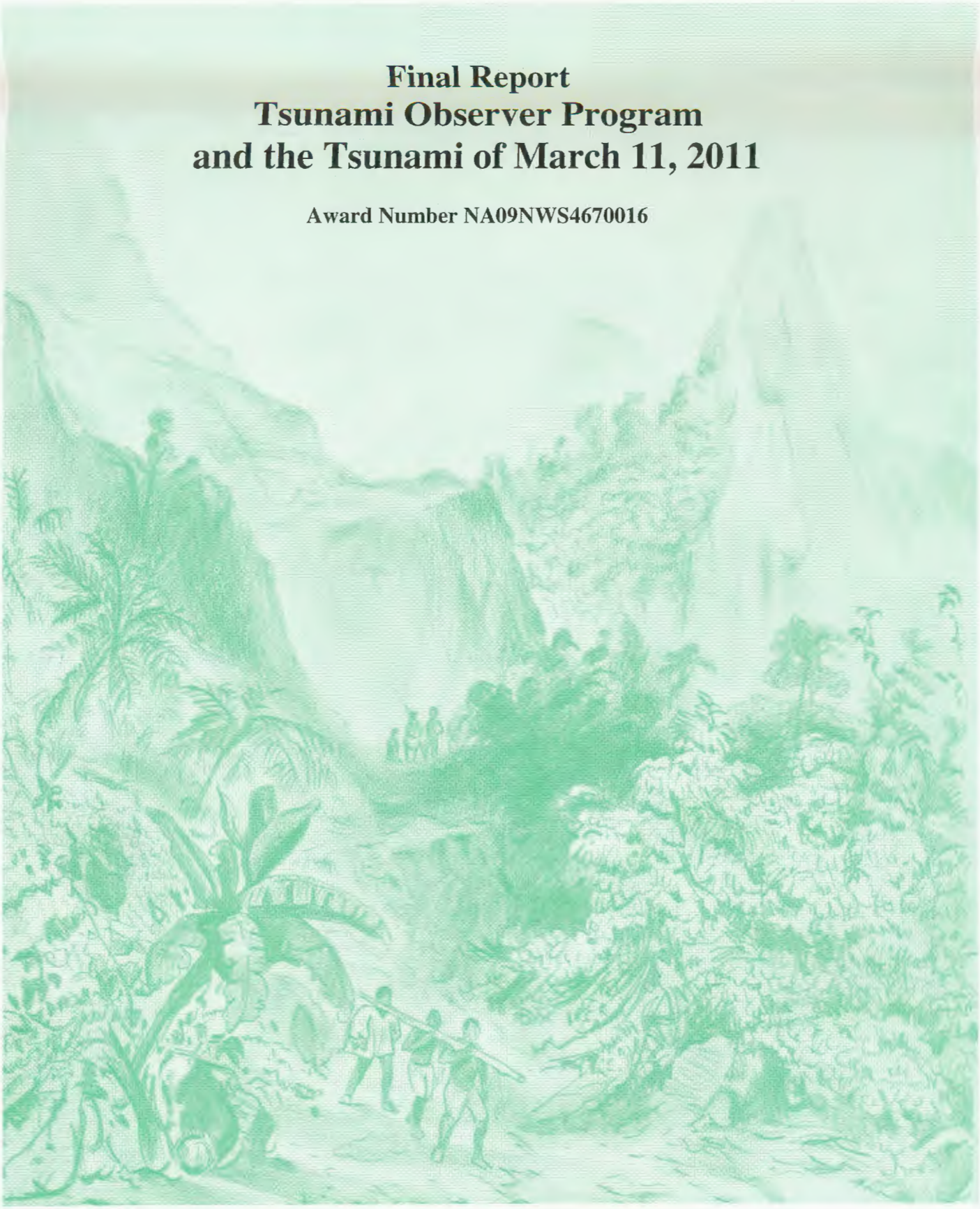
ENVIRONMENTAL CENTER
UNIVERSITY OF HAWAI'I

Final Report
Tsunami Observer Program and the Tsunami of March 11, 2011

Award Number NA09NWS4670016



A Unit of Water Resources Research Center

Final Report
Tsunami Observer Program and the Tsunami of March 11, 2011

Award Number NA09NWS4670016

By
Jacquelin Miller, PhD
Statewide Coordinator for Tsunami Observer Program

Volker Roeber, PhD
Oahu Team Leader, Tsunami Observer Program
and Data Manager for March 11, 2011 Tsunami Event

Prepared for
Kevin Richards
Earthquake and Tsunami Program Planner
State of Hawaii, Civil Defense

Submitted by
Environmental Center
Water Resources Research Center
University of Hawaii

Principal Investigator
Philip Moravcik, Junior Specialist
Water Resources Research Center, University of Hawaii

September 2012

Tsunami Observer Program and the Tsunami of March 11, 2011

Jacquelin Miller, PhD, Statewide Coordinator for Tsunami Observer Program

Volker Roeber, PhD, Oahu Team Leader, Tsunami Observer Program and Data Manager for March 11, 2011 Tsunami Event

The Tohoku-oki great earthquake of M_W 9.0 ruptured the mega-thrust fault offshore of Miyagi and Fukushima in Northeastern Honshu at 5:46 am Coordinated Universal Time (UTC) on March 11, 2011. This event generated strong shaking across the region and a large tsunami that devastated the coastal communities with run-up heights of more than 10 m. The tsunami, which registered 6.7 m amplitude at a coastal Global Positioning System (GPS) buoy and 1.75 m at an open-ocean Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoy, triggered warnings across the Pacific. The tsunami reached Hawaii at 3:00 am HST, 7 hours after the earthquake, and caused localized impacts across the island chain. The Pacific Tsunami Warning Center finally cancelled the warning at 8:36 am on March 12, 2011 when the amplitude of water-level oscillations decreased to less than 1 m around all islands.

The mission of the Tsunami Observer Program (TOP) is to obtain accurate measurements of water run-up (elevation above mean sea level) and inundation distances resulting from tsunami waves for use in preparing emergency response and evacuation maps for the State of Hawaii. Hence, the March 11, 2011 earthquake and tsunami triggered the initiation of a statewide alert to all TOP volunteers in the Program. The Statewide Program Manager for the TOP first learned of the event through a special news announcement on TV but shortly thereafter received the official telephone call from State Civil Defense. Immediately thereafter, the TOP manager initiated calls to Volker Roeber, Oahu Team Leader, and George Curtis and Dan Walker, Technical Directors. Calls to Team Leaders Pete Hendricks and Tom Daniels, West Hawaii; David Grooms, Maui; and Chuck Blay, leader for Kauai; were also made as soon as possible. Despite many attempts, the TOP manager was not able to reach any TOP observers on the East side of the Big Island. However, each of the island team leaders in turn initiated their appropriate island phone tree tsunami notification calls to their respective observers. (Figs. 1-4). Since the arrival time for Hawaii was not expected until approximately 2:30 am, there was sufficient time to notify most of the Observers. Given the magnitude of the quake and images of the destructive tsunami that were widely disseminated on the TV news, all of our Observers were cautioned to wait until daylight before trying to make any measurements or photographs. The TOP manager spent the evening making dozens of phone calls and e-mails to confirm what coastal areas statewide would be covered and making modifications where observers could not be reached or were otherwise determined to be off island. At approximately 2:00 am the Program Manager chose to evacuate her house (marina front with approximately 5 feet elevation) for higher ground. She returned to the house about 4:30 am and shortly thereafter began communications again with the Observers statewide to see how their preparations for observations were progressing. All island coordinators and their teams were able to make measurements of run-up and inundation data points throughout the state on each of the four main islands. We were also aided on the Big Island by Jim Kauahikaua, Scientist-in-Charge, U.S. Geological Survey, Hawaiian Volcano Observatory, Tyler Paikuli-Campbell, Archaeologist, Kaloko-Honokohau National Historical Park, National Park Service and Frank A. Trusdell, U.S.

