacific Ocean)

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KALUAIHAKOKO STREAM – KAMALO GULCH KAMAOLE GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KAMAOLE GULCH (continued)								
K	1,893[1]	37	253	14.9	59.2	59.2	59.2	0.0
L	2,211[1]	56	290	13.0	74.5	74.5	74.5	0.0
M	2,422[1]	48	277	13.6	81.6	81.6	81.6	0.0
N	2,609[1]	50	280	13.4	89.0	89.0	89.0	0.0
O	2,803[1]	69	311	12.1	98.6	98.6	98.6	0.0
P	3,022[1]	66	465	8.1	103.5	103.5	103.7	0.2
Q	3,098[1]	71	609	6.4	106.5	106.5	106.8	0.3
R	3,241[1]	50	306	7.3	109.5	109.5	110.3	0.8
S	3,377[1]	129	581	6.8	115.7	115.7	116.7	1.0
T	3,579[1]	69	304	11.9	119.3	119.3	119.3	0.0
KAMILOLOA GULCH								
A	715[1]	465	1,455	9.5	10.0	10.0	10.9	0.9
B	1,330[1]	455	933	13.4	20.4	20.4	21.3	0.9
KAOPALA GULCH								
A	50[2]	120	355	7.6	19.4	19.4	19.8	0.4
B	215[2]	115	357	7.9	24.1	24.1	24.1	0.0
C	280[2]	115	1,212	2.7	31.7	31.7	31.7	0.0
D	675[2]	17	90	13.3	37.2	37.2	37.2	0.0
E	1,050[2]	60	188	11.5	45.4	45.4	45.4	0.0
F	1,250[2]	120	1,323	3.0	60.0	60.0	60.0	0.0
G	1,445[2]	70	1,093	3.1	65.7	65.7	65.7	0.0
H	1,910[2]	21	144	21.3	68.5	68.5	68.5	0.0

[1] Stream distance in feet above confluence with Pacific Ocean

[2] Stream distance in feet above mouth

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KAMAOLE GULCH – KAMILOLOA GULCH
KAOPALA GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KAUAULA STREAM								
A	760[1]	36	114	35.0	14.1	14.1	14.1	0.0
B	1,720[1]	51	189	21.1	54.9	54.9	54.9	0.0
C	2,560[1]	51	199	20.1	107.8	107.8	107.8	0.0
KAUNAKAKAI STREAM								
A	500[2]	1,728	2,261	6.6	5.3 / 6.1 / 6.1[3]	6.1[4]	6.1[4]	0.0
B	1,157[2]	1,555	4,806	3.7	7.7 / 8.4 / 8.4[3]	8.4[4]	8.4[4]	0.0
C	1,480[2]	1,273	5,318	2.8	8.2 / 8.8 / 8.8[3]	8.8[4]	8.8[4]	0.0
D	1,634[2]	1,178	5,700	2.6	8.5 / 9.6 / 9.6[3]	9.5[4]	9.6[4]	0.1
E	1,914[2]	670	3,043	4.9	8.7 / 9.7 / 9.7[3]	9.6[4]	9.7[4]	0.1
F	2,306[2]	249	1,220	12.3	9.3 / 9.8 / 10.1[3]	9.8[4]	9.8[4]	0.0
G	2,507[2]	212	1,172	12.8	11.4 / 11.8/ 12.1[3]	11.8[4]	11.9[4]	0.1
H	3,033[2]	247	1,842	8.1	14.0 / 15.3 / 14.3[3]	15.3[4]	15.3[4]	0.0
I	3,500[2]	167	1,358	11.1	19.9 / 19.9 / 19.9[3]	19.9[4]	20.2[4]	0.3
J	4,000[2]	203	1,527	9.8	27.5 / 27.5 / 27.5[3]	27.5[4]	27.6[4]	0.1
K	4,498[2]	95	1,019	14.7	33.3 / 33.3 / 33.3[3]	33.3[4]	33.7[4]	0.4
L	5,002[2]	140	1,307	11.5	50.6 / 50.6 / 50.6[3]	50.6[4]	50.9[4]	0.3

[1] Stream distance in feet above confluence with Auau Channel (Pacific Ocean)

[2] Stream distance in feet above confluence with Pacific Ocean

[3] Landward of left levee/Riverward of levees/Landward of right levee*

[4] Elevations calculated without consideration of levees

*Note: References to left and right are based on looking in the downstream direction

