The Maui County
Hazard Mitigation Plan

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TABLE OF CONTENTS

Chapter I Introduction

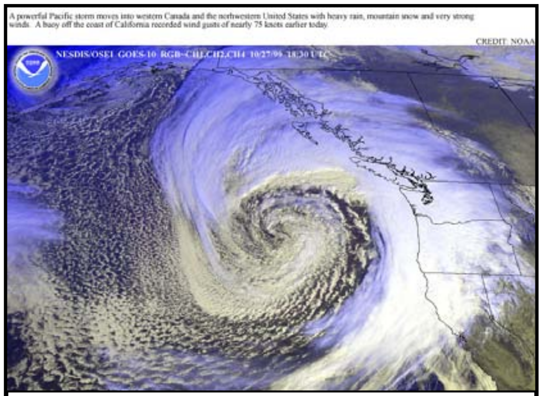
"The most recent disaster fades from memory just before the next one strikes…"

Ancient Japanese Proverb

The Cost of Disasters

Property damage resulting from natural hazards has become exceedingly costly, for both the disaster victims, and the American taxpayer. From 1989 to 1993, the average annual loss from natural disasters was $3.3 billion nationally, the past 4 years has seen that amount increase to 13 billion annually. (FEMA, IS393, April 1998) Over 6,000 people have been killed and 50,000 injured from natural disasters in the past 25 years. (FEMA, 1998)

The second most active hurricane season in the Pacific on record in the United States occurred in 1995. There were a total of 19 named storms, 11 reaching hurricane strength. The end result was 58 people dead and more than $5.2 billion in property losses. Aside from the direct costs, or those damages and losses directly attributable to the disaster, Americans also suffer from indirect costs, most of which may take much longer to recover from. Direct costs are short term and may include such costs as tree removal, setting up an emergency shelter, debris removal and the cost of repairs to public, private and commercial sectors. Indirect costs are those incurred sometime after the event, perhaps six months or more. These long-term costs include the permanent loss of employment, loss of tax revenues from business relocation health expenses incurred from a permanent injury or counseling to deal with the loss of a loved one.



A powerful Pacific storm moves into western Canada and the northwestern United States with heavy rain, mountain snow and very strong winds. A buoy off the coast of California recorded wind gusts of nearly 75 knots earlier today.

CREDIT: NOAA

Image Provided by the Pacific Disaster Center

Recovery from disasters requires resources to be diverted from other public and private programs, adversely affecting the productivity of the economy. Business interruption insurance only covers a small part of actual losses. Loss of economic productivity and downtime in tourism not really accounted by the public or private sector.

Costs of Disasters in Hawaiian Islands
1959 - present

Date	Disaster	Location	Amount of Damage*
9/10-11/92	Hurricane Iniki	Kauai, Hawaiian Islands	$ 1.6 billion
11/23/83	Hurricane Iwa	Kauai, Oahu	$239 million
1/8-10/80	Kona Storm	Maui	$ 12.9 million
5/23/60	tsunami	Hilo, Hawaii	$ 23 million
8/4-6/59	Hurricane Dot	Kauai, Hawaii, Oahu	$ 6 million (Kauai)
4/1946	tsunami	Hilo, Hawaii	$ 2.6 million

*Dollars given in the year damage occurred

What is Hazard Mitigation?

Hazard mitigation is action taken to permanently reduce or eliminate long-term risk to people and their property from the effects of natural hazards.

As the direct and indirect costs of disasters continue to rise, it becomes particularly critical that preparing for the onslaught of damage from these events must be done in order to reduce the amount of damage and destruction. This strategy is commonly known as mitigation. The purpose of multi-hazard mitigation is twofold: 1) to protect people and structures from harm and destruction; and 2) to minimize the costs of disaster response and recovery. Hazard mitigation planning is the process that analyzes a community's risk from natural hazards, coordinates available resources, and implements actions to reduce risks. (Tennessee Emergency Management Agency).

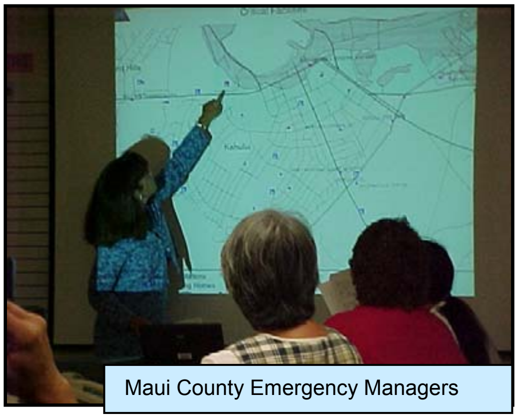
To ensure the national focus on mitigation, the Federal Emergency Management Agency (FEMA) introduced a National Mitigation Strategy in 1995. The National Strategy promotes the partnership of government and the private sector to "build" safer communities. Hazard mitigation encourages all Americans to identify hazards that may affect them or their communities to take action to reduce risks.

Mitigation Benefits

Mitigation actions help safeguard personal and public safety. Retrofitting bridges, for example, can help keep them from being washed out, which means they will be available to fire trucks and ambulances in the event of a storm. Installing hurricane clips and fasteners can reduce personal and real property losses for individuals and reduce the need for public assistance in the event of a hurricane. Increasing coastal setbacks reduces the risk of deaths and property losses from tsunamis and storm surge. Increased setbacks also reduce the risk of property losses from coastal erosion.

Another important benefit of hazard mitigation is that money spent today on preventative measures can significantly reduce the impact of disasters in the future, including the cost of post-disaster cleanup.

Formal adoption and implementation of this strategy will help Maui gain credit points under the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) Community Rating System (CRS). CRS provides discounts on flood insurance premiums for property owners in communities that participate in this voluntary program. For example, points are given to municipalities that form a Local Hazard Mitigation Committee (LHMC). Communities also receive points if they involve the public in the planning process, coordinate with other agencies, assess the hazard and their vulnerability, set goals, draft an action plan (local hazard mitigation strategy), and adopt, implement and revise the plan.



Maui County Emergency Managers

There are many categories to gain credit for public education and awareness activities regarding floodplain management and mitigation. Non-federally owned open space land in floodplains can also help a municipality gain credit points under the CRS program. In addition, vegetated open-space land enhances the natural and beneficial functions that floodplains serve and helps prevent flood damage.

The adoption of this mitigation strategy will enhance Maui's eligibility for federal grants, which include FEMA's pre-disaster Flood Mitigation Assistance Program (FMAP) and its post-disaster Hazard Mitigation Grant Program (HMGP). Pre-disaster planning will also help post-disaster operations become more efficient. For instance, procedures and necessary permits can be identified prior to the disaster and therefore, permit-streamlining procedures can be put into place. Priorities for mitigation during reconstruction can also be identified, helping to reduce the high costs of recovery after a disaster. The state emergency response effort will run more smoothly because of the guidance provided in this strategy.

Perhaps the most important benefit from a county hazard mitigation strategy is that it will minimize the social and economic disruption from multiple hazards. One need only look at the impact that Hurricane Iniki had on the people of Kauai. Unemployment six months after the storm was running at over 16 percent. (Pers. Comm. Mike Hamnett, October 9, 2000) Six years after the storm, several hotels had not reopened and until the recent upturn in tourism, Kauai's economy was lagging significantly behind the rest of the State. (Pers. Comm. Hamnett, October 9, 2000)

Sustainable Communities

A resilient community is one that lives in harmony with nature's varying cycles and processes.