Geological Survey, Hawaiian Volcano Observatory.

Tsunami Observers

Approximately 20 observers participated in the Tsunami Observer Program and recorded measurements of run-up and inundation at statewide locations. The majority of these observers were on the island of Oahu but measurements were obtained from all major islands except Lanai and Molokai.

Results of the Run-up and Inundation Measurements

The locations and results of our measurements and the observers responsible for collecting the data are shown in tables 1-4. The geographic locations for each measurement were entered into Google Earth by Roeber and this in turn provided the data set used by Moravcik for the site locations illustrated in Figures 5-8. It should be noted that more run-up values were obtained for this tsunami than all other tsunamis of record.

After the March 11th tsunami event the TOP observers measured local run-up heights as well as inundation limits over several days and at many times. Our convention is to use Mean Sea Level (MSL) as a baseline. Therefore, the data were corrected to MSL for tidal elevations at the time of our measurements. This is also the reference for bathymetry and topography data used by many researchers, e.g. the Tsunami Mapping Project at the Department of Ocean and Resources Engineering of the University of Hawaii. Detailed tidal information from the main tide gauges in Hawaii, such as Honolulu, Kahului, Kawaihae, or Nawiliwili, is shown in 1 min increments (http://tidesandcurrents.noaa.gov/tsunami/). The data show predicted as well as observed tidal signals with residuals. For the correction the tidal elevation at the particular date and time was selected from the tide table. We assumed that the tidal elevation is uniform for locations near the gauge. The difference between MSL and the actual tide level was then added to or subtracted from the observed run-up height depending on whether the observation was taken during a tide level above or below MSL. The run-up observations from Oahu's North shore were corrected by using a chart from Haleiwa (http://tidesandcurrents.noaa.gov/noaatidepredictions), since there is a significant time lag between the North and the South shores of that island. Because of the difficulty of accurately determining mean sea level at the time of the measurements, all run-up values were rounded to the nearest whole number with a break at 5" being rounded down and 6 inches rounded up.

The observed inundation limits were NOT corrected for tides because it is difficult to estimate the local beach slope. Depending on the applied methodology the accuracy of the run-ups is approximately +-0.5 ft. The inundation limits probably contain an error of several feet.

Oahu

Highest run-up on the Island of Oahu was measured at about 17 feet just NW of Camp Erdman on the north shore (ONS2) by Dan Walker and his team. The entire north shore experienced higher run-up values than any of the other shorelines (table 1). The Mader/Miller team reported about 10 feet just seaward of the traffic signal at the intersection of Hawaii Kai Drive and Kalanianaole near Sandy Beach (OSS13). The Keating/Helsley team reported an estimated (not measured) run-up of 13 feet at the far eastern end of Queens Beach near the inlet (east of OSS19). Other high values were recorded at Baby Makapu'u (OSS17) by the Miller/Yamada team of 8 feet, and the Donelle and Bill Lennan team measured a run-up of about 13 feet at Sandy Beach (OSS21). Run-ups along most of the southern coast along the Maunalua Bay to Kahala beach area were made by Volker and Schloesser and Miller and Watkins and ranged from 5-6 feet (OSS7-OSS9). Run-up

and Inundation limits along the western shore of Oahu were diligently recorded by Mark Suiso. Maximum run-up on this western shore was measured at about 10 feet at Hakimo (OWS12), Mailiili (OWS10), Makua North (OWS3), and Makaha (OWS7). Several other areas along this shoreline had run-ups of 7 and 9 feet with a mean value of 8 feet (OWS4, OWS6, OWS8, OWS13, OWS15).

Inundation limits were more difficult to measure accurately due to the slopes of the beaches. In addition, conspicuous 5 to 10 minute period oscillations of sea level were observed for several days following the quake adding to the difficulty in estimating sea levels at the time of the measurements. Inundation limits ranged widely from the 27-67 feet inundations measured off Kahala beach areas (OSS2, OSS9) to almost 250 feet at the parking area adjacent to Maunalua Bay (OSS18, again a reflection of the relatively flat slope of the shoreline.

Damage

No significant damages along the eastern-Sandy Beach shoreline were noted by our observers. In some cases minor damage to the beach Naupaka was visible (especially at Baby Makapuu) (OSS17) and in the case of Queens Beach-Ermas a number of large (1x2 feet by about 4 inch thick) concretions were tossed up on the beach (Erik Miller, personal communication). Damage on Oahu was limited to its harbors primarily due to seiches. According to the Coast Guard, 200 boats at Keehi Small Boat Harbor near Sand Island were affected after docks broke free from their moorings with the boats still attached. Many of the boats floated aimlessly in the lagoon, colliding with each other and in one instance, slamming into the Sand Island Bridge. The damage was estimated at $3.3 million. At Haleiwa harbor the "tsunami resistant" dock buckled and snapped away from the embankment

Molokai

We did not receive any tsunami observer data from the island of Molokai however we did hear that substantial damage to several small boats occurred especially on the east side of the island. According to Hawaii News Now, KGMB, *"On Molokai at least six houses have been flooded, damaged or knocked off their foundation including one where an SUV washed into the house. Most of the damage came on the east side of the island."*

Maui

David Grooms, the TOP leader for Maui, was able to guide his team of observers to make measurements of run-up and inundation at several locations on Maui. They recorded maximum run-up at La Perousse Bay of 8 ft 3 inches (MES8) and maximum inundation inland of 156 feet.

Joseph Fell-McDonald reported a run-up height at Kanahena cove Ahihi Bay at 6 feet with 22 feet inland inundation (MES9) and a run-up height of 4 feet 4 inches occurred with an inundation distance of 18 feet at 7299 Makena Alanui Drive (MES10). On March 16, 2011 he also reported that wave run-up height reached a maximum at La Perouse Bay of 8 ft 3 inches. Maximum inland inundation was measured at 156 feet (MES8).

Frannie Coopersmith reported wave damage at Baldwin Beach Park (MES1) just west of Paia town. Waves damaged the beach area and lifeguard stations. Water reached into the parking lot. No measurements were made but estimated run up was 5-7 feet. The parking lot was closed for a few days.

According to observer Jeannie Pezzoli, water washed over North Kihei road in the condominium residential area south of Sugar Beach (MES2). No run-up measurements or damage

to condominiums were reported; however, damage could have occurred had the water not funneled up a dry river channel just adjacent to the residential property. She also reported that water from the tsunami extended approximately 600 feet eastward along W. Lipoa Road and reached St. Teresa church on the south side of Lipoa road just west of South Kihei road (MES5). Water extended approximately 1000 feet inland from the shoreline along Kulanihakoi road in Kihei (MES6). This east-west road is also near a dry river channel that empties into the ocean. At Kalepolepo Park, (north Kihei), south of Kaonoulu St., water extended approximately 500 feet inland (MES7). This location is also up a dry river channel that empties into the ocean.

In addition to the individual measurements and reports cited above, informal observations were reported by Maui TOP leader David Grooms for Kahului Harbor and nearby coastal areas. Runup was 5 feet along Puunene ave (MES3). Inundation along Puunene ave was approximately 0.2 miles from the coast line at the Hideaway restaurant (Latitude 20° 53.513' N; Longitude 156° 28.094' W.) to the McDonalds (MES4) across from the Puunene Post Office just south of Kamehameha Ave. Some damage was experienced by the Hideaway restaurant and the east-west trending fence was torn apart, along the northern border of the parking area of the old site for the Superferry. Some cars within the lot were moved and banged against each other. Water entered the parking areas of both the Hideaway restaurant and 1st Hawaiian Bank just to the south. He found no other noticeable locations of inundation around Kahului Harbor. David Grooms also reported that most boats left Maalaea harbor in response to the tsunami warning from Civil Defense. Some damage was experienced by those that remained. Water washed over the breakwater at Maalaea Harbor and left debris scattered along the roadway. Some boulders and wood structures were moved as much as 30 feet (MES11).