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KAUAULA STREAM - KAUNAKAKAI STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KAWELA GULCH								
A	150[1]	1,187	3,289	5.2	5.8	5.8	6.6	0.8
B	705[1]	1,106	2,724	6.2	8.7	8.7	9.7	1.0
C	1,180[1]	664	1,624	10.5	12.4	12.4	13.4	1.0
D	1,725[1]	338	1,314	12.9	28.6	28.6	29.3	0.7
KEAWANUI GULCH								
A	774**	*	*	*	9.9**	9.9**	*	*
B	1,835**	*	*	*	40.5**	40.5**	*	*
KIHEI GULCH 1								
A	1,219[2]	248	463	2.2	8.6	8.6	9.4	0.8
B	1,388[2]	213	436	2.3	9.8	9.8	10.5	0.7
C	1,902[2]	168	337	3.0	15.8	15.8	16.8	1.0
D	2,305[2]	110	188	4.5	21.3	21.3	21.6	0.3
E	2,352[2]	110	301	2.7	21.6	21.6	22.5	0.9
F	2,528[2]	98	114	6.3	26.2	26.2	26.3	0.1
G	3,011[2]	60	107	6.7	37.1	37.1	37.3	0.2
H	3,232[2]	30	93	7.7	42.5	42.5	43.0	0.5
I	3,585[2]	28	87	8.1	54.2	54.2	54.3	0.1
J	3,770[2]	43	75	6.9	62.8	62.8	62.8	0.0
K	3,932[2]	52	157	3.3	71.3	71.3	71.3	0.0
L	4,080[2]	60	86	6.0	87.1	87.1	87.1	0.0
M	4,210[2]	40	75	6.9	96.6	96.6	96.7	0.1

[1]Stream distance in feet above confluence with Kalohi Channel (Pacific Ocean)

[2]Stream distance in feet above confluence with Pacific Ocean

*Data not available

**Distance and Water Surface Elevation values estimated from Flood Profile

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KAWELA GULCH – KEAWANUI GULCH – KIHEI GULCH 1

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
KIHEI GULCH 2								
A	990	34	134	24.1	31.7	31.7	31.7	0.0
B	1,500	104	306	11.4	82.2	82.2	82.2	0.0
KIHEI GULCH 3								
A	960	51	208	13.4	49.2	49.2	49.2	0.0
B	1,620	134	209	13.4	93.8	93.8	93.8	0.0
KIHEI GULCH 4								
A	700[1]	88	193	10.4	35.8	35.8	35.8	0.0
B	1,550[1]	33	92	20.7	90.5	90.5	90.5	0.0
KOPE GULCH								
A	1,667[1]	98	397	7.2	46.6	46.6	46.8	0.2
B	2,756[1]	103	268	9.4	74.5	74.5	74.5	0.0
C	3,568[1]	89	251	9.7	97.1	97.1	97.2	0.1
D	4,300[1]	126	274	8.4	131.5	131.5	131.5	0.0
LIILIOHOLO GULCH								
A	810[1]	49	171	17.5	21.8	21.8	21.8	0.0
B	1,550[1]	56	161	18.7	51.6	51.6	51.6	0.0

[1] Stream distance in feet above confluence with Pacific Ocean

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

KIHEI GULCH 2 – KIHEI GULCH 3 – KIHEI GULCH 4 – KOPE GULCH – LIILIOHOLO GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
MAHINAHINA GULCH								
A	1,172[1]	201	1,390	1.7	42.0	42.0	42.0	0.0
MILE 84 STREAM								
A	900[2]	1,869	6,327	2.2	7.0	7.0	7.8	0.8
B	1,980[2]	1,251	3,239	10.5	16.5	16.5	17.3	0.8
C	2,700[2]	626	1,860	6.4	17.5	17.5	18.5	1.0
NAPILI GULCH 2-3								
A	1,440[3]	99	115	9.7	22.8	22.8	22.8	0.0
B	1,920[3]	42	87	11.7	39.2	39.2	39.2	0.0
NAPILI GULCH 4-5								
A	950[4]	102	348	3.7	31.7	31.7	32.5	0.8
B	1,800[4]	103	151	8.6	57.9	57.9	57.9	0.0
C	3,280[4]	25	117	11.1	116.0	116.0	116.3	0.3
OHIA GULCH								
A	590[4]	212	846	7.1	10.5	10.5	11.3	0.8
B	1,150[4]	138	725	8.3	22.8	22.8	23.2	0.4

[1] Stream distance in feet above confluence with Pailolo Channel (Pacific Ocean)
[2] Stream distance in feet above confluence with Pacific Ocean
[3] Stream distance in feet above mouth
[4] Stream distance in feet above confluence with Napili Bay