David Godschalk, Timothy Beatley, et al

"Disaster resilient" communities employ a long range, community-based approach to mitigation. Mitigation advocates communities to proactively address potential damage that could occur from hurricanes, coastal erosion, earthquakes, flooding and other natural hazards. When natural hazard mitigation is combined with the standards of creating sustainable communities, the long-term beneficial result is smarter and safer development that reduces the vulnerability of populations to natural disasters while reducing poverty, providing jobs and promoting economic activity, and most importantly, improving people's living conditions (Munasinghe and Clarke 1995). In addition to community sustainability's criteria of social, environmental and economic protection, there is also the criterion that development must be disaster resistant (Institute for Business and Home Safety 1997).

Resilient communities may bend before the impact of natural disaster events, but they do not break. They are constructed so that their lifeline systems of roads, utilities, infrastructure, and other support facilities are designed to continue operating in the midst of high winds, rising water and shaking ground. Hospitals, schools, neighborhoods, businesses and public safety centers are located in safe areas, rather than areas prone to high hazard. Resilient and sustainable communities' structures are built or retrofitted to meet the safest building code standards available. It also means that their natural environmental habitats such as wetlands and dunes are conserved to protect the natural benefits of hazard mitigation that they provide.

Hawaii Coastal Zone Management Booth at the Project Impact Fair in Hana

The Maui County Hazard Mitigation Strategy advocates the concepts of disaster resilient and sustainable communities. Maui is committed to building a disaster resistant community and achieving sustainable development through the commitment of County government and its policymakers to mitigate hazard impacts before disaster strikes. Additionally, Maui will achieve a disaster resilient, and therefore, safer community, through the process of completing its Hazard Risk and Vulnerability Assessment (RVA), and Multi-Hazard Mitigation Strategy (HMS) and through the implementation of mitigation programs and policies. The County will have the capability to implement and institutionalize hazard mitigation through its human, legal and fiscal resources, the effectiveness of intergovernmental coordination and communication, and with the knowledge and tools at hand to analyze and cope with hazard risks and the outcomes of mitigation planning.

Goal 11: Cultural Awareness

Established in 1993, the President's Council on Sustainable Development set forth new goals for sustainable development. These ten goals – *Health and the Environment*; *Economic Prosperity*; *Equity*; *Conservation of Nature*; *Stewardship*; *Sustainable Communities*; *Civic Engagement*; *Population*; *International Responsibility*; and *Education* – are interdependent and essential towards realizing economic prosperity, environmental protection, and social equity. However, the Council overlooked *Goal 11 . . . . . Cultural Awareness*.

It is essential to consider culture regardless, particularly when "sustainability" in the context of the economy, environment, population, or even the resiliency of communities towards natural disasters. Culture is a key thread that binds the very fabric of these and other goals together. Across the nation and throughout the world, lessons are being learned from aboriginal peoples with respect to land use, watershed management, marine and terrestrial conservation, and sustainability based on the respect and balance between man and nature. Today, the term "cultural profiling" has become a new buzzword in the planning and decision-making process. No longer will federal, state, and county governments be discussing projects and programs in a culturally sterile vacuum.

In ancient as well as contemporary Hawaii, Hawaiian people shared a unique relationship with their environment. It is a symbiotic relationship based on a physical and spiritual bond that developed enduring socio-cultural values, beliefs, and practices. On a spiritual level, it was believed by the ancient Hawaiians that both man and the earth were born from the same spirit world. As such, a physical respect for the environment was shown by the way Hawaiians approached the use of animate (i.e., plants, birds, fish) as well as inanimate (i.e., stones, water, rain) resources. Permission and guidance was always sought from the gods, ancestors, and a people's council (*Aha Ki'ole*) consisting of skilled practitioners knowledgeable in medicine, agriculture, weather, astronomy, as well as many other specialties. Through these physical and spiritual "checks and balances", "*pono*" or "to make things right" could be maintained between man and his environment.

Examples of these "checks and balances" can be experienced through ancient Hawaiian beliefs that have been passed down through "*oli*" (chant) or "*mo'olelo*" (stories). For instance, Hawaiian people have a saying – "He kiu ka pua kukui na ka makani" – used to describe the falling of kukui blossoms as a sign of the coming of strong winds. This proverb demonstrates the observant nature of the ancient Hawaiians with respect to their environment. The Kukui blossom was a sturdy flower that required tremendous effort to dislodge. As such, during winter months the falling of Kukui blossoms was nature's sign of an approaching storm or hurricane. The Hawaiians, being practical people, would insure that their homes had secured lashings, personal belongings were stowed, and that other necessary precautions were taken.

The Hawaiians also studied the behavior of animals such as the wild boar. "*Kakaika pua pua'a i ka malie he ino*" meant that a storm was approaching if you observed a herd of wild boar running in a single file. Again, it is this idea of being a part of nature, rather than conquering it.

Ancient sustainable practices such as (1) stream clearance to prevent flooding and to insure the consistent flow of water and nutrients to agricultural fields and ocean fishponds; (2) reforestation to protect watersheds and natural systems; and (3) beneficial land use practices through the implementation of *ahupua'a* (land divisions) governed by people's councils insured the *pono* or balance between man and nature. These practices were done not because you had to do them, but because it was the right thing to do with respect to benefiting the community rather than one's self.

Other rational practices that maintained this natural balance consisted of the construction of temporary coastal villages that would be used for fishing during the summer months and later abandoned as winter's inclement weather approached the islands. Even the ancient Hawaiians knew when to practice coastal retreat. Permanent settlements were constructed out of the natural flood plain areas and individual homes were elevated on stone platforms and built into the forested areas in order to mitigate the energy of storms and hurricanes.

So what can we learn from all of this? The answer is . . . . . "As much as we can." There are definite lessons that can be learned from our cultural past. However, physical lessons alone are not enough to build sustainable communities. A restructuring of public values and attitudes need to be perpetuated in order to accomplish sustainable goals and to build hazard resilient communities that rely not only on hard, structural solutions, but natural, ecological protective measures that are based on traditional knowledge and scientific study.

Chapter II Planning Process

Process

The development of the Maui Hazard Mitigation Strategy began during the Maui Project Impact grant period. The Maui County Project Impact Coordinator invited directors and staff from public agencies, private businesses and organizations, and community representatives to participate in the various committees with several of these participants serving as members of the Steering Committee, Education & Awareness Committee, Business & Industry Committee, Technical Standard Committee, Hana/East Maui Committee, and Lahaina/West Maui Committee. Pacific Disaster Center provided technical support to all committees. Project Impact Community Partners are noted at the end of this chapter. Additional information on Maui Project Impact activities related to the planning processes is located in Appendix A. The goal of developing a hazard mitigation strategy for Maui County has remained constant. This chapter describes the planning process.

Planning Approach and Methods

Maui County also participates actively in the State Hazard Mitigation Forum, helping to guide hazard mitigation planning and activities in the State while receiving guidance from the Mitigation Planning Committee, The Multi-hazard Scientific Advisory Committee and other committees.

The methods used in the hazard mitigation planning process have been drawn from several sources. These include the process delineated in the NOAA Coastal Services Center Community Vulnerability Assessment Tool: http://www.csc.noaa.gov/products/nchaz/startup.htm. The Federal Emergency Management Agency's guidance series, *getting started, Understanding Your Risks – Identifying Hazards and Estimating Losses* and *developing the Mitigation Plan* (FEMA 386-1, 2, 3) were referenced during the planning process.

Elements of this process were developed over several years of hazard mitigation preparedness and planning in the State of Hawaii. Maui County participated in the 1996 Coastal Hazard Mitigation Workshop, supported jointly by NOAA's Office of Ocean and Coastal Resources Management and FEMA Region IX. This workshop allowed counties and jurisdictions to share ideas about hazard mitigation. Following this, the Statewide Hazard Mitigation Forum was established in 1998. Maui County has had representation from the Maui County Planning Department as a full member and the Civil Defense Agency as an ex-officio member.