Kauai

Run-ups on the east side of Kauai reported by the team of Blay and Siemers were substantially higher than those observed at most areas on Oahu, and ranged from a high of 17+ feet at Moloaa Bay (KES1, KES2) to about 9 feet at the Anahola Beach near the lifeguard station (KES5). The few observations from the South side gave values of from 3-8 feet (KSS1, KSS2, KES9, KES8).

Hawaii (The Big Island)

Run-up values recorded by the team of Daniel and Hendricks for the Big Island were generally high ranging from 6-10 feet along the west shore. Highest value in this area was measured at the north northwest corner of the new Kawaihae Small Boat Harbor (HNWS8) where a run-up of 10 feet was recorded. Significant damage was experienced along the Kona coast with damages to houses, businesses, hotels and roads fronting the ocean when waves overtopped the shoreline breakwater/wall and flooded Alii Drive. For example, an outrigger canoe was washed into the lobby of the King Kamehameha Hotel. Estimates of losses on the Big Island were in the tens of millions of dollars. One of the most dramatic losses and the highest measured run-up on the Big Island of 16 feet was measured by Walker at Napoopoo where a vacant two story house was washed into Kealakekua Bay (HWS17). It floated in the bay for several days with just the roof exposed above the water surface but eventually broke apart and was lost completely. Measurements along the eastern most side of the Big Island were made by Walker and included run-ups of 4 to 6 feet in the Hilo to Apua point area (HES10, HES11, HES12, HSES13, HSES14, HSES15). The Punaluu beach run-up was measured at 7 feet (HSS16).

Conclusions/Recommendations

Based on our experiences in responding to the March 11, 2011 Japanese Tsunami event we have the following recommendations for future actions by the Tsunami Observer Program:

1. We must insure that back-up coordinators are available when key island coordinators are off island. This became a real problem on the island of Hawaii when we were unable to reach many of the observers on the Hilo side. Fortunately, in the months that have followed since the March 11, 2011 event, we have been able to significantly expand our Observer team on the Big Island and we are much better prepared now. The newly revised and expanded phone key for Big Island Observers is shown in Figure 4. Future training sessions will emphasize the need to notify other members of your island observer group and your phone tree when you plan to be off island.

2. Additional efforts need to be made to insure that sufficient observers will be trained and available on all islands and for all shorelines. It became obvious that more observers are needed particularly on the outer islands so that we will still have sufficient observers to cover those that are off island at any given time.

3. We have found that relying on GPS data alone to locate measurement sites can be very inaccurate. It appears that there can be considerable variation in GPS readings from one instrument to another and furthermore that the readings may be influenced by local weather and power lines. There also was an inconsistency in the reporting of the coordinates. Some were reported in degrees, minutes, and seconds, some in degrees and decimal minutes, and others in decimal degrees. Since the modeling programs being used by the University use decimal degrees, we will instruct our observers in the future to set their GPS units to report all coordinates in decimal degrees. Subsequent efforts to rectify the GPS values have been very time consuming. A much closer approximation of the "real" location of the data measurements can be achieved using Google Earth and detailed descriptions of the locations, particularly proximity to any definitive land marks that will appear on Google Earth, combined with a photographic record of the run-up and site. In the future, we will urge our observers to record the GPS values and then verify the locations with Google earth. Future training will emphasize the use of Google Earth, physical in-hand maps that can be marked in the field of the areas being measured, and photographs along with GPS coordinates in decimal degrees as procedures for mapping our measurements.

4. All our observers reported that they had difficulty in determining "mean sea level" i.e. where to place the "seaward" pole. When we first began the measurements in the afternoon of March 12th, there was a continuous oscillation of sea level of about a 5 to 7 minute period. It also appeared that the lowering of the sea level was more prominent or observable than the following rise of water. The seiches were still observable on the late afternoon of March 12th and the next day. Determining where to place the "seaward" pole is likely a primary source of error in our run-up measurements.

5. Photographic records of the debris line or other evidence of run-up have been shown to be essential. In several cases, excellent photographic records of the debris lines were made immediately after the tsunami even though actual measurements could not be made for several days or even weeks later. With the photographic records, observers

were able to return to exact locations and make excellent measurements at a much later time. We intend to emphasize the need for photographic records at all sites in all subsequent trainings.

6. Inundation measurements are of limited value in calculations of flood limits since inundation is so dependent on beach slope. However, given accurate locations of the observations with GPS and Google Earth, specific inundation limits will be of use in estimating flood limits in specific coastal areas.

7. At the time of the March 11, 2011 event we were seriously deficient in the number of Observers for the Hilo and Hamakua sides of the Big Island. Since then we have added two additional observers on the Hilo side and one new Observer for the Kona side. Our Big Island team leaders are actively working on obtaining more Observers for Hawaii Island.

8. We are also deficient in the number of observers for Maui. Our team leader on Maui, David Grooms, is actively soliciting new observers through the University of Maui to expand his pool.

9. Lastly, we were unable to obtain any actual measurements for the islands of Molokai, Lanai, or Niihau. Again, our team leaders on Maui and Kauai are actively working to enlist volunteer tsunami observers on these islands to resolve this problem. We now have a couple new observers on the island of Molokai.

10. The data gathered for this report will be incorporated into the work being carried out to update the tsunami inundation and evacuation maps for the State of Hawaii by Volker Roeber and Kwok Fai Cheung of the University of Hawaii, Department of Ocean and Resources Engineering in cooperation with State Civil Defense.

Acknowledgments

It is important to give proper credit to the volunteer Tsunami Observers who diligently carried out their measurements and reported their observations to us then helped in reviewing the data to insure that the measurements and their locations were accurately recorded. And finally, Philip Moravcik of the UH Manoa Water Resources Research Center, contributed immeasurably to the development of this report including preparation of the site maps and assisting in the review and editing of the data and text during final compilation of the report. In addition the efforts of George Curtis and Dan Walker in providing guidance and support in all aspects of this work also need to be acknowledged. The following is a list of the Tsunami Observers, Team Leaders and others, for each island, that contributed data to this report:

Statewide Personnel
George Curtis, Technical Director
Dan Walker, Technical Director
Jackie Miller, Tsunami Observer Program Manager

Oahu
Volker Roeber, Oahu Team Leader and Data Manager for March 11, 2011 Event
Susan Fite
Chuck and Barbara Helsley (Observations only)
Bill and Donelle Lennan
Charles Mader

Erik Miller (Observations only and Video recordings)
Fabian Schloesser
Mark Suiso
Dan Walker
Anna Marie Watkins
Su Yamada

Hawaii (Big Island)
Tom Daniel, Co-Team Leader, Kona side
Pete Hendricks, Co-Team Leader, Kona side
Dan Walker

Others who Contributed to the Measurements on the Big Island:
Jim Kauahikaua, Scientist-in-Charge
Volcano National Park:
USGS Hawaiian Volcano Observatory
PO Box 51, 1 Crater Rim Road
Hawaii National Park, HI 96718
Frank A. Trusdell,
U.S. Geological Survey--Hawaiian Volcano Observatory.
Hawaii National Park, HI
Tyler Paikuli-Campbell, Archaeologist,
Kaloko-Honokohau National Historical Park, National Park Service