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

FLOODWAY DATA

MAHINAHINA GULCH – MILE 84 STREAM – NAPILI GULCH 2-3 – NAPILI GULCH 4-5 – OHIA GULCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
OLOWALU STREAM								
A	2,000[1]	137	299	15.3	50.9	50.9	50.9	0.0
B	2,460[1]	188	349	13.9	61.5	61.5	61.5	0.0
C	2,820[1]	236	380	10.3	73.2	73.2	73.2	0.0
PUKOO GULCH								
A	630[2]	366	867	3.3	9.0	9.0	9.7	0.7
B	760[2]	101	261	11.1	10.4	10.4	11.4	1.0
C	900[2]	127	313	9.3	14.8	14.8	15.8	1.0
UNNAMED STREAM AT KUAU POINT								
A	520[1]	131	751	3.4	19.0	19.0	19.8	0.8
B	1,200[1]	138	496	5.1	25.3	25.3	25.9	0.6

[1] Stream distance in feet above mouth

[2] Stream distance in feet above confluence with Pailolo Channel (Pacific Ocean)

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HAWAII

FLOODWAY DATA

OLOWALU STREAM – PUKOO GULCH
UNNAMED STREAM AT KUAU POINT

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
WAIAKOA GULCH								
A	3,018[1]	93	511	13.3	54.3	54.3	54.3	0.0
B	3,538[1]	173	629	10.8	62.9	62.9	63.9	1.0
C	4,584[1]	219	1,030	6.6	85.0	85.0	85.0	0.0
D	5,338[1]	221	672	10.1	103.6	103.6	104.5	0.9
E	5,782[1]	231	693	9.8	114.0	114.0	115.0	1.0
F	6,018[1]	78	480	14.0	124.3	124.3	124.3	0.0
G	6,838[1]	98	518	13.1	149.2	149.2	149.4	0.2
H	7,854[1]	102	528	12.9	175.9	175.9	175.9	0.0
I	8,490[1]	87	499	13.6	197.3	197.3	197.3	0.0
J	9,023[1]	84	503	13.5	215.9	215.9	215.9	0.0
K	9,231[1]	114	552	12.3	223.0	223.0	223.9	0.9
WAIALUA STREAM								
A	370[2]	427	2,475	4.1	11.4	11.4	12.3	0.9
B	690[2]	477	3,699	2.8	11.9	11.9	12.8	0.9
C	1,260[2]	120	735	13.9	14.3	14.3	15.3	1.0
WAIEHU STREAM								
A	1,720[3]	100	1,014	7.0	50.7	50.7	50.9	0.2
B	3,017[3]	135	478	11.1	80.2	80.2	80.2	0.0

[1] Stream distance in feet above Limit of Tsunami Inundation (Limit of Tsunami Inundation is approximately 1,035 feet downstream of Piilani Highway)
[2] Stream distance in feet above confluence with Pailolo Channel (Pacific Ocean)
[3] Stream distance in feet above mouth

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

WAIAKOA GULCH – WAIALUA STREAM
WAIEHU STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
WAIHEE RIVER								
A	1,190[1]**	*	*	*	30.9**	30.9**	*	*
B	2,170[1]**	*	*	*	72.1**	72.1**	*	*
C	2,630[1]**	*	*	*	79.2**	79.2**	*	*
D	3,700[1]**	*	*	*	122.0**	122.0**	*	*
E	4,771[1]**	*	*	*	162.5**	162.5**	*	*
F	6,050[1]**	*	*	*	204.3**	204.3**	*	*
WAIKAPU STREAM								
A	4,500[2]	126	491	4.6	25.6	25.6	26.2	0.6
B	5,467[2]	249	589	3.8	30.2	30.2	30.2	0.0
C	7,000[2]	58	248	9.0	38.4	38.4	38.4	0.0
D	7,747[2]	41	235	9.5	44.2	44.2	44.3	0.1
E	7,772[2]	179	1,085	2.1	48.7	48.7	49.0	0.3
F	8,000[2]	128	713	3.1	48.8	48.8	49.2	0.4
G	8,500[2]	57	207	10.8	51.1	51.1	51.1	0.0
H	9,000[2]	71	338	6.6	59.1	59.1	59.4	0.3
I	9,500[2]	60	390	5.8	62.6	62.6	63.3	0.7
J	10,000[2]	62	258	8.7	68.6	68.6	68.8	0.2
K	10,500[2]	42	415	5.4	72.0	72.0	72.6	0.6
L	11,042[2]	93	296	7.6	83.8	83.8	83.8	0.0
M	11,500[2]	90	271	8.3	90.7	90.7	90.8	0.1
N	12,013[2]	57	340	6.6	95.6	95.6	95.9	0.3
O	13,500[2]	19	145	15.5	113.9	113.9	113.9	0.0
P	14,000[2]	64	421	5.3	120.2	120.2	121.2	1.0
Q	15,326[2]	44	228	9.5	135.2	135.2	135.2	0.0