The Maui County mitigation strategy is multi-hazard in scope. It addresses wind hazards (hurricanes and strong winds); hydrologic hazards (floods, coastal storms, stream flooding, dam brakes, landslides); coastal erosion (beach lifecycle and erosion); seismic hazards (earthquakes); tsunami, drought and wildfire.

The planning approach for Maui County involved the following:

- Briefed County Officials and invited participation from public and private agencies, organizations and groups. Discussed process and gained agreement on approach.

- Gathered available county asset data; used interviews and meetings to collect data. Assessed data availability and condition of data. Gathered and reviewed available hazard studies and assessments for Maui County.

- Used meetings to educate about hazard mitigation, risk and vulnerability and planning process.

- Held public forums and meetings to get suggestions and ideas to address problems. Incorporated these into the strategy.

- Met with the Disaster Mitigation Committee to review risk and vulnerability assessment and strategy development. Established criteria for prioritizing projects and programs.

- Set up maintenance plan to update strategy with new input, data, and accomplishments.

- Adopted the strategy formally.

- Implement strategy. Begin projects. Review goals and objectives, revise appropriately, and continue iterative process as needed.

Maui County fully intends to involve the general public for future iterations of its multi-hazard mitigation through public forums, the State Hazard Mitigation website (www.mothernature-hawaii.com), and the media. The Maui County Disaster Mitigation Committee will be the key agency organizing and conducting those activities relating to hazard mitigation planning. This body will be comprised of representatives from all levels of government and the private sector.

The following is a timeline of the activities that led to the Maui County Multi-Hazard Mitigation Strategy:

- March 1999 - Initial Project Impact Meeting

- April 5-7, 2000 - Project Impact Hazard Mitigation Workshop at Pacific Disaster Center.

- June 15, 2000 - County Council Economic Development Committee. Presentation by Will Orr, Prescott College, on “Growth Model with Hazard & Risk

Vulnerability Assessment." Presentation by Pam Pogue on "Integrating Hazard Mitigation on Maui County - Process and Planning."

- June 28, 2000 - Meeting with EOC personnel and Pam Pogue to discuss start of Plan. Representatives from the following departments of the County of Maui were invited to this meeting: Managing Director, Economic Development, Finance, Police, Fire, Public Works, Water Supply, Housing and Human Concerns, Parks and Recreation, Corporation Counsel, Planning. Representatives from the State of Hawaii: Civil Defense, Hawaii Air National Guard, District Health Services, Engineering, Highways, Airports, Harbors, Human Services, Civil Air Patrol, DMAT Hi-1, Department of Land and Natural Resources. The following organizations were also asked to send a representative: Maui Pacific Center, American Red Cross, NWS, Maui Economic Opportunity, RACES, Hawaiian Telephone Company, Maui VOAD, American Medical Response, Maui Electric, and Maui Memorial Medical Center.

- July 11, 2000 - Diane Zachary of Project Impact, Pam Pogue, Mike Hamnett and Cheryl Anderson from the State Hazard Mitigation Forum and University of Hawaii attended the Maui Planning Commission to explain Project Impact and hazard mitigation.

- August 7, 2000 - Public Meeting in Maui County Council Chambers on overview of hazard mitigation and processes occurring on Maui County by Pam Pogue.

- August 23, 2000 - Pam Pogue conducted a public meeting in the Maui County Council Chambers to share findings of work in process, and the risk and vulnerability assessment and to solicit public input on mitigation actions and awareness.

- September 15, 19, 24 and October 6, 2000 - Akaku TV, Maui Public Access Television, aired the August 23, 2000 public meeting by Pam Pogue.

- October 6, 2000 – Council of the County of Maui adopted "Resolution No. 00-140 SUPPORTING THE ESTABLISHMENT OF THE COUNTY OF MAUI AS A DISASTER RESISTANT COMMUNITY THROUGH A COMPRHENSIVE MITIGATION PROGRAM AGAINST NATURAL HAZARDS." (Appendix B.)

- October 11, 2000 – Mayor of the County of Maui signs a Proclamation that supports develops and implements a County Multi-Hazard Mitigation Program. (Appendix C.)

- October 11-13, 2000 - Maui Project Impact held a statewide hazard mitigation institute.

- December 2000 - Maui Civil Defense Agency received the draft of the Maui County Multi-Hazard Mitigation Strategy from Pam Pogue.

Project Impact Community Partners

County of Maui Mayor’s Office
Maui Fire Department
Maui Police Department
Planning Department
Department of Public Works
Department of Water Supply
Maui Civil Defense Agency
State of Hawaii Civil Defense Agency
State of Hawaii Coastal Zone Management Program
State of Hawaii Hazard Mitigation Forum
Akaku – Maui Community Television, Inc.
Alexander and Baldwin Properties, Inc.
American Institute of Architects, Maui Chapter
American Red Cross
Blue Hawaiian Helicopters
Central Pacific Bank
Department of Education – Maui District
Hale Makua
Hana/East Maui Community Sustainable Committee
Kamehameha Schools
Lahaina Restoration Foundation
Lahaina Action Committee
Lowe’s Home Improvement Warehouse
Maui Chamber of Commerce
Maui Community College
Maui Contractors Association
Maui Economic Development Board
Maui Electric Company, Ltd.
Maui Hotel Association
Maui Memorial Medical Center
The Maui News
Maui Pacific Center
National Weather Service
Pacific Disaster Center
Pacific Radio Group
University of Hawaii, Social Research Institute
U.S. Small Business Association
Voluntary Organizations Active in Disasters (VOAD)
Walter Vorfeld & Associates

Chapter III Mission and Goals of the Maui County Hazard Mitigation Strategy

Mission

The purpose of the Maui County Multi-Hazard Mitigation Strategy is to:

1. Provide a coordinated consistent set of goals for reducing or minimizing: human and property losses; major economic disruption; degradation of ecosystems and environmental critical habitats; destruction of cultural and historical resources from natural disasters;

2. Provide a basis for intergovernmental coordination in natural hazard mitigation programs at the state and county level;

3. Develop partnerships between the County and private sector, local communities and non-profit organizations in order to coordinate and collaborate natural hazard mitigation programs;

4. Identify and establish close coordination with county agencies responsible for implementing the sound practices of hazard mitigation through building standards and local land use development decisions and practices; and to

5. Provide for a continuing public education and awareness about the risks and losses from natural disasters, in addition to natural hazard mitigation programs, policies and projects.

Goals

The goals of the multi-hazard Maui Mitigation Strategy are to:

1. Protect public health, safety and welfare;

2. Reduce property damages caused by natural disasters;

3. Minimize social dislocation and distress;

4. Reduce economic losses and minimize disruption to local businesses;

5. Protect the ongoing operations of critical facilities;

6. Reduce the dependence and need for disaster assistance funding after natural disasters;

7. Expedite recovery disaster mitigation efforts during the recovery phase;

8. Promote non-structural flood and coastal erosion measures to reduce the risk of damage to the surrounding properties and environmental habitats; and to

9. Establish a Maui County Hazard Mitigation Committee to support, implement and revise the Maui multi-hazard mitigation strategy and to provide the support necessary for an ongoing forum for the education and awareness of multi-hazard mitigation issues, program, policies and projects.

10. Provide for adequate financial and staffing resources to implement the Maui Hazard Mitigation Strategy.

Methodology

The geographic scope of the plan includes the Islands of Maui, Moloka'i and Lana'i.