Maui
David Grooms, Team Leader
Ann (Frannie) Coopersmith (Observations only)
Joe Fell-McDonald
Jeannie Pezzoli (Observations only)

Kauai
Chuck Blay, Team Leader
David Burney
Rob Siemers

MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 1, Oahu Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
1	2011_OA01	ONS1	End of Road	21.579667	-158.23745	14-Mar-11	10:35	84	13	Dan Walker
2	2011_OA02	ONS2	Just NW of End of Camp Erdman	21.578550	-158.2291	14-Mar-11	11:04	122	17	Dan Walker
3	2011_OA03	ONS3	Near W. Gate to Dillingham	21.579150	-158.21535	14-Mar-11	11:22	124	13	Dan Walker
4	2011_OA04	ONS4	Kaiaka Park	21.585133	-158.116733	14-Mar-11	12:17	59	8	Dan Walker
5	2011_OA05	ONS5	Haleiwa Harbor Boat Ramp	21.593550	-158.106783	26-Mar-11	8:54	82	7	Dan Walker
6	2011_OA06	ONS6	Haleiwa Beach Park	21.597050	-158.102283	14-Mar-11	12:49	99	8	Dan Walker
7	2011_OA07	ONS7	Papailoa	21.612467	-158.095067	26-Mar-11	9:25	94	10	Dan Walker
8	2011_OA08	ONS8	Laniakea	21.619133	-158.085183	26-Mar-11	9:41	61	9	Dan Walker
9	2011_OA09	ONS9	Chun's	21.622300	-158.081583	26-Mar-11	9:56	74	13	Dan Walker
10	2011_OA10	ONS10	Leftovers	21.627783	-158.07395	26-Mar-11	10:21	71	12	Dan Walker
12	2011_OA11	ONS11	East Side of Waimea Bay	21.642000	-158.062717	14-Mar-11	13:29	88	15	Dan Walker
13	2011_OA12	ONS12	Log Cabins	21.659383	-158.057467	26-Mar-11	10:42	141	14	Dan Walker
14	2011_OA13	ONS13	East Side of Sunset Beach	21.674883	-158.039933	14-Mar-11	14:30	103	14	Dan Walker
15	2011_OA14	ONS14	Kawela Bay	21.697117	-158.008933	14-Mar-11	14:05	65	10	Dan Walker
16	2011_OA15	ONS15	NW Branch Malaekahana	21.669000	-157.93725	17-Mar-11	17:45	88	10	Dan Walker
17	2011_OA16	ONS16	Hukilau Beach	21.652833	-157.92785	17-Mar-11	17:30	67	8	Dan Walker
18	2011_OA17	ONS17	Pounders Beach	21.631500	-157.921033	17-Mar-11	17:12	107	10	Dan Walker

NA = No Data

MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 1, Oahu Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
19	2011_OA18	ONS18	S. Side of Kahana Bay	21.558450	-157.867167	17-Mar-11	16:41	44	5	Dan Walker
20	2011_OA19	OSS1	Hunakai, Beach Access 134 B	21.264490	-157.781231	12-Mar-11	12:20	42	6	Volker Roeber, Fabian Schloesser
21	2011_OA20	OSS2	Kahala near drainage channel	21.266313	-157.779269	12-Mar-11	12:26	27	6	Volker Roeber, Fabian Schloesser
22	2011_OA21	OSS3	Waialae Beach Park	21.269070	-157.777435	12-Mar-11	12:50	39	6	Volker Roeber, Fabian Schloesser
23	2011_OA22	OSS4	Wailupe near Kaimoko Pl	21.274774	-157.76536	16-Mar-11	17:10	43	4	Volker Roeber
24	2011_OA23	OSS5	Wailupe before Beach Park	21.275048	-157.764946	16-Mar-11	17:18	55	4	Volker Roeber
25	2011_OA24	OSS6	Wailupe before Beach Park	21.275737	-157.763206	16-Mar-11	17:30	55	4	Volker Roeber
26	2011_OA25	OSS7	Wailupe Beach Park	21.276175	-157.760301	16-Mar-11	17:45	40	5	Volker Roeber
27	2011_OA26	OSS8	Kawaikui Beach Park	21.278808	-157.745109	17-Mar-11	15:30	65	6	Volker Roeber
28	2011_OA27	OSS9	Kawaikui Beach Park	21.278844	-157.744987	15-Mar-11	15:35	67	5	Jackie Miller, Anna Marie Watkins
29	2011_OA28	OSS10	Seaword of Puuone St. No.of Waimanalo Bay Beach Park	21.335410	-157.695711	12-Mar-11	15:24	46	6	Jackie Miller,Anna Marie Watkins, Susan Fite
30	2011_OA29	OSS11	Seaward of Wailea St., Waimanalo	21.334417	-157.695	12-Mar-11	15:16	38	5	Jackie Miller,Anna Marie Watkins, Susan Fite
31	2011_OA30	OSS12	Seaward of Wailea St., Waimanalo	21.334417	-157.695	12-Mar-11	15:11	40	5	Jackie Miller,Anna Marie Watkins, Susan Fite
32	2011_OA31	OSS13	Hawaii Kai Drive and Kalanianole near Sandy Beach	21.290373	-157.665088	16-Mar-11	9:45	105	10	Charles Mader, Jackie Miller
33	2011_OA32	OSS14	Halona Cove beach	21.281833	-157.677733	16-Mar-11	13:25	70	4	Charles Mader, Jackie Miller
34	2011_OA33	OSS15	Erma's, SE of stop light near Sandy Beach	21.289957	-157.665774	16-Mar-11	14:00	135	8	Charles Mader, Jackie Miller
35	2011_OA34	OSS16	Erma's, near Sandy Beach	21.291008	-157.664063	16-Mar-11	9:00	164	8	Charles Mader, Jackie Miller

NA = No Data

MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 1, Oahu Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
36	2011_OA35	OSS17	Baby Makapu'u Beach	21.316217	-157.664733	16-Mar-11	11:30	74	8	Su Yamada, Jackie Miller
37	2011_OA36	OSS18	Hui Nalu Canoe Club	21.284383	-157.718283	22-Mar-11	10:35	249	4	Jackie Miller, Anna Marie Watkins
38	2011_OA37	OSS19	Alan Davis	21.291600	-157.662142	11-Mar-11	13:30	66	7	Donelle & Bill Lennan
39	2011_OA38	OSS20	Maunalua Bay	21.283383	-157.71645	11-Mar-11	15:00	130	4	Donelle & Bill Lennan
40	2011_OA39	OSS21	Sandy Beach Life Guard Tower 4B	21.285937	-157.671402	11-Mar-11	14:10	71	13	Donelle & Bill Lennan
41	2011_OA40	OSS22	Kahala Beach Public ROW 133A	21.265312	-157.779788	15-Mar-11	14:50	25	3	Jackie Miller, Anna Marie Watkins
43	2011_OA42	OWS1	Keawaula N	21.552666	-158.245920	19-Mar-11	12:00	84	7	Mark Suiso
44	2011_OA43	OWS2	Keawaula S	21.547600	-158.2406	19-Mar-11	12:11	170	10	Mark Suiso
45	2011_OA44	OWS3	Makua N	21.526983	-158.229	19-Mar-11	12:22	110	10	Mark Suiso
46	2011_OA45	OWS4	Makua S	21.506117	-158.229183	19-Mar-11	12:33	147	9	Mark Suiso
47	2011_OA46	OWS5	Ranch	21.483783	-158.230783	19-Mar-11	12:44	52	9	Mark Suiso
48	2011_OA47	OWS6	Keeau	21.478500	-158.222517	19-Mar-11	12:55	93	7	Mark Suiso
49	2011_OA48	OWS7	Makaha	21.460833	-158.208183	19-Mar-11	13:06	92	10	Mark Suiso
50	2011_OA49	OWS8	Lahilahi	21.441367	-158.190483	19-Mar-11	13:17	115	9	Mark Suiso
51	2011_OA50	OWS9	Pokai Bay	21.428283	-158.179617	19-Mar-11	13:28	96	6	Mark Suiso
52	2011_OA51	OWS10	Mailiili	21.408467	-158.177583	19-Mar-11	13:39	94	10	Mark Suiso
53	2011_OA52	OWS11	Maili	21.396233	-158.163417	19-Mar-11	13:50	95	4	Mark Suiso