[1] Stream distance in feet above confluence with Pacific Ocean
[2] Stream distance in feet above Kealia Pond

*Data not available
** Distance and Water Surface Elevation values estimated from Flood Profile

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

WAIHEE RIVER – WAIKAPU STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
WAIKAPU STREAM (continued)								
R	16,000	45	292	7.4	141.5	141.5	141.5	0.0
S	16,287	66	241	9.0	144.0	144.0	144.0	0.0
T	18,080	41	212	10.2	169.6	169.6	169.6	0.0
U	18,142	45	341	6.4	172.5	172.5	172.5	0.0
V	18,983	39	179	12.2	189.9	189.9	190.0	0.1
W	19,470	50	184	10.9	193.0	193.0	193.0	0.0
X	20,785	68	251	8.0	214.9	214.9	214.9	0.0
Y	22,117	140	262	7.7	243.9	243.9	243.9	0.0
Z	23,361	94	229	8.8	274.2	274.2	274.2	0.0
AA	24,802	102	268	7.5	317.5	317.5	317.5	0.0
AB	25,505	27	152	13.2	343.7	343.7	344.4	0.7
AC	26,170	156	317	6.4	362.6	362.6	362.6	0.0
AD	27,243	109	263	7.4	404.9	404.9	405.0	0.1
AE	27,358	44	201	9.7	406.9	406.9	407.0	0.1
AF	27,602	145	266	7.3	420.8	420.8	420.8	0.0
AG	28,352	101	247	7.9	448.3	448.3	448.3	0.0
AH	29,361	74	209	9.4	496.4	496.4	496.4	0.0
AI	29,632	32	156	12.5	505.3	505.3	505.8	0.5
AJ	30,436	60	193	10.1	547.9	547.9	548.8	0.9
AK	30,729	28	151	13.0	556.3	556.3	557.1	0.8
AL	31,527	49	181	10.8	596.6	596.6	597.4	0.8
AM	31,595	41	170	11.5	601.6	601.6	601.7	0.1
AN	32,418	52	188	10.4	637.9	637.9	638.9	1.0
AO	32,697	33	161	12.1	655.0	655.0	655.4	0.4
AP	33,074	27	150	13.0	667.6	667.7	668.1	0.4
AQ	33,643	22	141	13.9	697.5	697.5	697.8	0.3
AR	35,176	53	184	10.6	778.5	778.5	778.6	0.1

[1] Stream distance in feet above Kealia Pond

TABLE 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

MAUI COUNTY, HI

FLOODWAY DATA

WAIKAPU STREAM

4.3 Tsunami Inundation Boundaries

Inundation limits from the 1-percent annual chance tsunami were computed for most of the shoreline of the Islands of Lanai, Maui, and Molokai. The methodology employed in this computation is described in Section 4.1. The 1-percent annual chance tsunami inundation zone is divided into two districts. Where the depth of water from the tsunami exceeds 4.0 feet, the area is identified as Zone VE. The remainder of the area lying within the inundation limits of the 1-percent annual chance tsunami has a depth of flooding of less than 4.0 feet and is identified as a Zone AE. All AE and VE Zones are identified on the FIRM (Exhibit 3) except where cliff conditions exist or where the zones are too narrow to show because of map scale limitations. In areas where the AE and VE Zones are too small to be shown separately, only Zone VE is shown.

The Coastal High Hazard Zone consists of all areas that are identified by Zone VE. Special performance standards for construction in Coastal High Hazard Zones have been set by FEMA. The Coastal High Hazard Zones and areas of known bore formations are delineated on the FIRM.

The inundation limits for the 1-percent annual chance tsunami are based on existing conditions. Any modification or alteration to existing conditions may have a significant effect on the tsunami inundation limits. For example, any regarding or reduction of surface roughness in onshore areas, such as that caused by the removal of native vegetation, could increase the extent of inundation. Similarly, dredge and fill operations offshore could increase the extent of inundation, due to the effects of coastal bathymetry on tsunami wave setup. On the other hand, existing or planned coastal features such as natural reefs, seawalls, groins, jetties, or beach-stabilization projects may have a mitigating effect on tsunami inundation.