The first step in completing a multi-hazard Mitigation Strategy is to undertake a risk and vulnerability assessment (RVA). The RVA is a systematic way to categorize the effects of hazards and provides a way to identify, compare, and prioritize risks. The RVA establishes a factual basis and foundation to identify issues, and develop goals and objectives for the mitigation plan. Also important, the data from the risk and vulnerability assessment will establish a baseline in which to measure progress.

Meeting with the Mayor's Cabinet to discuss Hazard Mitigation Goals, June 2000

In order to begin to develop the risk and vulnerability assessment, the hazards had to be identified. For the purposes of this version of the Multi-Hazard Mitigation Strategy, the hazards were initially identified by a working group[1], then were presented to the Maui County Emergency Managers, the Mayor and his Cabinet and finally presented in a public hearing on August 7th, 2000. (The public hearing was taped and rebroadcast on by Akaku).

Once the hazards were selected, data was then collected from Federal, state and County agencies and the University of Hawaii. In order to profile each hazard, the data needed had to include information on how to determine the extent and magnitude of each hazard's impact on the community. Data included damage reports, FEMA Flood

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[1] This working group included a representative from: Maui Civil Defense, Maui County GIS and Planning Departments, Hawaii Coastal Zone Management, University of Hawaii Social Sciences Research Institute, the Pacific Disaster Center and Maui Project Impact.

Insurance Rate Maps (FIRMS), impacts from past events, and best available information on each hazard. More information on how each hazard has been profiled and prioritized for this report is explained in subsequent sections of this Strategy. Additional information was also obtained from numerous interviews with officials from Federal, State and County agencies, academic institutions and public comment through two scheduled public hearings.

After identifying the general areas at risk, data about population, property, economic and environmental resources at risk was gathered in order to determine how and where Maui County is vulnerable to the impact of various hazards. To more accurately understand the community's vulnerability it was also important to gather information on the existing protection systems, both physical and regulatory currently in place within Maui County.

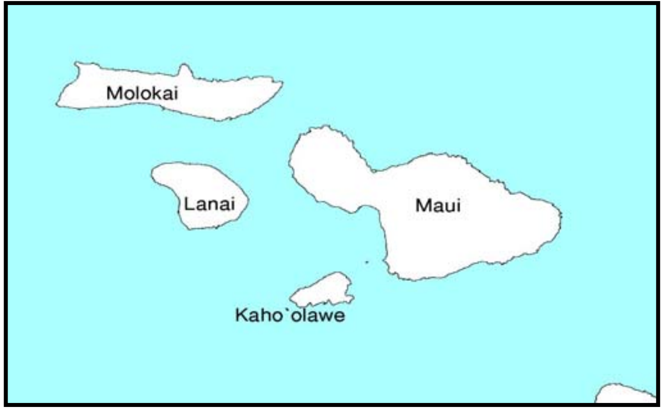
Once the results from the risk and vulnerability assessment were known, a clearer picture of the areas at risk, and an understanding of how and where Maui County is vulnerable to the impacts of these hazards in terms of damage to public infrastructure, critical facilities, environmental, societal and economic components was depicted using Geographic Information System (GIS) maps. In some cases, the results were combined with the Maui County tax assessors' information (TMK data) such as plat, lot and assessed structural values to give potential financial losses the community may face.

Based on the results of the RVA, the government capacity and available resources, mitigation actions were identified in order to address the various hazards' issues potentially affecting Maui County. These options will allow Maui County to choose ways in which to reduce the Counties vulnerability to natural hazard losses. In writing the strategy, community plans were read, in addition to existing policies and on-going programs. If Maui County focuses on strengthening existing plans, programs, policies and procedures, and incorporates mitigation as part of the on-going process of County management, it can avoid the duplication of efforts, thus saving time and money, and achieve multiple objectives. The mitigation actions resulting from the Multi-Hazard Mitigation Strategy should be incorporated into the Maui County Emergency Operations Plan, the community comprehensive plans, and other pertinent planning and implementation tools available such as local zoning, building and subdivision ordinances.

Maui County Geography and Demographics

Maui Geography and Climate

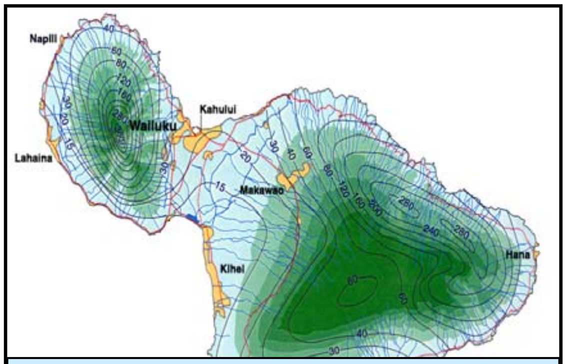
The Island of Maui was formed by two volcanic cones, Haleakala in East Maui and the Puu Kukui on West Maui. A relatively flat isthmus, formed of sand blown inland when the sea was somewhat younger during the late Pleistocene period joins the two cones. East Maui is geologically younger than West Maui, as apparent by the absence of deeply incised canyons and extensive areas of volcanic lava and cinders on the leeward slopes of Haleakala. The lands more suitable for agriculture, including the gentle slopes of central Maui and tablelands of West Maui, resulted from alluvial deposits and the decomposition of basaltic materials.



Rainfall varies considerable from one part of the Island to the other. The windward areas of Maui get heavier rainfall than the leeward side. In East Maui, the highest rainfall area is on the windward side of Haleakala between 2,000 and 4,000 foot elevations, where the median annual rainfall is 200 to 300 inches. On the western side of the island, median annual rainfall near the summit of Puu Kukui is approximately 350 inches. In contrast, leeward locations in central Maui such as Kihei have a mean annual rainfall of 10 inches.

The Effects of the Island Topography on Climate

The topography of Maui plays a key role in defining the climatic zones on the island. The volcanic slopes of Haleakala and Pu'u Kukui are very effective at forcing moist trade wind air upwards to facilitate the formation of clouds and showers. Hence, windward areas of Maui are very wet, averaging about 350 inches of rainfall per year over Pu'u Kukui, and about 280 inches per year over Haleakala. Conversely, subsiding air over the leeward slopes of the island suppresses cloud and shower development leaving these areas dry. Along the leeward coasts of both Haleakala and Pu'u Kukui, the annual average rainfall is only about 10 inches. The effects of Maui's topography is clear when the windward rainfall values are compared to the 28 inch estimate of average annual rainfall over the open ocean near the Hawaiian Islands (Elliot and Reed 1984).



Maui Rainfall map provided by NOAA National Weather Service

Trade winds are also deflected around the volcanic masses and funneled through gaps and valleys, causing localized accelerations and leeward eddies. A notable example is a feature known as the “Maui vortex”, which is a persistent circulation that exists during trade wind conditions. The vortex usually occurs over the western slopes of Haleakala and can result in the re-circulating of pollutants from sugar cane burning in Maui’s Central Valley. In a recent case, strong open ocean trades of about 20 to 30 miles per hour were further enhanced through deeply cut valleys in Pu’u Kukui. Gusts from this event were estimated to be more than 70 miles per hour.