NA = No Data

MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 1, Oahu Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
54	2011_OA53	OWS12	Hakimo	21.391850	-158.157417	19-Mar-11	14:01	76	10	Mark Suiso
55	2011_OA54	OWS13	Ulehawa	21.375050	-158.140917	19-Mar-11	14:12	76	7	Mark Suiso
56	2011_OA55	OWS14	Zablan	21.359417	-158.131667	19-Mar-11	14:23	103	6	Mark Suiso
57	2011_OA56	OWS15	Kahe	21.359490	-158.13173	19-Mar-11	14:34	70	9	Mark Suiso

NA = No Data

MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 2, Hawaii (Big Island) Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
1	2011_BI1	HWS1	Ahuli Beach, S Honokohau	19.667200	-156.02785	3/28/3/28	9:58	43	6	Tom Daniel, Pete Hendricks
2	2011_BI2	HWS2	South of pond, N end K-H NHP	19.686367	-156.03268	28-Mar	11:34	160	6	Tom Daniel, Pete Hendricks
3	2011_BI3	HWS3	South of Wawaloio Beach	19.712667	-156.048817	28-Mar	12:25	76	8	Tom Daniel, Pete Hendricks
4	2011_BI4	HNWS4	Front of 46 Puako Beach Road	19.969467	-155.844217	28-Mar	13:50	64	7	Tom Daniel, Pete Hendricks
5	2011_BI5	HNWS5	Puako Swale, 700ft S. of boat ramp	19.972083	-155.832167	28-Mar	14:32	ND	7	Tom Daniel, Pete Hendricks
6	2011_BI6	HNWS6	Puako Boat ramp	19.974066	-155.8315	28-Mar	14:40	75	6	Tom Daniel, Pete Hendricks
7	2011_BI7	HNWS7	Kawaihae Main Harbor, SE corner	20.031833	-155.8255	28-Mar	15:15	70	4	Tom Daniel, Pete Hendricks
8	2011_BI8	HNWS8	NNW corner , new Kawaihae small boat harbor	20.029467	-155.829183	28-Mar	15:32	20	10	Tom Daniel, Pete Hendricks
9	2011_BI9	HNWS9	SE of Kawaihae Small Boat Harbor	20.027950	-155.8265	28-Mar	16:00	15	5	Tom Daniel, Pete Hendricks
10	2011_BI10	HES10	Hilo- Pauahi St.	19.723150	-155.078083	5-Apr	11:21	50	7	Dan Walker
11	2011_BI11	HES11	Hilo - near Suisan	19.725917	-155.06995	5-Apr	11:12	52	5	Dan Walker
12	2011_BI12	HES12	Coconut Island	19.730300	-155.0687	5-Apr	10:43	34	4	Dan Walker
13	2011_BI13	HSES13	Opihikau	19.425050	-154.882917	9-Apr	23:33	60	7	Dan Walker
14	2011_BI14	HSES14	Apua Point	19.257850	-155.1934	11-Apr	9:05	42	6	Dan Walker
15	2011_BI15	HSES15	Apua Point	19.258650	-155.1948	11-Apr	9:36	40	5	Dan Walker
16	2011_BI16	HSS16	Punaluu	19.135733	-155.504817	8-Apr	8:27	100	8	Dan Walker
17	2011_BI17	HWS17	Napoopoo	19.470383	-155.921183	8-Apr	10:45	380	16	Dan Walker
18	2011_BI18	HWS18	Keahou Bay	19.561250	-155.96215	8-Apr	13:50	100	14	Dan Walker

ND = No Data

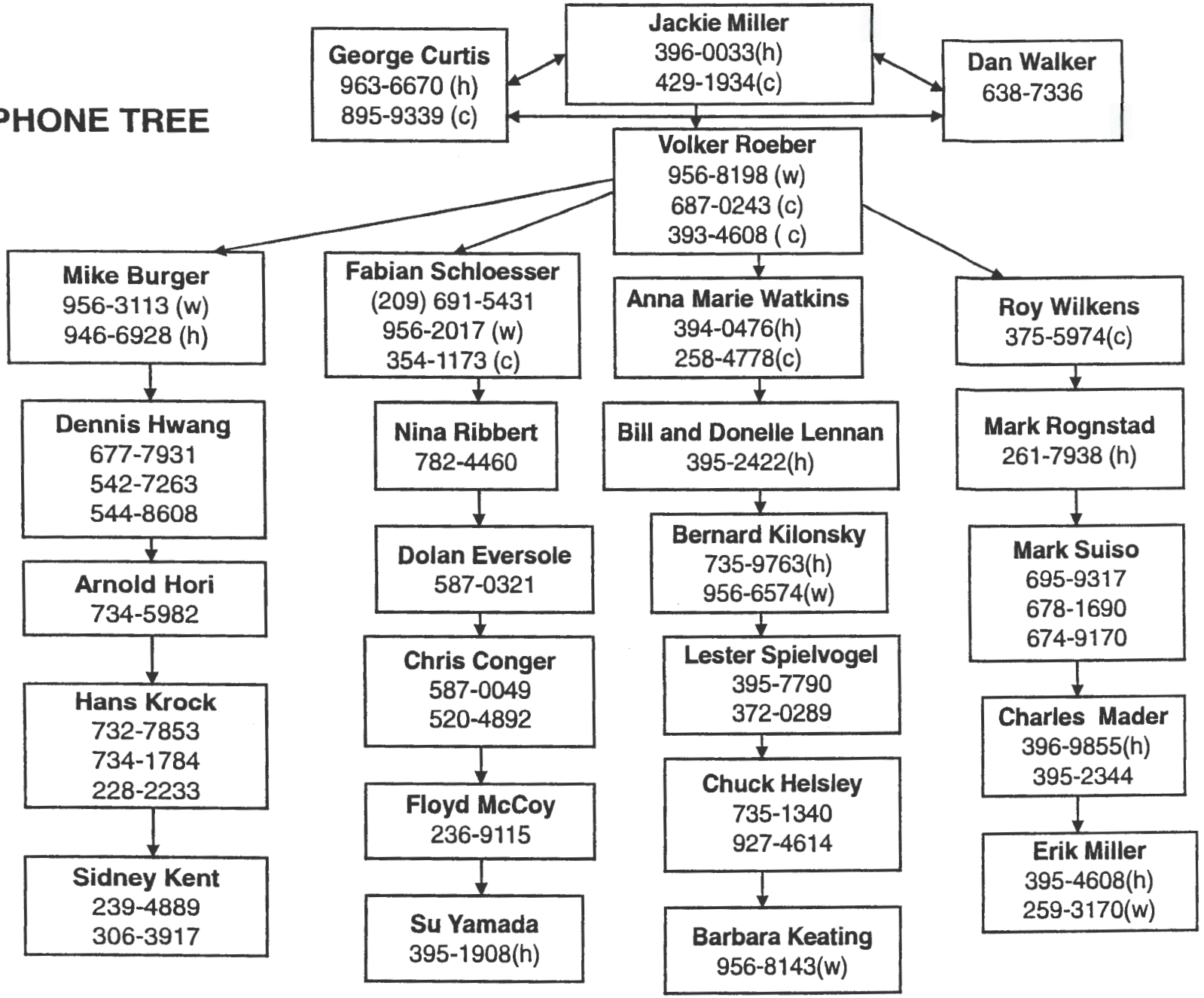
MARCH 11, 2011 TSUNAMI RUN-UP AND INUNDATION MEASUREMENTS IN HAWAII
TSUNAMI OBSERVER PROGRAM