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no base flood elevations are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent annual chance floodplain, areas within the 0.2-percent annual chance floodplain, and to areas of 1-percent annual chance flooding where average depths are less than 1 foot, areas of 1-percent annual chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent annual chance flood by levees. No base flood elevations or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent annual chance floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent annual chance floodplains. Floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations are shown where applicable.

7.0 OTHER STUDIES

Numerous reports have been prepared on various floodprone areas on the Islands of Maui and Molokai. Those reports were compared with the results of this FIS. Differences in riverine flood elevations and floodplain boundaries are caused primarily by dissimilar flood discharges. These discharge differences can be attributed to either different hydrologic methods or newer, more extensive stream gage data being employed. Other factors that can account for differences in flood elevations and boundaries are the stream cross-section data, computer programs and topographic maps, and the assumptions and estimations used in the hydraulic analyses of the floodplains.

For streams studied by detailed methods, comparisons of riverine flood determinations provided in the most recent reports with those of this study are summarized below.

ISLAND OF MAUI

A Flood Hazard Information (FHI) report for the Island of Maui was prepared by the USACE in 1971 (USACE, 1971). The island was divided into five regions, and discharge-drainage area relationships for each region were plotted based on the gaging stations in each region. The methodology employed in this study is more refined, has a longer period of gage data, and utilizes more stream gage data than the FHI report.

Iao Stream

A Flood Hazard Area Map was prepared in April 1973 (State of Hawaii, April 1973). A report was also prepared by the USACE in 1975 (USACE, April 1975). Because of the flood-control project on the stream, these past studies have been superseded by the study presented in the September 25, 2009 FIS.

Kahoma Stream

A Flood Hazard Area Map for Kahoma Stream was printed in August 1973 (State of Hawaii, 1973). Discharges for the report are somewhat higher than those determined for this study. Floodplain boundaries are wider as a result of the higher discharges. The USACE FHI report shows boundaries similar to the Flood Hazard Area Map.

Kahului Area

A Type 10 FIS for Kahului was completed in 1971 (U.S. Department of Housing and Urban Development, 1971)

Kihei Area

Several studies for this area were performed in 1970 and 1971. A USACE Flood Plain Information Study in January 1970 included Waiako Gulch, Kulanihakoi Gulch, Waipuilani Gulch, and Keoka Gulch (USACE, 1970). The 1971 FHI report also studied this area, except for Waiakoa Gulch. A Type 10 FIS studied Kulanihakoi Gulch, Waipuilani Gulch, and Keokea Gulch in 1970 (U.S. Department of Housing and Urban Development, 1972). In 1981, the Kihei Flood Control Study examined several alternatives to the Kihei flood problem. Although none of the alternatives were found to be feasible at the time, it was suggested that the structures be used to form the basis of the new flood-control program. Differences between these areas and this study can be attributed mainly to the disparity in hydrologic methods and the topographic information.

Olowalu Area

A Flood Hazard Area Map was printed in November 1971 (State of Hawaii, 1974). Floodplain boundaries for Olowalu Stream are very similar in width and shape to this study, and elevations and discharges are also in close agreement.

Wailuku Area

A flood-control study (State of Hawaii, April 1973) and FIS have been published for the Iao Stream in the Wailuku area. However, these studies have not addressed the problem of shallow flooding in the Wailuku town area.

ISLAND OF MOLOKAI

In January 1966, the USACE completed a report on four drainage basins on east Molokai-Waialua Stream, Wawaia Gulch, Kamalo Gulch, and Kawela Gulch (USACE, 1966). The 1-percent annual chance flood discharges given and the floodplains indicated by the USACE study are smaller than those depicted in the current study. The hydrology for the USACE report was prepared from an elevation of the records of five stream gaging stations; the hydrology of this study reflects 11 additional years of flood records and data gathered from 21 stream gaging stations. The difference in floodflow magnitudes is reflected by the wider floodplain boundaries than those delineated in the USACE report. Roughness coefficients for channels and overbanks are similar for both studies. Water-surface profiles for the 1-percent annual chance flood discharges are higher for this study than the previous study done by the state.

Kamiloloa Stream

A detailed flood-control project report for the Kapaakea Homestead area, located along the Kamiloloa Stream, was completed in December 1976. The study was conducted to evaluate the extent of the flood problems in the area and to develop an effective, economical, and acceptable plan for reducing or preventing future floods. Field and office studies included site inspections, topographic surveys and subsurface, hydraulic, economic, and environmental investigation (USACE, Topographic Maps, Kaunakakai and Kamiloloa Areas, Island of Molokai, December 1976).