Moloka’i Geography and Climate

The island of Moloka’i was formed primarily by the joining of two separate shield volcanoes approximately 1.8 million to 1.3 million years ago. Mauna Loa is to the west and Kamakou is to the east with a plain in between. Lava from the younger East Moloka’i Volcano flowed across the lowland of the Ho’olehua Saddle and terminated against the flank and side scarps of the West Moloka’i Volcano. This is composed of eroded sediment of the East and West Moloka’i Volcanoes. Near the end of the active volcanism, the northern flank of the East Moloka’i Volcano slid into the ocean leaving behind the towering pali (cliffs) on the northeast coast of the island

A third volcanic episode approximately 300,000 years ago was a comparatively small one. It formed a 2500 acre peninsula in the sea below the steep cliffs of the north side of Moloka’i Island proper. This is the Kalaupapa Peninsula, which is virtually isolated from the rest of the island by cliffs 1600 to 2000 feet high. Erosion, deposition, slumping and secondary volcanic events have modified the topography. The resulting shape of the island is elongated in the east-west direction, much in the shape of a peanut. It is 38 miles long and 10 miles wide. It has an area of 260 square miles and a shoreline of a little more than 100 miles.

East Moloka’i has a range of mountains whose highest peak, Kamakou, is 4,970 feet high. Stream erosion has cut large amphitheater-headed valleys into its northern coast; smaller and narrower valleys are found on its southern side, with an alluvial plain down to the sea. In contrast, West Moloka’i has a sloping mountain, Maunaloa, which reaches an altitude of 1,380 feet. It has rolling arid land rather than valleys and is considerably drier than East Moloka’i. East Moloka’i supports the rain forest of Kamakou Preserve (2,774 acres) near the summit while West Moloka’i supports plantations, ranches and small farms. Pelekunu Preserve is located along Moloka’i’s extremely rugged north coast, featuring the tallest sea cliffs in the world.

Bisecting the island, the broad Ho’olehua Saddle forms a low-lying coastal plain along the south shore. The southeastern edge of the island is bordered by an alluvial plain constructed from a series of semi-contiguous alluvia fans associated with upland gulches. Three of the broader areas, formed at the base of the three major gulches of Kaunakakai, Kawela, and Kamalo’o, have played important roles in early human settlement of the southeast coastline. The deep loose soils, the presence of streams and springs, the low, irregular shoreline, and the relative protection and resources of the broad reef platform provided and inviting physical environment for early human occupation in the southern coastal area.

Moloka’i has a warm year around temperature that fluctuates little between the seasons. The average yearly temperature is 74 degrees F and ranges between 6 and 7 degrees above and below. During the winter months (December through March) the nighttime temperatures may drop to the lower 60’s with more rain and stronger water currents coming to the island. The eastern portion of the island receives notably more rain than the western portion, which lies in the rain shadow of the Kamakou highlands. The average annual rainfall at the Moloka’i airport, which is located in the middle of the island, is 20”. The annual mean precipitation is 20” in West Moloka’i and 35” in East Moloka’i. The rainfall is highest on the west and windward slope of East Moloka’i, decreasing rapidly toward the leeward coast. The kona storms are major storms that come from the south and often drop huge volumes of rain. They occur once or twice a year and may drop 8 to 10 inches of rain in a short time. These storms are island-wide and normally occur between October and April. The trade-wind rains are more local in character and occur through the year. They come in from the northeast and drop most of their moisture in the northerly windward highlands, seldom on the southern or lee side of the island. The greater part of the yearly rainfall in the highlands is from the trade-wind rainstorms.

Population

In April 2000, Maui County has a population of 128,094 people. This includes Maui, Moloka’i, and Lana’i. This is an increase in population of 42 percent over 1990 and an 81 percent increase since 1980 (Maui County Data Book 2000).

Area	1980 Population	1990 Population	2000 Population	Percentage Change		
				1980-1990	1990-2000	1980-2000
Maui Cty	70847	100374	128094	42%	28%	81%
Hana	1423	1895	1855	33%	10%	30%
Makawao	19005	29207	36476	54%	25%	92%
Wailuku	32111	45685	61346	42%	34%	91%
Lahaina	10284	14574	17967	42%	23%	75%
Molokai	5905	6587	7257	12%	10%	23%
Lanai	2119	2426	3193	14%	32%	51%

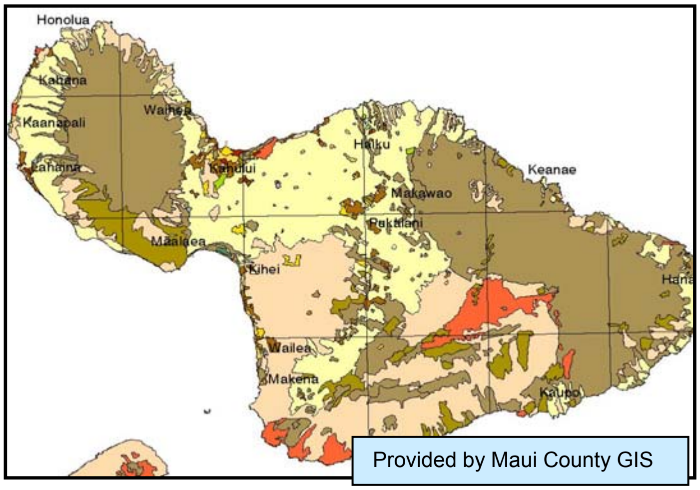
Combined number of residents and visitors determines Maui’s infrastructure and service needs. The population of residents and visitors increased substantially between 1980 and 2000. The average daily visitor census for Maui County has remained fairly constant from 1990 to 2000. The low was 37,060 (1991) while the high was 43,992 (1999).

Population projections developed by the Department of Economic Development and Tourism estimates the 2020 population to be as follows: resident population 151,200;

average daily visitor population 76,000; the total population of 227,000. This would be an increase of about 57,000 or 34 percent (Maui County Data Book 2000).

Land Use

Maui County is the second largest of the four Hawaiian counties. It comprises a total of 1175 square miles of land. Maui has 728.6 square miles, Moloka'i has 260.9 square miles, Lana'i has 140.4 square miles, and Kaho'olawe has 45.0 square miles. The Island of Maui has 149 miles of shoreline, Moloka'i has 106 miles, Lana'i has 52 miles, and Kaho'olawe has 36 miles (Maui County Data Book, 2002).



Provided by Maui County GIS

The State Land Use Commission has classified 25,516 acres in Maui County as urban, 310,396 as conservation, 406,792 as agricultural, and 8,196 as rural. The Federal government owns 4.6 percent of all land, the state and counties own 33.6 percent, and private ownership equals 61.8 percent (Maui County Data Book 2003).

Response Agencies

Maui County Civil Defense Agency is entrusted with the protection of life and property within the County of Maui during emergency or disaster situations. The agency operates under the authority of Chapters 127 and 128 of the Hawaii Revised Statutes, as amended, and Section 8-15.1 of the Maui County Charter. The agency is responsible for administering and operating the various Local, State and Federal Civil Defense Programs for the County. This includes planning, preparing, and coordinating civil defense operations in meeting disaster situations and coordinating post-disaster recovery operations involving State and/or Federal assistance.

The Mayor of Maui County serves as a Deputy Director of Civil Defense, in addition to his normal duties. A small four person staff that includes the Civil Defense Administrator, Plans and Operations Specialist, a Civil Defense Staff Specialist, and a Civil Defense Technician manages the day to day operations of the agency. During disaster situations the Emergency Operating Center can be activated to include Emergency Mangers from various governmental and private organizations. The Maui County Civil Defense Agency also works at maintaining and upgrading the Civil Defense Siren Warning System, trains governmental and civilian volunteer emergency response force, and pursues a public awareness program on emergency preparedness.

