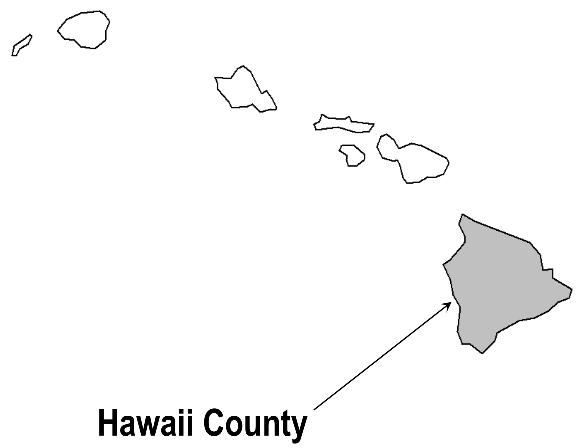
FLOOD INSURANCE STUDY

VOLUME 1 OF 11

HAWAII COUNTY, HAWAII



REVISED: September 29, 2017

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
155166V001B

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:	May 3, 1982
First Revised FIS Date:	September 16, 1988 (FIRM panels only)
Second Revised FIS Date:	July 16, 1990
Third Revised FIS Date:	May 16, 1994
Fourth Revised FIS Date:	June 2, 1995
Fifth Revised FIS Date:	April 2, 2004
Sixth Revised FIS Date:	September 29, 2017

TABLE OF CONTENTS

VOLUME 1 – September 29, 2017

Page

FIGURES

TABLES

VOLUME 2 – September 29, 2017

FIGURES (Continued)

TABLE OF CONTENTS (continued)
VOLUME 2 – September 29, 2017

TABLES (Continued)

VOLUME 3 – September 29, 2017

EXHIBITS

VOLUME 4 – September 29, 2017

TABLE OF CONTENTS (continued)
VOLUME 4 – September 29, 2017 (Continued)

VOLUME 5 – September 29, 2017

VOLUME 6 – September 29, 2017

*Profiles for Palai Stream 188P(a) and Palai Stream A 193P not printed

TABLE OF CONTENTS (continued)

VOLUME 7 – September 29, 2017

Exhibit 1 – Flood Profiles (continued)

VOLUME 8 – September 29, 2017

Exhibit 1 – Flood Profiles (continued)

VOLUME 9 – September 29, 2017

Exhibit 1 – Flood Profiles (continued)

TABLE OF CONTENTS (continued)

VOLUME 10 – September 29, 2017

VOLUME 11 – September 29, 2017

FLOOD INSURANCE STUDY
HAWAII COUNTY, HAWAII

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) investigates the existence and severity of flood hazards in, or revises and updates previous FISs for the geographic area of Hawaii 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 FIS 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 Hawaii 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.

For the May 3, 1982, original FIS, the hydrologic and hydraulic analyses were prepared by the U.S. Army Corps of Engineers (USACE), Pacific Ocean Division, for the Federal Emergency Management Agency (FEMA), under Interagency Agreement No. IAA-H-10-77, Project Order No. 4. The analyses covered work completed in December 1981.

For the September 16, 1988, FIS revision, hydrologic and hydraulic analyses for the streams were conducted by M & E Pacific, Inc., under subcontract to the USACE, Pacific Ocean Division. These analyses were used to prepare the previous FIS for Hawaii County, Hawaii (FEMA, 1982).

Additional hydrologic and hydraulic analyses for the 1988 revision were performed by the USACE, Pacific Ocean Division, for FEMA, under Interagency Agreement No. IAA-84-E-1506, Project Order No. 1. The analyses covered work that was completed in October 1985. For the South Kohala and Hamakua areas, the hydrologic analyses were carried out by the USACE, Pacific Ocean Division, and hydraulic analyses were conducted by Wilson Okamoto & Associates, Inc., under subcontract to the USACE, Pacific Ocean Division.

The hydrologic and hydraulic analyses, also for the 1988 revision, for most riverine flooding sources in the North Kona and South Kona areas were performed by the U.S. Department of Agriculture, Soil Conservation Service (SCS). These analyses were taken from the December 1984 <u>North Kona Flood Plain Management Study</u> (U.S. Department of Agriculture, 1984) and the July 1977 <u>South Kona Flood Hazard Analyses</u> report (U.S. Department of Agriculture, 1977).

For the July 16, 1990, FIS revision, the detailed flooding information on Waikoloa Stream, Waikoloa Stream Tributary, and Kamuela Stream was incorporated from data prepared by the USACE, Honolulu District.

For the May 16, 1994, FIS revision, the floodway limits and elevations for six streams were defined. Floodway analyses have been completed for selected reaches of Keopu Drainageway, Keopu Drainageway Overflow, Holualoa Drainageway, Waiaha Drainageway, Waiaha Drainageway Splitflow No. 2, and Kaumalumalu Drainageway. In addition, the detailed study of Keopu Drainageway was modified to incorporate more detailed topographic data.

The hydraulic analyses for the 1994 revision were performed by Ensign & Buckley, Consulting Engineers, for FEMA, under Contract EMW-91-C3133. This restudy was completed in November 1991.

For the June 2, 1995, FIS revision, the Letter of Map Revision (LOMR) issued on June 7, 1994 was incorporated. The June 7, 1994 LOMR was a reissuance of a LOMR that was issued on September 9, 1991, which had not been included when the FIRM panels were republished on May 16, 1994.

The hydrologic and hydraulic analysis for the Waiakea and Palai Stream area was conducted by URS Corporation for FEMA, under Contract EMW-2000-CO-0247, Task Order 040 documented in a report titled Hilo, Hawaii County, Hawaii Flood Hazard Assessment. The streams that were studied include Palai Stream, Palai Stream A, Palai Stream C, Palai Stream Splitflow, Waiakea Flood Control Channel, Waiakea Stream, Waiakea Tributary No. 1, Waiakea Tributary No. 2, Waiakea Tributary No. 3, and Waiakea Tributary No. 3A. This work was completed on May 29, 2002.

For the April 2, 2004, FIS revision, the results of new detailed riverine flooding for the Kaluiiki Branch and Waipahoehoe Stream tributaries of Alenaio Stream were incorporated. The data for this Limited Map Maintenance Program study were prepared by the USACE, Honolulu District, under Interagency Agreement EMW-96-IA-0195, Project Order No. 8.

The revision and hydrologic analysis for the Puukapu flood study was conducted by Dewberry as a subcontractor to R. M. Towill Corporation (RMTC). The streams that were studied include Lower Lanimaumau Stream, Upper Lanimaumau Stream, Kamuela Stream, Unnamed Stream No. 3, and Unnamed Stream No. 1, tributary into Piakuli Reservoir. These streams were studied as stated in the agreement between RMTC and the Department of Public Works, County of Hawaii, on May 4, 2004. The Piakuli Reservoir is within the area of Puukapu Retarding Reservoir.

In addition, the revision included a new detailed coastal hurricane storm surge and wave height analysis which was performed by Dewberry and Exponent as subcontractors to RMTC under FEMA contract number EMW-2003-CO-0046, and now as part of this FIS revision. Dewberry conducted the storm surge, wave height analyses, and hazard mapping, while Exponent performed the hurricane selection, generation of storm meteorological data and stillwater frequency analysis. This work was completed in August 2008.

For this FIS revision, the flood zones for many approximate-study and detailed-study streams throughout the county were updated using georeferenced maps provided by Hilo, Hawaii County's tax parcel maps, and 2010-2012 USDA-NRCS imagery base maps to show better historical floodplain riverine floodplain fitting. These updates were primarily focused on areas with high population or areas with significant floodplain issues, although additional approximate-study updates occurred in other areas of the island. Updates occurred on portions of Four Mile Creek, Four Mile Creek Tributary No. 1, Four Mile Creek Tributary No. 2, Halawa Gulch, Halelua Gulch, Holualoa Drainageway, Holualoa Drainageway Tributary, Honokaa Drainage A, Honokaa Drainage B, Honokaa Drainage C, Honokaa Drainage No. 1, Honokaa Drainage No.2, Honokaa Drainage No.3, Kapua Gulch, Kohakohau Stream, Kumakua Gulch, Palai Stream, Palai Stream C, Palai Stream D, Palai Stream E, Palai Stream F, Pali Akamoa Gulch, South Kona Watercourse No. 1-12 and 21-25, Waiaha Drainageway, Waiaha Drainageway Splitflow No. 1, Waiaha Drainageway Splitflow No. 2, Waiaha Drainageway SPlitflow No. 3, Waiaha Draiangeway Tributary, Waiakea Stream, Waikoloa Stream, Waikoloa Stream Tributary, Wailoa Stream, Wailuku River, Wainaia Gulch, Waipahoehoe Stream, Waipiele Gulch, Waipio Stream, Waiulaula Gulch, The work was performed by BakerAECOM for Hawaii County and completed in March 2014.

Furthermore, redelineation of the Alenaio Stream was performed to reflect the accreditation of the levees 2A, 12B, 12C, and 20. In addition, redelineation of tsunami flood inundation using new bathymetric and topographic LiDAR data was also performed for the exposed Hawaii County coastal areas, including area of Hilo Bay. This work was performed by BakerAECOM for FEMA under Contract Number HSFEHQ-09-D-0368. BakerAECOM also performed a quality assurance and quality control on a floodway study in the South Kona Area. R. M. Towill Corporation was contracted by the United States Army Corps of Engineers, Honolulu District (Contract No. W9128A-08-001 Task Order 006) to restudy select watercourses (South Kona Watercourses 1 to 12 and Watercourses 21 to 25).

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held for each FIS revision. 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.

For the May 3, 1982, original FIS, data used were obtained from the Pacific Ocean Division of the USACE, the U.S. Geological Survey (USGS), and the SCS. A tsunami conference was held on February 23, 1977, with coastal engineering and tsunami experts from the University of Hawaii, the Joint Tsunami Research Effort of the National Oceanic and Atmospheric Administration (NOAA), the USACE, the Oahu Civil Defense Agency, and FEMA, to select tsunami study methods to be used in that report.

For the September 16, 1988, FIS revision, an initial CCO meeting was held on August 2, 1983, to determine limits of detailed study areas for revisions and updates to the FIS dated May 3, 1982 (FEMA, 1982). The meeting was attended by representatives of FEMA, Hawaii County, and the study contractor. An intermediate/final CCO meeting was held on October 21, 1985, by FEMA, the community, and the study contractor to discuss the results of the study analysis.

For the July 16, 1990, FIS revision, the final meeting was held on July 31, 1989, and was attended by FEMA, representatives of the community, and the study contractor.

For the May 16, 1994, FIS revision, an initial CCO meeting was held on May 24, 1990, with representatives of the County of Hawaii and FEMA. The streams to be studied and the limits of study for each stream were identified at this meeting. During the preparation of the study, Ensign & Buckley conducted telephone discussions with representatives of the County of Hawaii, the USACE, and the SCS, the agency that produced the original analyses of these flooding sources. The results of the study were reviewed at the final CCO meeting held on January 26, 1993, which was attended by representatives of the community and FEMA Region IX. All problems raised at that meeting have been addressed in that study.

For this FIS revision, the final CCO meeting was held on August 9, 2011 in Hilo, HI and was attended by representatives from Hawaii County, the State of Hawaii, FEMA, and BakerAECOM.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers Hawaii County, Hawaii. For the May 3, 1982, original FIS, the following streams of the Island of Hawaii were studied in part or as a whole by detailed methods:

SOUTH KOHALA AREA

Auwaiakeakua Gulch
Gulch 2 – Hapuna
Gulch 3 – Hapuna
Gulch 4 – Puako
Kamakoa Gulch
Lanimaumau Stream

SOUTH HILO AREA

Alenaio Stream
Four Mile Creek
Palai Stream
Shallow flooding tributaries to Four Mile Creek
(Four Mile Creek Tributaries 1, 2, and 3)
Shallow flooding tributaries to Palai Stream
(Palai Streams A through F)
Waiakea Stream
Waiakea Tributaries Nos. 1, 2, and 3

KAU AREA

Ninole Gulch

HAMAKUA AREAS

Honokaa Drainages A through D
Honokaa Drainages 1, 2, and 3

NORTH KONA AREA

Hienaloli Drainageway
Holualoa Drainageway and Tributary
Horseshoe Bend Drainageway
Kaumalumalu Drainageway
Keopu Drainageway
Waiaha Drainageway and Tributary

SOUTH KONA AREA

South Kona Watercourse Nos. 1, 3, 7, 8, 19, 20, 24, and 25

The methodology employed to delineate inundation limits of tsunamis of the selected recurrence intervals was agreed upon at the tsunami conference held on February 23, 1977.

For the September 16, 1988, FIS revision, the following streams were studied by detailed methods in the SCS North Kona Flood Plain Management Study and South Kona Flood Hazard Analyses report (U.S. Department of Agriculture, 1984; U.S. Department of Agriculture, 1977). These streams are presented as approximate streams in this FIS, based on stream criteria of less than 3 feet average depth or less than 1 square mile drainage area:

Kainaliu Drainageway
Kaumalumalu Drainageway Tributaries 1, 2, and 3
Kawanui Drainageway
Kawanui-Lehuula Drainageway
Lahuula Drainageway
South Kona Watercourse Nos. 2, 4-6, 9-18, and 21-23

In addition to the above listed approximate streams, the following streams were studied by approximate methods:

All gulches between Hawi and Makepala
Gulch near Kawaihae
Gulches in Hilo area
Kamuela area gulches – South Kohala
Makahuna Gulch
Makeahua Gulch
Puliha Stream
Waiaha Springs
Wailuku Stream
Waiulaula Gulch

Approximate 1-percent annual chance floodplain boundaries along the following 13 streams narrowed to widths of less than 200 feet and are not included in the FIRM in their entirety:

Kaumaluamlu Drainageway Tributaries 1, 2, and 3
Kawanui Drainageway
South Kona Watercourse Nos. 4-6, 14-16, 18, 22, and 23

Approximate 1-percent annual chance floodplain boundaries at the upstream reaches of the following seven streams have been deleted where the flooding narrowed to widths of less than 200 feet: South Kona Watercourse Nos. 2, 9, 11-13, 17, and 21.

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 Hawaii County.

For the July 16, 1990, FIS revision, the detailed flooding information on Kamuela Stream, Waikoloa Stream, and Waikoloa Stream Tributary was incorporated.

For the May 16, 1994, FIS revision, the floodway limits and elevations for six streams for which a detailed study has been completed were defined. Floodway analyses have been completed for selected reaches of Holualoa Drainageway, Kaumalumalu Drainageway, Keopu Drainageway, Keopu Drainageway Overflow, Waiaha Drainageway, and Waiaha Drainageway Splitflow No. 2. In addition, the detailed study of Keopu Drainageway has been modified to incorporate more detailed topographic data.

The 1994 revision also incorporates a previously issued LOMR dated October 1, 1992. The revision along Waikoloa Stream, for a reach of approximately 1,600 feet downstream of Lindsey Road, was performed by the Earth Technology Corporation (ETC). This LOMR, which superseded the previously issued LOMR dated April 22, 1992, was issued to more accurately align the revised 1-percent annual chance floodplain based on the roads shown on the topographic map prepared by ETC.

For the June 2, 1995, revision, the LOMR issued on June 7, 1994 was incorporated. The LOMR was a reissuance of a LOMR originally issued on September 9, 1991, which had not been included when the FIRMs were republished on May 16, 1994. This LOMR request, which affects the unnamed drainageway within the Komohana Kai subdivision, is based on new hydrologic and hydraulic analysis and more detailed topographic information. As a result of this request, the 1-percent annual chance floodplain shifted along the unnamed drainageway within the Komohana Kai subdivision. In addition, the width of the Special Flood Hazard Area, the area subject to inundation by the base (1-percent annual chance) flood, increases and decreases by a maximum of 150 feet, from approximately 200 feet upstream of Kuakini Highway to approximately 2,200 feet downstream.

For the April 2, 2004, FIS revision, the Kaluiiki Branch was studied from its confluence with the Waipahoehoe Stream upstream to approximately 200 feet upstream of Akala Road. The Waipahoehoe Stream was studied from the same confluence upstream to approximately 40 feet upstream of Akala Road. No floodway was computed for either tributary. Because of the steep gradient of both tributaries, supercritical flow is present through most of the stream sections. Average velocities range from 9.0 to 13.0 feet per second. The County has adopted the 1-percent annual chance floodplain as the floodway for many similar streams because of high current velocities.

The April 2, 2004 revision incorporated the results of the Puukapu Flood Study and the Hilo, Hawaii County, Hawaii Flood Hazard Assessment. The streams studied in detail in The Puukapu

Flood Study were Kamuela Stream; Lower Lanimaumau Stream; NRCS Diversion Channel; Unnamed Streams 1, 2, and 3; and Upper Lanimaumau Stream. The Puukapu Flood Study covered the area of Waimea, located at South Kohala District, Hawaii County, Hawaii. Riverine flood hazards on the streams to be studied as part of the Contract with Hawaii County (Consultant Contract No. 04153) were:

- Kamuela Stream: From its upstream confluence with Lanimaumau Stream to its downstream confluence with Lanimaumau Stream through diversion
- Lanimaumau Stream: From the upstream existing Limit of Detailed Study to the NRCS diversion channel entrance
- Unnamed Stream: From Mile Marker 54 of Mamahaloa Highway (Hwy 19) to 3,000 feet beyond the existing Limit of Study (Unnamed Stream 1). Unnamed Streams 2 and 3 were not in contract.

The Hilo, Hawaii County, Hawaii Flood Hazard Assessment studied the following streams in detail: Palai Stream, Palai Stream A, Palai Stream C, Waiakea Flood Control Channel, Waiakea Stream, Waiakea Tributary No. 1, Waiakea Tributary No. 2, and Waiakea Tributary No. 3. The entire reaches of these streams were studied except for the following:

- Palai Stream: From upstream of Kinoole Street (station 16,400) to 100 feet above Haihai Street.
- Palai Stream A: From the confluence with Palai Stream to the shallow flooding breakout along Ainaola Drive downstream of Haihai Street.
- Palai Stream C: From the confluence with Palai Stream A to 250' west of Ko'ele Street.
- Waiakea Stream: From the upstream limit of the tsunami study (station 1,855) to the limit of detailed study.

The flood zones for several streams throughout the county, listed in section 1.2, were updated using Hawaii County's tax parcel maps to depict better historical floodplain riverine floodplain fitting. The updates were focused on areas with high population or areas with significant floodplain issues, although additional approximate-study updates occurred in other areas of the island.

The hurricane storm surge and wave height analysis that was incorporated extends from Upolu Point at the western limit to Cape Kumukahi at the eastern limit for a total reach length of 193 miles.

For this revision, the following streams of the Island of Hawaii were studied by detailed methods in addition to the above listed detailed streams:

South Kona Watercourse No. 2, 4, 5, 5A, 6, 8A, 9, 11, 12, 21, 22, and 23

In addition, select areas of Hawaii County were re-delineated for tsunami flood inundation based on effective tsunami profiles and using new topographic data, including the area of Hilo Bay.

This update also incorporates the results of mappable LOMCs (i.e., Letters of Map Amendment and LOMRs) issued by FEMA for the letters listed in Table 1, "Letters of Map Change."

Table 1: Letters of Map Change

Flooding Source(s)/Project Identifier	Date Issued	Type
Gulch 2 – Hapuna South Kohala Resort Corporation	May 14, 1991	LOMR
Upper Waiakea Stream area	June 11, 1991	LOMR
Waikoloa Stream	April 22, 1992	LOMR
Waikoloa Stream	October 1, 1992	LOMR
Palai Stream A	April 26, 1994	LOMR
Komohana Kai Subdivision	June 7, 1994	LOMR
Kealakekua Bay Estates	July 29, 1994	LOMR
Malulani Gardens Phase I	May 26, 1995	LOMR
Keopu Drainageway Map Correction	June 14, 1995	LOMR
Hualalai Development Site	April 10, 1996	LOMR
Hilo Restorative Care Center	June 3, 1996	LOMR
Heahea Heights Subdivision	June 5, 1996	LOMR
Alenaio Stream Flood Control Project	February 5, 1999	LOMR
Douter Coffee Farm Improvements	January 6, 2000	LOMR
Waiakea Acres II	April 27, 2000	LOMR
Kukio Bay Beach Club	July 27, 2000	LOMR
Hilo Scattered Lots	August 15, 2000	LOMR
Kaumalumalu Drainageway	September 19, 2000	LOMR
Malulani Gardens, Phase III	August 7, 2001	LOMR
Subdivision of Lots 15 & 20	September 12, 2001	LOMR
Waikoloa Lots 1, 2, and 7 Subdivision	December 27, 2001	LOMR
White Sand Subdivision and Beach Club	May 3, 2002	LOMR
Waikoloa Subdivision, Lots 1, 2, and 7	February 25, 2003	LOMR
Kona Hawaiian Village	April 24, 2003	LOMR
Palai Stream Group FIRM Update	July 15, 2003	LOMR
Kaiulani Subdivision	October 16, 2003	LOMR
Bolton Development	January 20, 2004	LOMR
Mohala Village Commercial Development	February 27, 2004	LOMR
Mamalahoa Highway Bypass Road	February 28, 2005	LOMR
Hilo Scattered Lots – Leie Road Lots	June 17, 2005	LOMR
Uh Hilo University Park	October 16, 2006	LOMR
Mohouli Street Extension, Ainako Avenue to Komohana Street	December 21, 2006	LOMR
Holualoa Art Village	February 28, 2007	LOMR
Royal Kamehameha Garden (Kona Mauka Estates)	March 25, 2008	LOMR
Mohouli Street Flood Zone	July 17, 2009	LOMR
Kaluiiki Stream and Unnamed Stream	December 17, 2009	LOMR
Kawailani Street Bridge Replacement	February 16, 2010	LOMR
Ainako Stream Flood Zone	August 23, 2010	LOMR
Tributary 1 to Waipahoehoe Stream	September 7, 2010	LOMR

Flooding Source(s)/Project Identifier	Date Issued	Type
Waiakea Tributary 3A Flood Zone	October 15, 2010	LOMR
Ainako Stream Flood Zone	August 23, 2010	LOMR
South Kona Watercourse No. 1, South Kona Watercourse No. 2	May 10, 2011	LOMR
Waiakea Tributary No. 3A and 3B	March, 4, 2013	LOMR
Puako Area (Auwaiakeakua Gulch)	December 16, 2013	LOMR
South Kona Watercourse No. 13	February 7, 2014	LOMR
Waikoloa Stream	February 21, 2014	LOMR
Four Mile Creek Tributary No. 1	September 22, 2014	LOMR
North Kona District Flood Hazard Study	October 28, 2014	LOMR
Keopu Drainageway	January 26, 2015	LOMR
Palai Stream	February 9, 2015	LOMR

LOMRs included in Table 1, "Letters of Map Change", may have been superseded or partially superseded by subsequent letters of map change issued by FEMA. LOMR case number 15-09-1007P is an active LOMR, but has not yet been made effective.

The streams studied as part of the Puukapu flood study were divided into two groups by their geographic locations: Area A1 and Area A2.

Area **A1**: This area includes the upper portion of Lanimaumau Stream that flows into the NRCS diversion channel and the unnamed streams flowing to the dam. Generally the streams located at east of Puukapu Retarding Dam are grouped to Area **A1**.

Area **A2**: This area includes the remaining portion Kamuela Stream, Lanimaumau Stream, and the diversion channel that combines both aforementioned streams. Generally the streams located at west of Puukapu Retarding Dam are grouped to Area **A2**.

Approximate analyses were used to study the overflows from Lower Lanimaumau Stream and Unnamed Stream 3.

The hurricane storm surge and wave height hazard was studied in whole using detailed methods for the western and southeastern coastline of Hawaii from Upolu Point to Cape Kumukahi. No detailed analysis was performed on eastern coastline north of Cape Kumukahi to Upolu Point.

2.2 Community Description

Hawaii County comprises the Island of Hawaii and covers an area of 4,030 square miles, or about 63 percent of the total land areas of the State of Hawaii. The island is 93 miles long and 76 miles wide and has 318 miles of shoreline. In addition to being the largest of the Hawaiian Islands, the "Big Island" of Hawaii is also geologically the youngest, having been formed from five volcanoes: Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. Of the five volcanoes, only Mauna Loa and Kilauea are still active, and intermittent lava flows from these volcanoes continue to contribute to the land mass of the island. The two highest points on the island are the peaks of Mauna Kea and Mauna Loa, at elevations of 13,796 feet and 13,649 feet, respectively. Distribution of the land by elevation shows that 5 percent of the land is above 10,000 feet, 32 percent is higher than 5,000 feet, and approximately 80 percent of the land exceeds 1,000 feet.

The State of Hawaii is unique because it has only two levels of government: State and county. Hawaii County is subdivided into nine judicial districts: North Kohala, South Kohala, Hamakua, North Kona, South Kona, North Hilo, South Hilo, Puna, and Kau. The population of the island in 2010 was 185,079.Future population gains are predicted for the South Hilo, South Kohala, and North Kona districts.

Nearly 76 percent of the land has a slope of less than 10 percent, but much of that is only slightly less than 10 percent.

In Hawaii County, streams develop slowly because of the high permeability of water into the soil, especially in areas of recent lava flows. Sheetflow is prevalent because of the slow development of the soil mantle. Perennial streams are located mainly on the northeastern slopes of Mauna Kea and Kohala Mountains.

Hawaii County produces more than half of the beef and diversified agricultural crops grown in the State. Other principal industries include tourism. The county also claims the only coffee industry in the United States; the largest orchid-growing industries in the world; and rapidly expanding export industry in papayas, macadamia nuts, various tropical flowers, and foliage.