Table 3, Maui Run-up and Inundation Data, March 11, 2011

	Data ID	Site No.	Location	Latitude	Longitude	Date	Time	Inundation [feet]	Tide Corrected Run-ups (rounded) [ft]	Observer
1	2011_M1	MES1	Baldwin Beach Park	20.914170	-156.393060	ND	ND	ND	7	Frannie Coopersmith
2	2011_M2	MES2	No. Kihei road south of Sugar Beach	20.785740	-156.467000	12-Mar-11	13:00	ND	3	Jeannie Pezzoli
3	2011_M3	MES3	Puunane Ave.	20.891883	-156.468233	12-Mar-11	10:00	ND	5	David Grooms
4	2011_M4	MES4	McDonalds just So. Of Kamehameha Ave.	20.887917	-156.463900	12-Mar-11	10:00	1900	8	David Grooms
5	2011_M5	MES5	W. Lipoa Rd south side just west of So. Kihei Rd.	20.747600	-156.455200	12-Mar-11	13:00	600	5	Jeannie Pezzoli
6	2011_M6	MES6	Kulanihakoi Rd in Kihei	20.761590	-156.456500	3/12/2011	13:00	1000	7	Jeannie Pezzoli
7	2011_M7	MES7	Kalepolepo Park (No. Kihei) south of Kaonoulu St.	20.765450	-156.457380	3/12/2011	13:00	500	5	Jeannie Pezzoli
8	2011_M8	MES8	La Perouse	20.599536	-156.419911	16-Mar-11	6:15	156	8	Joseph Fell-McDonald
9	2011_M9	MES9	Kanahena Cove, Ahihi Bay	20.618400	-156.436700	16-Mar-11	5:35	22	6	Joseph Fell-McDonald
10	2011_MA10	MES10	7299 Makena Alanui Dr.	20.651900	-156.438720	16-Mar-11	5:20	18	4	Joseph Fell-McDonald
11	2011_MA11	MES11	Maalaea Harbor	20.794440	-156.514170	16-Mar-11	13:00	ND	2	David Grooms