MAUI COUNTY CIVIL DEFENSE AGENCY
EMERGENCY MANAGERS

- Mayor of the County of Maui
- Managing Director of the County of Maui
- Maui County Public Information Officer
- Maui County Police Department
- Maui County Fire Department
- Maui County Department of Parks and Recreation
- Maui County Department of Public Works and Waste Management
- Maui County Department of Water Supply
- Maui County Department of Housing and Human Concerns
- Maui County Department of the Corporation Counsel
- Maui County Planning Department
- Maui County Department of Finance
- State of Hawaii Department of Transportation/Harbors Division
- Radio Amateur Civil Emergency Service
- Amateur Radio Emergency Service
- Disaster Medical Assistance Team HI-1

- Verizon Hawaii

- Civil Air Patrol
- Maui Visitors Bureau
- American Medical Response
- Voluntary Organizations Active In Disaster
- State of Hawaii Department of Transportation/Highways Division
- State of Hawaii Department of Transportation/Airports Division
- State of Hawaii Department of Education
- State of Hawaii Department of Land and Natural Resources
- State of Hawaii Department of Human Services
- State of Hawaii Department of Defense/Hawaii National Guard
- National Weather Service
- American Red Cross
- Maui Economic Opportunity
- Maui Electric Company, Ltd.

- State of Hawaii Department of Health

Maui County Project Impact

In support of the Disaster Resilient and Sustainable Community concept, FEMA has developed an initiative called Project Impact. Project Impact encourages communities to move from the current reliance on response and recovery to an emphasis on mitigation, preparedness and disaster management. Under this initiative, communities are demonstrating the economic benefits of pre-disaster mitigation.

Meeting of the Maui Project Impact Technical Standards Subcommittee, August, 2000

Maui County initiated their two-year Project Impact community disaster mitigation program in May 1999. The Project Impact Program (1999-2001) is currently under the auspices of the County of Maui Office of Economic Development. FEMA provided the County with a two-year grant of $300,000. Maui's Project Impact efforts is focusing on the following objectives:

Completing an island-wide survey to identify the current strengths and weaknesses of Maui's disaster mitigation efforts and guide future efforts;

Drafting and implementing isolated community preparedness plans for West Maui/Lahaina and East Maui/Hana regions to reduce the negative impact resulting from becoming isolated during and after disasters; and Implementing an island-wide public education and disaster mitigation awareness campaign to educate the public and encourage disaster mitigation behavior.

To date, thirty-five businesses and organizations have become Maui Project Impact Partners, joining forces with other county and state agencies to reduce hazards on the Island of Maui.

Development of the Multi-Hazard Mitigation Strategy will help Maui Project Impact meet its second objective and better integrate its efforts with the County in order to accomplish the successful implementation of this Strategy.

Project Impact Booth at Hana Fair, July, 2000

Chapter IV Hazard Identification and Analysis

Hazards identification and analysis helps in making decisions about which hazards merit special attention; what actions might be taken to reduce the impact of those hazards and what resources are likely to be needed to successfully implement the hazard mitigation measures.

Hydrologic, Wind, and Seismic Hazards

Hazards Identification

Identifying the hazards is the first step in any effort to reduce community vulnerability. Identifying the risk and vulnerability for a community is the primary factor in determining how to allocate finite resources to address what mitigation actions to take. The hazard analysis involves identifying all of the hazards that potentially threaten Maui County and then analyze them individually to determine the degree of threat that is posed by each natural hazard. By addressing risk and vulnerability through hazard mitigation, Maui County will only then reduce societal, economic and environmental exposure to natural hazards impacts.

All hazards that may potentially occur in the community should be identified. This includes both natural and secondary hazards – situations when one hazard triggers others sequentially. For example, severe flooding that damaged buildings storing hazardous water-reactive chemicals could result in critical contamination problems that would dramatically escalate the type and magnitude of events. Dam failures may occur as a result of an earthquake creating a dangerous flash flooding scenario for communities on the other side of the dam. In areas of steeper, unstable slopes, identifying the secondary effects of coastal storms and/or tsunamis may include flood and debris damage resulting in rockslides or landslides. Additionally, coastal erosion results from serious damage impacted on the coastline in the event of a tsunami, hurricane and/or kona storm.

For the purposes of the Maui County Hazard Mitigation Strategy, the following hazards will be addressed:

- Hydrologic
- Coastal erosion
- Wind
- Seismic
- Tsunamis
- Drought
- Wildfire

By collecting information for each potential hazard that may affect Maui County, several determinations have been made:

(1) which hazards merit special attention;
(2) what actions might be taken to reduce the impact of those hazards; and
(3) What resources are likely to be needed?

Historical data of past damages was also reviewed. This data provided information on past damage costs, areas impacted, repetitive loss areas and those areas hardest hit.

HYDROLOGIC HAZARDS: INLAND AND COASTAL FLOODING

Floods

Hydrologic hazards include inland and coastal floods, storm surge, coastal erosion and droughts. It is important to understand the interrelationship of hydrologic hazards with other hazard groups. For example: extreme rainfall from a kona storm can cause flooding, and sometimes flash flooding, and winds from a hurricane exacerbate storm surge, high surf and coastal erosion.

Flooding is the accumulation of water within a water body and the overflow of excess water onto adjacent floodplain lands. *(FEMA, Multi Hazard Identification and Risk Assessment, 1997)* The floodplain is the land adjoining the channel or river, stream, ocean or other watercourse or water body that is susceptible to flooding. Flooding is the result of large-scale weather systems generating prolonged rainfall or on-shore winds. Other causes of flooding include locally intense thunderstorms and dam failures. Floods are capable of undermining buildings and bridges, eroding shorelines and stream banks, tearing out trees, washing out access routes, and causing loss of life and injuries. Flash floods, characterized by rapid onset and high velocity waters, carry large amounts of debris.

Seasonal Pattern

The northwesterly trade winds directly influence the climate of the islands. Generally, leeward locations are much drier and sunnier than the windward slopes. Conversely, the windward side gets heavier rainfall than the leeward side. Rainfall varies considerably, however, from one part of the island to the other. On Haleakala, the 2.000 to 4,000 foot elevations receive 200 to 300 inches of rainfall each year. (FEMA

Flood Insurance Study or FEMA FIS, August 3, 1998). On the western side of Maui, the average rainfall near the summit of Puu Kukui is 350 inches. In sharp contrast, leeward locations in south Maui receive an average of 10 inches. (FEMA FIS, 1998).

The climatic pattern is much the same on Moloka'i and Lana'i. It also has two seasons of winter and summer but with a slight variation in the months. The wetter season extends from December through March while the dry summer season is June through August. The average rainfall for Moloka'i is somewhat less than Maui. The eastern slopes of Kamakou receive an average of 150 plus inches a year, tapering off to 10-12 inches per year in places in the western part of Moloka'i. This disparity in annual rainfall on the two islands arises from the fact that the Hawaiian Islands extend over a latitudinal belt that is a zone of desiccation throughout the world except where marine air masses are forced to rise over mountain barriers. Orographic rainfall results in the cooling of the uplifted air masses, creating extremely high rainfall under the ideal conditions of mountain elevation and trend, and wind direction and velocity.

Damage

Water related damage caused by inland and coastal flooding in the United States account for over 75 percent of federal disaster declarations (FEMA Multi Hazard Identification and Risk Assessment, 1997). Floods occur in all 50 states and US Territories. FEMA estimates that over 9 million households and $390 billion in property are at risk from flooding. In Hawaii, floods caused by rainstorms, tsunamis, and hurricanes claimed more than 350 lives and caused more than $475 million in damages before 1983. From January 1983 – July 1992, twelve lives were lost due to various floods in Hawaii.