The climatic pattern of the island is characterized by a two-season year a summer lasting from approximately May through October and a winter lasting from approximately October through April. Mild temperatures and moderate humidity characterize the island climate. Diversity in meteorological conditions exists as a result of topographic variations throughout the island. Temperatures range from 58 degrees Fahrenheit (°F) to 90°F at sea level, to freezing at the summits of Mauna Kea and Mauna Loa, an average temperature decline of 1°F for every 200- to 300-foot rise in elevation. Average rainfall for the island ranges between 25 and 30 inches per year, but varies due to terrain with higher rainfalls at lower elevations. Annual rainfall varies from 7 inches at Kawaihae on the leeward coast, to 142 inches at Hilo on the windward side, and more than 300 inches on the slopes of Mauna Kea. Hawaii's heaviest rains come from winter storms between October and April. Frequently, the heaviest storm rains do not occur in areas with the greatest average rainfall. Relatively dry areas may receive, within a day or a few hours, totals exceeding half of their average annual rainfall.

A detailed description of the areas studied by both detailed and approximate methods follows:

NORTH KOHALA AREA

The District of North Kohala lies on the northern end of the Island of Hawaii. North Kohala appears to be the geologically oldest area on the island. The area has an annual rainfall of 40 inches, and the region from Hawi to Makapala has several deep gulches. Specifically, 15 gulches between Hawi and Makapala were analyzed by approximate methods. With the closing of the sugar mill, the land is used mainly for agricultural purposes.

SOUTH KOHALA AREA

The South Kohala District is noted primarily for livestock and truck farming. With the annual rainfall ranging from 10 to 15 inches, the semi-arid region has little potential for other agriculture use.

However, a potential for tourism exists, which is evident from recently completed resort developments.

Four gulches within the Kawaihae area - Gulch 1, Waiulaula, Makeahua, and Makahuna - were delineated as approximate study areas. Gulch 1, Waiulaula, and Makeahua Gulches are similar in relief features, in that they are well-defined throughout, with heavy vegetation in the lower reaches and somewhat sparser vegetation in the higher reaches. Makahuna Gulch is well-defined upstream of Waimea-Kawaihae Road, and downstream sections have been channelized and are clear of vegetation. Runoff from the uninhabited watersheds of Gulch 1, Waiulaula, and Makahuna Gulches empties into Kawaihae Bay.

Along the Kawaihae coast of the South Kohala District, gulches studied by detailed methods were Gulch 2-Hapuna, Gulch 3-Hapuna near Hapuna Beach, Kamakoa Gulch, Gulch 4-Puako, and Auwaiakeakua Gulch, in the Puako area. Primary developments in the area are the Puako Beach subdivision and the Waikoloa development by Boise Cascade.

In the Waimea-Kamuela area of the South Kohala District, economic life centers on cattle ranching and truck farming. With a year-round average annual temperature of 50°F to 60°F, the growing and grazing industry proceeds continuously. Annual precipitation in Kamuela Town is approximately 40 inches; 3 miles upstream, in the Kohala Mountains, the average annual precipitation is 170 inches per year.

The Waimea Plateau lies between the slopes of Mauna Kea and the Kohala Mountains. Flows from these mountains travel through the plateau via two outlets, Waikoloa and Lanimaumau Streams.

The intermittently flowing Lanimaumau Stream begins in the steep Kohala Mountains. Unlike Waikoloa Stream, Lanimaumau Stream traverses through flat agricultural farmlands, through some residential development such as Kuhio Village, and finally over rolling meadows to its final destination, which is a lava tube near the Parker Ranch Race Track. It drains a basin of approximately 39 square miles.

SOUTH HILO AREA

Waiakea Stream, Palai Stream, and Four Mile Creek are three of the five tributaries within the principal Wailoa River system, which drains a total area of about 160 square miles. The other tributaries are Alenaio and Kawili Streams. From the summits of Mauna Loa to the Hilo shore, the contributing drainage areas show increasing development, with the areas below the 1,500-foot elevation primarily developed for commercial, residential, and agricultural purposes. Alenaio Stream, studied by detailed methods, drains an area of approximately 8.5 square miles. The Waiakea Stream drainage basin is approximately 35.4 square miles in size.

The Palai Stream drainage basin, with a drainage area of 9.13 square miles, extends about 10.5 miles from Waiakea Pond to the slopes of the Waikea Forest, with elevations ranging from sea level to approximately 1,800 feet. Below the 1,500-foot elevation, the basin is largely developed or planned for commercial, residential, or agricultural development. The study includes Palai Stream and its tributaries, extending approximately 5.5 miles upstream from the mouth at Waiakea Pond.

Four Mile Creek, located just south of Palai Stream, drains an area of about 22.6 square miles. The study covers Four Mile Creek for a distance of 2 miles upstream of Kanoelehua Avenue. Located downstream of Kanoelehua Avenue, a recently constructed flood-control channel conveys discharge to the Waiakea-Uka Flood Control Basin.

Wailuku River was evaluated by approximate methods. This stream is the largest of the Hilo watercourses, with a drainage area of approximately 177.0 square miles.

In addition to the primary streams, other streams studied by approximate methods within the vicinity of the South Hilo area are Pukihae Stream and two unnamed gulches near Hilo. These well-defined deep streams are typical of the many streams found between Hilo and Hawi along the Hamakua coast.

KAU AREA

Ninole Gulch, which is situated on the Kau coast near the southern tip of the island, lies within a relatively unpopulated region covered by a fairly recent lava flow devoid of vegetation. While the area is characterized by a lack of well-defined gulches, Ninole Gulch is defined by earthen dikes protecting the Sea Mountain Golf Course and the Aspen Institute. At the mouth of the gulch, the intermittently flowing Ninole Gulch becomes perennial as a result of the continuously flowing Ninole Springs.

HAMAKUA AREA

The Hamakua district is comprised of several small communities scattered along the coastal belt. Agricultural activities in the area include taro, truck farm produce, macadamia nuts, and cattle ranching.

Honokaa town, located at 1,100 feet along the Hamakua coast, is covered in this study. A detailed shallow flooding analysis was conducted for this area, which is primarily prone to sheetflow and shallow flooding. The Honokaa drainage basin covers an area of approximately 2.4 square miles.

NORTH KONA AREA

On the central leeward coast of Hawaii, the North Kona District is defined by relatively recent lava flows and the absence of well-defined drainage channels. Starting from the slopes of Mount Hualalai and Mauna Loa, vegetation increases with lower elevations, except near the shore, which is used for cattle grazing. With an annual rainfall ranging from 20-40 inches, the diverse vegetation ranges from none above the 8,500-foot elevation; sparse between 8,500 and 6,000 feet; moderately fertile in the forest reserves between 6,000 and 3,500 feet; and fertile in the agricultural zone between 3,500 and 800 feet.

The area consists of a series of narrow, underdeveloped drainageways that flow to the ocean. Seven intermittent drainageways totaling 300 miles in length were identified during the study as having flood hazard potential. They included the Kainaliu, Kawanui/Lehuula, Kaumalumalu, Holualoa/Horseshoe Bend, Waiaha, Hienaloli, and Keopu drainageways.

Soils in this area may be classified into three major groups based on the amount of volcanic ash or organic matter covering the basaltic material. These groups are volcanic ash soils, organic soils, and young, unweathered lava.

The floodplain areas in this study are composed of urban, agricultural and forest land. In addition, a preliminary survey shows historical, archaeological, recreational, wetland-and-endangered-plant, and animal sites scattered throughout the study area (U.S. Department of Agriculture, 1984).

SOUTH KONA AREA

Located on the western slopes of Mauna Loa, the South Kona area consists of a series of narrow drainage areas with underdeveloped watercourses that drain into the Pacific Ocean. Twenty-five such watercourses were identified as having flood hazard potential.

All watercourses within the study area are intermittent. Much of the flood flow percolates into lava formations and reaches the ocean as surface flow only after periods of intense and sustained rainfall. The drainage area, above 6,000 feet, appears not to contribute to surface runoff. This area includes nearly barren lava, volcanic ash, pumice, and cinders.

The rainfall distribution in the project area is predominantly influenced by the sheltering effect of Mauna Loa. Mauna Loa reaches a height of 13,677 feet and shelters much of the project area from the predominant northeast trade winds. In the vicinity of the South Kona Area orographic rainfall averages 73 inches annually to about 44 inches per year near the coast.

Soils in the drainage area are dominated by well-drained, very shallow soils formed from organic matter over pahoehoe lava or fragmental “Aa” lava. The thickness of the organic layer increases with increasing rainfall but is generally less than 10 inches. The vegetation consists of ohia, tree fern, koa, guava, christmas berry, pasture grasses, coffee, and macadamia nuts (U.S. Department of Agriculture, 1977).

2.3 Principal Flood Problems

The island of Hawaii is subject to flooding from stream overflow, tsunamis, and hurricanes. In some areas along the coast, all three types of flooding may occur. A major flood hazard on Hawaii is tsunami inundation. 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 of Hawaii County. Sources of these tsunamis are varied and are located in North and South America, the Aleutian Islands, Japan, Kamchatka, the islands lying between the Philippines and Samoa, and even Hawaii itself. The City of Hilo has been most severely damaged over the years. 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 2014 indicate that only 13 storms Category 1 or higher have come within a 200 nautical mile radius of the Hawaiian Islands. The island of Hawaii has not experienced direct hurricane landfall, however, the island has been impacted from hurricane-generated wind and waves. Three hurricanes have made landfall or had notable impacts to the Hawaiian archipelago.

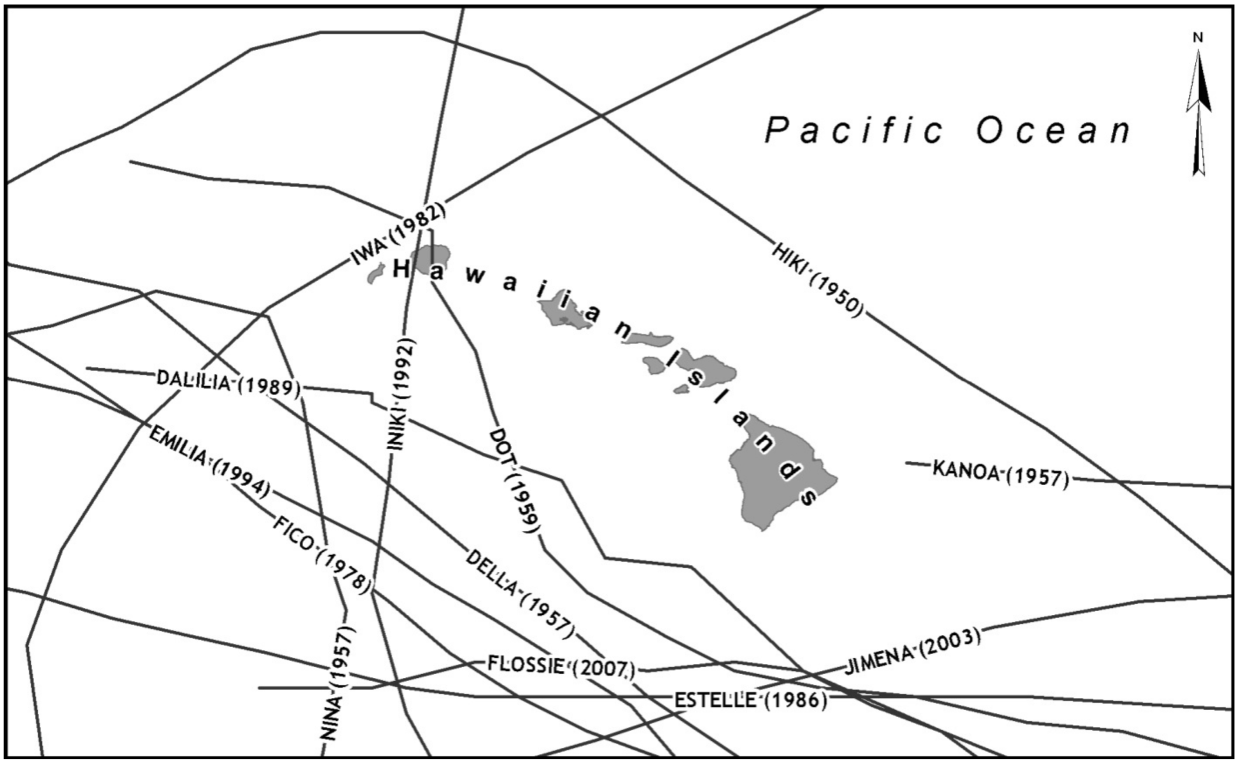


Figure 1. Hurricane tracklines within a 200 nautical mile radius of the Hawaiian Islands (1949-2014).

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 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 Local Mean Sea Level 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, undefined streamflow patterns, isolated depressions in topography, inadequate drainage facilities, and changed drainage conditions because of development.

On November 1, 2000, torrential rains struck the eastern portion of Hawaii. The National Weather Service reported approximately 27 inches of record rainfall at the Hilo International Airport within a 24-hour period. More than three feet of rain fell on some areas of the island, causing flooding in many areas of the county. The highest rainfall total was at Kapapala Ranch in Ka'u, where more than 36 inches was recorded within a 24-hour period. In Hilo, the Waiakea-Uka area was inundated with approximately 29 inches, the Piihonua area had approximately 24 inches, Mountain View had nearly 29 inches, and Glenwood had 26 inches. Public and private damage from the flood waters has been estimated at $70 million. Tropical Storm Iselle made landfall on August 7, 2014. The heavy winds and rain caused significant damage, particularly to the island agriculture. This led to a major disaster declaration in September 2014. The heaviest rainfall occurred on Hawaii Island where the Kulani National Wildlife Refuge reported 15 inches of rainfall. Rainfall-related flood problems in the detailed and approximate study areas are further discussed by flooding sources in the following paragraphs.

NORTH KOHALA AREA

Most of the 15 gulches within the district are heavily vegetated and well-defined at the lower reaches below Mahukona-Niulii Road. Above Mahukona-Niulii Road, the gulches are less defined and less densely vegetated. No major flood problems have been identified, and only minimal damage by sheet runoff has been reported in the Hawi and Kapaau areas.

SOUTH KOHALA AREA

For the approximate study areas of Gulch 1 and Makeahua and Makahuna Gulches, no major flood conditions are identified. Coastal areas of the South Kohala District from Kawaihae to Puako are subject to shallow flooding. Specifically, Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch, and Auwaiakeakua Gulch usually contain the runoff in the higher segments, but become undefined in the lower regions, causing shallow flooding conditions.

In the Waimea region, rock outcrops and sharp bends of Waikoloa Stream form restrictive sections that enhance flooding. This condition is most evident in the area immediately downstream of the Lindsey Street bridge. Here, the floodwaters of Waikoloa Stream tend to back up and overflow because of exaggerated, acute channel bends and thick foliage immediately downstream of the bridge. During flood stages, water overtops the bridge and floods the vicinity. Further downstream, however, the entire flow is maintained within the Waikoloa Stream floodplain.

On March 14, 2004, heavy rain and showers closed and damaged several roads in the area. The rain also forced Waikoloa Stream over its banks, and the flood waters in turn damaged water mains that supplied Kamuela with drinking water. Damages to the roadways alone were more than half a million dollars.

In the past, overflow of Lanimaumau Stream has caused severe economic damage. The storm of August 1958, for example, resulted in damage to truck-farm crops from floodwater as deep as 2.5 feet. Total estimated damage was $186,380. Recently, this flood damage potential has been reduced by the construction of the Puukapu Channel (FEMA, 1982).

SOUTH HILO AREA

Alenaio Stream flows indicate a floodprone situation. On July 25, 1966, the overflow points were the Kapiolani Street bridge, the Ululani Street bridge, the Kinoole Street bridge, the Kilauea Street bridge, and Waiolama Canal. The diversion dam above Kinoole Street (Ponahawai box drain) clogged, and the ensuing full flow along the stream resulted in the complete collapse of homes in the vicinity of Osorio Lane. The precipitation from the July 25 storm has been estimated as having a 2-percent annual chance recurrence interval. Flow impediments increased the magnitude of flooding caused by the event. Conditions that abet flooding in the area are the blockage of the streambed with existing pipe crossings and the heavy growth of grass on the streambed and banks.

During the period February 18-25, 1979, intense rainfall resulted in extensive flooding, especially in the low-lying areas of Hilo. More than 100 homes along the Palai/Four-Mile Creek drainageway were inundated, forcing a general evacuation of the area. Stream overflow onto Kanoelehua Avenue caused disruption of traffic.

The aforementioned storm events represent a mere sample of the extreme nature of flooding experienced in the area. Principal flood problems within the study limits include stream overflow along drainageways and surface runoff resulting from inadequate interior drainage.

KAU AREA

The Kau district has been subjected to severe floods in Naalehu, Waiohinu, and Pahala, but improvements in these locations have lessened flood hazards. Overall, the flood threat has been reduced in the desert region of the island, especially at Ninole Gulch, where protective earthen dikes were built to minimize flooding.

HAMAKUA AREA

The Town of Honokaa, located in the northern Hamakua region, is subject to sheetflow flood problems, as a result of the lack of well-developed stream channels in the area.

Notable floods in the area include those of April 1961 and November 1979. The rare floods of April 2-3, 1979, were one of flash nature, combining the elements of intense rainfall and steeply sloped mountains to produce rapidly concentrating runoff. Damages to sugar, farming, and cattle ranching industries were reported. During this storm, nearly all culverts were overtopped, including those that crossed the interstate defense highway. Those culverts were designed to handle 2-percent annual chance discharges, according to Hawaii State standards. At several locations, channel cross sections upstream of culverts contained areas twice as large as or larger than the size of the culvert. Some county bridges were overtopped as well.

Thunderstorm rain over Mauna Kea and the Kohala Mountains during the 1979 storm caused severe damage to the east Hawaii area, including the Town of Honokaa. Sugarcane and diversified agriculture in the area suffered the heaviest loss. Roads, bridges, water supply pipes, and other public works were damaged by floodwater as well. As an indication of the flood magnitude, the neighboring Ahualoa Stream was recorded at 4,100 cubic feet per second (cfs) on November 17-18, 1979. This station has been in operation since 1963 and the previous known maximum flow was 760 cfs on January 14, 1979.

NORTH KONA AREA

Historically, several flood problems have been noted within the North Kona District. Floods in Kailua-Kona result primarily from Waiaha Springs. Sheet runoff from the steep slopes of the Holualoa Watershed has also caused some flood problems. Records indicate that Kainaliu was also subject to flood hazards, as the flood of April 29, 1963, caused damages that amounted to $50,000.

Storms in the area occur in a few drainageways, not the whole study area, resulting in storm damages that are concentrated in specific drainageways. Since 1955, 22 storms have damaged the area. The most recent storms occurred in October 1968, October 1974, and February 1982.

Damages from the October 1968 flood were estimated at about $95,000, and were centered in the Holualoa/Horseshoe Bend and Kaumalumalu drainageways. Public facilities including county roads, bridges, and domestic water systems suffered damages in excess of $400,000 from floodwater, debris, and erosion. Kuakini Highway and Alii Drive were washed out in several locations, causing disruption to traffic. A 100-foot by 40-foot section of Mamalahoa Highway at Holualoa was ripped out by the raging floodwaters. Floodwater also damaged about 40 residences along Mamalahoa Highway and Alii Drive. The USGS Waiaha Stream at Luawai Stream gage (No. 16759300) measured a peak discharge of 3,100 cfs, which approximates a 4-percent annual chance (25-year) storm event.

The October 1974 storm was centered over the area between Holualoa and Kainaliu, with most of the damages occurring in the Town of Kainaliu and the Holualoa/Horseshoe Bend Drainageway below Kuakini Highway. This storm was of short duration and the rain gage at Kainaliu (No. 73.2) measured 3.77 inches in a 2-hour period, which approaches a 1-percent annual chance event.

The February 1982 storm was centered over the North Kona area from Keopu to Kaumalumalu drainageways. The Big Island Civil Defense Authority estimated damages in excess of $3 million. The Keopu drainageways suffered the most damage, with over $1 million in losses to roads and residences in the Keopu Heights Subdivision and to commercial buildings in the Town of Kailua. The USGS gage on Waiaha Stream at Luawai (No. 16759300) measured a peak discharge of 3,500 cfs or about a 4-percent annual chance storm. Rain gages at Lanihau (No. 68.2) and Holualoa (No. 69.16) also had rainfall amounts that approximated a 4-percent annual chance storm (U.S. Department of Agriculture, 1984).

SOUTH KONA AREA

Flooding problems have been largely a result of localized high intensity rainfall from about 1,000 to 5,000 feet in elevation. Such storms can occur anywhere along the mountain slopes of South Kona. In addition to these localized storms, a few general storms have occurred that affected the entire study area. According to storm damage reports by the SCS (U.S. Department of Agriculture, 1977), 17 damaging floods have occurred since 1956. Other floods occurred before then but no detailed accounts are available. Accurate data on rainfall and floodflows are nonexistent, but general accounts are available from storm damage reports.

On March 31, 1956, rainfall was estimated at about 8 to 12 inches, with the highest intensity occurring from 6 to 9 p.m. This rainfall amount was greater than the 1-percent annual chance, 24-hour frequency (U.S. Department of Agriculture, 1977). On April 29, 1963, approximately 4 inches of rain fell within 2 hours. Total rainfall amount was equivalent to the 1-percent annual chance, 24-hour-frequency storm.

On November 20, 1967, heavy rains fell at elevations of approximately 4,000 feet in the Honaunau area. The rains generated stream flow that caused serious damage to the Honaunau Post Office building, farm roads, and buildings surrounding the Post Office. The rains began at 2 p.m. and subsided at 4:35 p.m. During this period, 4 inches of rainfall were measured. This rainfall amount was equivalent to the 1-percent annual chance, 24-hour-frequency storm. On May 26, 1976, rainfall began at about 3 p.m. and continued until about 7 p.m. Although the only recording rain gage (USGS) in the area was not functioning properly at the time, the estimated rainfall at the Honaunau Post Office for the 4-hour duration was about 5 inches. This rainfall amount had a recurrence interval greater than once in 100 years.

2.4 Flood Protection Measures

Hawaii County exercises floodplain regulation, which gives the county authority to examine all construction permits for possible flood hazard risk and either accept or reject the permit or require adequate floodproofing.

A tsunami warning system has been developed for the entire State of Hawaii. This warning system was designed to provide sufficient time for evacuation from tsunami danger zones.

Hawaii County has constructed, or plans to construct, flood-control improvements, with State and Federal governmental assistance. A description of these joint efforts follows:

NORTH KOHALA AREA

Consistent with the lack of flood problems in the North Kohala District, no existing flood-control projects are planned for the region.

SOUTH KOHALA AREA

No flood-control projects are planned for the Kawaihae area, as the flood potential is minimal. Further, along the Kawaihae to Kailua-Kona coast, the Hapuna Beach-Puako gulches (Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch, and Auwaiakeakua Gulch) have not been improved for flood-control purposes. Except for small drainage ditches along the coastal areas below Kamakoa Gulch, no project flood protection alterations exist in the area. For the Puukapu watershed in the Kamuela area, a retarding dam and diversion channel were constructed through a joint undertaking of Hawaii County, the State of Hawaii, and the SCS. The Puukapu Channel was designed to divert 1-percent annual chance frequency storm runoff from the Lanimaumau Stream to Paiakuli Reservoir. The diversion channel has a capacity of 1,450 cfs.

SOUTH HILO AREA

The completion of the USACE Waiola River Flood-Control Project in August 1965 upgraded the capacity of Waiakea Stream to transmit the 1-percent annual chance flood. Within a year after completion, the 2-percent annual chance flow of the July 25, 1966, storm tested the flood-protection channel, and no flood damage occurred in the Waiakea Stream section of Hilo.

In 1974, the incremental construction on the Waiakea-Uka Flood Water Disposal Project was initiated by local interests. Phase I of the project, completed in 1976, consisted of excavation of 7,600 feet of a planned 9,600-foot open channel, construction of two bridges across the channel, and partial construction of the detention basin. Phase II, which would complete the project, includes: 1) Palai culvert – to divert a portion of the flow from Palai Stream into Four-Mile Creek; 2) open channel – the remaining 2,000 feet of open channel (unlined, trapezoidal); 3) detention basin – completion of the basin to allow storage and dissipation of floodwater and unlined spillway to discharge flow in excess of basin capacity. Phase II construction was completed in 2001. The final project length is approximately 3,461 feet long. In August 2006, the channel was inspected for the USACE and found acceptable for continuing eligibility in the Rehabilitation and Inspection Program.

The Alenaio Stream flooding problem has been reduced in the upper region by the Wailuku-Alenaio Watershed Project, initiated by the SCS. The project collected streamflow from the watershed above the Alenaio Stream and transferred the flow to Waipahoehoe and Kaluiiki Streams, which are tributaries to Alenaio Stream. This project also diverts flow from the Piihonua watershed to Wailuku River above Akolea Road. While this project alone has not alleviated flood hazards in Lower Alenaio below Komohana Road, residents in Kaumana, Chongmanville, Piihonua, and Ainako have benefitted greatly.

Hawaii County has completed the Manuelele diversion project in the Ainako area, which drains Kaumana Terrace waters into the Wailuku River. Other completed county projects include channel work on Alenaio Stream between Komohana Road and Kapiolani Street, and a diversion parallel to Komohana Road that intercepts and transfers upstream Alenaio flow to the Wailuku River. The installation of both projects has reduced flood damage in downtown Hilo.

KAU AREA

In Pahala, the flood problem of excessive sheet runoff has been alleviated with construction of flood diversion structures near the sugar plantation. In Naalehu Village, a debris basin and floodwater channel were constructed in 1965, with additional improvements and modifications completed in 1969. The SCS designed the 1-percent annual chance frequency flood protection project under the authority of the Watershed Protection and Flood Prevention Act. These improvements at Pahala and Naalehu have served to minimize the flood hazard in the Kau District.

HAMAKUA AREA

At present, no major flood-control projects exist in the Hamakua area.

NORTH KONA AREA

Flood-control projects for areas have been developed for areas near Disappearing Sands Beach, Holualoa Bay, the resort developments, and inland to the Alii Kai subdivision. The flood-control measures include a channel system, siltation and catchment basins, bridge crossings, and streambed deepening. These measures have been designed for a 1-percent annual chance frequency flood.