Kuluakoi Area

A Flood Hazard Area Map was prepared in June 1974 (State of Hawaii, Map FP-21, April 1973). Boundaries shown on that map are very similar to those shown in this study.

Pukoo Area

A Flood Hazard Area Map was prepared in October 1973 (State of Hawaii, October 1973). Elevations determined for that map are higher and floodplain boundaries are wider than those shown in this study. This is the result of lower discharges being used in this study.

All coastal flood elevations and boundaries of the selected recurrence intervals were analyzed in this study by a methodology not used in earlier reports. This study has employed the latest knowledge of tsunami elevation-frequency relationships and runup characteristics. Consequently, the tsunami flood elevations and boundaries differ from those given in earlier reports, although in a few areas the results are similar.

Information pertaining to revised and unrevised flood hazards for each area within Maui County has been compiled into this FIS. Therefore, this FIS supersedes all previously printed FIS Reports, FHBMs, FBFMs, and FIRMs for all of the areas within Maui County.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this FIS can be obtained by contacting FEMA, Federal Insurance and Mitigation Division, 1111 Broadway, Suite 1200, Oakland, California 94607-4052.

9.0 BIBLIOGRAPHY AND REFERENCES

1. Cardone, V.J, Greenwood, C.V., and Greenwood, J.A.. (1992). Unified Program for the Specification of Hurricane Boundary Layer Winds over Surfaces of Specific Roughness, Contract Report CERC-92-1, U.S. Army Engineering Waterways Experiment Station, Vicksburg, Mississippi.

2. Charles L. Bretschneider and P. G. Wybro (authors). (July 1976). Tsunami Inundation Prediction, presented at 15th International Conference on Coastal Engineering. Honolulu, Hawaii.

3. Charles L. Bretschneider, H.K. Krock, E. Nakazaki, and F.M.Caciano (authors). (1986). Roughness of Typical Hawaiian Terrain For Tsunami Run-up Calculations, A Users Manual.

4. Federal Emergency Management Agency. (February 2007). Atlantic Ocean and Gulf of Mexico coastal guidelines update, Final Draft. Federal Emergency Management Agency, Washington, D.C.

5. Federal Emergency Management Agency. (April, 2003). Appendix D: Guidance for Coastal Flooding Analyses and Mapping. Washington, D.C.

6. Federal Emergency Management Agency. (August 1, 2005). Procedure Memorandum No. 37 – Protocol for Atlantic and Gulf Coast Coastal Flood Insurance Studies in FY05. Washington, D.C.

7. Federal Emergency Management Agency, Federal Insurance Administration. (July 1989). Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping, Third Draft. Washington, D.C.

8. Gourlay, M. R. (1996). Wave Set-Up on Coral Reefs. 2. Set-Up on Reefs with Various Profiles. Coastal Engineering, Vol.28, 17-55.

9. Hydrologic Engineering Center. November 2002. HEC-RAS River Analysis System. Hydraulic User's Manual. Version 3.1. US Army Corps of Engineers, Davis, Ca.

10. Le Provost, C.,Lyndard, F., Molines, J.M., Genco, M.L., and Rabilloud, F. (1998). A Hydrodynamic Ocean Tide Model Improved by Assimilating a Satellite Altimeter-Derived Data Set. Journal of Geophysical Research v.103, p. 5513-5529.

11. Luettich, R. A., Westerink, J. J., and Scheffner, N. W. (1992). ADCIRC: An Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries, Report 1: Theory and Methodology of ADCIRC-2DDI and ADCIRC-3DL, Technical Report DRP-92-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

12. M & E Pacific, Inc., 1978. Manual For Determining Tsunami Runup Profiles On Coastal Areas of Hawaii, Prepared for Dept. of the Army Pacific Ocean Div., Corps of Engineers, Honolulu, Hawaii.

13. Maui County Department of Public Works. (November 1977). Draft Environmental Impact Statement, Kihei Drainage Project, Maui County, Hawaii. Lahaine, Maui, Hawaii.

14. RMTC, A joint venture of R. M. Towill, URS, Dewberry, Schaaf & Wheeler, Terra Point, Airborne 1 and Sea Engineering. Tsunami Risk Study for Coastal Flood Insurance Restudy of Island of Lanai in Maui County, HI. Prepared for FEMA Region IX, September 2009.

15. Scheffner, N.W. et al. (1999). Use and Application of the Empirical Simulation Technique: User's Guide. Technical Report CHL-99-21. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS, 194 p.

16. State of Hawaii, Department of Land and Natural Resources, in cooperation with the U.S. Army Corps of Engineers, Pacific Ocean Division. (November 1974). Map FP-24, Olowalu Flood Hazard Area, Olowalu, Maui, Hawaii. Honolulu, Hawaii.