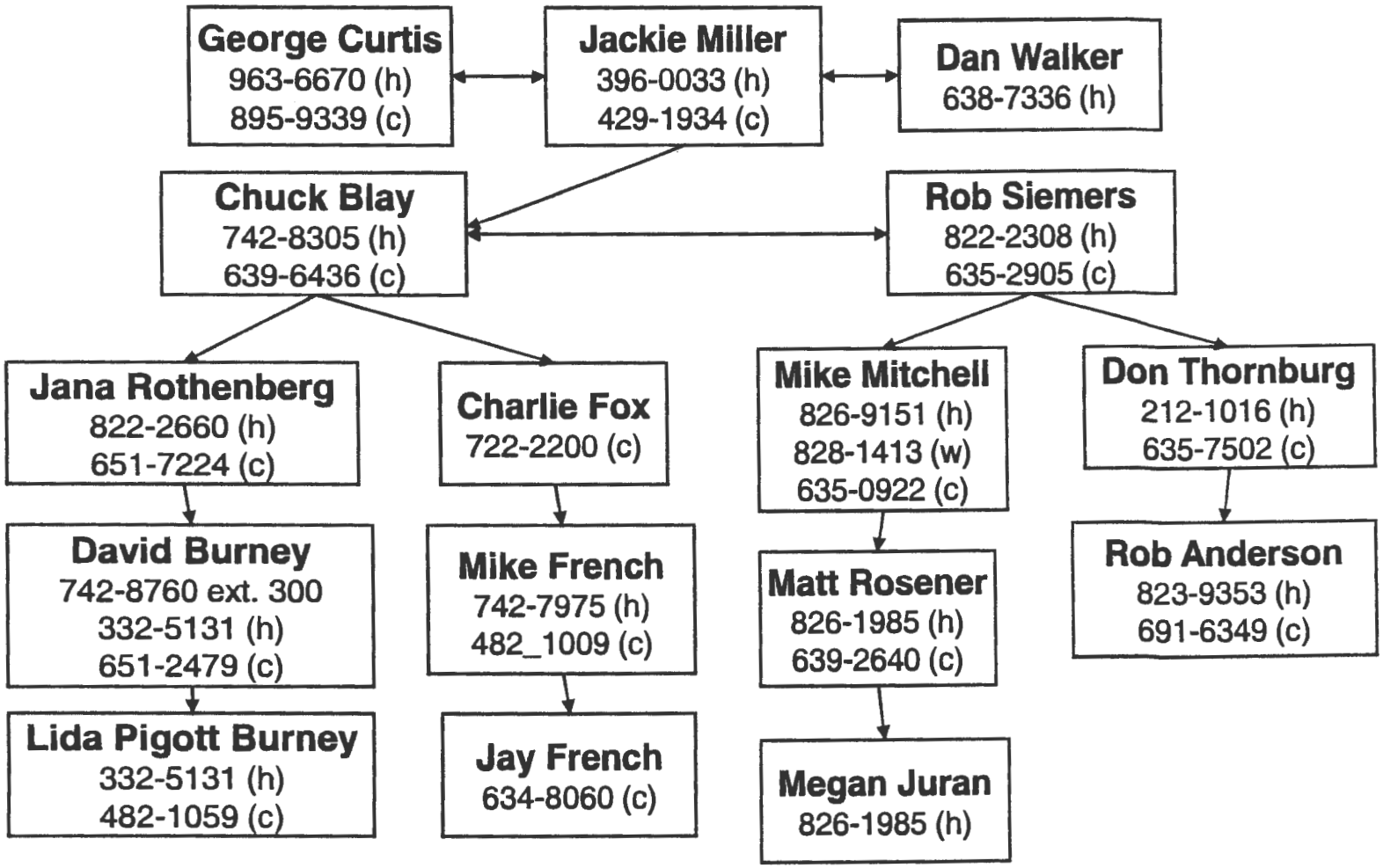
ND = No Data

Figure 1
O'AHU PHONE TREE



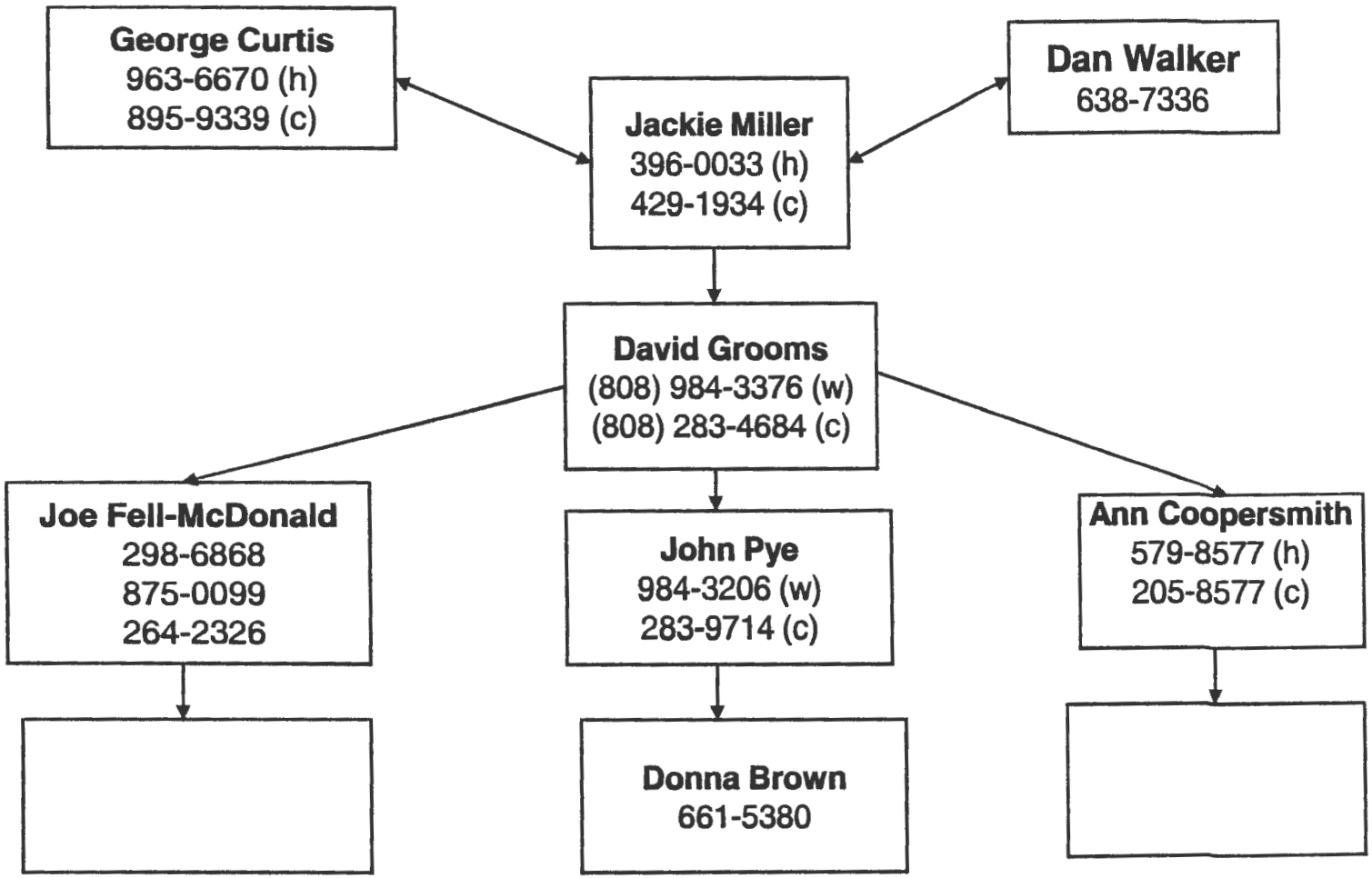
Note: If you cannot reach the person below you, please move down and make their calls
All telephone numbers are area code (808) unless otherwise shown

Figure 2, KAUAI PHONE TREE



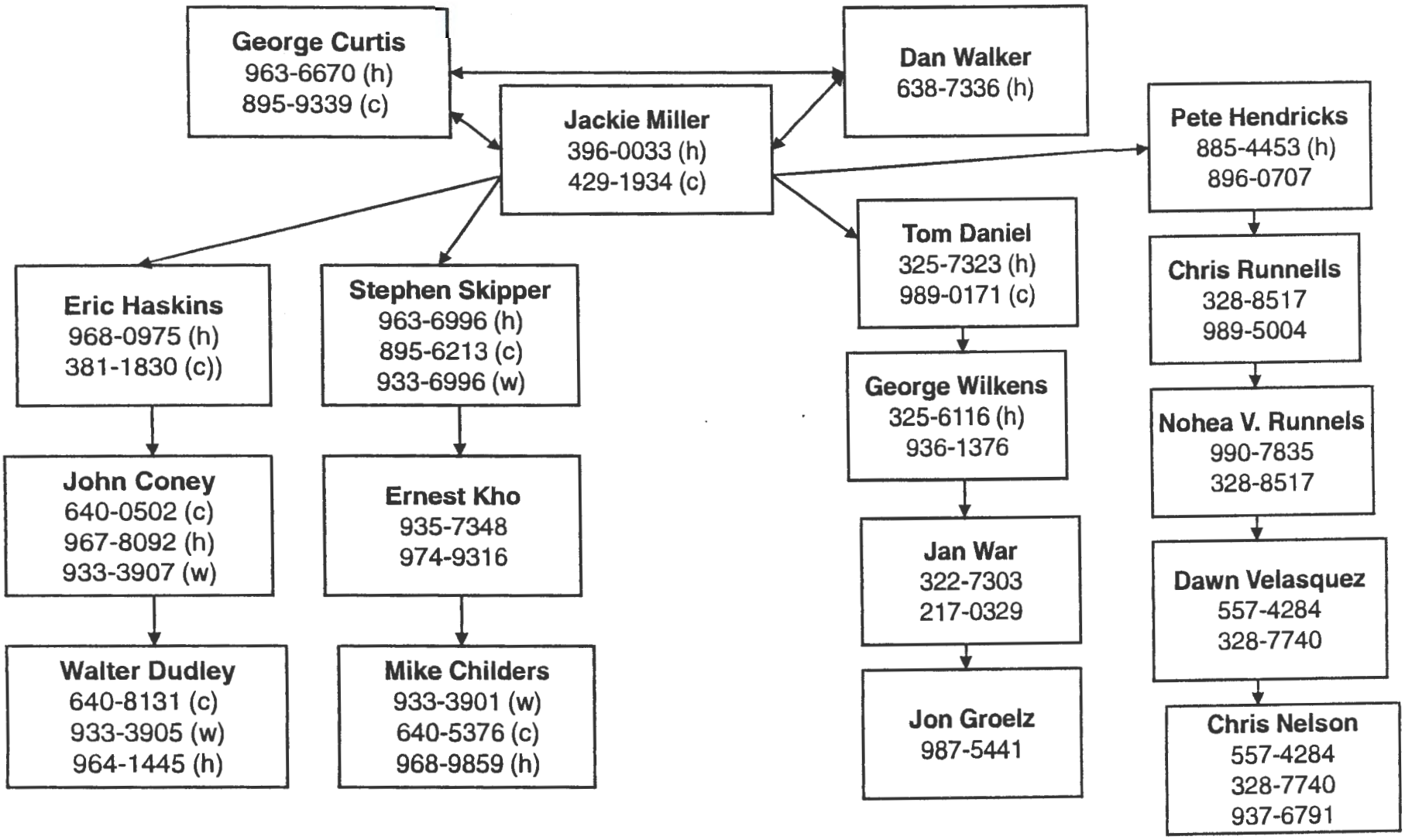
Note: If you cannot reach the person below you, please move down and make their calls.
All telephone numbers are area code (808) unless otherwise shown.

Figure 3, MAUI PHONE TREE



Note: If you cannot reach the person below you, please move down and make their calls.
All telephone numbers are area code (808) unless otherwise shown.

Figure 4, HAWAI'I (BIG ISLAND) PHONE TREE



Note: If you cannot reach the person below you, please move down the list and make their calls. All telephone numbers are area code (808) unless otherwise shown.