The previously serious flooding conditions in the Kailua and Kainaliu areas have been alleviated with the construction of flood-control projects, mainly the Keopu Channel and Kainaliu Diversion Flood Control System. Both projects were designed to accommodate a 1-percent annual chance flood. The Keopu Channel has a capacity to divert 3,200 cfs, and the four Kainaliu diversion structures were designed to transmit 100 cfs, 130 cfs, 300 cfs, and 175 cfs, respectively.

The two existing dams in the area have been adjusted to the Waiaha Drainageway and are presently being used for livestock purposes. The Luawai Reservoir is at an elevation of 2,500 feet and the other unnamed dam is at an elevation of 3,200 feet. The Luawai Reservoir has a storage capacity of about 3 million gallons, while the unnamed reservoir has less capacity. Both of these reservoirs have earth embankments of less than 5 feet.

SOUTH KONA AREA

A study of the South Kona area was conducted by the SCS at the request of the County of Hawaii (U.S. Department of Agriculture, 1977). Based on this study, the SCS has recommended structural and nonstructural flood protection measures for the county to implement. Nonstructural measures include:

1) Preserving the conservation and agricultural land use areas above Mamalahoa Highway.

2) Establishing and maintaining appropriate vegetative cover on sediment- and debris-producing areas.

3) Enforcing county grading ordinances.

4) Implementing land use zoning to restrict future development within identified floodplains, or requiring proper structural design to prevent floodwater damage from the 1-percent annual chance event.

Recommended structural measures are:

1) Relocating or floodproofing buildings that are floodprone.

2) Improving road culverts and bridges.

3) Developing a diversion system using lava tubes.

4) Requiring all structural or land improvements to compensate for increased runoff.

2.5 Levees

For purposes of the NFIP, FEMA only recognizes levee systems that meet, and continue to meet, minimum design, operation, and maintenance standards that are consistent with comprehensive floodplain management criteria. The Code of Federal Regulations, Title 44, Section 65.10 (44 CFR 65.10) describes the information needed for FEMA to determine if a levee system provides protection from the 1% annual chance flood. This information must be supplied to FEMA by the community or other party when a flood risk study or restudy is conducted, when FIRMs are revised, or upon FEMA request. FEMA reviews the information for the purpose of establishing the appropriate FIRM flood zone.

Levee systems that are determined to provide protection from the 1% annual chance flood are accredited by FEMA. FEMA can also grant provisional accreditation to a levee system that was previously accredited on an effective FIRM and for which FEMA is awaiting data and/or documentation to demonstrate compliance with Section 65.10. These levee systems are referred to as Provisionally Accredited Levees, or PALs. Provisional accreditation provides communities and levee owners with time to obtain the necessary data to confirm the levee's certification status. Accredited levee systems, PALs and levee symbology are shown on the FIRM and identified in Table 2. If the required information for a PAL is not submitted within the required timeframe, or if information indicates that a levee system not longer meets Section 65.10, FEMA will de-accredit the levee system and issue an effective FIRM showing the levee-impacted area as a SFHA.

FEMA coordinates its programs with USACE, who may inspect, maintain, and repair levee systems. The USACE has authority under Public Law 84-99 to supplement local efforts to repair flood control projects that are damaged by floods. Like FEMA, the USACE provides a program to allow public sponsors or operators to address levee system maintenance deficiencies. Failure to do so within the required timeframe results in the levee system being placed in an inactive status in the USACE Rehabilitation and Inspection Program. Levee systems in an inactive status are ineligible for rehabilitation assistance under Public Law 84-99.

FEMA coordinated with the USACE, the local communities, and other organizations to compile a list of levees that exist within Hawaii County. Table 2, "Levees," lists all levees shown on the FIRM for this FIS Report. The USACE Levee ID provides the identification number of levees that are included in the USACE National Levee Database; the number may not match numbers based on other identification systems that were listed in previous FIS reports. Levees identified as PALs in the table are labeled on the FIRM to indicate their provisional status.

Please note that the information presented in Table 2, "Levees", is subject to change at any time. For that reason, the latest information regarding any USACE structure presented in the table should be obtained by contacting USACE and accessing the USACE national levee database. For levees owned and/or operated by someone other than the USACE, contact the local community.

Table 2: Levees

Community	Flooding Source	Levee Location	Levee Owner	USACE Levee ID	FIRM Panel(s)	Levee Status
Hawaii County, Unincorporated Areas	Kamuela Stream	Left Bank	Hawaii County Public Works Department	1911051001	1551660168E	Accredited
Hawaii County, Unincorporated Areas	Lanimaumau Stream	Left Bank	Hawaii County Public Works Department	1911051002	1551660168E	Accredited
Hawaii County, Unincorporated Areas	Alenaio Stream (south bank downstream of Komohana St)	South Bank	Hawaii County Public Works Department	1911051014	1551660904F	Accredited
Hawaii County, Unincorporated Areas	Alenaio Stream (south bank downstream of previous levee)	South Bank	Hawaii County Public Works Department	1911051014	1551660904F	Accredited
Hawaii County, Unincorporated Areas	Alenaio Stream (north bank upstream of Kapiolani St)	North Bank	Hawaii County Public Works Department	1911051014	1551660904F	Accredited

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 exceedance) 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 the May 3, 1982, original FIS and the September 16, 1988, FIS revision, 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 station flood-frequency curves were determined using the procedures outlined in the Water Resources Council Bulletin No. 17 (Water Resources Council, 1976). A generalized skew coefficient of -0.05 was used for all station frequency curves.

Using the station flood-frequency curves, discharges at selected recurrence intervals were determined. Each set of discharges was then correlated to various basin and climatological characteristics using a regression equation of the following form:

$$Q_T = aX_1\, b_1\, b_2 \ldots b_n,\ X_2 \ldots X_n$$

Where Q_T is the discharge corresponding to recurrence intervals of T years,

a_1, b_1, $b_2 \ldots b_n$ are constants, and
$X_1, X_2 \ldots X_n$ are basin and climatological characteristics.

Regression constants were computed using the method of least squares. Statistical tests were made to eliminate those basin and climatological characteristics that had little or no significance. From the final equations for discharges corresponding to selected recurrence intervals, a flood-frequency curve can be constructed for any site, once the values of the significant characteristics are determined.

An examination of all gaging station records yielded 35 stations with adequate records for flood-frequency analysis. Station flood-frequency curves were computed and discharges for the selected recurrence intervals were determined for these 35 stations.

A multiple regression analysis was conducted by using the records for the entire island, and also by separating the records into the windward and leeward stations. In terms of standard error and multiple correlation, the best relationships were found by using the windward and leeward division.

The most significant basin and climatological characteristics for the windward area of Hawaii were found to be drainage areas (DA) and mean annual precipitation (PA), while those for the leeward area were drainage area (DA) and the 2-year, 24-hour precipitation (P24-2).

The regression equations for the windward grouping for the 10-, 2-, 1-, and 0.2-percent annual chance floods were:

$$Q_{10} = 313\ (DA)^{0.67}\ (PA)^{1.27}$$
$$Q_{50} = 641\ (DA)^{0.64}\ (PA)^{0.70}$$
$$Q_{100} = 822\ (DA)^{0.64}\ (PA)^{0.50}$$
$$Q_{500} = 1361\ (DA)^{0.62}\ (PA)^{0.10}$$

The regression equations for the leeward grouping for the 10-, 2-, 1-, and 0.2-percent annual chance floods were:

$$Q_{10} = 8.7\ (DA)^{0.55}\ (P24\text{-}2)^{2.62}$$
$$Q_{50} = 24.1\ (DA)^{0.72}\ (P24\text{-}2)^{2.35}$$
$$Q_{100} = 34.3\ (DA)^{0.77}\ (P24\text{-}2)^{2.26}$$
$$Q_{500} = 62.1\ (DA)^{0.88}\ (P24\text{-}2)^{2.14}$$

Where:

(DA)	=	Drainage Area
(PA)	=	Mean Annual Precipitation in hundreds of inches
(24-2)	=	2-year 24-hour precipitation in inches

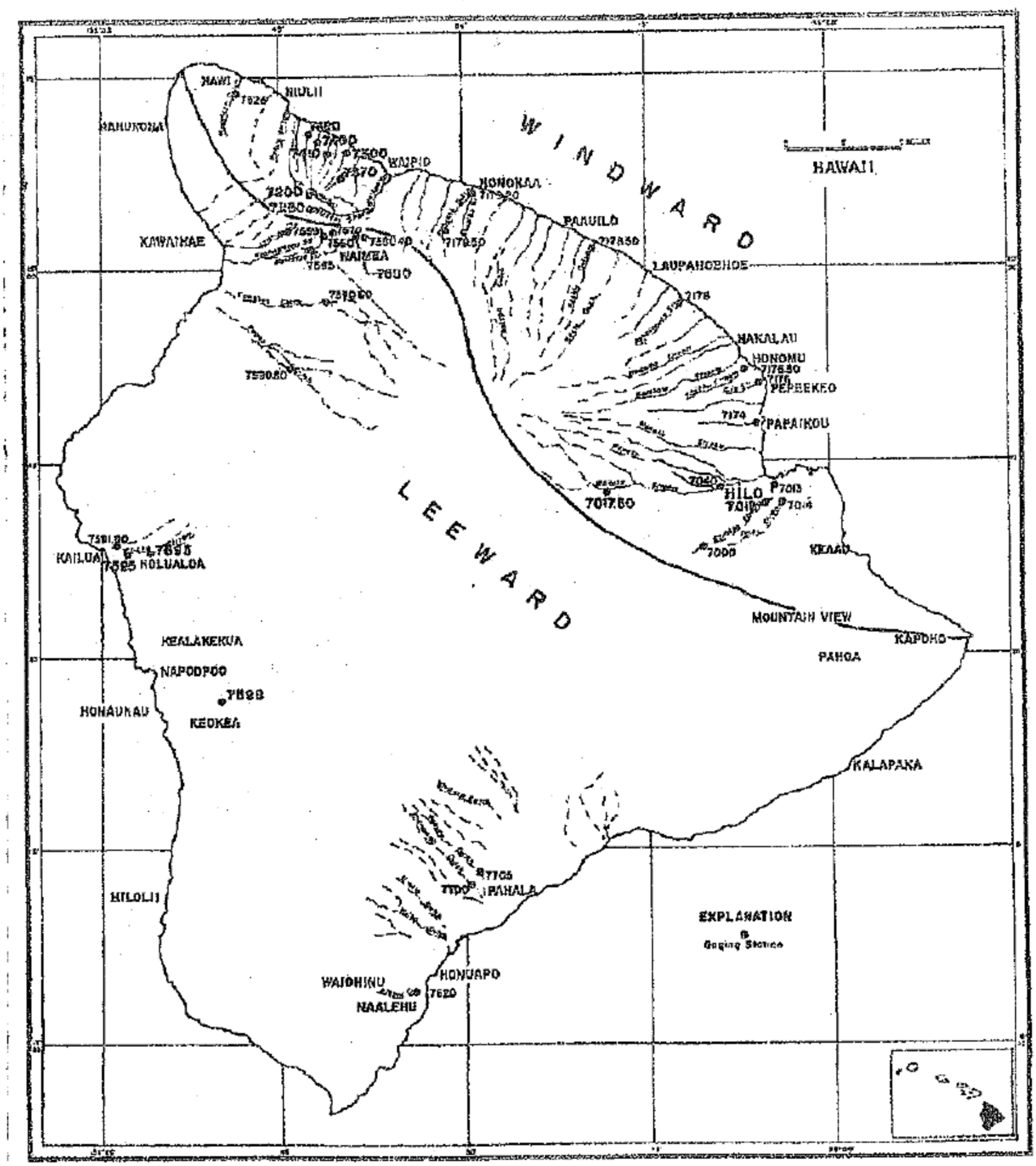


Figure 2: Division of Stations, Windward and Leeward Groups

For Alenaio Stream, a regional analysis relating discharge to drainage area was used in lieu of the multiple regression technique. Data from 12 stream gaging stations near Alenaio Stream were used. Individual discharge-frequency curves for these stations were calculated following procedures based on the Water Resources Council Bulletin No. 17 (Water Resources Council, 1976). The 10-, 2-, 1-, and 0.2-percent annual chance discharges were plotted against their respective areas to determine regional discharge drainage area relationships. From these curves, discharges for Alenaio Stream were determined.

For Waiakea Stream, discharges were determined by a flood flow frequency analysis. Guidelines developed in Water Resources Council Bulletin No. 17b were used (Interagency Advisory Committee on Water Data, 1982). The revised analysis of the revised discharges and the channel capacity of Waiakea Stream determined that a portion of the flow from Waiakea Stream escapes during significant flood events and flows overland into Waiakea Tributary No. 2 in the vicinity of Kawailani Street. A split flow analysis was completed for the 10%, 2%, 1%, and 0.2% annual-chance discharges. Because the calculated split flow was significantly higher than the calculated regression equation flows for Tributary No. 2, the split flow discharges were used for this tributary. Discharges were reduced along Waiakea Stream approximately 500 feet upstream of Kawailani Street to just upstream of the confluence of Waiakea Tributary No. 2 to account for the diverted flow.

Discharges for Waiakea Tributary No. 1 and Waiakea Tributary No. 3 were determined by rural regression equations.

The hydrologic analyses for the North Kona streams studied by detailed methods were developed in the December 1984 North Kona Flood Plain Management study (U.S. Department of Agriculture, 1984). The hydrologic analyses were based on SCS methodology found in Section 4 of the SCS National Engineering Handbook (U.S. Department of Agriculture, 1972). A computer program (Technical Release No. 20) was used to compute peak discharges at all cross sections for the 10-, 2-, 1-, and 0.2-percent annual chance frequency storms (U.S. Department of Agriculture, 1965).

Runoff curve numbers used in the SCS hydrologic method were estimated from soils and land use information and compared with previous hydrologic studies done in the area. Soil information was obtained from the 1973 Soil Survey of the Island of Hawaii, State of Hawaii, published by the SCS in cooperation with the University of Hawaii Agricultural Experiment Station (U.S. Department of Agriculture, 1973). Rainfall data were obtained from the National Weather Service, Technical Paper No. 43 (U.S. Department of Commerce, 1962).

The North Kona area has three active stream gages: right branch Waiaha Drainageway near Holualoa (No. 16759200), Waiaha drainageway at Luawai (No. 16759300), and Keopu Drainageway near Kailua (No. 16759180). The former two are continuous recording gages with a period of record from 1961 to 1980; the latter is a crest gage station with a record period from 1965 to 1980. Based on the Water Resources Council guidelines (Water Resources Council, 1976), frequency-discharge curves for all three gages were compared to frequency-discharge curves as derived from the computer output. Curve numbers were adjusted so that peak discharges were compatible with Water Resources Council estimates.

For the July 16, 1990, FIS revision, discharges for the Waikoloa Stream, Waikoloa Stream Tributary, and Kamuela Stream are included in the Summary of Discharges table (Table 3). Floodways were not calculated for any of the streams incorporated into this revision.

For the May 2, 2004 FIS revision, hydrologic analysis was performed to determine the peak discharges for the study streams at the selected recurrence intervals (10-, 2-, 1-, and 0.2-percent annual chance) using HEC-HMS and HEC-GeoHMS programs from USACE, Hydrologic Engineering Center. HEC-GeoHMS model was used to delineate water boundaries, compute time of concentration and obtain geometric parameters for channel routing. LiDAR data was used to generate 10-foot DEM as the base of hydrologic analysis.

For the HEC-HMS rainfall-runoff model, several methods were chosen to determine input parameters. The USACE hypothetical rainfall distribution was applied using the precipitation gages options. The NRCS unit hydrograph method was used as the transformation method. The initial and constant loss rate method was used as the loss rate method. The Muskingum-Cunge 8 point cross section was used for the channel routing. The diversion option was used to represent the infiltration loss in the reservoir and infiltration basins. The storage-stage relationship for the Puukapu Reservoir and infiltration basins were obtained from previous studies. The HEC-HMS results indicated that Puukapu Reservoir could withhold the flows from all flood frequencies and there was no outflow over the spillway.

For this FIS revision, BakerAECOM performed a quality assurance and quality check on a hydrologic analysis. The hydrologic analysis was performed to determine the peak discharges for the South Kona study watercourses at the selected recurrence intervals (10-year, 25-year, 50-year, 100-year, and 500-year) using various methods such as HEC-HMS, FEMA Regression Equations, and County of Hawaii Plate. HEC-GeoHMS program from USACE, Hydrologic Engineering Center was used to delineate water boundaries, compute time of concentration and obtain geometric parameters for reach routing. LiDAR bare earth data was used to generate terrain model as the base of hydrologic analysis.

For the HEC-HMS rainfall-runoff model, several methods were chosen to determine input parameters. The Soil Conservation Services (SCS) Type I 24-hour storm was used as the rainfall distribution patter. The Natural Resource Conservation Services (NRCS) unit hydrograph method was used as the transformation method. The curve number method was used as the loss rate method. The Muskingum-Cunge 8 point cross section was used for the reach routing. The HEC-HMS results were recommended to be applied in the hydraulic analysis in conclusion.

A summary of the drainage area - peak discharge relationships for all the streams studied by detailed methods is shown in Table 3, "Summary of Discharges."

Table 3: Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
AINAKO STREAM					
At Waianuenue Avenue	1.24	[1]	[1]	1,850	[1]
ALENAIO STREAM					
At confluence with Wailoa River	8.72	[1]	[1]	6,000	9,840
AUWAIAKEAKUA GULCH					
At mouth	68.93	1,550	6,400	10,500	29,000

[1]Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
FOUR MILE CREEK At Kanoelehua Avenue	22.64	3,380	5,975	7,165	9,740
Upstream of Tributary No. 1	2.70	935	1,535	1,840	2,605
FOUR MILE CREEK (SHALLOW FLOODING)					
Downstream of Ainalako Avenue	1.40	[1]	[1]	1,205	[1]
Upstream of Ainalako Avenue	0.49	[1]	[1]	1,205	[1]
FOUR MILE CREEK TRIBUTARY NO. 1					
At confluence with Four Mile Creek	19.76	3,545	5,475	6,565	8,950
At Kulaloa Road	1.50	[1]	[1]	3,533	[1]
FOUR MILE CREEK TRIBUTARY NO. 3					
At Ainalako Drive	0.91	[1]	[1]	915	[1]
GULCH 2- HAPUNA					
At confluence with Hapuna Bay	10.92	420	1,300	1,950	4,400
At confluence with Waialea Bay	4.05	210	570	800	1,650
GULCH 4 – PUAKO					
At mouth	3.54	215	565	790	1,650
HIENALOLI DRAINAGEWAY					
At mouth	4.11	1,550	2,690	3,690	5,180
HIENALOLI DRAINAGEWAY SPLITFLOW					
At Hawaii Belt Road	*	[1]	[1]	830	[1]
HOLUALOA DRAINAGEWAY					
At mouth	4.15	900	1,750	2,590	4,070

*Data Not Available

[1]Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
HONOKAA DRAINAGE A					
At Mamane Street	0.66	[1]	[1]	582	[1]
HONOKAA DRAINAGE B					
At Mamane Street	0.18	[1]	[1]	253	[1]
HONOKAA DRAINAGE C					
At Mamane Street	0.20	[1]	[1]	271	[1]
HONOKAA DRAINAGE D					
At downstream limit of detailed study	0.20	[1]	[1]	271	[1]
HONOKAA DRAINAGE NO. 1					
At Mamane Street	0.71	[1]	[1]	609	[1]
HONOKAA DRAINAGE NO. 2					
At Mamane Street	0.62	[1]	[1]	560	[1]
HONOKAA DRAINAGE NO. 3					
At Mamane Street	0.33	[1]	[1]	370	[1]
HORSESHOE BEND DRAINAGEWAY					
At mouth	*	650	960	1,310	1,910
KAINALIU DRAINAGEWAY					
4,300 feet upstream of the Pacific Ocean	*	[1]	[1]	610	[1]
KALUIIKI BRANCH					
Approximately 1,500 feet upstream of confluence with Waipahoehoe Stream	*	[1]	[1]	2,740[2]	[1]

*Data Not Available
[1]Discharge not determined
[2]Discharge determined from Floodway Data Table

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
KAWANUI-LEHUULA DRAINAGEWAY					
4,000 feet upstream of the Pacific Ocean	*	[1]	[1]	590	[1]
KAMUELA STREAM					
At Waipahoehoe Stream	2.82	1,320	2,510	3,150	4,950
At Kaluiiki Branch	2.31	1,150	2,200	2,750	4,340
At confluence with Waikoloa Stream	0.69	[2]	[2]	919	[2]
At Kamuela Stream	0.63	[2]	[2]	645	[2]
Point 10 (at Kinohou Street)	0.471	323	538	644	817
Point 11 (before confluence with Lanimaumau Stream)	0.535	343	586	707	899
KAUMALUMALU Drainageway at mouth	9.86	1,040	2,750	4,040	4,840
KAWANUI-LEHUULA DRAINAGEWAY					
Approximately 4,000 feet upstream of the Pacific Ocean	*	[2]	[2]	590	[2]
KEOPU DRAINAGEWAY	*				
At Hawaii Belt Road		560	1,120	1,610	2,460
KUPULAU FLOOD DITCH					
At divergence from Palai Stream A	[1]	[2]	[2]	2,144	[2]
Downstream of divergence from Palai Stream C	[1]	[2]	[2]	1,263	[2]
LOWER LANIMAUMAU STREAM					
Point 12 (at Mamalahoa Highway)	0.02	19	27	33	41
Point 13 (at entrance to Kuhio Village)	0.89	307	615	775	1,017

*Data Not Available
[1]Computed from split flow
[2]Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
MOHOULI STREET DRAINAGE					
At 6.200 feet upstream of Komohana Street	0.60	[3]	[3]	750	[3]
At Komohana Street	0.60	[3]	[3]	750	[3]
NINOLE GULCH					
At confluence with Ninole Gulch	21.47	6,900	9,200	10,800	14,800
At USGS Station	8.97	4,300	6,800	7,900	11,000
NRCS DIVERSION CHANNEL					
Point 3 (at Highway)	1.02	838	1,803	2,027	2,402
PALAI STREAM					
At mouth[1]	7.7	760	1,330	1,550	2,220
At Puanko Street	6.8	1,275	1,960	2,265	3,120
At Kanoelehua Avenue	5.2	1,070	1,600	1,860	2,530
At Golf Course near Kehaulani Street	4.9	1,020	1,525	1,775	2,410
PALAI STREAM A					
1,940 feet downstream of Kaulike Street	3.68	[3]	[3]	294	[3]
At Ainaola Drive	3.61	[3]	[3]	470	[3]
PALAI STREAM A-SPLITFLOW NO. 3					
At confluence with Palai Stream A	[2]	[3]	[3]	112	[3]
PALAI STREAM C					
At confluence with Kupulau Flood Ditch	[2]	[3]	[3]	173	[3]
At Divergence from Kupulau Flood Ditch	[2]	[3]	[3]	411	[3]
At Haihai Street	[2]	[3]	[3]	563	[3]

[1]Discharge based on HEC-HMS results combined with linear decreasing of flows due to lava tubes
[2]Computed from split flow
3Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
PALAI STREAM D					
At mouth	*	[1]	[1]	280	[1]
PALAI STREAM E					
At Alaloa Street	*	[1]	[1]	240	[1]
PALAI STREAM F					
At confluence with Palai Stream	*	[1]	[1]	3,445	[1]
GULCH NO. 4 – PUAKO					
At mouth	3.54	215	565	790	1,650
SOUTH KONA WATERCOURSE NO. 1					
At mouth	13.79	715	2,389	3,512	6,780
SOUTH KONA WATERCOURSE NO. 2					
At confluence with No. 3	5.71	251	792	1,149	2,190
SOUTH KONA WATERCOURSE NO. 3					
At mouth	5.98	266[2]	887[2]	1,304[2]	2,497[2]
SOUTH KONA WATERCOURSE NO. 4					
At confluence with No. 3	4.59	170	580	859	1,720
SOUTH KONA WATERCOURSE NO. 5					
At mouth	1.60	141[2]	585[2]	854[2]	1,612[2]
At Mamaloahoa Highway	0.82	94[2]	354[2]	508[2]	926[2]
SOUTH KONA WATERCOURSE NO. 5A					
Approximately 90 feet upstream of confluence with No.5	*	72[2]	284[2]	413[2]	765[2]
SOUTH KONA WATERCOURSE NO. 6					
At mouth	8.72	399[2]	1348[2]	1,976[2]	3,858[2]

*Data Not Available
[1]Discharge not determined
[2]Hydraulic model includes lateral structure reduction of flow

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
SOUTH KONA WATERCOURSE NO. 7					
At confluence with No.8	8.03	402	1,382	2,056	4,070
SOUTH KONA WATERCOURSE NO. 8					
At mouth	8.45	413[1]	1,417[1]	2,103[1]	4,157[1]
SOUTH KONA WATERCOURSE NO. 9					
At confluence with No. 11	2.1	217[1]	832[1]	1,211[1]	2,225[1]
SOUTH KONA WATERCOURSE NO. 10					
At confluence with No. 11	1.28	128[1]	508[1]	742[1]	1393[1]
SOUTH KONA WATERCOURSE NO. 11					
At confluence with No. 12	16.8	1,105[1]	3,573[1]	5,162[1]	9,879[1]
SOUTH KONA WATERCOURSE NO. 12					
At mouth	17.71	1,160[1]	3,731[1]	5,392[1]	10,367
SOUTH KONA WATERCOURSE NO. 13					
At mouth	11.1	650	2,730	2,960	4,470
At confluence with No. 17	4.94	334	1,280	1,410	2,040
SOUTH KONA WATERCOURSE NO. 14					
At confluence with No. 13	0.54	9	45	109	582
SOUTH KONA WATERCOURSE NO. 15					
At confluence with No. 17	2.07	199	918	939	1,310
SOUTH KONA WATERCOURSE NO. 16					
At confluence with No. 15	2.35	228	950	971	1,340
SOUTH KONA WATERCOURSE NO. 17					
At confluence with No. 13	5.23	316	1,410	1,500	2,300