17. State of Hawaii, Department of Land and Natural Resources, in cooperation with the U.S. Army Corps of Engineers, Pacific Ocean Division. (October 1973). Map FP-19, Pukoo Flood Hazard Area, Pukoo, Molokai, Hawaii. Honolulu, Hawaii.

18. State of Hawaii, Department of Land and Natural Resources, in cooperation with the U.S. Army Corps of Engineers, Pacific Ocean Division. (August 1973). Map FP-1, Kahoma Stream Flood Hazard Area, Lahaina, Maui. Honolulu, Hawaii.

19. State of Hawaii, Department of Land and Natural Resources, in cooperation with the U.S. Army Corps of Engineers, Pacific Ocean Division. (April 1973). Map FP-15, Iao Stream Flood Hazard Area, Wailuku, Maui, Hawaii. Honolulu, Hawaii.

20. State of Hawaii, Department of Land and Natural Resources, in cooperation with the U.S. Army Corps of Engineers, Pacific Ocean Division. (April 1973). Map FP-21, West Molokai Flood Hazard Area, Kaluakoi, Molokai, Hawaii. Honolulu, Hawaii.

21. Tetra Tech, Inc. 2006. Maui County Hydrologic Analysis for Waihee Stream, Waiehu Stream, Waikapu Stream, Kope Gulch, Kalepa Gulch, and Unnambed Channels. Prepared for the County of Maui Department of Planning, November 2006.

22. University of Hawaii, Hawaii Institute of Geophysics. (May 1976). Tsunami Wave Runup Heights in Hawaii. Harold G. Loomis (author). Honolulu, Hawaii.

23. University of Hawaii, Department of Geology. (1973). Atlas of Hawaii. Honolulu, Hawaii. University Press.

24. U.S. Army Corps of Engineers, Coastal Engineering Research Center. (1984). Shore Protection Manual, Volumes I and II, 4th Edition. Washington D.C.

25. U.S. Army Corps of Engineers, Galveston District. (1975). Guidelines for Identifying Coastal High Hazard Zones. Galveston, Texas.

26. van der Meer, J.W. (2002). Wave Run-up and Overtopping at Dikes. Technical Report, Technical Advisory Committee for Water Retaining Structures (TAW), Delft, Netherlands.

27. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (September 1998). HEC-RAS, Version 2.2. Davis, California.

28. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (March 2008). HEC-RAS, Version 4.0. Davis, California.

29. U.S. Army Corps of Engineers. (February 1998). Kuau Flood Insurance Study Topo Survey, Scale 1:20, Contour Interval 1 foot.

30. U.S. Army Corps of Engineers. (Flown March 1984). Topographic Maps Compiled from Air Photos, Scale 1:2,400, Contour Interval 5 feet. Wailuku Area, Island of Maui.

31. U.S. Army Corps of Engineers, Pacific Ocean Division. (September 1977). Plan of Study Review Report for Flood Control and Allied Purposes, Kihei District, Maui. Honolulu, Hawaii.

32. U.S. Army Corps of Engineers, Waterways Experiment Station. (August 1977). Technical Report H-77-16, Tsunami-Wave Elevation Frequency of Occurrence for the Hawaiian Islands. J. R. Houston, R. D. Carver, and D. C. Markle (authors).

33. U.S. Army Corps of Engineers. (Flown January 1977). Topographic Maps Compiled from Air Photos, Scale 1:4,800, Contour Interval 10 feet. Kelia Pond-Maalea Area, Island of Maui.

34. U.S. Army Corps of Engineers. (Flown January 1977). Topographic Maps Compiled from Air Photos, Scale 1:4,800, Contour Interval 10 feet. Lahaina Area, Island of Maui.

35. U.S. Army Corps of Engineers. (Flown January 1977). Topographic Maps Compiled from Air Photos, Scale 1:4,800, Contour Interval 10 feet. Haiku-Waihee Area, Island of Maui.

36. U.S. Army Corps of Engineers. (Flown January 1977). Topographic Maps Compiled from Air Photos, Scale 1:2,400, Contour Interval 5 feet. Kahului Area.

37. U.S. Army Corps of Engineers. (Flown December 1976). Topographic Maps Compiled from Air Photos, Scale 1:2,400, Contour Interval 5 feet. Wailea-Makena Area, Island of Maui.

38. U.S. Army Corps of Engineers. (Flown December 1976). Topographic Maps Compiled from Air Photos, Scale 1:1,200, Contour Interval 2 feet. Kihei-Wailea Area, Island of Maui.