Figure 5

Oahu, Hawaii. Location and height of run-ups measured by Tsunami Observers with the Statewide Tsunami Observer Program following the March 11, 2011 Japanese tsunami

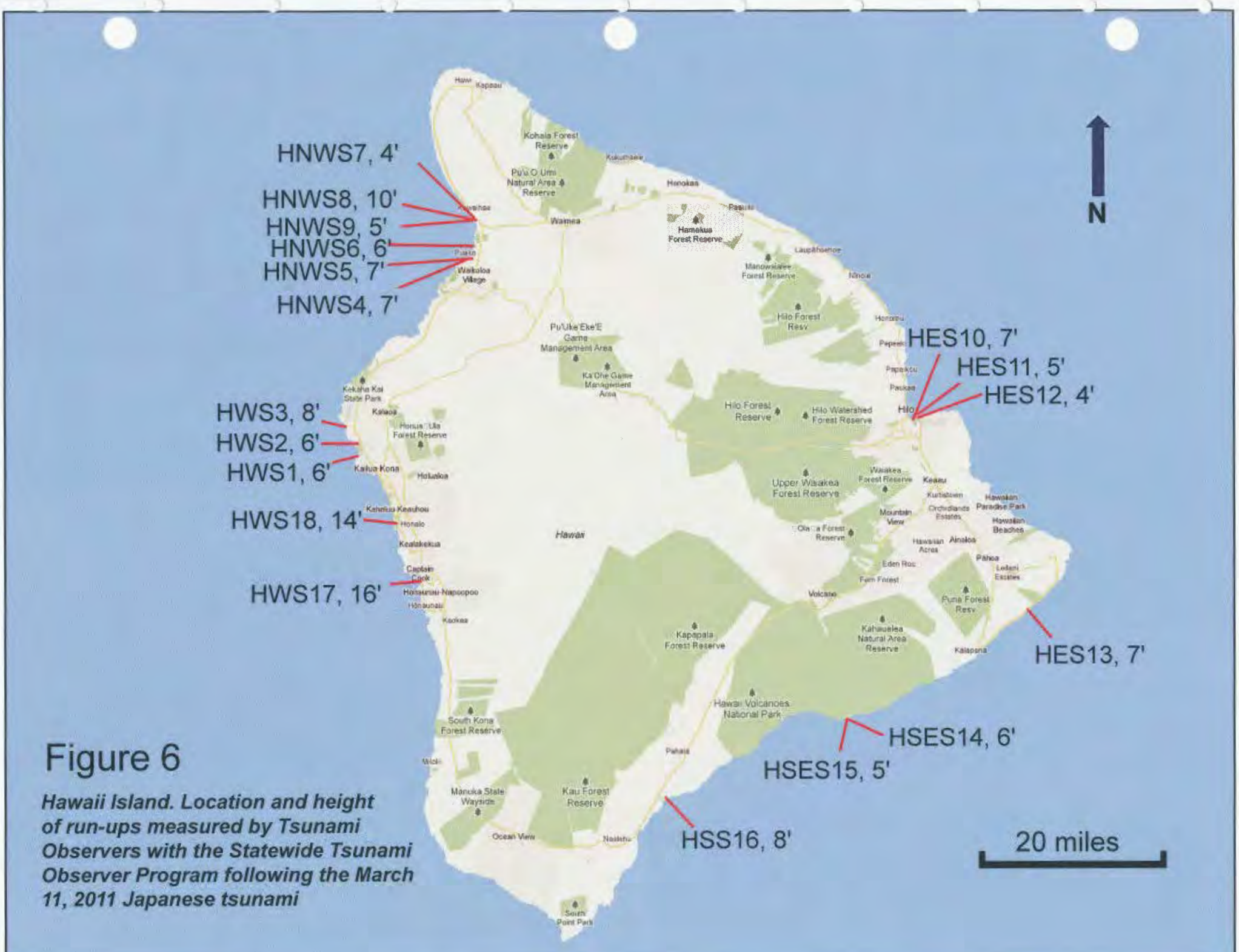


Figure 6

Hawaii Island. Location and height of run-ups measured by Tsunami Observers with the Statewide Tsunami Observer Program following the March 11, 2011 Japanese tsunami

Figure 7

Maui, Hawaii. Location and height of run-ups measured by Tsunami Observers with the Statewide Tsunami Observer Program following the March 11, 2011 Japanese tsunami

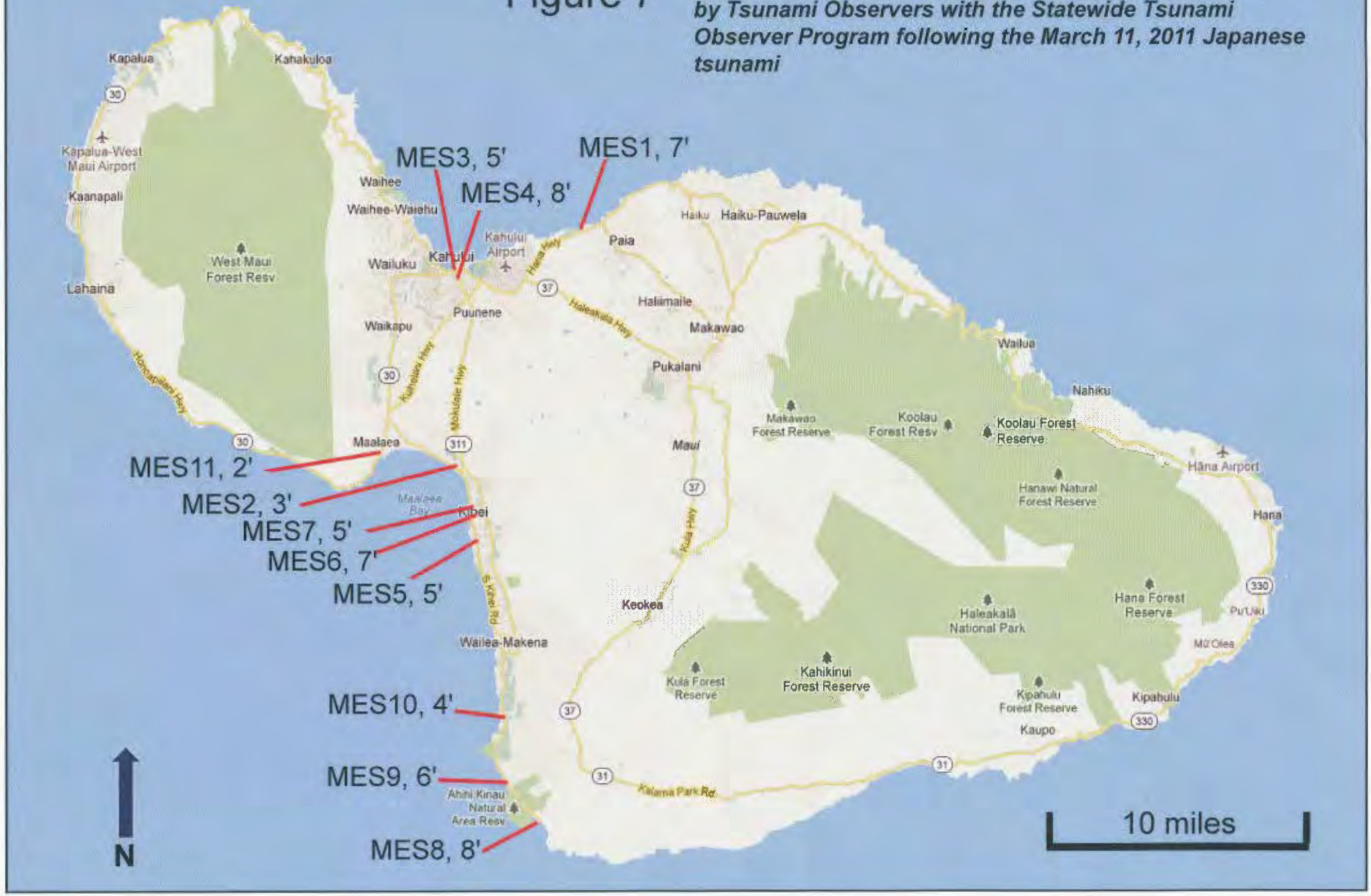


Figure 8

Kauai, Hawaii. Location and height of run-ups measured by Tsunami Observers with the Statewide Tsunami Observer Program following the March 11, 2011 Japanese tsunami