[1]Hydraulic model includes lateral structure reduction of flow

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
SOUTH KONA WATERCOURSE NO. 18					
At confluence with No. 17	1.84	80	411	458	737
SOUTH KONA WATERCOURSE NO. 19					
At confluence with No. 20	3.99	332	1,700	1,780	2,840
SOUTH KONA WATERCOURSE NO. 20					
At mouth	13.2	673	3,760	4,040	6,790
SOUTH KONA WATERCOURSE NO. 21					
At mouth	7.56	494	2,035	3,021	5,854
SOUTH KONA WATERCOURSE NO. 22					
At confluence with No. 21	0.92	111	494	723	1,319
SOUTH KONA WATERCOURSE NO. 23					
At confluence with No. 21	6.76	425	1,707	2,530	4,927
SOUTH KONA WATERCOURSE NO. 24					
At confluence with No. 25	3.11	138	569	865	1,769
SOUTH KONA WATERCOURSE NO. 25					
At mouth	3.78	211	855	1276	2,504
TRIBUTARY 1 TO AINAKO STREAM					
At confluence with Ainako Stream	1.24	[1]	[1]	1,850	[1]

[1]Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
TRIBUTARY 2 TO AINAKO STREAM					
At confluence with Ainako Stream	1.11	[1]	[1]	1,680	[1]
TRIBUTARY 3 TO AINAKO STREAM					
At confluence with Ainako Stream	0.83	[1]	[1]	1,380	[1]
TRIBUTARY 4 TO AINAKO STREAM					
At confluence with Ainako Stream	0.74	[1]	[1]	1,285	[1]
TRIBUTARY 1 TO WAIAKEA TRIBUTARY NO. 3					
At confluence with Waiakea Tributary No. 3	0.16	[1]	[1]	41	[1]
TRIBUTARY 2 TO WAIAKEA TRIBUTARY NO. 3					
At confluence with Waiakea Tributary No. 3	0.16	[1]	[1]	48	[1]
TRIBUTARY 3 TO WAIAKEA TRIBUTARY NO. 3A	0.28	[1]	[1]	72	[1]
TRIBUTARY 4 TO WAIAKEA TRIBUTARY NO. 3A					
At confluence with Waiakea Tributary No. 3A	0.46	[1]	[1]	119	[1]

[1]Discharge not determined

Table 3: Summary of Discharges – continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
TRIBUTARY 1 TO WAIAKEA TRIBUTARY NO. 3B					
At confluence with Waiakea Tributary No. 3B	0.15	[1]	[1]	39	[1]
TRIBUTARY 2 TO WAIAKEA TRIBUTARY NO. 3B					
At confluence with Waiakea Tributary No. 3B	0.16	[1]	[1]	40	[1]
TRIBUTARY 1 TO WAIPAHOEHOE STREAM					
At 2,510 feet upstream of the confluence with Waipahoehoe Stream	0.10	[1]	[1]	376	[1]
TRIBUTARY TO MOHOULI STREET DRAINAGE					
At confluence with Mohouli Street Drainage	0.16	[1]	[1]	320	[1]
UNNAMED STREAM NO. 1					
Point 4 (at Mamalahoa Highway)	0.263	285	432	493	594
Point 5 (downstream confluence point with Unnamed Stream No. 2)	0.540	524	803	927	1,135
Point 6 (at confluence with Unnamed Stream No. 3)	2.452	1,726	3,409	3,900	4,774
Point 7 (at Hawaiian Farms Subdivision)	6.412	[1]	81	155	256
UNNAMED STREAM NO. 2					
Point 8 (upstream of confluence with Unnamed Stream No. 1)	0.260	235	351	411	511

[1]Discharge not determined

Table 3: Summary of Discharges – continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
UNNAMED STREAM NO. 3					
Point 9 (upstream of confluence with Unnamed No. 1)	0.760	371	745	884	1,136
UNNAMED TRIBUTARY TO ALEANIO STREAM	0.87	[1]	[1]	1, 450	[1]
UPPER LANIMAUMAU STREAM					
Point 1 (upstream of confluence with Lower Lanimaumau Stream)	0.767	668	1,455	1,623	1,902
Point 2 (at confluence with Lower Lanimaumau Stream)	0.816	685	1,510	1,687	1,907
WAIAHA DRAINAGEWAY					
At mouth	13.53	2,770	5,190	7,110	10,650
WAIAKEA STREAM					
1,000 feet upstream of Komohana Street	35.4	2,010	4,580	6,230	12,000
WAIAKEA TRIBUTARY NO. 1					
At confluence with	0.11	[1]	[1]	355	[1]
At Kawailani Street	0.01	[1]	[1]	150	[1]
WAIAKEA TRIBUTARY NO. 2					
At Kawailani Street	0.33	[1]	[1]	875	[1]
WAIAKEA TRIBUTARY NO. 3					
At confluence with	1.08	[1]	[1]	1650	[1]
At Kawailani Street	0.26	[1]	[1]	390	[1]

[1]Discharge not determined

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
WAIAKEA TRIBUTARY NO. 3A					
At confluence with Waiakea Tributary No. 3	13.43	[1]	[1]	3,440	[1]
At confluence with Tributary 1 to Waiakea Tributary No. 3A	11.24	[1]	[1]	2,881	[1]
At confluence with Tributary 2 to Waiakea Tributary No. 3A	11.08	[1]	[1]	2,840	[1]
At confluence with Tributary 3 to Waiakea Tributary No. 3A	10.93	[1]	[1]	2,792	[1]
At confluence with Tributary 4 to Waiakea Tributary No. 3A	10.65	[1]	[1]	2,720	[1]
WAIAKEA TRIBUTARY NO. 3B					
At confluence with Waiakea Tributary No. 3A	13.43	[1]	[1]	3,440	[1]
WAIKOLOA STREAM					
At downstream limit of detailed study	4.14	[1]	[1]	3,652	[1]
At Lindsay Road	3.50	[1]	[1]	4,500[2]	[1]
At upstream limit of detailed study	2.01	[1]	[1]	2,094	[1]

[1]Discharge not determined

[2]Discharge decreases in the downstream direction due to the presence of split/overland flow and the use of updated regression equations.

Table 3: Summary of Discharges - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
WAIKOLOA STREAM OVERLAND FLOW					
At divergence from Waikoloa Stream	*	[1]	[1]	375	[1]
WAIKOLOA STREAM SPLIT FLOW					
At divergence from Waikoloa Stream	*	[1]	[1]	936	[1]
WAIKOLOA STREAM TRIBUTARY					
At confluence with Waikoloa Stream	0.33	[1]	[1]	521	[1]

*Data Not Available
[1]Discharge not determined

Discharges were not available for the coastline, Four Mile Creek, Gulch 3–Hapuna, Holualoa Drainageway Tributary, Kamakoa Gulch, Keopu Drainageway Overflow, Keopu Drainageway Overflow Tributary, Palai Stream (Above Haihai Street), Waiaha Drainageway Tributary, Waiaha Splitflow No. 1, Waiaha Splitflow No. 2, Waiaha Splitflow No. 3, Waikoloa Stream Tributary, and Waipahoehoe Stream.

Coastal Analyses

For this FIS revision, 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 NOAA National Ocean Service (NOS) hydrographic surveys, collected from 1900 to 2005. The USACE Joint Airborne Light Detection and Ranging (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. All soundings were converted to the Local Mean Sea Level vertical 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 six islands of the state of Hawaii that are 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 conve
rted to meters. LiDAR elevations were delivered in the Local Mean Sea Level vertical datum; therefore no vertical datum conversion was necessary. LiDAR data can be acquired from the NOAA webpage.

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 4, “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 statute miles of at least two islands in the study area. Eleven hurricane and tropical storm events were selected for storm surge modeling. The storm surge model projected the potential range of tracks future storms may take by duplicating the eleven storm events and by shifting each storm event laterally by one radius to reach maximum wind speed. In total, 100 storms were generated for developing stillwater elevations within the study area using this method.

Table 4: Summary of Historical Storm Events Selected for
Development of Hurricane 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 Empirical Simulation Technique (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 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 the State of Hawaii, obtained using the ADCIRC and EST models, are summarized in Table 5, "Summary of Coastal Hurricane Stillwater Elevations." Locations of the surge stations are shown in Figure 3, "Stillwater Station Location Maps". Please note that the station numbers for surge stations do not coincide with transect numbers.

Table 5: Summary of Coastal Hurricane Stillwater Elevations

STATION	LONGITUDE	LATITUDE	ELEVATION (ft LOCAL MEAN SEA LEVEL)†			
	(NAD83)		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
1	-155.85248	20.27200	0.66	0.82	1.04	2.01
2	-155.88688	20.26360	0.66	0.82	1.03	1.97
3	-155.90655	20.22878	0.66	0.83	1.06	2.02
4	-155.90938	20.20287	0.66	0.83	1.05	1.96
5	-155.90364	20.17385	0.66	0.84	1.08	2.00
6	-155.89791	20.14010	0.66	0.83	1.04	1.95
7	-155.89102	20.11426	0.66	0.84	1.05	1.99
8	-155.88060	20.09153	0.66	0.85	1.07	2.04
9	-155.86884	20.07521	0.66	0.84	1.07	2.10
10	-155.85296	20.06297	0.66	0.84	1.08	2.16
11	-155.84087	20.04838	0.66	0.86	1.11	2.26
12	-155.82877	20.03450	0.66	0.88	1.16	2.43
13	-155.82566	20.02484	0.66	0.89	1.17	2.36
14	-155.82771	20.01109	0.66	0.86	1.10	2.27
15	-155.82847	19.99254	0.66	0.87	1.12	2.32
16	-155.83172	19.98848	0.66	0.84	1.08	2.23
17	-155.83107	19.98196	0.66	0.87	1.12	2.31
18	-155.83413	19.97511	0.66	0.89	1.15	2.44
19	-155.84317	19.97314	0.66	0.85	1.08	2.23
20	-155.85701	19.96532	0.66	0.84	1.05	2.12
21	-155.86685	19.95114	0.66	0.84	1.06	2.15
22	-155.87187	19.94517	0.66	0.86	1.09	2.26
23	-155.87929	19.94337	0.66	0.82	1.02	2.05
24	-155.87952	19.93606	0.66	0.85	1.07	2.22
25	-155.88895	19.93297	0.66	0.82	1.02	2.00

TABLE 5 - SUMMARY OF COASTAL HURRICANE STILLWATER ELEVATIONS

STATION	LONGITUDE (NAD83)	LATITUDE	ELEVATION (ft LOCAL MEAN SEA LEVEL) † 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
26	-155.89109	19.92753	0.66	0.82	1.03	2.04
27	-155.89341	19.92205	0.66	0.84	1.06	2.19
28	-155.88980	19.91521	0.66	0.88	1.14	2.45
29	-155.90201	19.90823	0.66	0.84	1.06	2.16
30	-155.90748	19.89853	0.66	0.82	1.03	1.93
31	-155.91020	19.88774	0.66	0.85	1.08	2.12
32	-155.91570	19.88115	0.66	0.84	1.07	2.12
33	-155.92278	19.87460	0.66	0.84	1.06	2.02
34	-155.92414	19.85833	0.66	0.88	1.16	2.39
35	-155.92785	19.85565	0.66	0.87	1.13	2.25
36	-155.93787	19.85183	0.66	0.86	1.11	2.23
37	-155.94887	19.85517	0.66	0.83	1.05	1.83
38	-155.96666	19.85355	0.66	0.83	1.05	1.84
39	-155.98065	19.84535	0.66	0.83	1.03	1.82
40	-155.98908	19.83358	0.66	0.84	1.06	1.92
41	-155.99797	19.82850	0.66	0.81	1.00	1.75
42	-156.00005	19.82195	0.66	0.85	1.06	1.94
43	-156.00744	19.81604	0.66	0.84	1.04	1.86
48	-156.03942	19.78499	0.66	0.82	1.02	1.84
49	-156.05015	19.77594	0.66	0.82	1.00	1.75
50	-156.05178	19.76564	0.66	0.83	1.01	1.80
51	-156.05304	19.75269	0.66	0.83	1.03	1.84
52	-156.05750	19.74694	0.66	0.82	1.00	1.77
53	-156.05680	19.73694	0.66	0.83	1.03	1.86
54	-156.06400	19.72927	0.66	0.82	1.00	1.76
55	-156.05324	19.71403	0.66	0.83	1.03	1.79
56	-156.05182	19.70382	0.66	0.83	1.01	1.74
57	-156.04703	19.69166	0.66	0.82	1.01	1.74
58	-156.03631	19.68675	0.66	0.83	1.04	1.85
59	-156.02936	19.67334	0.66	0.84	1.04	1.87
60	-156.03371	19.66662	0.66	0.82	1.02	1.84
61	-156.03412	19.65257	0.66	0.82	1.01	1.76
62	-156.02491	19.64467	0.66	0.82	1.02	1.76

TABLE 5 - SUMMARY OF COASTAL HURRICANE STILLWATER ELEVATIONS

STATION	LONGITUDE	LATITUDE	ELEVATION (ft LOCAL MEAN SEA LEVEL)†			
	(NAD83)		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
63	-156.01401	19.64268	0.66	0.83	1.03	1.76
64	-156.00081	19.63542	0.66	0.84	1.04	1.85
65	-155.99619	19.63722	0.66	0.85	1.07	1.99
66	-155.98735	19.62272	0.66	0.85	1.05	1.95
67	-155.98151	19.60872	0.66	0.83	1.03	1.86
68	-155.97469	19.59074	0.66	0.84	1.05	1.84
69	-155.97041	19.57948	0.66	0.84	1.05	1.89
70	-155.96897	19.56375	0.66	0.80	0.98	1.58
71	-155.96740	19.54986	0.66	0.82	1.01	1.73
72	-155.95962	19.54317	0.66	0.83	1.04	1.84
73	-155.95796	19.53338	0.66	0.83	1.03	1.84
74	-155.96273	19.51614	0.66	0.81	0.99	1.70
75	-155.95176	19.50012	0.66	0.82	1.02	1.79
76	-155.95134	19.48435	0.66	0.82	1.00	1.80
77	-155.93754	19.47700	0.66	0.82	1.01	1.85
78	-155.93101	19.48145	0.66	0.83	1.04	1.89
79	-155.92179	19.47330	0.66	0.83	1.03	1.94
80	-155.92944	19.45903	0.66	0.81	0.99	1.81
81	-155.92402	19.45190	0.66	0.83	1.02	1.94
82	-155.92268	19.44262	0.66	0.82	1.01	1.95
83	-155.92274	19.43275	0.66	0.82	1.01	1.96
84	-155.91426	19.42304	0.66	0.83	1.03	2.03
85	-155.90859	19.41127	0.66	0.83	1.03	2.05
86	-155.91174	19.40398	0.66	0.82	1.03	2.01
87	-155.90239	19.38053	0.66	0.81	1.01	2.07
88	-155.89968	19.37046	0.66	0.81	1.00	2.10
89	-155.88825	19.34589	0.66	0.82	1.03	2.21
90	-155.88614	19.33408	0.66	0.82	1.03	2.22
91	-155.89195	19.32189	0.66	0.80	1.00	2.16
92	-155.89031	19.31410	0.66	0.81	1.01	2.20
93	-155.89091	19.29284	0.66	0.82	1.03	2.21
94	-155.89848	19.26379	0.66	0.82	1.03	2.23
95	-155.90229	19.25175	0.66	0.81	1.01	2.18

TABLE 5 - SUMMARY OF COASTAL HURRICANE STILLWATER ELEVATIONS

STATION	LONGITUDE (NAD83)	LATITUDE	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
96	-155.90147	19.23790	0.66	0.82	1.03	2.22
97	-155.90344	19.20893	0.66	0.82	1.06	2.24
98	-155.91002	19.18788	0.66	0.82	1.05	2.19
99	-155.91295	19.17324	0.66	0.82	1.04	2.19
100	-155.92018	19.15517	0.66	0.81	1.02	2.15
101	-155.91817	19.14161	0.66	0.82	1.02	2.20
102	-155.91830	19.10765	0.66	0.82	1.03	2.23
103	-155.91161	19.07922	0.66	0.82	1.03	2.26
104	-155.89490	19.06380	0.66	0.82	1.02	2.28
105	-155.88447	19.04838	0.66	0.82	1.03	2.30
106	-155.87907	19.02956	0.66	0.81	1.03	2.32
107	-155.85841	19.01868	0.66	0.81	1.03	2.33
108	-155.80509	19.00575	0.66	0.81	1.01	2.14
109	-155.77461	18.98714	0.66	0.82	1.02	1.99
110	-155.74957	18.97105	0.66	0.81	1.00	1.94
111	-155.71898	18.95912	0.66	0.80	1.01	1.82
112	-155.69744	18.94340	0.66	0.81	1.02	1.85
113	-155.68613	18.93133	0.66	0.80	1.00	1.83
114	-155.68091	18.90780	0.66	0.79	0.99	1.86
115	-155.66759	18.91278	0.66	0.81	1.02	1.94
116	-155.63854	18.93447	0.66	0.80	1.00	1.80
117	-155.61770	18.96595	0.66	0.82	1.04	2.03
118	-155.60445	18.96482	0.66	0.80	1.00	1.94
119	-155.59537	18.97220	0.66	0.81	1.01	1.97
120	-155.58871	18.98601	0.66	0.81	1.00	1.98
121	-155.58057	19.00803	0.66	0.81	1.01	1.98
122	-155.55717	19.03477	0.66	0.81	1.00	2.10
123	-155.55058	19.06360	0.66	0.82	1.01	2.10
124	-155.53802	19.08481	0.66	0.82	1.02	2.23
125	-155.52437	19.11038	0.66	0.84	1.05	2.26
126	-155.50757	19.11852	0.66	0.82	0.99	2.08
127	-155.50228	19.13226	0.66	0.84	1.05	2.29
128	-155.47240	19.14105	0.66	0.82	1.02	2.18

TABLE 5 - SUMMARY OF COASTAL HURRICANE STILLWATER ELEVATIONS

STATION	LONGITUDE	LATITUDE	ELEVATION (ft LOCAL MEAN SEA LEVEL)†			
	(NAD83)		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
129	-155.44868	19.14749	0.66	0.81	0.99	2.10
130	-155.42833	19.16571	0.66	0.81	1.00	2.10
131	-155.39240	19.19240	0.66	0.83	1.04	2.13
132	-155.35193	19.20755	0.66	0.82	1.01	1.95
133	-155.32865	19.23454	0.66	0.82	1.02	2.01
134	-155.30358	19.25216	0.66	0.83	1.03	1.99
135	-155.28217	19.26353	0.66	0.83	1.03	1.92
136	-155.25337	19.26699	0.66	0.83	1.03	1.88
137	-155.21673	19.25686	0.66	0.83	1.02	1.82
138	-155.19361	19.25440	0.66	0.79	0.97	1.71
139	-155.16645	19.26017	0.66	0.82	1.03	1.88
140	-155.14529	19.26817	0.66	0.82	1.03	1.89
141	-155.11147	19.28335	0.66	0.82	1.02	1.94
142	-155.08128	19.30012	0.66	0.81	1.01	1.89
143	-155.05423	19.31468	0.66	0.81	1.02	2.04
144	-155.02147	19.32484	0.66	0.81	1.02	2.11
145	-154.97108	19.34676	0.66	0.81	1.02	2.18
146	-154.96504	19.35984	0.66	0.82	1.04	2.21
147	-154.94666	19.37139	0.66	0.81	1.01	2.25
148	-154.92800	19.39156	0.66	0.82	1.02	2.25
149	-154.90896	19.40305	0.66	0.81	1.01	2.15
150	-154.88929	19.41285	0.66	0.80	0.99	2.10
151	-154.86938	19.43079	0.66	0.82	1.02	2.18
152	-154.84000	19.45282	0.66	0.81	1.01	2.13
153	-154.82380	19.46741	0.66	0.81	1.01	2.07
154	-154.81216	19.49238	0.66	0.81	1.01	2.13
155	-154.81428	19.49929	0.66	0.82	1.05	2.19
156	-154.80632	19.52281	0.66	0.81	1.01	2.12

†These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami or hurricane wave hazards may dominate in certain areas. Please refer to the FIRM panels for regulatory elevations.