Flood damage can result from the effects of short and long-term increases in water levels through precipitation, wave action, high-velocity flows, erosion and debris. Coastal flooding can originate from a number of sources. Coastal storms such as hurricanes and kona storms, and ocean disturbances such as seismic activity and sub-ocean landslides which can cause tsunamis, generate the most significant coastal flood damage. Coastal storms and hurricanes create coastal flooding along the open ocean coastline. Whether situated on a coastal headland, barrier beach, or bluff sitting high atop the coast, the ocean-land interface is a place of great danger and sudden transformation during storms. (The Hidden Costs of Coastal Hazards, 2000)

(AP PHOTO)

Under the National Flood Insurance Program (NFIP), FEMA is required to develop flood risk data for use in both insurance rating and floodplain management. FEMA develops these data through Flood Insurance Studies (FIS). In FISs, both detailed and approximate analyses are employed. Generally detailed analyses are used to generate flood risk data only for developed or developing areas of communities. For undeveloped areas where little or no development is expected to occur, FEMA uses approximate analyses to generate flood risk data.

Using the results of the FIS, FEMA prepares a Flood Insurance Rate Map (FIRM) that depicts the Special Flood Hazard Areas (SFHAs) within the studied community. SFHAs are areas subject to inundation by a flood having a one percent chance or greater occurring in any given year. This flood, which is referred to as the 100-year flood (or base flood), is the national standard on which the floodplain management and insurance requirements of the NFIP are based. The FIRM shows Base Flood Elevations (BFEs) and flood insurance risk zones. The FIRM also shows areas designated as a regulatory floodway. The regulatory floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 100-year flood discharge can be conveyed without increasing the BFE more than the specified amount. Within the Special Flood Hazard Area (SFHAs) identified by approximate analyses, the FIRM shows only the flood insurance zone designation. The FEMA FIRM designations are defined below.

FEMA Flood Insurance Rate Map Definitions

VE Zones
Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone A
Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE
Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, whole foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH
Zone AO is the flood insurance rate zones that correspond to the areas of 100-year shallow flooding (usually areas of ponding) where depths average are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO
Zone AO is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-depths derived from the detailed hydraulic analyses are shown within this zone

500-Year Flood Zone (or Zone X)
Zone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, and to areas of 100-year flooding where average depths are less than 1 foot, areas of flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No base flood elevations or depths are shown within this zone.

Types of Flooding Events, Frequency, Magnitude and Location

Coastal Storms

Major flooding events in Hawaii are caused by storms, storm surge, high surf and tsunamis (tsunamis will be covered in Seismic Hazards section). The climate of Hawaii is characterized by a two-season year; cool and warm. Floods occur during both seasons. Major floods typically occur during the rainy winter (October through April) and account for 84 percent of the floods in the islands. (State of Hawaii Flood Hazard Mitigation Plan, December 1996) Four types of storms produce heavy precipitation in Hawaii:

Kona storms. These wintertime storms, from November to April, are in the wettest period of the year and locally called the *Hoo'ilo* season. The trade winds from the northwest slacken during this time, allowing storms from the south to more easily approach the islands. Hence the name *kona* which means leeward direction indicates the direction from which these storms come. The *kona* winds are generally warmer carrying moisture, which is dropped as rain over the entire island, more or less evenly. The lower elevations and southern, drier side of the islands get most of their rainfall at this time. It is about 25-30 inches each season. Because of the potential combination of high winds and heavy rains, these events could cause coastal erosion, and inland and coastal flooding over larger geographic areas of Maui and Moloka'i, thereby creating a greater impact on the islands.

Frontal Storms. Frontal storms usually occur during the period from December through March. They originate over the Pacific Ocean as a result of the intersection between polar and tropical Pacific air masses and move eastward over the Islands. Rainfall from these storms is enhanced by mountainous areas (such as Haleakala and the West Maui mountains on Maui and Kamakou on Moloka'i) and can be accompanied by widespread precipitation. The effects of frontal storms are often greater within the mountainous regions of Maui and Moloka'i. Heavy rainfall, continuous over a period of several hours, quickly creates disaster conditions in high sloping areas such as these, prone to landslides and flash flood conditions in lowlands with poor drainage.

Upper level lows. Upper level lows and troughs can occur any time of the year. In many instances, upper level lows have little or no effect on the lower levels of the atmosphere. However, these lows are sometimes able to tap into the marine layer and induce heavy showers that sometimes produce flash flooding.

Tropical Cyclones. Hurricanes or tropical storms hitting or passing by the Hawaiian Islands cause heavy rains, storm surge, high winds and surf. Impacts from these events have included coastal erosion, severe inland and coastal flooding. Extensive wind damage can occur from the stronger tropical cyclones (hurricanes and tropical storms).

History of flooding on Maui

Island-wide stream flooding because of heavy rains

DATE	DESCRIPTION
November 19. 1900	Flash flood
December 23, 1906	Flash flood
January 14, 1916	Flash flood
April 18, 1918	Flash flood
August 10, 1930	Flash flood
November 18, 1930	Flash flood
January 2, 1946	Flood
December 20, 1946	Flash flood
April 2, 1948	Flash flood
November 30, 1950	Flash flood
February 22, 1951	Flash flood
May 12-13, 1960	Flood
October 24, 1961	Flash flood
March 13, 1963	Flooding
January 23, 1965	Flash flood
March 13-16,1968	Flooding
November 28, 1968	Minor flooding
January 28, 1971	Flooding
April 19, 1974	Flash flood
January 6-14, 1980	Flooding
August 3-4, 1981	Flooding
October 27-28, 1981	Flooding
March 30-31, 1982	Flooding
April 1-3, 1982	Flooding
July 16-17, 1982	Flooding
December 23-24, 1982	3-5" of rain
May 23, 1984	Minor flash floods
December 24-25, 1984	Flash flood
October 17-18, 1985	Flash flood
November 18, 1985	Minor flash floods
February 15, 1986	Flash flood
November 10-11, 1986	Minor flash floods
April 21-22, 1987	Minor flash floods
April 26, 1987	Flash flood
May 5-6, 1987	10" of rain, flash flooding
January 28-29, 1988	Flash flood
November 4-5, 1988	Extensive flooding

December 5-6, 1988	Flash flood
February 10-11, 1989	Minor flash floods
March 1-4, 1989	Minor flash floods
January 14-22, 1990	Up to 20" of rain, flooding
January 27, 1991	Flooding
March 19-21, 1991	Flooding
July 21-23, 1993	Flooding, remnants of H. Dora

West Maui stream flooding because of heavy rains

DATE	DESCRIPTION
January 26, 1916	Lahaina & Olowalu flooded
November 30, 1950	Flash flooding at Lahaina
May 12-13, 1960	Kahoma Stream
October 31, 1961	West Maui, Kahoma Stream
March 17-18,1967	7" in 5.5 hrs at West Maui
January 28, 1971	Lahaina, Kauaula Stream (Hale, Cannery, Kelawe Camp)
February 24, 1972	5-8" in 5 hrs at West Maui, Lahaina
November 24, 1974	Ka'anapali, Honokawai
May 5-6, 1987	10" of rain, flash flooding in Lahaina
December 5-6, 1988	Over 10" of rain
January 19-20, 1997	Flooding Lahaina

Northwest Maui stream flooding because of heavy rains

DATE	DESCRIPTION
November 2, 1961	Flash flooding at Napili, Honolua
December 19, 1964	Flooding
March 17, 1967	Napili Bay
March 24, 1967	Heavy rains at Napili Bay
March 13-16, 1968	24" in 48 hrs at Napili Beach, Honolua Pa'akea