39. U.S. Army Corps of Engineers. (December 1976). Topographic Maps, Scale 1:4,800, Contour Interval 10 feet. Hawala-Kamalo Area, Island of Molokai.

40. U.S. Army Corps of Engineers. (December 1976). Topographic Maps, Scale 1:4,800, Contour Interval 10 feet. Kaunakakai and Kamiloloa Areas, Island of Molokai.

41. U.S. Army Corps of Engineers, Pacific Ocean Division. (April 1975). Design Memorandum No. 2, Iao Stream. Honolulu, Hawaii.

42. U.S. Army Corps of Engineers. (January 1975). Topographic Maps, Scale 1:2,400, Contour Interval 5 feet. Lahaina-Honolua Area, Island of Maui.

43. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (October 1973). HEC-2 Water Surface Profiles, Generalized Computer Program. Davis, California.

44. U.S. Army Corps of Engineers, Pacific Ocean Division. (August 1973). Survey Report for Flood Control and Allied Purposes, Kahoma Stream, Lahaina, Maui, Hawaii. Honolulu, Hawaii.

45. U.S. Army Corps of Engineers. (August 1973). Topographic Maps, Scale 1:2,400, Contour Interval 5 feet. Olowalu Area, Island of Maui.

46. U.S. Army Corps of Engineers, Pacific Ocean Division, in cooperation with the State of Hawaii, Department of Land and Natural Resources. (August 1971). Report R39, Flood Hazard Information, Island of Maui, Hawaii. Honolulu, Hawaii.

47. U.S. Army Corps of Engineers, Honolulu District. (January 1970). Flood Plain Information Study, Kihei, Maui, Hawaii. Honolulu, Hawaii.

48. U.S. Army Corps of Engineers, Pacific Ocean Division. (January 1966). Flood Plain Information Study, East Molokai, Hawaii. Honolulu, Hawaii.

49. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (May 2005). HECRAS, River Analysis System, Version 3.1.3. Davis, California.

50. U.S. Department of Agriculture, Soil Conservation Service. (March 1976). Final Environmental Impact Statement, Honolua Watershed, Maui County, Hawaii. Lahaina, Maui, Hawaii.

51. U.S. Department of Housing and Urban Development, Federal Insurance Administration. (1972). Type 10, Flood Insurance Study, Kihei Area, Island of Maui, Hawaii.

52. U.S. Department of Housing and Urban Development, Federal Insurance Administration. (1971). Type 10, Flood Insurance Study, Kahului, Maui.

53. U.S. Department of the Interior, Geological Survey. (Halawa, Island of Molokai, 1973; Ilio Point, Island of Molokai, 1974; Kamalo, Island of Molokai, 1973; Kaunakakai, Island of Molokai, 1973). Maps of Flood-Prone Areas, Scale 1:24,000, Contour Interval 40 feet.

54. U.S. Department of the Interior, Geological Survey. (July 1968). Report R30, Flood of March 24, 1967, Kihei and Olowalu Areas, Maui, Hawaii. S. H. Hoffard (author). Honolulu, Hawaii.

55. U.S. Department of the Interior, Geological Survey. (Haiku, Island of Maui, 1957; Halawa, Island of Molokai, 1952, Photorevised 1968; Hana, Island of Maui, 1957; Honolua, Island of Maui, 1956; Ilio Point, Island of Molokai, 1952, Photorevised 1968; Kahukuloa, Island of Maui, 1955; Kamalo, Island of Molokai, 1952, Photorevised 1968; Kaunakakai, Island of Molokai, 1952, Photorevised 1967; Kaupo, Island of Maui, 1957; Kaenae, Island of Maui, 1957; Kipahulu, Island of Maui, 1957; Lahaina, Island of Maui, 1956; Lualailua Hills, Island of Maui, 1957; Maalaea, Island of Maui, 1923, Photorevised 1954; Makena, Island of Maui, 1954; Molokai Airport, Island of Molokai, 1952, Photorevised 1968; Nahiku, Island of Maui, 1957; Olowalu, Island of Maui, 1955; Paia, Island of Maui, 1954; Puuo Kali, Island of Maui, 1922, Photorevised 1922; Wailuku,

Island of Maui, 1955). 7.5-Minute Series Topographic Maps, Scale 1:24,000, Contour Interval 40 feet.

56. U.S. Water Resources Council. (March 1976). "Guidelines for Determining Flood Flow Frequency," Bulletin 17.

57. U.S. Geological Survey. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. United States Geological Survey Water-Supply Paper 2339.