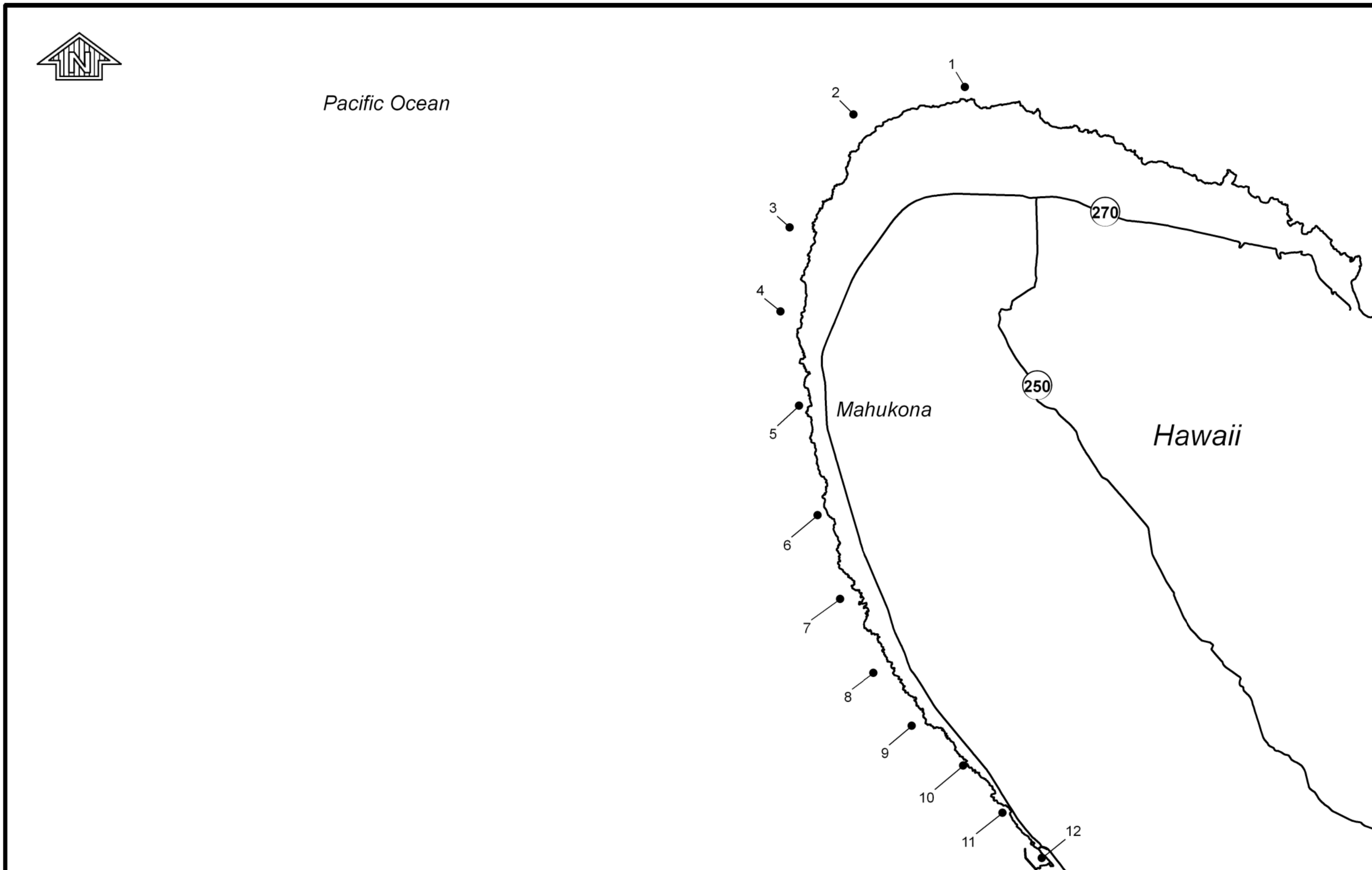


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 1

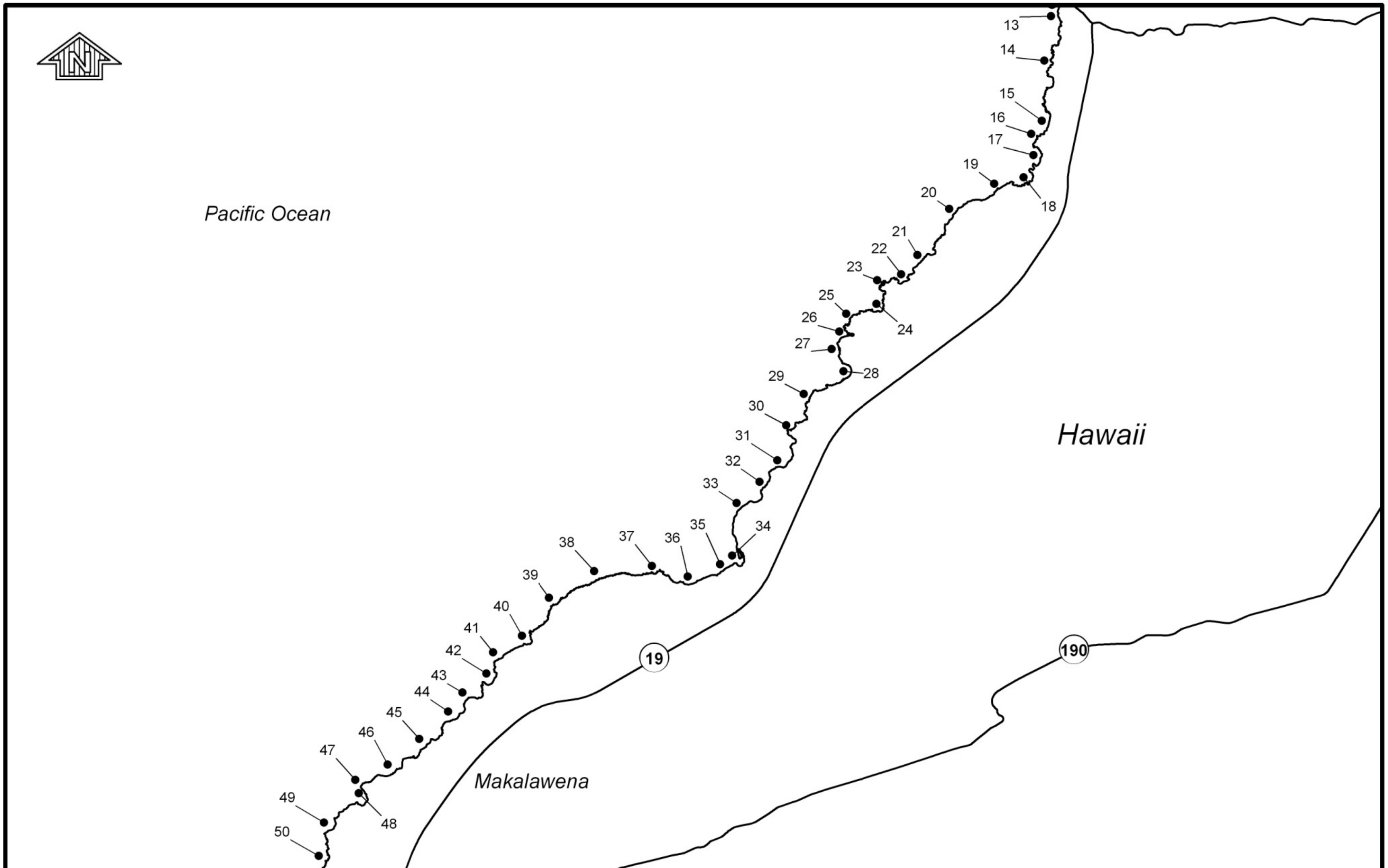


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 2

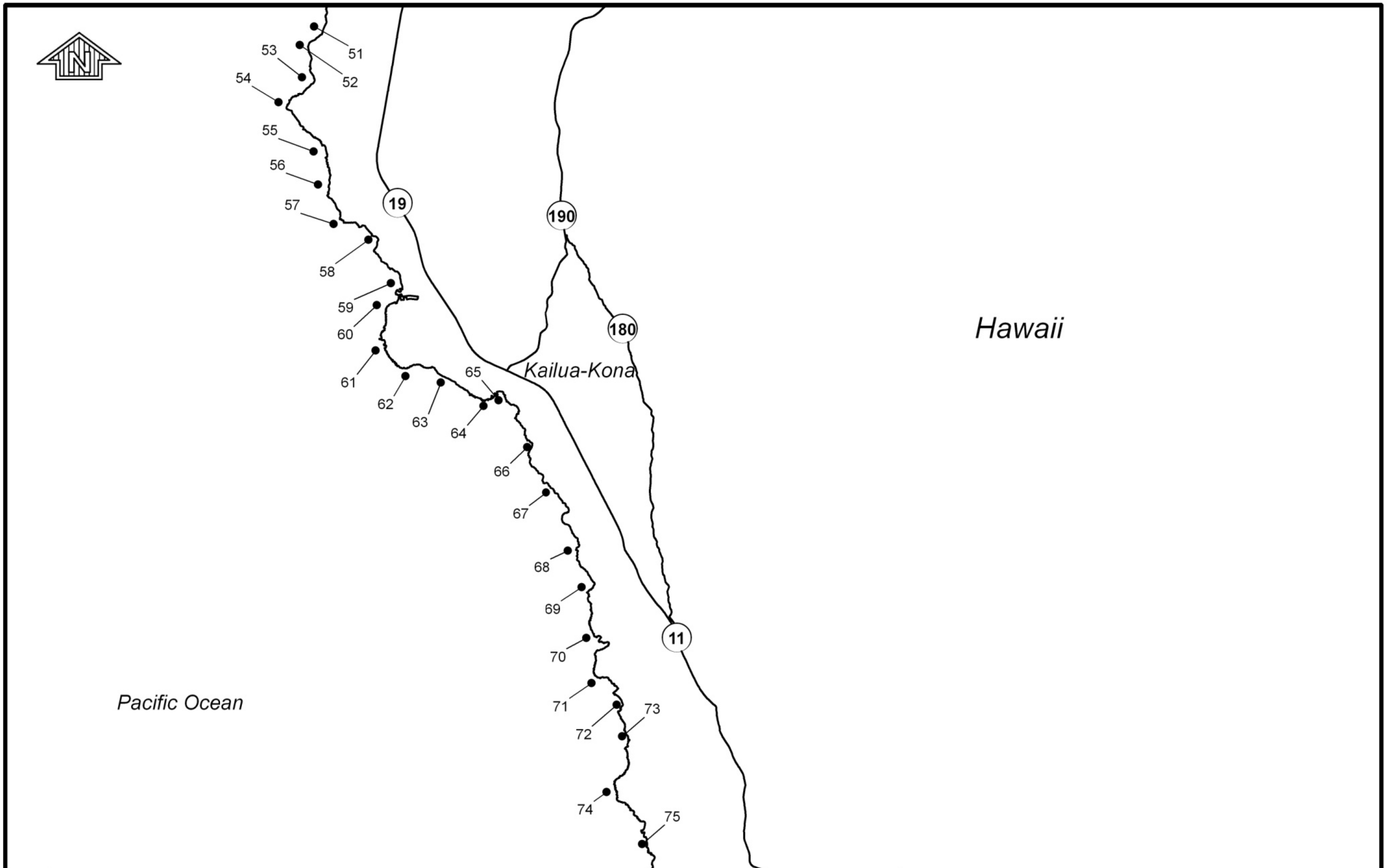


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 3

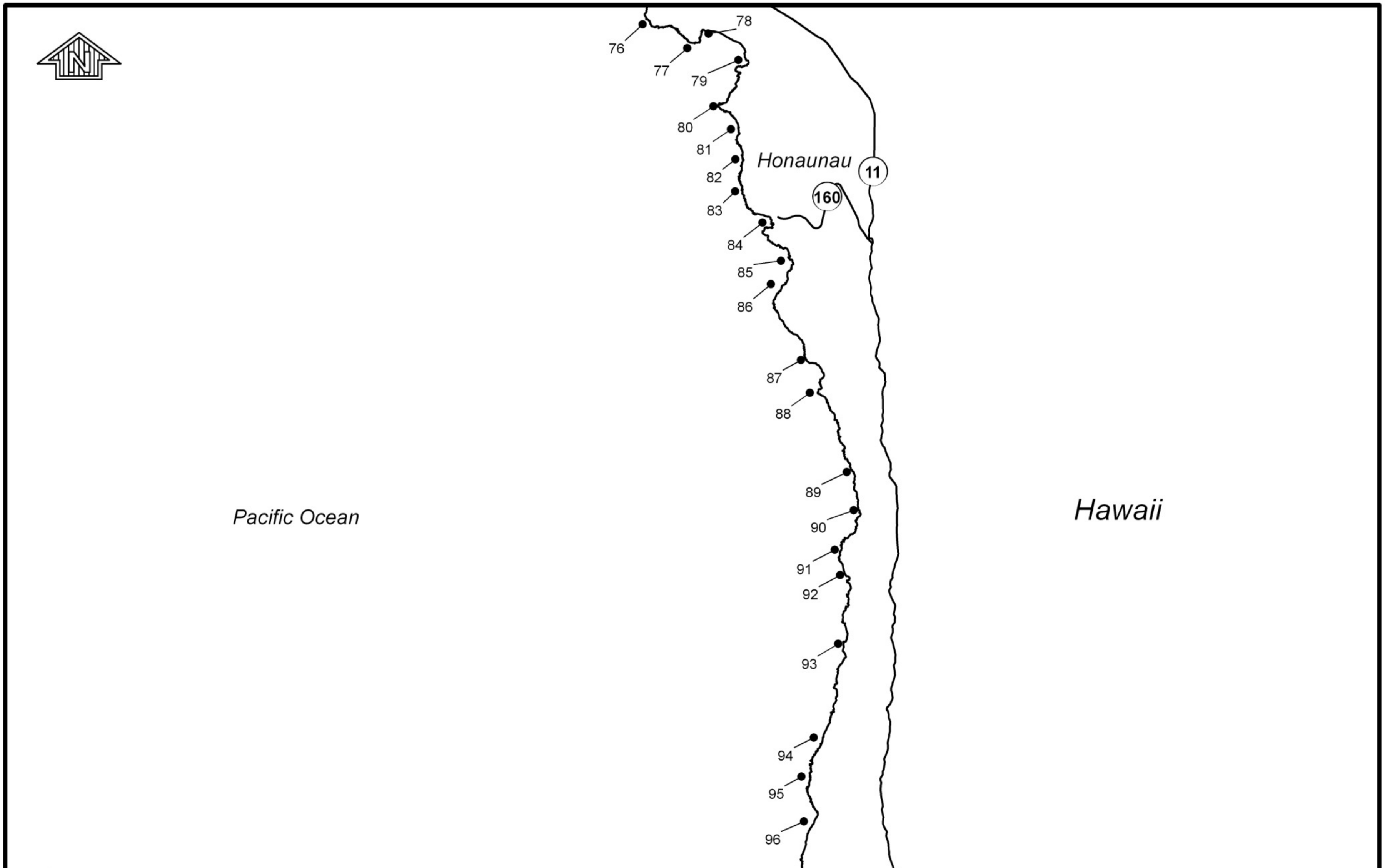


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 4

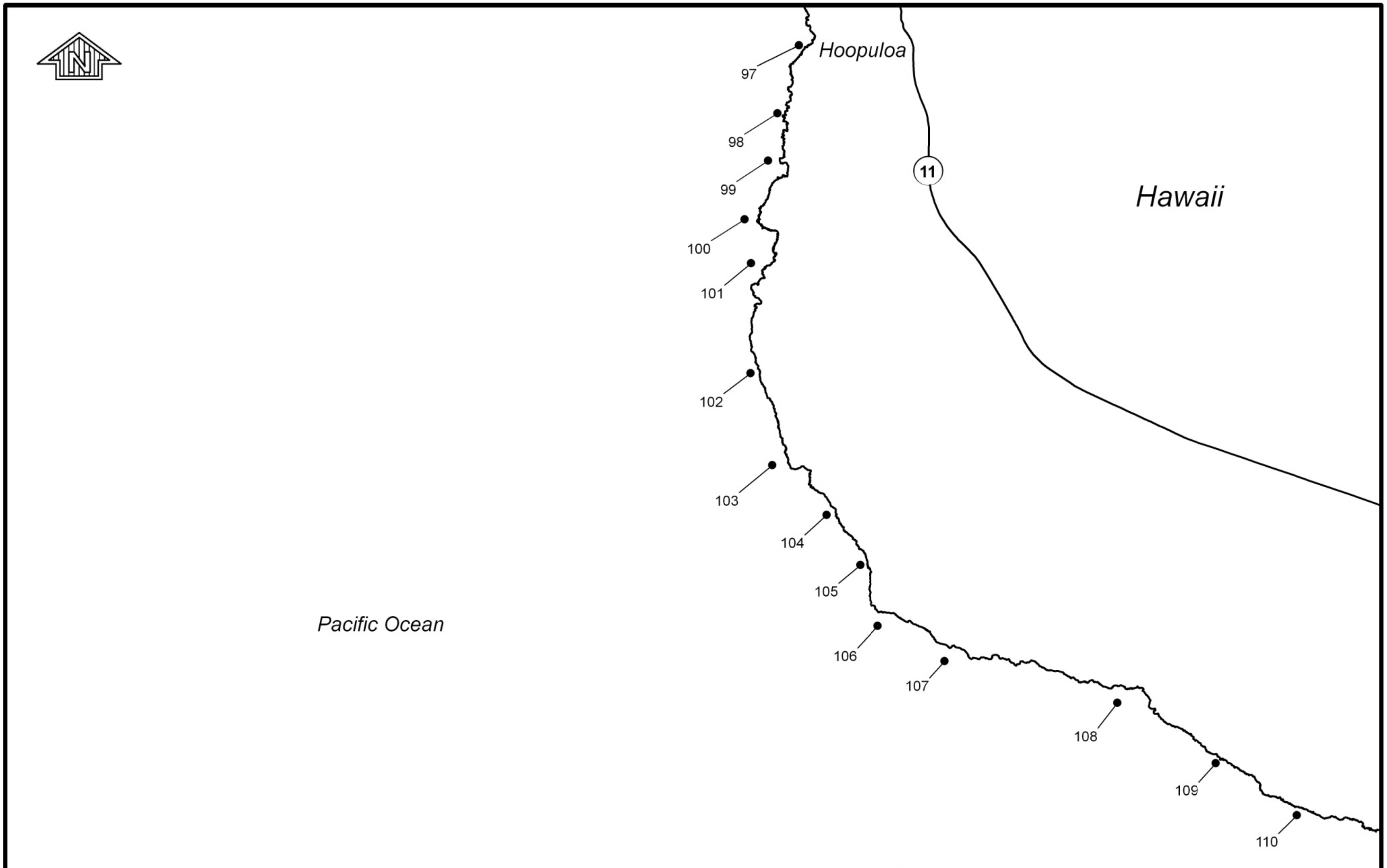


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 5

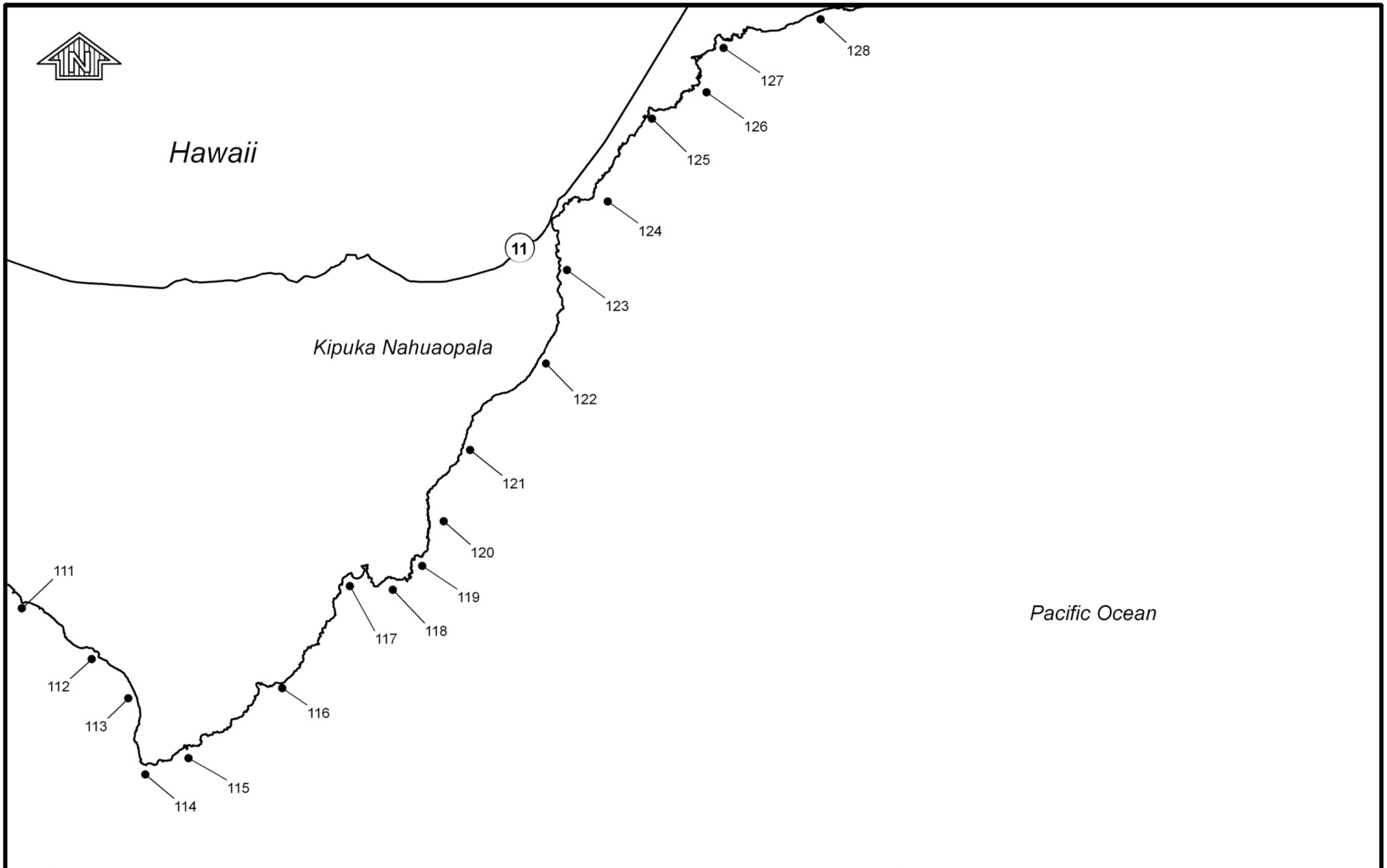


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 6

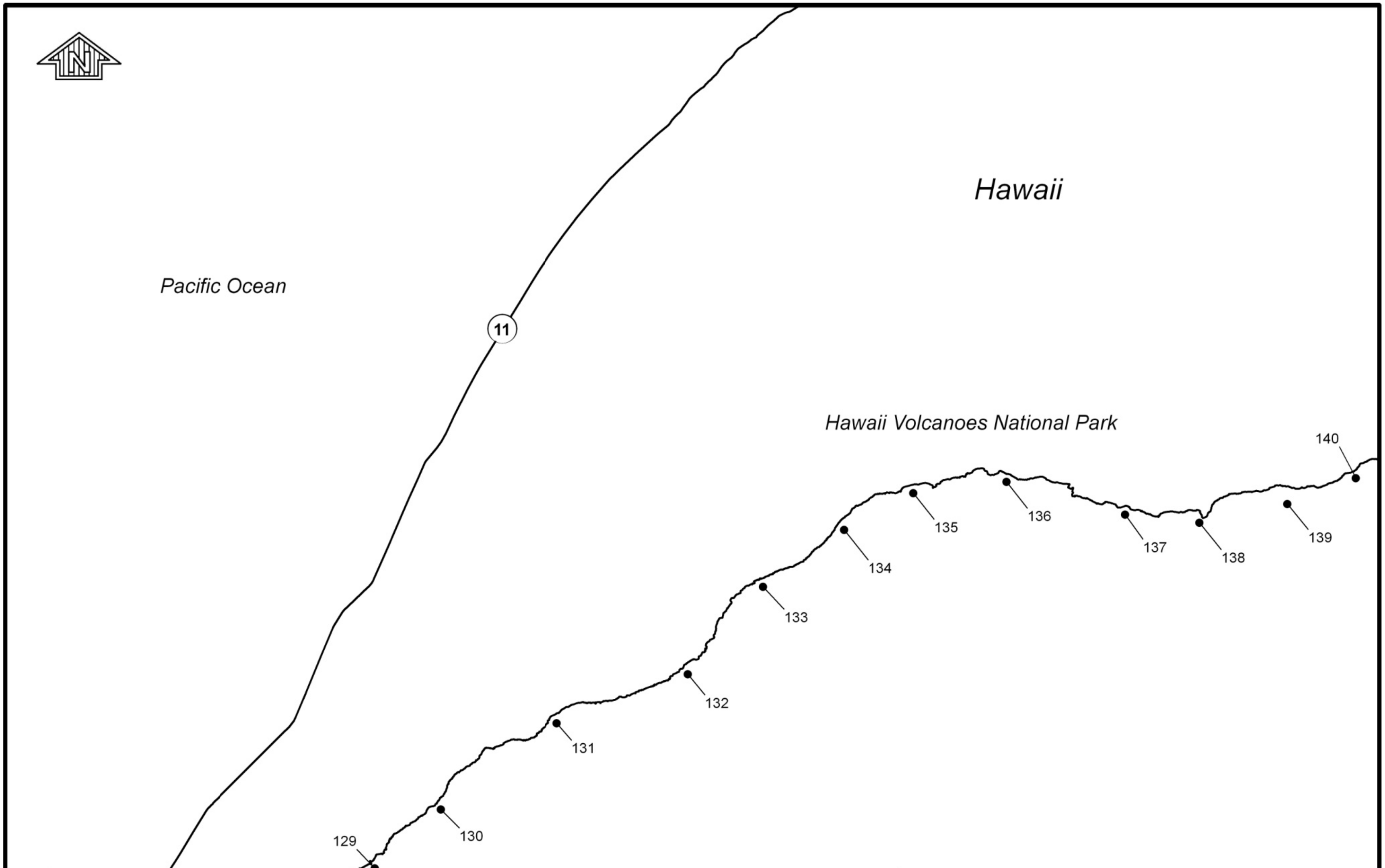


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 7

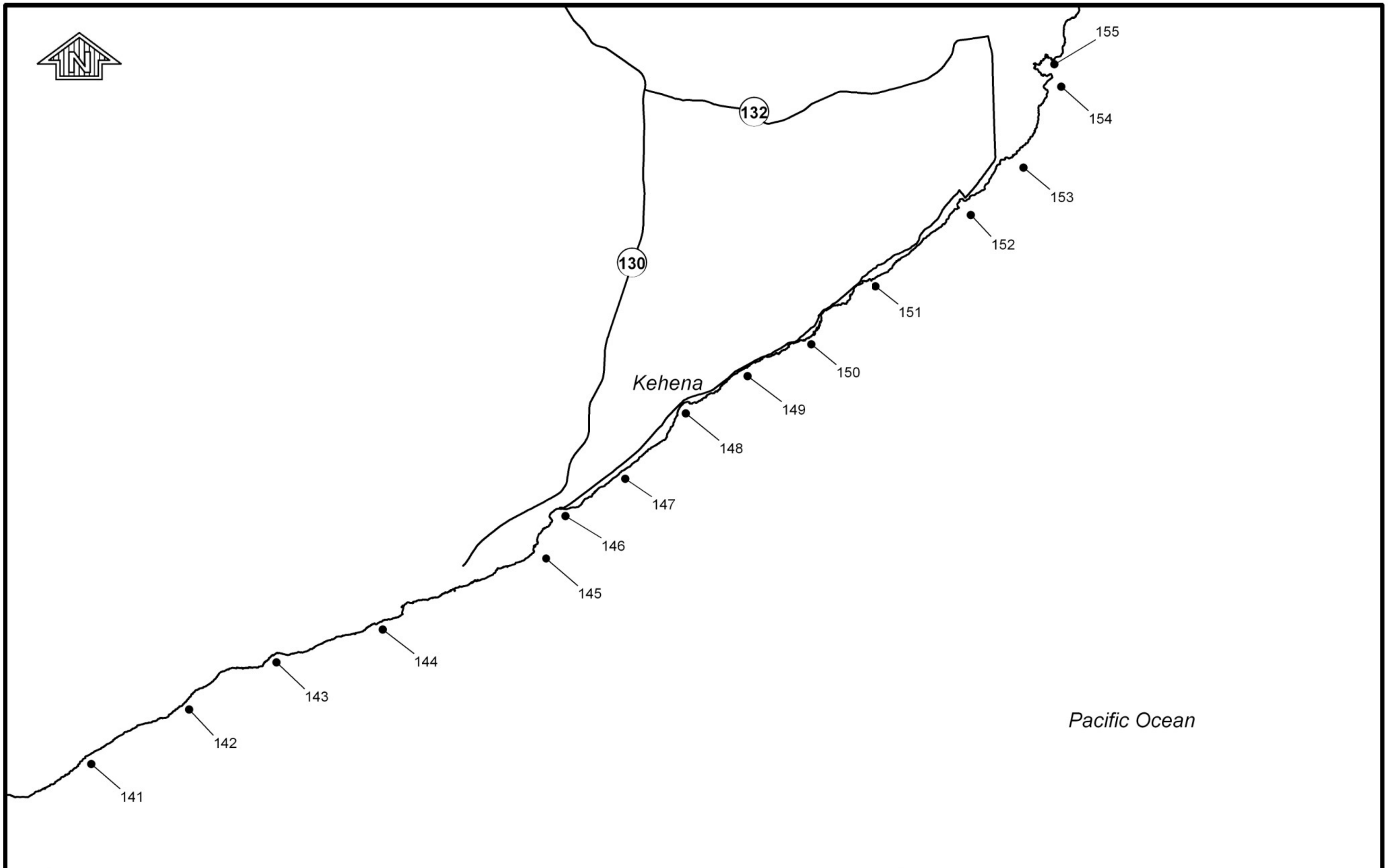


Figure 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 8

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.

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

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).

For the Map 3, 1982, original FIS and September 16, 1988, FIS revision, the hydraulic analyses for the North Kona streams studied by detailed methods were determined in the December 1984 North Kona Flood Plain Management study (U.S. Department of Agriculture, 1984).

Channel cross-section data taken from the topographic maps (R. M. Towill Corporation, 1977) and surveyed cross sections were compiled for input into the USACE HEC-2 water-surface profile computer program (USACE, 1973). Output data from this program were used to develop elevation-discharge and topwidth-discharge rating curves for each cross section. The elevation-discharge rating curves were used with the peak discharge information from the TR-20 output (U.S. Department of Agriculture, 1965) to obtain water-surface elevations at each cross section for the 10-, 2-, 1-, and 0.2-percent annual chance events. These elevations were adjusted to conform to known high-water marks from the February 1983 storm.

The hydraulic analyses for the South Kona streams studied by detailed methods were determined in the July 1977 South Kona Flood Hazard Analyses report (U.S. Department of Agriculture, 1977).

Several watercourses experience high channel losses as a result of seepage and natural storage. The natural storage is composed of both surface depressions and subsurface openings, such as lava tubes. Seepage losses are the result of porous lava formations beneath the streambeds. These losses, seepage and storage, were neglected in the computation of the water-surface profiles because of insufficient data for accurate estimates. Interviews with local people also indicated that the lava tubes and streambeds are being filled by an accumulation of debris and sediment.

Procedures used are described in Section 5 of the SCS National Engineering Handbook and Technical Release 61 (U.S. Department of Agriculture, undated; U.S. Department of Agriculture, 1976). Cross-section data taken from topographic maps (U.S. Department of Agriculture, October 1976) were plotted and compiled for input into the SCS Water-surface Profile Computer Program, or WSP2 (U.S. Department of Agriculture, 1976). The output data from the WSP2 computer program developed rating tables (elevation-discharge) for each cross section. These rating tables were used with the peak flow frequency information from the TR-20 program, which was used to obtain water-surface elevations at each cross section for the 10-, 2-, 1-, and 0.2-percent annual chance frequency flood events.

For the remaining streams studied by detailed methods, the USACE HEC-2 step-backwater program was used in the computation of water-surface elevations for selected recurrence intervals (USACE, 1973). Parameters for HEC-2, such as channel roughness coefficients, were obtained from field reconnaissance and photographs of individual detailed-study areas. An effort was made to utilize channel roughness coefficients established by the USGS for similar conditions by viewing stereo-photo records. Cross sections used in the backwater analyses were derived from both topographic maps furnished by the USACE and supplemental field-surveys. Information on bridges and culverts was obtained from the State of Hawaii Department of Transportation and verified by field inspections.

For most streams, the starting water-surface elevation was assumed at normal depth as a result of the relatively steep slopes that produce supercritical flow. Control sections such as bridges and culverts, which reduced channel slope, and other restrictions were analyzed for backwater profile effects.

For most of the remaining flooding sources, aerial survey maps at a scale of 1:4,800, contour intervals 10 feet, were provided by the USACE (USACE, 1977). For selected areas, maps at a scale of 1:2,400, with 5-foot contour intervals, were available (USACE, January 1977). Maps for portions of the coastline of Hawaii County were developed from USGS topographic maps, at a scale of 1:24,000 enlarged to 1:12,000, contour interval 20 feet (U.S. Department of the Interior, 1959, et cetera). For portions of the Hilo area, aerial survey maps at a scale of 1:1,200 were used (USACE, 1977).

The following is a description of the sources and sources of data used in the detailed studies of the watercourses:

<u>SOUTH KOHALA AREA</u>

Along the Kawaihae to Kalilua-Kona coast of Hawaii, the hydraulic bases for Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch, and Auwaiakeakua Gulch were obtained from field surveys that supplemented topographic maps furnished by the USACE (USACE, 1977). Roughness factors were based on field observations.

In the Waimea study area, the hydraulic computations for the Lanimaumau Stream were based on topographic information furnished by the USACE and on field surveys for cross-sectional and roughness factors. The Puukapu Watershed Plan of the SCS (U.S. Department of Agriculture, 1961) provided data on the Paiakuli diversion channel. Channel improvements for Kuhio Village II (R. M. Towill Corporation, September 1977) were also incorporated.

<u>SOUTH HILO AREA</u>

The bases for the Waiakea Stream 2002 revised study was the effective models. The downstream detailed study of Hilo's Waiakea Stream was based on data from several sources. After field verification of the cross-sectional data, the as-built ground data from construction plans of the Wailoa Stream and Tributaries Flood-Control Project completed in 1965 (USACE, 1965) were adopted for study usage. These plans, along with the Lanikaula Street Extension plans (Hawaii County, 1967), field determination of roughness coefficients, hydrologic data, and topographic maps provided by the USACE, formed the basis for the Waiakea Stream study.

The upstream detailed study of Waiakea Stream was based on data obtained from several sources. Plans of the Waiakea Stream improvements between Golden Shower Tree Estates and Kawailani Street bridge (County of Hawaii, 1983) were utilized. These flood-control measures have been recently constructed. The Waiakea Stream improvements between Kawailani and Komohana bridges (County of Hawaii, 1976) were incorporated into the study. Flood protection systems located at Kupulau Road (County of Hawaii, 1976), Lehua Heights Subdivision (Imata and Associates, Inc., undated), and Golden Shower Tree Estates (Imata and Associates, Inc., 1982) were also adopted for use. The plans, along with field investigations, hydrologic data, and topographic maps provided by the USACE (USACE, 1984, et cetera), were the basis of data used on Waiakea Stream.

For the revision, several independent models were created to represent sub-critical and super-critical flow conditions along the Upper Reach. The majority of the Lower Reach is super-critical. A sub-critical portion of stream exists near the bridge at the intersection of Kinoole and Mohouli Streets, however. The upper and lower reaches overlap between river stations 7,500-7,800. The modeling from the upper reach was used in this area to provide a smooth transition. Two split flow situations occur along the upper reach of Waiakea Stream: near Kawailani Street and between stream stations 17,460 and 17,700. These two areas were modeled in HEC-2 (USACE, 1973).

The 2002 revised Waiakea Tributary No.1, Waiakea Tributary No.2, and Waiakea Tributary No. 3 studies utilized the effective USACE HEC-2 models (USACE 1973). Tributary No. 1 was updated based on as built information. Tributary No. 2 was modified to accommodate breakout flow from Waiakea Stream. Also, a split flow model was developed to estimate breakout flows in the vicinity of Komomala Drive.

For Alenaio Stream, field surveys were conducted to obtain data on bridge geometry, roughness coefficients, and cross-section data. Field data were supplemented with data from prior reports, including Hilo Drainage and Flood Control by Wilson, Okamoto & Associates (Wilson, Okamoto and Associates, Inc., 1967) and Alenaio Stream Flood-Control Improvements, Plan and Profiles, by Neighbor Island Consultants (Neighbor Island Consultants, undated). Additional topographic maps and information were obtained from the USACE (USACE, 1977).

For Palai Stream and tributaries, data on bridge geometry, roughness coefficients and cross-section characteristics were obtained through field surveys. The Flood Plain Management Planning Assistance Report for Palai Stream and Four Mile Creek, prepared by the USACE in 1981 (USACE, 1981) was used to supplement field data. Plans for the widening of Palai Street bridges (County of Hawaii, June 1983) were also incorporated in the study. The topographic maps used in the study were furnished by the USACE (USACE, 1984, etcetera).

For the 2002 study, Palai Stream and Palai Stream A were studied using HEC-2 (USACE, 1973). The starting water surface elevations for Palai Stream were taken from the effective study. The starting water surface elevation for Palai Split Flow was based on the water surface elevation where split flow occurs. Water surface elevations for Palai Stream C were determined using the Haestad FlowMaster Software.

Cross sections used in the backwater analyses of Four Mile Creek and tributaries were derived from USACE topographic maps (USACE, 1984, et cetera) and field surveys. Bridge and culvert information was obtained through field investigation.

KAU AREA

In computing the flood hazards for the Honokaa town area, the detailed study was based on channel roughness factors determined by field inspections and on basic topographic maps provided by the USACE (USACE, 1977), supplemented by field-surveyed cross sections.

HAMAKUA AREA

In computing the flood hazards for the Honokaa town area, the detailed study was based on basic topographic maps (USACE, 1980), as well as field inspections. In order to supplement these data sources, plans from the Honokaa-Paahau (State of Hawaii, 1952) and Honokaa Park developments (County of Hawaii, 1974) were used.

NORTH KONA AREA

Locations of the major drainageways studied by detailed methods in North Kona were determined from topographic maps (R. M. Towill Corporation, 1977), field inspections, information from local residents at several public meetings, and a helicopter survey of the damaged area just after the storm in February 1982. A total of seven drainageways were identified as having definite flow patterns and potential for causing the most damage.

SOUTH KONA AREA

Locations of the watercourses studied by detailed methods in South Kona were determined from the 5-foot and 10-foot contour interval maps (U.S. Department of Agriculture, October 1976), stereoscopic delineation from aerial photographs, field inspections, and USGS topographic quadrangle maps. The contributing drainage areas were delineated and measured from the USGS 7.5-minute quadrangle maps (U.S. Department of the Interior, 1959, et cetera).

The 10-, 2-, and 0.2-percent annual chance floods were not completed for the following streams. Therefore, only 1-percent annual chance elevations are shown on the profiles:

Four Mile Creek (shallow flooding area)
Four Mile Creek Tributary No. 3
Honokaa Drainages 1 through 3, and A through D
Palai Stream (Above Haihai Street)
Palai Stream Tributaries A through F
Waiakea Tributaries No. 1, 2, and 3

Approximate flooding in some parts of the North Kona and South Kona areas was taken from the December 1984 North Kona Flood Plain Management study (U.S. Department of Agriculture, 1984) and the July 1977 South Kona Flood Hazard report (U.S. Department of Agriculture, 1977).

Plans from the Waimea Road improvements (County of Hawaii, 1969), the Kuhio Village Roads construction (Kuhio Village Roads Construction Plans, undated), and the Hawaii Belt road (State of Hawaii, 1952) were adopted for use in the study.

For the remaining approximate analyses, a computerized normal depth routine was implemented to establish the 1-percent annual chance water-surface elevations. Cross-section data for approximate study areas were derived directly from aerial topographic survey maps, with channel roughness factors (Manning's "n") selected on the basis of field investigations (U.S. Department of the Interior, 1967).

For the May 16, 1994, FIS revision, analyses conducted for this study mostly used the hydraulics computed and prepared by the SCS for its North Kona Flood Management Study that was adopted for the previous FIS. These models used the USACE HEC-2 step-backwater computer program (USACE, 1973). The models were also based on orthophotographic maps with contour intervals of 5 feet below an elevation of 250 feet and 10 feet above an elevation of 250 feet (U.S. Department of Agriculture, 1984). The channel and overbank roughness values as selected by the SCS ranged from 0.05 to 0.20. Because of relatively steep channel slopes, starting water-surface elevations were assumed at normal depth. In order to perform the floodway analyses, it was necessary that the original HEC-2 models be adjusted so that the model analyses results reasonably matched the adopted 1-percent annual chance profiles. The adjustment consisted of modifying channel roughness values and adding or modifying cross sections and bridge modeling data.

Floodway determinations were prepared using the adjusted SCS HEC-2 models for the six streams studied. The criteria for determining the floodway widths were as follows:

Maximum rise in water-surface elevation – 1.0 foot

Maximum rise in energy gradeline for supercritical stream reaches – 1.0 foot

Maximum fringe or overbank flow velocity – 10 feet per second (cfs)

Maximum channel flow capacity
Kaumalumalu Drainageway – 10 fps
All other drainageways – 15 fps

The velocity limitations for the channel are based on County of Hawaii criteria and soil conditions as defined in the Soil Survey of Island of Hawaii, State of Hawaii (U.S. Department of Agriculture, 1973). According to this soil survey, the soils through which all streams pass, except the Kaumalumalu Drainageway, are underlain by Pahoehoe lava bedrock. According to the County of Hawaii, this lava material has high erosion resistance, while velocities of up to 15 fps are used for channel designs. The soils through which the Kaumalumalu Drainageway passes are underlain by fragmental "Aa" lava for which a velocity limitation of 10 feet per second has been adopted.

The revision along Waikoloa Stream was based on better topographic information and improved hydraulic modeling. The revised hydraulic analysis was performed using the USACE HEC-2 step-backwater computer program. According to the revised analysis, base flood elevations have increased for a reach of approximately 600 feet downstream of Lindsey Road. As a result of increased base flood elevations and better topographic data, the 1-percent annual chance floodplain has increased in some areas, most significantly on the north overbank of Waikoloa Stream. In addition, areas of 1-percent annual chance shallow flooding, which are the result of breakout on both the south and north overbanks, have been defined. These areas have average depths of less than 0.5 foot, and are therefore shown as Zone X on FIRM Panel 0168. A topographic map produced by ETC at a scale of 1:360, with a contour interval of 2 feet, was utilized to delineate the new 1-percent annual chance floodplain boundaries.

Flood Profile Panel 376 for Waikoloa Stream was revised to reflect the effects of the hydraulic analysis.

For the April 2, 2004, FIS revision, cross sections were derived from 1997 orthophotography at a scale of 1"=200', with 4-foot contours, and field surveys. Roughness coefficients were determined from field inspection and ranged from 0.04 to 0.08. No stream gages are present; thus, regional regression equations from a recent USACE hydrologic study of Alenaio Stream were used to determine discharges (USACE, 1990).

Furthermore, the USACE hydraulic program, HEC-RAS, was used to conduct the hydraulic analysis. Water surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods were obtained as the results of the hydraulics analysis.

Geometry data was extracted from the LiDAR-derived TIN using HEC-GeoRAS and imported to HEC-RAS. Peak discharges at the discharge change locations in the HEC-RAS flow file came from the discharges computed at the downstream locations in the hydrologic analysis (HEC-HMS output). Starting flow boundary conditions were obtained from estimating channel bed slope at downstream cross sections and input as normal depth in HEC-RAS.

The 1- and 0.2-percent annual chance floodplain boundaries and floodway boundary were delineated using HEC-GeoRAS based on the HEC-RAS outputs. The floodplain boundary was smoothed using GIS tools and manually adjusted by engineering judgment where HEC-RAS data did not provide sufficient and reasonable results. The floodway analysis was performed for upper Lanimaumau Stream up to the entrance of the NRCS diversion channel, Unnamed Stream 1, Kamuela Stream and lower Lanimaumau Stream to its downstream diversion. The floodway was computed based on the equal conveyance reduction from each overbank areas. The floodway data at the selected cross sections was shown in the Floodway Data Table. All the streams were modeled under subcritical flow regime except the NRCS diversion channel. The channel was concrete-lined and was modeled as supercritical flow regime.

Manning's roughness coefficients assigned in the hydraulic analysis were based on the engineering judgment. General guideline followed the methodology specified in "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains" (USGS Water-Supply Paper 2339). The coefficients were also supplemented by the field observations, field photographs, and aerial imagery. The Manning's n for the channel ranges from 0.013 to 0.07 and the Manning's n for overbank areas ranges from 0.052 to 0.0 75. The lower value of Manning's n (0.013) was used for concrete materials observed in the NRCS diversion channel, baffled chute structure, and drop structure.

For this FIS revision, BakerAECOM performed a quality assurance and quality check on a hydraulic analysis. The United States Army Corps of Engineer's (USACE) hydraulic program, HEC-RAS (version 4.1), was used to conduct the hydraulic analysis. Water surface profiles for the 10-year, 25-year, 50-year, 100-year, and 500-year floods were obtained as the results of the hydraulics analysis.

Geometry data was extracted from the LiDAR-derived TIN using HEC-GeoRAS and imported to HEC-RAS. Peak discharges at the discharge change locations in the HEC-RAS flow file came from the discharges computed at the downstream locations in the hydrologic analysis (HEC-HMS output). Starting flow boundary conditions were obtained from estimating channel bed slope at downstream cross sections and input as normal depth in HEC-RAS or using known water surface elevations at the vicinity of the confluence point of two watercourses. Split flow analysis was performed to determine the amount of flow that overflows to other watercourses or exit main system.

The 100-year and 500-year floodplain boundaries and floodway boundary were delineated using HEC-GeoRAS based on the HEC-RAS outputs. The floodplain boundary was smoothed using GIS tools and manually adjusted by engineering judgment where HEC-RAS data did not provide sufficient and reasonable results. The floodway was computed based on the equal conveyance reduction from each overbank areas. The final results were converted to Method 1, where left and right encroachment stations were specified for each cross section. The floodway data at the selected cross sections was shown in the Floodway Data Table. All the watercourses were modeled under subcritical flow regime.

Manning's roughness coefficients assigned in the hydraulic analysis were based on the engineering judgment and field investigation. General guideline followed the methodology specified in "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains" (United States Geological Survey Water-Supply Paper 2339). The coefficients were also supplemented by field photographs and aerial imagery. The Manning's n for the channel ranges from 0.015 to 0.065 and the Manning's n for overbank areas ranges from 0.015 to 0.065. The lower value of Manning's n (0.015) was used for concrete and asphalt materials.

Coastal Hydraulic Analysis

Tsunami

For the entire shoreline of Hawaii County, all of which was studied by detailed methods, tsunami wave elevations were determined utilizing a length of record of 138 years (1837-1975). A hybrid finite element numerical model was developed to supplement historical data in determining the 10 largest tsunami elevations from 1837 to 1975. The finite element model provides an accurate, representative response of the island to tsunami activity, as a result of rapid bathymetric and/or wave height variations. The numerical model was adjusted and verified by comparing numerical calculations with tide gage recordings of tsunamis that occurred in 1960 and 1964. Tsunami elevations 200 feet inland from the shoreline for Hawaii County were determined using the USACE report prepared by the U.S. Army Waterways Experiment Station in conjunction with Japanese Tsunamis in Hawaii – A Preliminary Report, By D. C. Cox (USACE, August 1977; D. C. Cox, 1980).

Tsunami elevations, as the wave travels inland, and the maximum inundation limits were determined utilizing a study entitled Tsunami Inundation Prediction (C. L. Bretschneider, 1976). Runup elevations and inundation limits are dependent upon initial tsunami elevations, ground elevation 200 feet inland, roughness factors (Manning's "n"), terrain slope, and Froude's Number (F=1 for non-bore; F=2 for bore information).

For this FIS revision, the Hawaii County coast subject to tsunami inundation was redelineated using new topographic data. The 1% annual chance tsunami coastline profiles providing the starting tsunami flood elevations (referenced to Local Mean Sea Level) at the shoreline are included in Exhibit 2 – Tsunami Coastline Profile. The same methodology for determination of the tsunami bore propagation and inland inundation limits previously used for FIS revision were also applied for this revision.

Hurricane

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 4, "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 4 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.

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 condition 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.

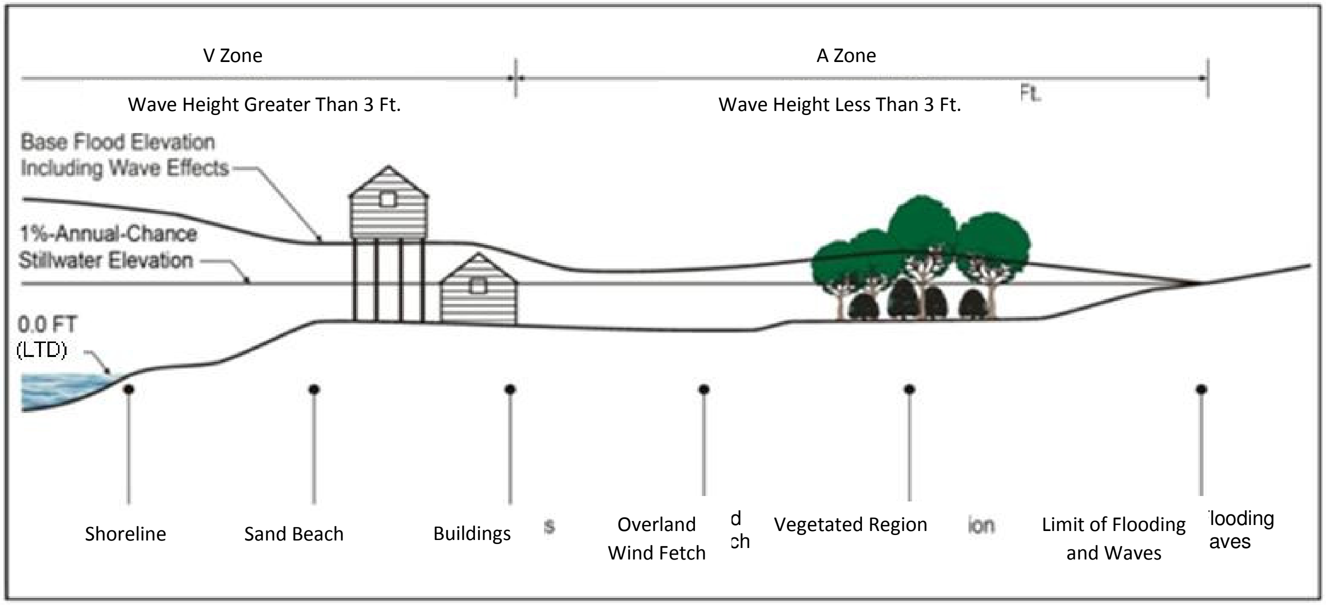


Figure 4: Transect Schematic

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 or mean low water 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 Mean Low Water (MLW) to Mean Lower Low Water (MLLW), and 0.8 m increase in depth from MLLW to Mean Sea Level (MSL)). The USACE Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) provided bathymetric LiDAR for the six 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 MSL and merged with the NOAA dataset. The USACE Honolulu District provided a 2004 hydrographic survey of Honolulu Harbor. Depths were adjusted from MLLW to MSL 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 MSL 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 of the state of Hawaii that were 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 the MSL datum, and later shown as Local Mean Sea Level.

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-percent annual chance 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 5, "Transect Location Maps," illustrates the location of each transect. 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 local topography, vegetation, or cultural development within the community undergoes major changes. The transect data for the Island of Hawaii is presented in Table 6, "Transect Descriptions," which describes the location of each transect. In addition, Table 6, "Transect Descriptions," 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. It should be noted that the data in Tables 5 and 6 reflect only the hurricane storm surge hazard and do not include tsunami elevations.

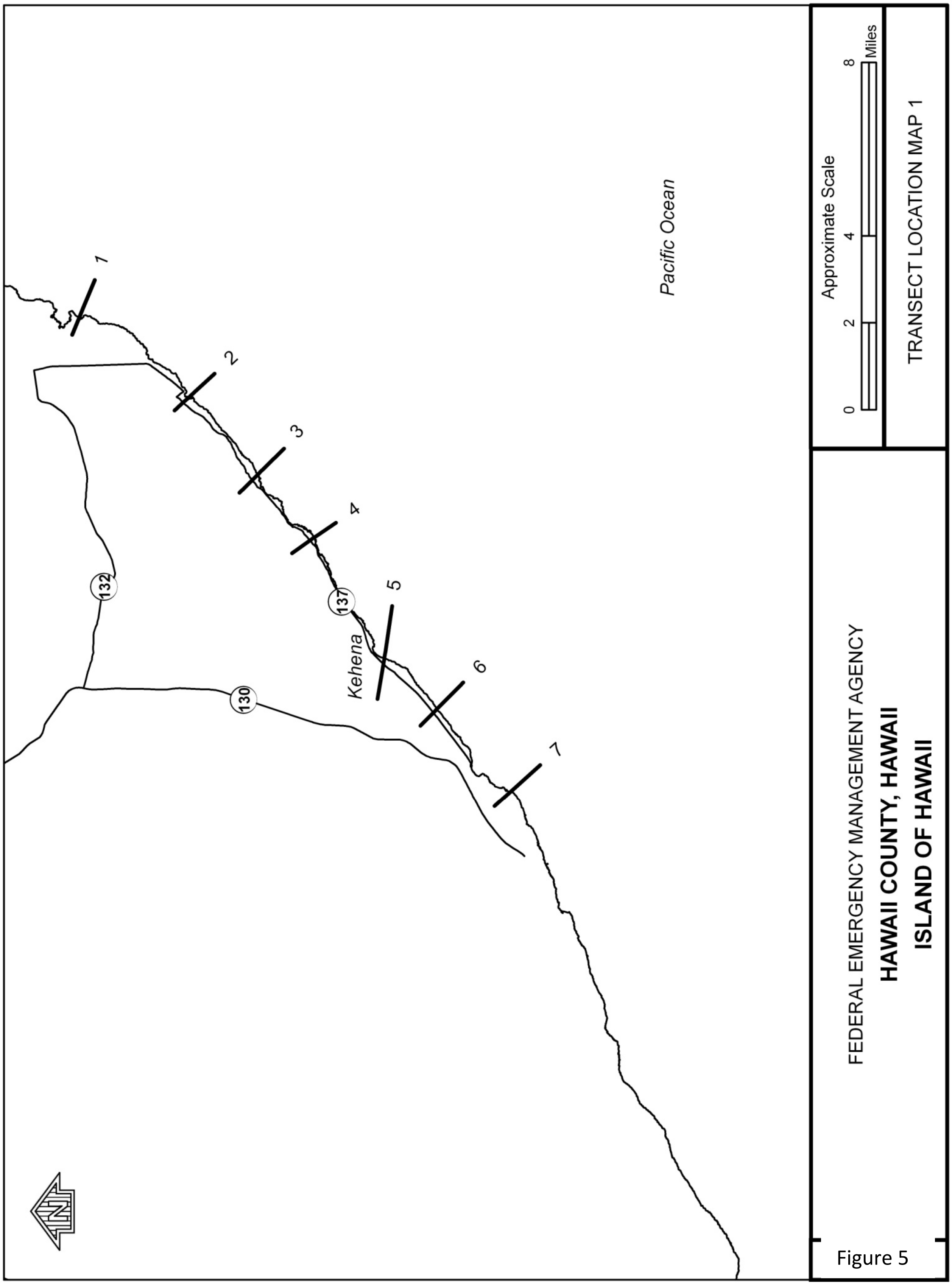
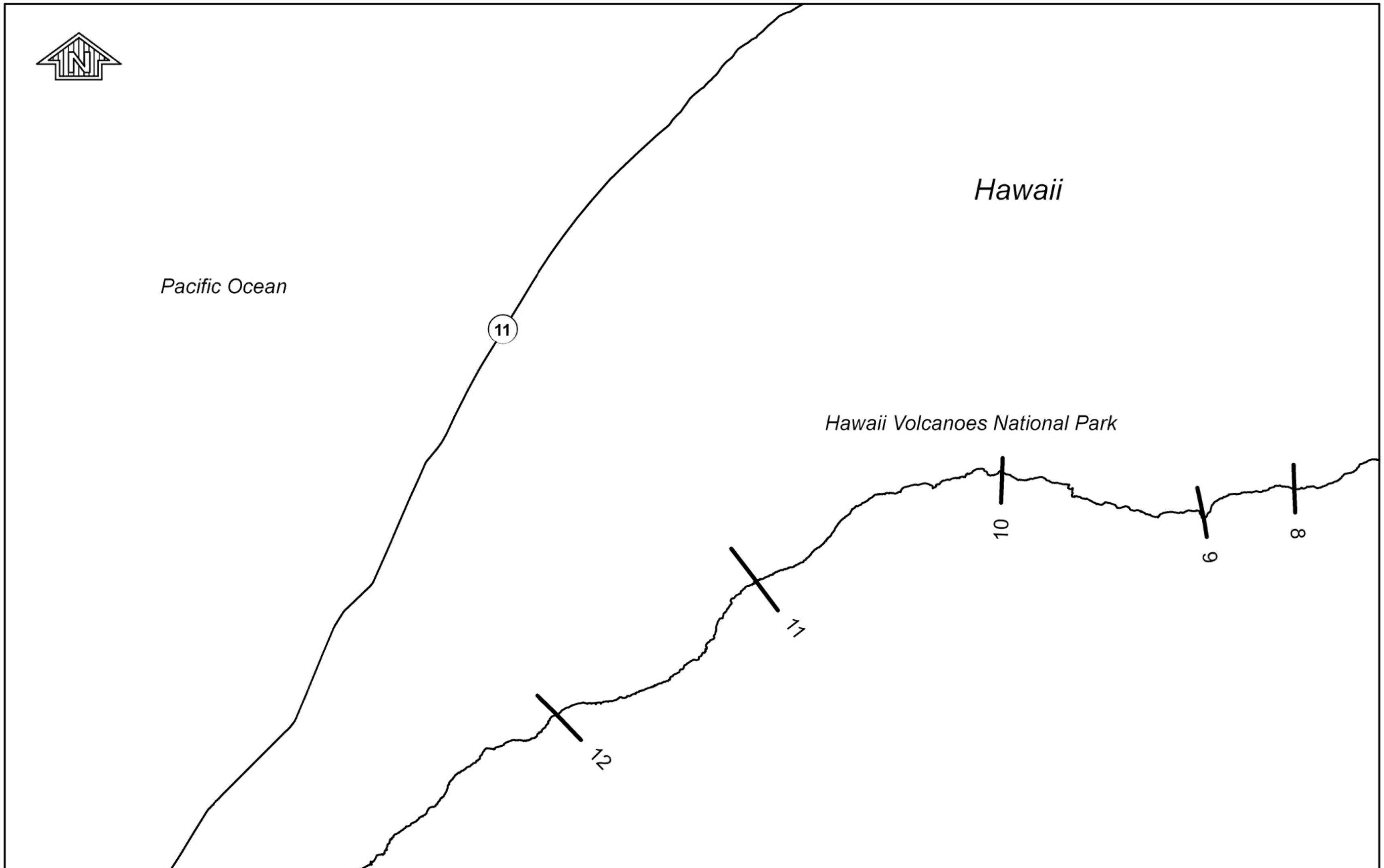


Figure 5: Transect Location Maps



Approximate Scale

0 2 4 8 Miles

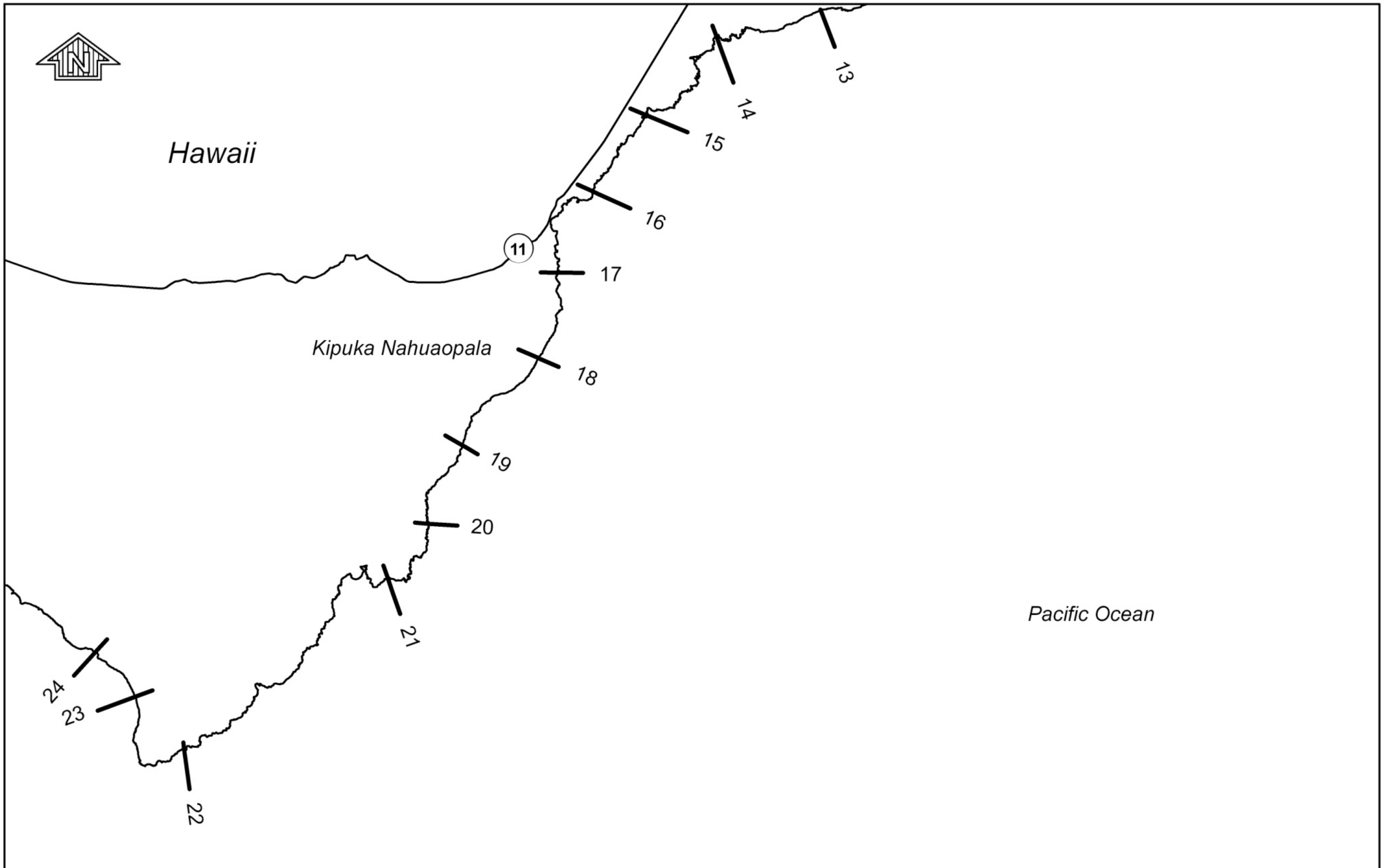
TRANSECT LOCATION MAP 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Figure 5



FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

TRANSECT LOCATION MAP 3

Figure 5

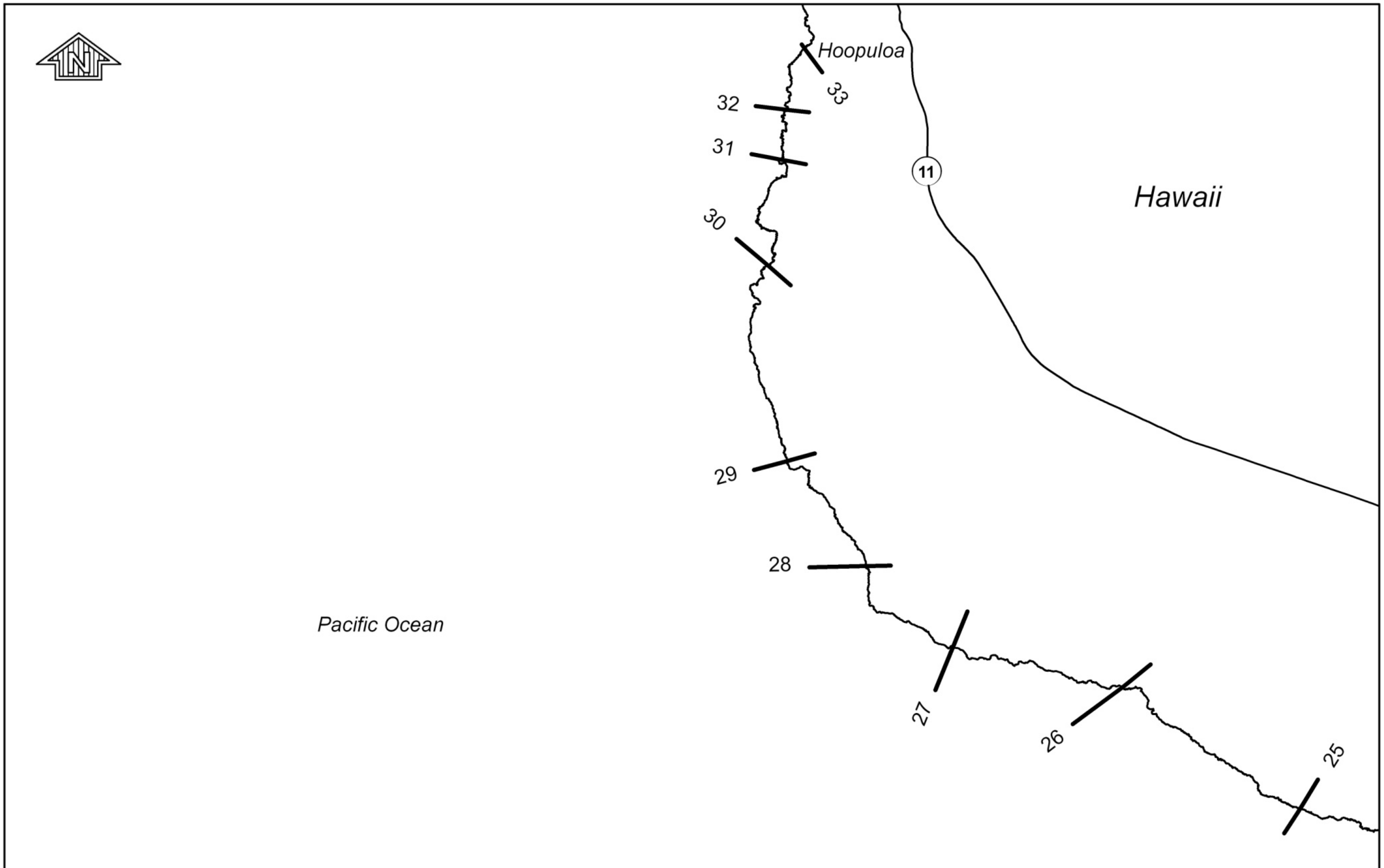


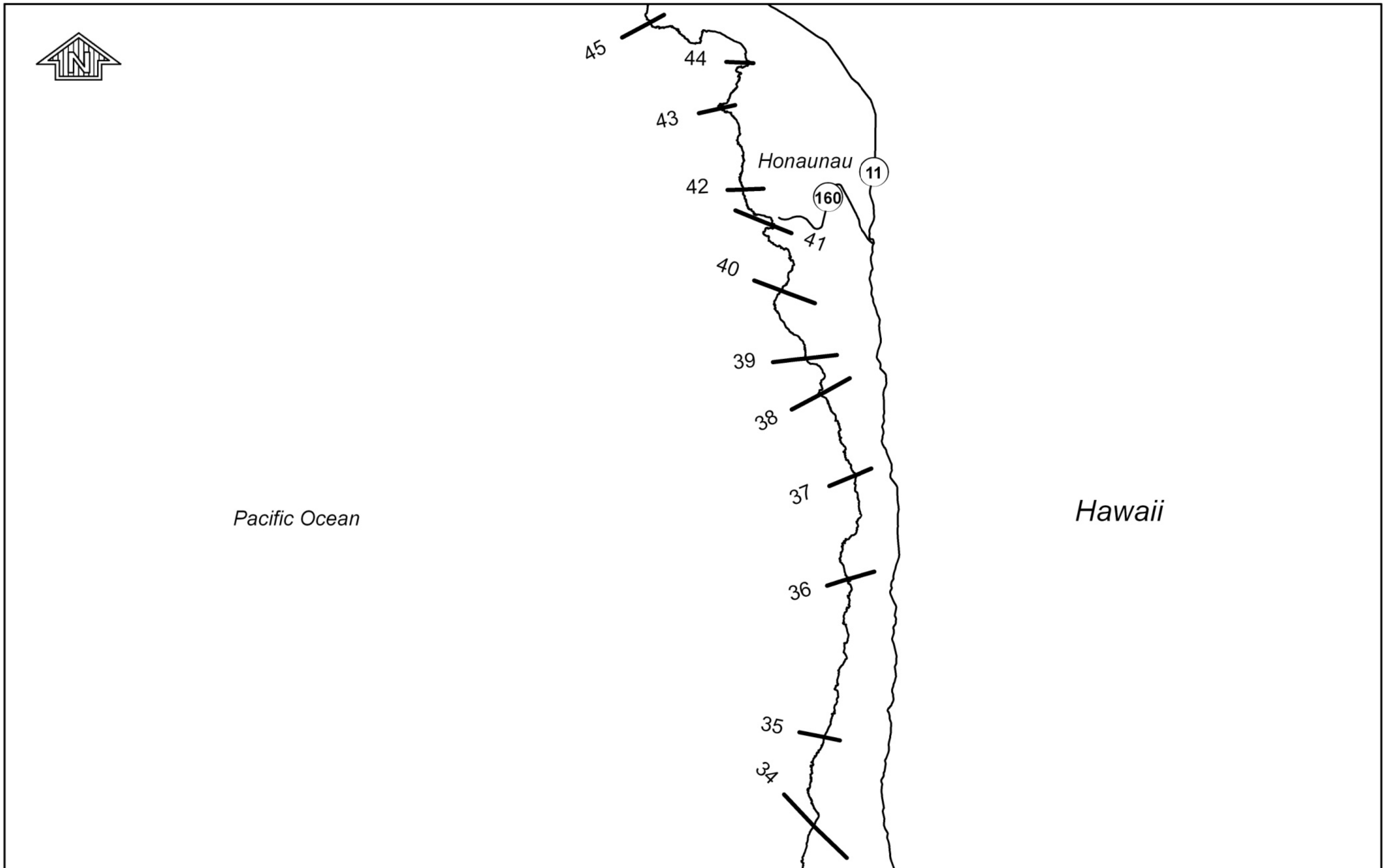
Figure 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

TRANSECT LOCATION MAP 4



FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 5

Figure 5

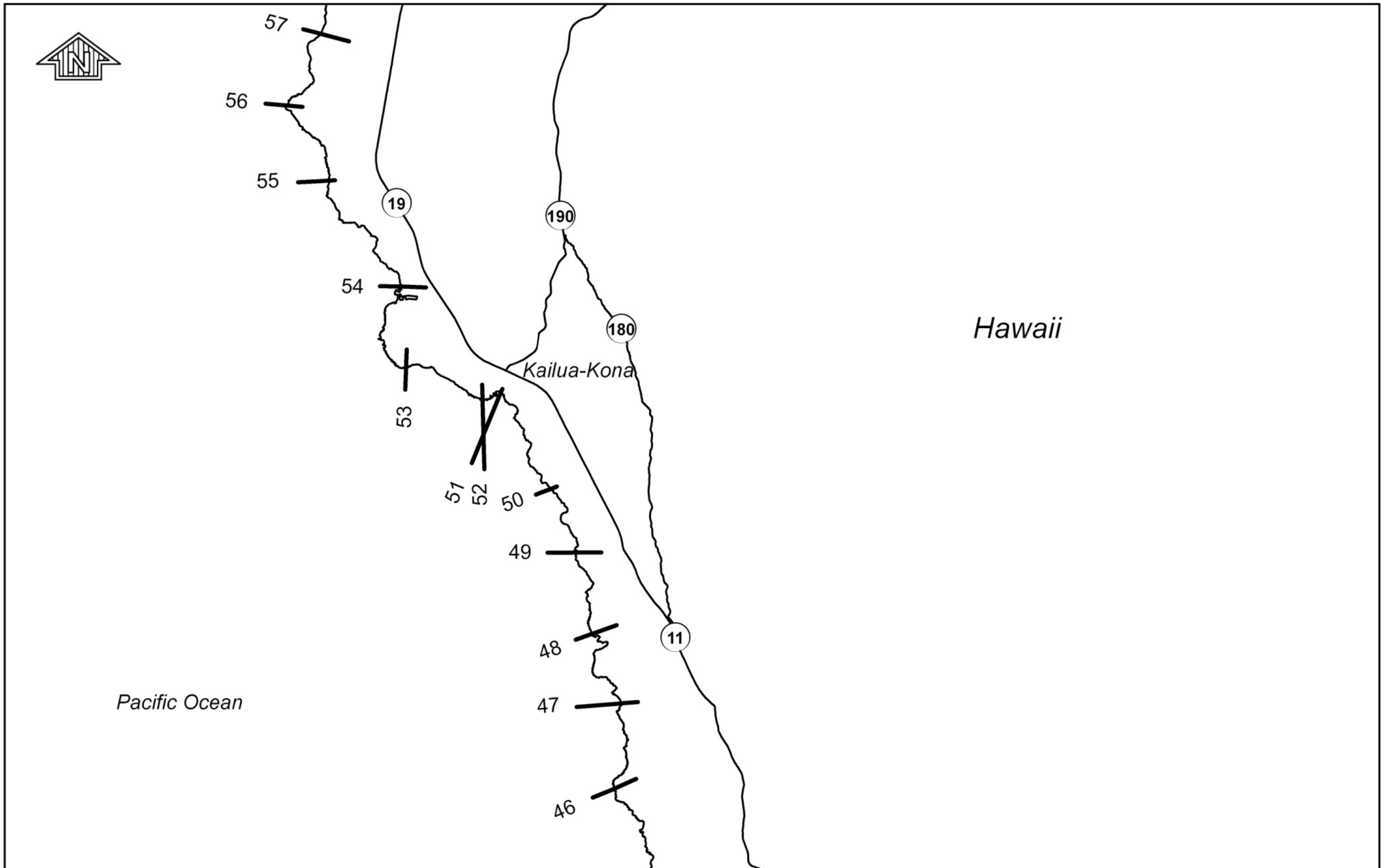


Figure 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

TRANSECT LOCATION MAP 6

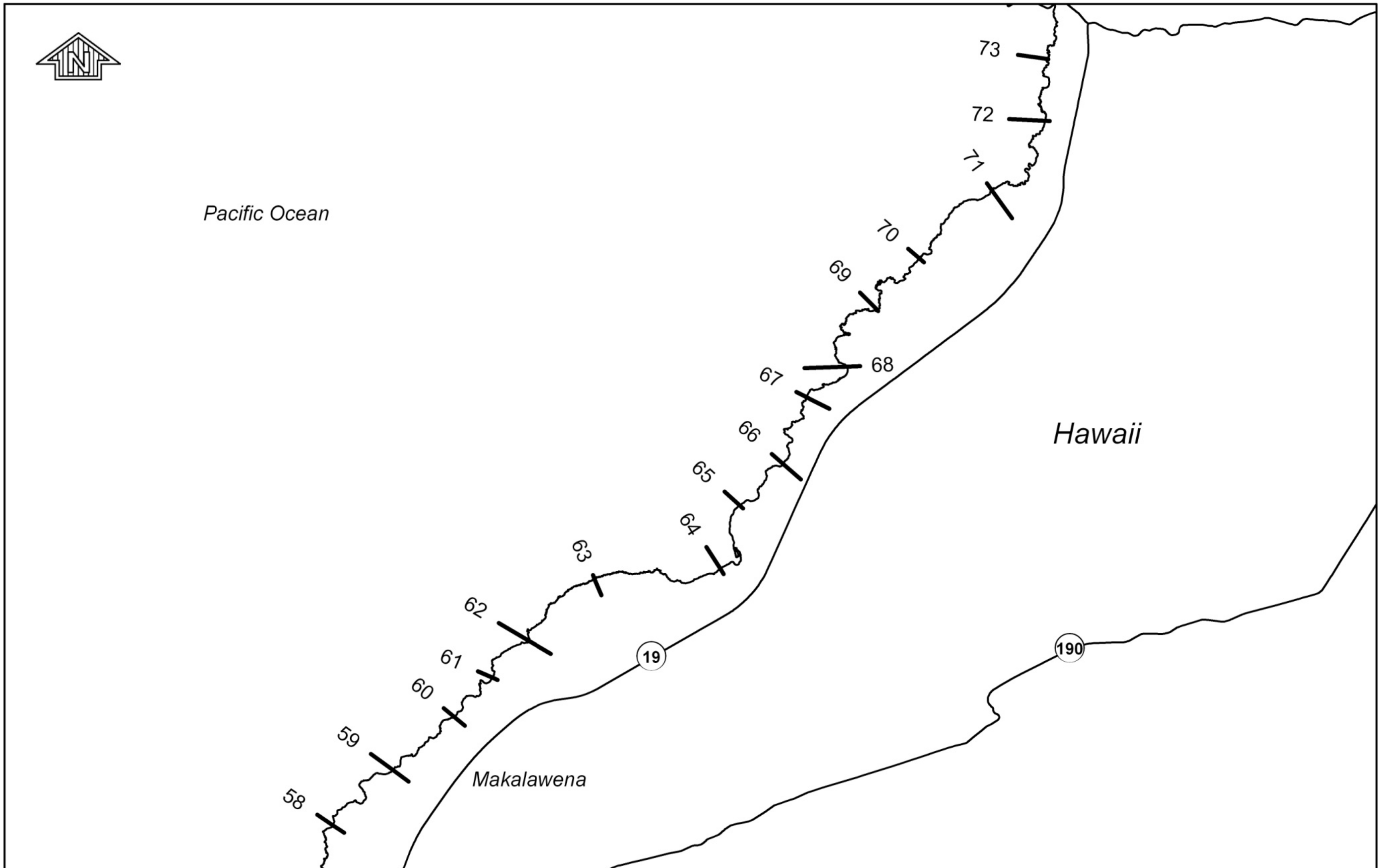


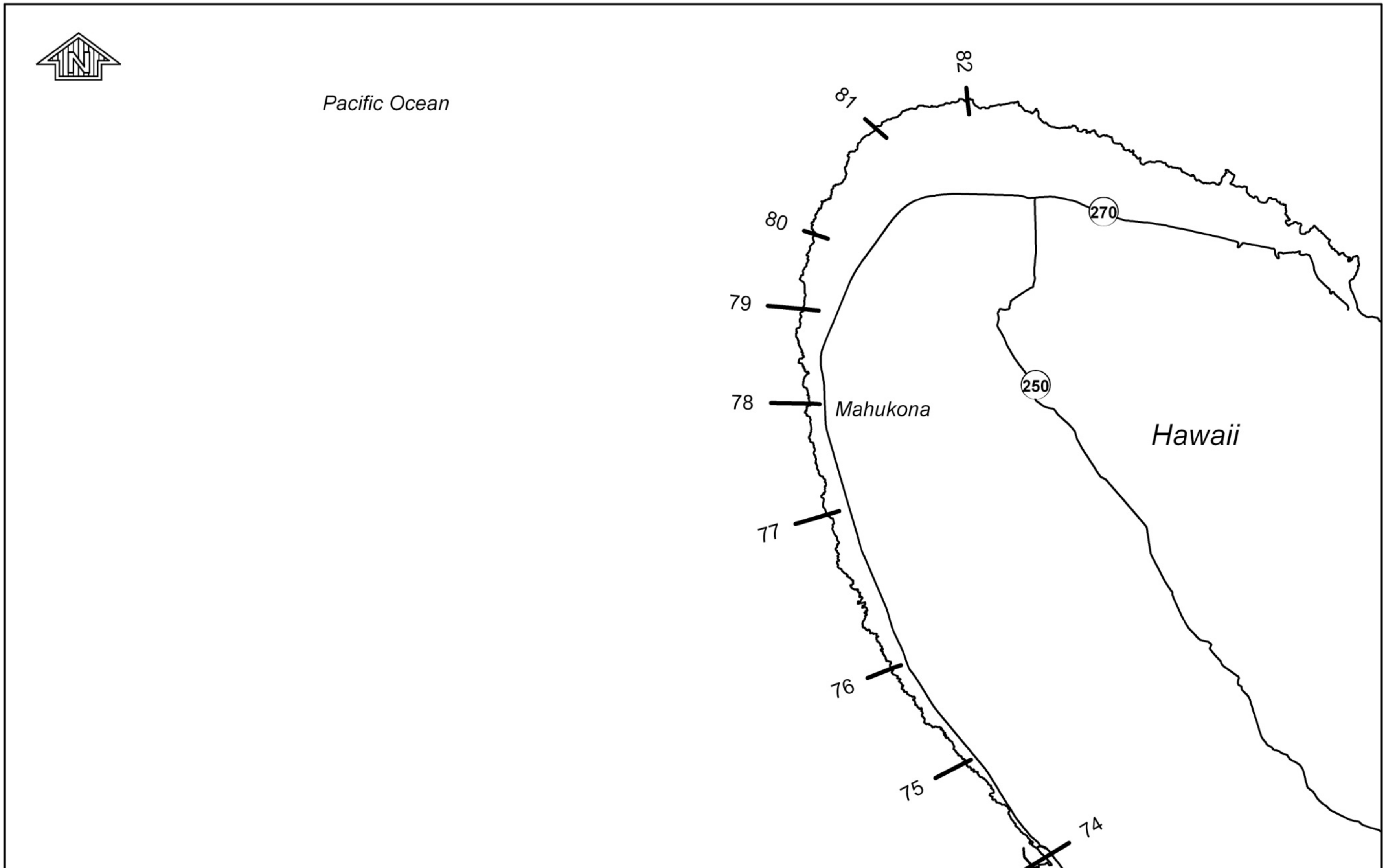
Figure 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

TRANSECT LOCATION MAP 7



FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

ISLAND OF HAWAII

TRANSECT LOCATION MAP 8

Figure 5

Table 6: Transect Descriptions

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
1	On the Pacific Ocean coastline, on the eastern side of the island, approximately 1,250 ft southwest of Kapoho Point, located in Halekamahina, at N 19.493006°, W 154.817385°.	1.0	4.7	8.8
2	On the Pacific Ocean coastline, on the eastern side of the island, approximately 680 ft north of Lae O Kahuna, located in Pahoiki, at N 19.456762°, W 154.844084°.	1.0	5.0	9.2
3	On the Pacific Ocean coastline, on the eastern side of the island, approximately 2,100 ft southwest of Paakikii, located in Kauaea, at N 19.433389°, W 154.869494°.	1.0	6.1	11.0
4	On the Pacific Ocean coastline, on the eastern side of the island, approximately 880 ft southwest of Kalepa Point, located in Kanakaloloa, at N 19.414722°, W 154.890669°.	1.0	5.9	35.2[1]
5	On the Pacific Ocean coastline, on the eastern side of the island, approximately 2,700 ft northeast of Waipuku Point, located in Kehena, at N 19.391206°, W 154.930592°.	1.0	5.6	26.4[1]
6	On the Pacific Ocean coastline, on the eastern side of the island, approximately 1.16 miles, southwest of Waipuku Point, located in Keokea Kikala, at N 19.373748°, W 154.947726°.	1.0	5.6	14.9[1]
7	On the Pacific Ocean coastline, on the eastern side of the island, approximately 1.01 miles northeast of Punahaha, located in Kalapana, at N 19.348517°, W 154.974673°.	1.0	6.3	31.9[1]
8	On the Pacific Ocean coastline, on the eastern side of the island, approximately 990 ft west of Kahue Point, located southwest of Kealakomo, at N 19.26496°, W 155.164261°.	1.0	5.8	16.0[1]
9	On the Pacific Ocean coastline, on the eastern side of the island, approximately at Apua Point, located approximately 1.4 miles east of the Puna District line, at N 19.255892°, W 155.192228°.	1.0	5.2	10.2[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)[†] 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
10	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 880 ft southwest of the intersection of Halape Trail and Puna Kau Trail, in Halape, at N 19.270174°, W 155.254687°.	1.0	4.6	8.6
11	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 420 feet from the point where the Ka'aha Trail turns in a northeasterly direction, located in Kapapala, at N 19.236638°, W 155.331001°.	1.0	5.6	26.1[1]
12	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 1,520 ft southwest of Waiwelawela Point, located approximately 2345 feet northeast of the Hawaii Volcanoes National Park southeastern boundary, at N 19.195293°, W 155.392647°.	1.0	6.1	39.3[1]
13	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 2,060 feet west of Kamehame Hill, at N 19.143859°, W 155.471816°.	1.0	6.0	24.2[1]
14	On the Pacific Ocean coastline, on the southeastern side of the island, at Punalu'u Harbor, located in Punalu'u, at N 19.136013°, W 155.504166°.	1.1	5.4	10.0
15	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 280 ft southwest of Kawa Bay, located in Hilea Nui, at N 19.1116°, W 155.525732°.	1.1	4.6	8.7
16	On the Pacific Ocean coastline, on the southeastern side of the island, approximately 2,010 ft northeast of Puu o Kaau, located in Honu'apo, at N 19.087957°, W 155.542095°.	1.0	5.9	10.7
17	On the Pacific Ocean coastline, on the southeastern side of the island, at Puhioi, located in Kaunamano, at N 19.062998°, W 155.552893°.	1.0	6.2	57.1[1]
18	On the Pacific Ocean coastline, on the southern side of the island, approximately 1.33 miles, northeast of Manaka'a Point, located in Kipaeae, at N 19.036659°, W 155.559256°.	1.0	5.8	35.0[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)[†] 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
19	On the Pacific Ocean coastline, on the southern side of the island, approximately 1,900 ft north of Kahilipali Point, at N 19.009693°, W 155.582687°.	1.0	8.0	26.0[1]
20	On the Pacific Ocean coastline, on the southern side of the island, at Ka'alela, located in Wai'ohinu, at N 18.985486°, W 155.593085°.	1.0	7.0	12.3
21	On the Pacific Ocean coastline, on the southern side of the island, at Kai'ole Bay located in Ka'alu'alu, at N 18.96894°, W 155.605831°.	1.0	4.8	9.0
22	On the Pacific Ocean coastline, on the southern side of the island, at Koulana Bay located in Kipukahanalua, at N 18.916939°, W 155.668837°.	1.0	4.9	9.1
23	On the Pacific Ocean coastline, on the southern side of the island, approximately 1.5 miles, north of Kalae Point, located in Kai'o, at N 18.9321°, W 155.683813°.	1.0	6.6	40.4[1]
24	On the Pacific Ocean coastline, on the southern side of the island, approximately 640 ft northwest of Mokuhonu, located in Pu'u'oha'upu, at N 18.945987°, W 155.695966°.	1.0	5.5	12.9[1]
25	On the Pacific Ocean coastline, on the southern side of the island, approximately 900 ft east of Kaimuuwala, located in Kahuku, at N 18.973115°, W 155.748008°.	1.0	6.5	17.3[1]
26	On the Pacific Ocean coastline, on the southern side of the island, approximately 1,300 ft west of Pohue Bay, located in Kanonone, at N 19.010773°, W 155.802921°.	1.0	4.9	9.1
27	On the Pacific Ocean coastline, on the southern side of the island, approximately 2,250 ft northwest of Awili Point, located in Keawaiki, at N 19.02322°, W 155.85535°.	1.0	5.6	10.9[1]
28	On the Pacific Ocean coastline, on the southwestern side of the island, at Kaikekua, located in Manuka, at N 19.048137°, W 155.882145°.	1.0	6.6	37.5[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)[†] 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
29	On the Pacific Ocean coastline, on the southwestern side of the island, approximately 1,000 ft north of Kamoi Point, located in Kaulanamauna, at N 19.080496°, W 155.906969°.	1.0	7.1	12.4
30	On the Pacific Ocean coastline, on the western side of the island, at Kapua Bay, located in Kapua, at N 19.140752°, W 155.912391°.	1.0	5.2	12.1[1]
31	On the Pacific Ocean coastline, on the western side of the island, at Kapulau Point located in Honomalino, at N 19.173659°, W 155.908589°.	1.0	5.3	9.7
32	On the Pacific Ocean coastline, on the western side of the island, approximately 850 ft north of Kapukawaaki, located in Milolii, at N 19.189131°, W 155.906942°.	1.1	5.6	14.1[1]
33	On the Pacific Ocean coastline, on the western side of the island, approximately 2,750 ft northeast of Makahiki Point, located in Papa, at N 19.208207°, W 155.901465°.	1.1	5.8	32.1[1]
34	On the Pacific Ocean coastline, on the western side of the island, at Kipahoehoe Bay, located in Kipahoehoe, at N 19.23696°, W 155.898816°.	1.0	5.8	27.2[1]
35	On the Pacific Ocean coastline, on the western side of the island, approximately 2,750 ft southwest of Keananuionaha Point, located in Kaapuna, at N 19.264337°, W 155.895265°.	1.0	5.9	35.7[1]
36	On the Pacific Ocean coastline, on the western side of the island, approximately 4,300 ft northeast of Auau Point, located in Kaohe, at N 19.313319°, W 155.887836°.	1.0	5.7	30.4[1]
37	On the Pacific Ocean coastline, on the western side of the island, approximately 1.24 miles southeast of Papakolea Point, located in Waiea, at N 19.345198°, W 155.886027°.	1.0	5.9	28.9[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)[†] 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
38	On the Pacific Ocean coastline, on the western side of the island, approximately 550 ft south of Kimukoko Point, located in Kimukoko, at N 19.370474°, W 155.896289°.	1.0	5.0	9.3[1]
39	On the Pacific Ocean coastline, on the western side of the island, approximately 300 ft southeast of Palianihi Point, located in Hookena, at N 19.381354°, W 155.901092°.	1.0	5.0	8.9[1]
40	On the Pacific Ocean coastline, on the western side of the island, approximately 1,770 ft northeast of Loa Point, located in Kauleoli, at N 19.4022°, W 155.908631°.	1.0	5.3	14.8[1]
41	On the Pacific Ocean coastline, on the western side of the island, approximately 1,400 ft northeast of Puuhonua Point, located in Honaunau, at N 19.422279°, W 155.91133°.	1.0	5.8	10.4
42	On the Pacific Ocean coastline, on the western side of the island, at Kanoni Point, located in Honaunau, at N 19.433443°, W 155.920623°.	1.0	6.2	28.4[1]
43	On the Pacific Ocean coastline, on the western side of the island, at Palemano Point, located in Maluhia Camp, at N 19.458529°, W 155.92746°.	1.0	6.9	12.1
44	On the Pacific Ocean coastline, on the western side of the island, approximately 1.15 miles southeast of Cook Point, located in Napoopoo, at N 19.472568°, W 155.918738°.	1.0	4.8	8.9
45	On the Pacific Ocean coastline, on the western side of the island, approximately 900 feet southeast of Keawekaheka Point, located in Onouli, at N 19.485234°, W 155.948991°.	1.0	5.6	25.3[1]
46	On the Pacific Ocean coastline, on the western side of the island, approximately 900 feet south of Keikiwaha Point, located in Hokukano, at N 19.516947°, W 155.960315°.	1.0	6.1	21.6[1]
47	On the Pacific Ocean coastline, on the western side of the island, at Maihi Bay, located in Maihi, at N 19.543449°, W 155.957941°.	1.0	5.4	31.7[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
48	On the Pacific Ocean coastline, on the western side of the island, approximately 2,350 feet north of Kaukalaelae Point, located in Keauhou, at N 19.564898°, W 155.96709°.	1.0	4.6	15.7[1]
49	On the Pacific Ocean coastline, on the western side of the island, approximately 4,150 feet southeast of Kamoa Point, located in Kaumalumalu, at N 19.590088°, W 155.971966°.	1.0	6.7	24.0[1]
50	On the Pacific Ocean coastline, on the western side of the island, approximately 3,900 feet southeast of Puapuaa Point, located in Puapuaa, at N 19.609881°, W 155.979446°.	1.0	4.7	8.9
51	On the Pacific Ocean coastline, on the western side of the island, at Kailua Bay, located in Kailua, at N 19.639851°, W 155.995102°.	1.1	4.5	8.9[1]
52	On the Pacific Ocean coastline, on the western side of the island, at Kukailimoku Point, located in Lanihau, at N 19.637297°, W 156.000856°.	1.0	5.2	11.0[1]
53	On the Pacific Ocean coastline, on the western side of the island, at Keahuolu Point, located in Keahuolu, at N 19.647089°, W 156.024498°.	1.0	7.1	12.4
54	On the Pacific Ocean coastline, on the western side of the island, approximately 1,000 feet northeast of Maliu Point, located in Honokohau, at N 19.672362°, W 156.025989°.	1.0	4.4	8.4
55	On the Pacific Ocean coastline, on the western side of the island, approximately 1,700 feet north of Puhili Point, located in Ooma 2, at N 19.7051°, W 156.048249°.	1.0	5.4	9.8
56	On the Pacific Ocean coastline, on the western side of the island, at Keahole Point, located at the Keahole Point Coast Guard Reservation, at N 19.728365°, W 156.061499°.	1.0	6.0	10.8
57	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,700 feet northeast of Unualoha Point, located in Haleohiu, at N 19.75046°, W 156.050724°.	1.0	5.6	18.2[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
58	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,300 feet northeast of Makolea Point, located in Kaulana, at N 19.774568°, W 156.04711°.	1.0	5.4	9.8
59	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 3,900 feet northeast of Kawili Point, located in Makalawena, at N 19.791513°, W 156.028325°.	1.0	4.9	10.0[1]
60	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,870 feet northeast of Puialoa Point, located in Coast State Park, in Maniniowali, at N 19.807917°, W 156.009246°.	1.1	5.1	10.4[1]
61	On the Pacific Ocean coastline, on the northwestern side of the island, at Kukio Bay, located in Kukio 1, at N 19.820162°, W 155.997524°.	1.1	4.4	8.4
62	On the Pacific Ocean coastline, on the northwestern side of the island, at Kahuwai Bay, located in Kaupulehu, at N 19.831529°, W 155.986172°.	1.1	4.4	8.4
63	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 2,700 feet southwest of Mano Point, located approximately 1.67 miles northeast of Kaupulehu, at N 19.85091°, W 155.965898°.	1.0	5.7	10.4
64	On the Pacific Ocean coastline, on the northwestern side of the island, at Kiholo Bay, located in Kiholo, at N 19.853766°, W 155.926772°.	1.1	4.4	8.9[1]
65	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,550 feet northeast of Hou Point, located approximately 1.34 miles north of Kiholo, at N 19.8734°, W 155.920743°.	1.1	5.5	21.7[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
66	On the Pacific Ocean coastline, on the northwestern side of the island, at Keawaiki Bay, located in Keawaiki, at N 19.886203°, W 155.907282°.	1.1	6.0	12.7[1]
67	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 4,350 feet northeast of Weliweli Point, located in Kapalaoa, at N 19.906993°, W 155.900162°.	1.1	5.2	17.7[1]
68	On the Pacific Ocean coastline, on the northwestern side of the island, at Anaehoomalu Bay, located in Anaehoomalu, at N 19.916476°, W 155.887516°.	1.1	6.0	10.9
69	On the Pacific Ocean coastline, on the northwestern side of the island, at Honokaope Bay, located in Anaehoomalu, at N 19.933784°, W 155.877963°.	1.1	4.4	8.4
70	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 700 feet southwest of Keanapukalua, located in Lahuipuaa, at N 19.949776°, W 155.864934°.	1.1	6.3	11.3
71	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,900 feet southwest of Puako Point, located in Puako, at N 19.971131°, W 155.842754°.	1.1	6.1	11.0
72	On the Pacific Ocean coastline, on the northwestern side of the island, at Hapuna Bay, located in Ouli, at N 19.992506°, W 155.825989°.	1.1	4.3	8.3
73	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,100 feet south of Waiulaula Point, located in Waiulaula, at N 20.011704°, W 155.825843°.	1.1	4.9	15.4[1]
74	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1.1 miles northwest of Kukuii Point, located in Kawaihae, at N 20.033147°, W 155.829485°.	1.2	4.7	11.8[1]

Table 6: Transect Descriptions – continued

TRANSECT	LOCATION	ELEVATION (ft LOCAL MEAN SEA LEVEL)† 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
75	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 500 feet northwest of Kaiopae Point, located approximately 2.30 miles northwest of Kawaihae, at N 20.06363°, W 155.852062°.	1.1	6.2	35[1]
76	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1.1 miles southeast of Malae Point, located in Kalala, at N 20.092927°, W 155.874252°.	1.1	5.4	40[1]
77	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 2.5 miles northwest of Malae Point, located in Kaiholena, at N 20.14024°, W 155.894499°.	1.0	5.3	18.3[1]
78	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 2,300 feet southeast of Ka'oma Point, located in Lapakahi State Historical Park, in Lapakahi, at N 20.1744°, W 155.899785°.	1.1	4.8	12.4[1]
79	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 2,800 feet northeast of Kauilii Point, located in Kapaa 1-2 at N 20.203562°, W 155.90202°.	1.0	5.5	17.7[1]
80	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 4,850 feet northeast of Haena Point, located in Kukuipahu, at N 20.226546°, W 155.898403°.	1.0	5.3	18.8[1]
81	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 1,600 feet southwest of Limukoko Point, located in Puuepa 2, at N 20.259572°, W 155.879906°.	1.0	4.9	14.3[1]
82	On the Pacific Ocean coastline, on the northwestern side of the island, approximately 360 feet west of Upolu Point, located in Hualua 2, at N 20.268102°, W 155.851338°.	1.0	4.7	12.8[1]

†All elevations reflect the hurricane surge hazard unless noted otherwise
[1]Wave runup elevation

Table 7: Transect Data

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)[†] 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	1	0.7	0.8	5.7[1]	2.1	VE	8-9[3]
						AE	8[3]
		0.7	0.8	1.0	2.1	AE	7[2,3]
Pacific Ocean	2	0.7	0.8	6.0[1]	2.1	VE	9[3]
		0.7	0.8	1.0	2.1	VE	8[2,3]
						AE	8[2,3]
						AO	Depth 1
Pacific Ocean	3	0.7	0.8	7.1[1]	2.2	VE	9-11[3]
						AE	7-9[3]
Pacific Ocean	4	0.7	0.8	1.0	2.1	VE	35[2]
						AE	35[2]
Pacific Ocean	5	0.7	0.8	1.0	2.2	VE	26[2]
						AE	26[2]
Pacific Ocean	6	0.7	0.8	1.0	2.2	VE	15[2]
						AE	15[2]
Pacific Ocean	7	0.7	0.8	1.0	2.2	VE	32[2]
						AE	32[2]
Pacific Ocean	8	0.7	0.8	1.0	1.9	VE	16[2]
						AE	16[2]
Pacific Ocean	9	0.7	0.8	1.0	1.7	VE	10[2]
						AE	10[2]
Pacific Ocean	10	0.7	0.8	5.6[1]	1.9	VE	8-9
						AE	6-8
Pacific Ocean	11	0.7	0.8	1.0	2.0	VE	26[2]
						AE	26[2]

[†]All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)[†] 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	12	0.7	0.8	1.0	2.1	VE	39[2]
						AE	39[2]
Pacific Ocean	13	0.7	0.8	1.0	2.2	VE	24[2]
						AE	24[2]
Pacific Ocean	14	0.7	0.8	6.4[1]	2.3	VE	9-10[3]
						AE	6-9[3]
Pacific Ocean	15	0.7	0.8	5.7[1]	2.2	VE	8-9[3]
						AE	8[3]
		0.7	0.8	1.0	2.2	AE	7[2,3]
Pacific Ocean	16	0.7	0.8	6.9[1]	2.2	VE	9-11[3]
						AE	7-9[3]
Pacific Ocean	17	0.7	0.8	1.0	2.1	VE	57[2]
						AE	57[2]
Pacific Ocean	18	0.7	0.8	1.0	2.1	VE	35[2]
						AE	35[2]
Pacific Ocean	19	0.7	0.8	1.0	2.0	VE	26[2]
						AE	26[2]
Pacific Ocean	20	0.7	0.8	8.0[1]	2.0	VE	10-12
						AE	8-10
Pacific Ocean	21	0.7	0.8	5.8[1]	1.9	VE	9[3]
		0.7	0.8	1.0	1.9	VE	8[2,3]
						AE	8[2,3]
Pacific Ocean	22	0.7	0.8	5.9[1]	1.9	VE	9[3]
		0.7	0.8	1.0	1.9	VE	8[2,3]
						AE	8[2,3]

[†]All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)†				ZONE	BASE FLOOD ELEVATION (feet LMSL*)
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT		
Pacific Ocean	23	0.7	0.8	1.0	1.8	VE	40[2]
						AE	40[2]
Pacific Ocean	24	0.7	0.8	1.0	1.8	VE	13[2]
						AE	13[2]
Pacific Ocean	25	0.7	0.8	1.0	1.9	VE	17[2]
						AE	17[2]
Pacific Ocean	26	0.7	0.8	5.9[1]	2.1	VE	9
		0.7	0.8	1.0	2.1	AE	9[2]
Pacific Ocean	27	0.7	0.8	1.0	2.3	VE	11[2]
						AE	11[2]
Pacific Ocean	28	0.7	0.8	1.0	2.3	VE	38[2]
						AE	38[2]
Pacific Ocean	29	0.7	0.8	8.1[1]	2.2	VE	10-12
						AE	8-10
Pacific Ocean	30	0.7	0.8	1.0	2.2	VE	12[2]
						AE	12[2]
Pacific Ocean	31	0.7	0.8	6.3[1]	2.2	VE	8-10
						AE	6-8
Pacific Ocean	32	0.7	0.8	1.1	2.2	VE	14[2]
						AE	14[2]
Pacific Ocean	33	0.7	0.8	1.1	2.2	VE	32[2]
						AE	32[2]
Pacific Ocean	34	0.7	0.8	1.0	2.2	VE	27[2]
						AE	27[2]

†All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)[†] 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	35	0.7	0.8	1.0	2.2	VE	36[2]
						AE	36[2]
Pacific Ocean	36	0.7	0.8	1.0	2.2	VE	30[2]
						AE	30[2]
Pacific Ocean	37	0.7	0.8	1.0	2.2	VE	29[2]
						AE	29[2]
Pacific Ocean	38	0.7	0.8	1.0	2.1	VE	9.3[2,3]
						AE	9.3[2,3]
Pacific Ocean	39	0.7	0.8	1.0	2.1	VE	8.9[2,3]
						AE	8.9[2,3]
Pacific Ocean	40	0.7	0.8	1.0	2.0	VE	15[2]
						AE	15[2]
Pacific Ocean	41	0.7	0.8	6.8[1]	2.0	VE	9-10
						AE	7-9
Pacific Ocean	42	0.7	0.8	1.0	1.9	VE	28[2]
						AE	28[2]
Pacific Ocean	43	0.7	0.8	7.9[1]	1.8	VE	10-12[3]
						AE	8-10[3]
Pacific Ocean	44	0.7	0.8	1.0	1.9	VE	8-9
						AE	6-8
Pacific Ocean	45	0.7	0.8	1.0	1.8	VE	25[2]
						AE	25[2]

[†]All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation
[3]Elevations from tsunami hazards dominate

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)† 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	46	0.7	0.8	1.0	1.7	VE	22[2]
						AE	22[2]
Pacific Ocean	47	0.7	0.8	1.0	1.8	VE	32[2]
						AE	32[2]
Pacific Ocean	48	0.7	0.8	1.0	1.6	VE	16[2]
						AE	16[2]
Pacific Ocean	49	0.7	0.9	1.0	1.8	VE	24[2]
						AE	24[2]
Pacific Ocean	50	0.7	0.8	5.8[1]	1.8	VE	8-9
						AE	8
		0.7	0.8	1.0	1.8	AE	7[2]
Pacific Ocean	51	0.7	0.8	1.1	2.0	VE	9[2]
						AE	9[2]
Pacific Ocean	52	0.7	0.8	1.0	1.8	VE	11[2]
						AE	11[2]
Pacific Ocean	53	0.7	0.8	8.1[1]	1.8	VE	10-12
						AE	8-10
Pacific Ocean	54	0.7	0.8	5.4[1]	1.9	VE	8
						AE	5-8
Pacific Ocean	55	0.7	0.8	6.4[1]	1.7	VE	9-10
						AE	6-9
Pacific Ocean	56	0.7	0.8	7.0[1]	1.8	VE	9-11
						AE	9
		0.7	0.8	1.0	1.8	AE	8[2]

†All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)† 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	57	0.7	0.8	1.0	1.8	VE	18[2]
						AE	18[2]
Pacific Ocean	58	0.7	0.8	8.0[1]	1.8	VE	10
						VE	9[2]
		0.7	0.8	1.0	1.8	AE	9[2]
Pacific Ocean	59	0.7	0.9	1.0	1.8	VE	10[2]
						AE	10[2]
Pacific Ocean	60	0.7	0.8	1.1	1.9	VE	10[2]
						AE	10[2]
Pacific Ocean	61	0.7	0.8	5.4[1]	1.9	VE	8
						AE	5-8
Pacific Ocean	62	0.7	0.8	5.4[1]	1.9	VE	8
						AE	8
		0.7	0.8	1.1	1.9	AE	7[2]
Pacific Ocean	63	0.7	0.8	6.8[1]	1.8	VE	9-10
						AE	7-9
Pacific Ocean	64	0.7	0.9	1.1	2.2	VE	9[2]
						AE	9[2]
Pacific Ocean	65	0.7	0.8	1.1	2.0	VE	22[2]
						AE	22[2]
Pacific Ocean	66	0.7	0.8	1.1	2.1	VE	13[2]
						AE	13[2]
						AO	Depth 2
Pacific Ocean	67	0.7	0.9	1.1	2.2	VE	18[2]
						AE	18[2]

†All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)[†]				ZONE	BASE FLOOD ELEVATION (feet LMSL*)
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT		
Pacific Ocean	68	0.7	0.9	7.1[1]	2.4	VE	9-11
						AE	7-9
Pacific Ocean	69	0.7	0.8	5.5[1]	2.2	VE	8
						AE	6-8
Pacific Ocean	70	0.7	0.8	7.3[1]	2.1	VE	9-11
						AE	7-9
Pacific Ocean	71	0.7	0.8	7.2[1]	2.2	VE	9-11
						AE	7-9
Pacific Ocean	72	0.7	0.9	5.4[1]	2.3	VE	7-8
						AE	5-7
Pacific Ocean	73	0.7	0.9	1.1	2.3	VE	15[2]
						AE	15[2]
Pacific Ocean	74	0.7	0.9	1.2	2.4	VE	12[2]
						AE	12[2]
		0.7	0.9	5.8[1]	2.4	VE	8-9
						AE	6-8
Pacific Ocean	75	0.7	0.8	1.1	2.2	VE	35[2]
						AE	35[2]
Pacific Ocean	76	0.7	0.8	1.1	2.0	VE	40[2]
						AE	40[2]
Pacific Ocean	77	0.7	0.8	1.0	1.9	VE	18[2]
						AE	18[2]
Pacific Ocean	78	0.7	0.8	1.1	2.0	VE	12[2]
						AE	12[2]

[†]All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Includes wave setup
[2]Wave runup elevation

Table 7: Transect Data - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet LMSL*)[†] 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet LMSL*)
Pacific Ocean	79	0.7	0.8	1.0	2.0	VE	18[1]
						AE	18[1]
Pacific Ocean	80	0.7	0.8	1.0	2.0	VE	19[1]
						AE	19[1]
Pacific Ocean	81	0.7	0.8	1.0	2.0	VE	14[1]
						AE	14[1]
Pacific Ocean	82	0.7	0.8	1.0	2.0	VE	13[1]
						AE	13[1]

[†]All elevations reflect the hurricane surge hazard unless noted otherwise
*Local Mean Sea Level
[1]Wave runup elevation

All elevations are referenced to the Local Mean Sea Level. 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.

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.

Previously, all flood elevations shown in the FIS report and on the FIRM were referenced and labeled to National Geodetic Vertical Datum of 1929. By recommendation from NOAA/NGS, all Hawaii County FIS report and FIRM elevations in this revision will now be referenced to Local Mean Sea Level. This vertical datum change does not revise any of the elevations in the FIS report or on the FIRM. Structure and ground elevations in the community must, therefore, be referenced to the Local Mean Sea Level. For more information on Local Mean Sea Level, see the National Oceanic and Atmospheric Administration's (NOAA) tidal information webpage at http://tidesandcurrents.noaa.gov/datum_options.html.