North central Maui stream flooding because of heavy rains

DATE	DESCRIPTION
November 14. 1900	Kahului
February 13, 1903	Flash flood at Wailuku
January 14, 1916	17,000 cfs at Iao Valley
December 24, 1920	Storm, flooding at Wailuku
November 18, 1930	Flash flood Iao Stream
January 2, 1946	Flooding of Iao Stream
November 30, 1950	Flash flooding at Iao Valley, Wailuku
December 3, 1950	7550cfs, 5" rain in 2 hrs at Iao Stream
November 2, 1961	5700 cfs at Iao Stream
February 4, 1965	Sheet flow

January 27-28, 1971	5820 cfs at Iao Stream, 2 ft at Pai'a
February 8, 1972	3.5" in 1 hr at Wailuku
November 12, 1978	Flash flooding at Iao Valley, Kahului
March 30-31, 1982	Flooding at Iao Valley
May 5-6, 1987	10" of rain, flash flooding at Wailuku, Kahului
February 3-5, 1989	Flash flooding near Haiku
April 12-13, 1994	Flash flood, mud slides

Windward Haleakal'a stream flooding because of heavy rains

DATE	DESCRIPTION
April 25-28, 1965	Flash flood at Hana
April 15-16, 1968	East Maui esp. Honomaele Stream
October 27-28, 1981	Flooding - road to Hana
March 30-31, 1982	Flooding - road to Hana
July 21-22,1982	Flash flooding
August 1, 1982	Flash flooding, esp. Ka'anapali
May 23, 1984	Minor flash floods – road to Hana
February 15, 1987	10" rain
March 24, 1988	Flooding - road to Hana
March 19-21, 1991	Flooding - road to Hana
November 26-27, 1992	Severe flooding
October 23, 1993	Flash flood, mudslide
April 12-13, 1994	Flash flood, mudslide

Southwest Maui stream flooding because of heavy rains

DATE	DESCRIPTION
January 26, 1916	Flood – Kihei
January 29, 1930	Flash flooding at Kulat, Kihei
February 22, 1951	Flood – Kihei
December 21, 1955	Flood – Kihei
March 24, 1967	6" in 6 hrs at Kihei
January 28, 1968	Flood – Kihei
January 27-28, 1981	Flooding - 6ft at Kihei
December 5-6, 1988	Over 10" of rain at Kihei

Inland Flooding

Stream Flooding

Stream flooding is a very common occurrence on both Maui as can be expected from the deep V-shaped valleys of west Maui, carved as the result of one million years worth of stream flow. Along the eastern half of Maui, the mountains and valleys are much younger and as a result, the valleys and streams are not as well developed.

Most of the streams cut steeply down to the narrow coast of Hana, often in cascading waterfalls, a hallmark of this region. According to the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS), the greatest amount of rainfall occurs in West Maui (300 inches) at the summit, and nearly as high in east Maui (280 inches). (Fletcher 2000). Rainfall decreases dramatically toward southern Maui and west of West Maui and is the lowest (<15 inches) in the area of Lahaina and Kihei.

Damage

The north and central areas of Maui and the Hana Coast have the greatest stream flooding histories. Kahului, Maui's most urbanized area and location of the Island's major airport, commercial port and most of the retail and wholesale facilities, is a frequent victim of serious inland flooding events. (Pers. Comm. Roger Kawasaki, NOAA National Weather Service) Stream flooding is a particularly significant hazard in the areas where there are streams in close proximity to residential development such as in the south Maui area: Kalama Park, Kamole Beaches and Lipoa Avenue. The three principal streams in the area that flow westward and seaward only during periods of excessive rainfall are Kulanikakoi, Waipuilani, and Keokea Streams. They are narrow and poorly defined waterways. Localized depressions, ponds, swales and ditches are typical of areas along Kihei Road. Only seven gulches have well defined watercourses, and even these do not maintain stabilized channels completely across the lowland area to the ocean.

Stream flooding in the Kaupo region, which has half the rain fall as Hana, is a high risk. Here there are many stream mouths that flood during intense rain events. On the back coastal road from Kipahulu to Kaupo, there are many areas where the road suddenly dips down and becomes flooded from low water crossings. During the storm of 1968 this area experienced extensive damage as six miles of unpaved road was closed to traffic for several days, a result of four timber bridges and three culverts being destroyed). Areas particularly susceptible to flooding are Nuu, Huakini and Waiu Bay, Pakowai and Waiopai.

Stream flooding on Moloka'i

Because of the lack of rainfall over most areas of the island, the only perennial streams which reach the sea are those of the large valleys on the windward side of East Moloka'i. The permanence of the streams on the northern slope are the result of numerous high level springs which issue from the dike complex where exposed by erosion. Other streams are fed from the seepage of swamps. Due to the geological conditions such as the steepness of the terrain and the intermittent character of the heavy rainfall, the streams in most of the area have high flows and velocities during heavy rainfall. The streams on the southern slope of the East Moloka'i and most areas of West Moloka'i are perennial in the upper courses but these streams normally lose their water to seepage and evaporation long before reaching the coast. The expectation is after heavy rainfalls or Kona storms when flows in these streams reach the ocean.

Damage

The major flood problems are associated with the heavy flow of four water courses in East Moloka'i, the Wailua Stream, Wawaia Gulch, Kamalo Gulch, and Kawela Gulch. The primary causes of flood damages are overflow of the water courses, inadequate highway bridge openings and periodical accumulation of deposits on the stream beds which result in the reduction of flow capacity. Minor flooding problems are caused by overland sheet flow. Along the eastern limits of Wailua Valley, flooding due to water flowing rapidly down the steep hillside onto level areas causes ponding to occur. Sheet flow occurs at east Kawela and west Wawaia valleys when water rushes over cleared portions of the flood plain after intense rainfall. Due to the lack of drainage ditches and channels, the water runs as “sheet” flow towards the ocean.

Flash Floods

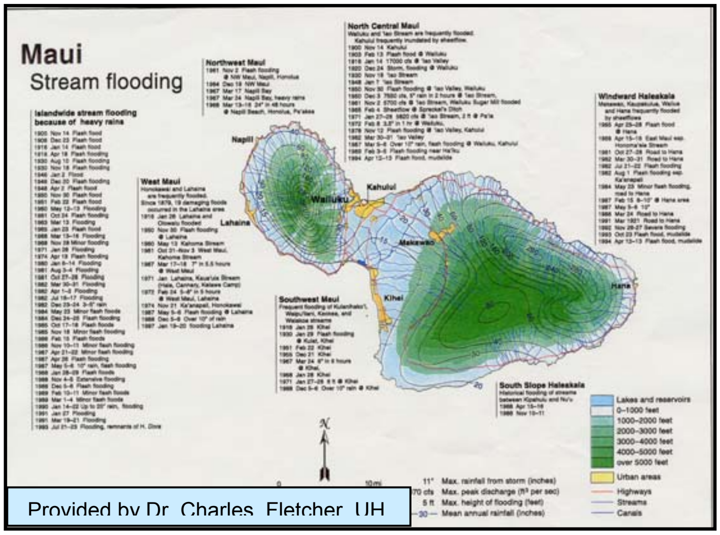
Flash floods are characterized by a rapid rise in water level, high velocity, and large amounts of debris. Flash floods are capable of tearing out trees, undermining buildings and bridges, and scouring new channels. Flash floods are more prevalent in areas where there is a predominance of clay soils that do not have high enough infiltration capacities to absorb water fast enough from heavy precipitation events.

Flash floods may also result from dam failure, causing the sudden release of a large volume of water in a short period of time. In urban areas, flash flooding is an increasingly serious problem due to the removal of vegetation, and replacement of ground cover with impermeable surfaces such as roads, driveways and parking lots. In these areas, and drainage systems, flash flooding is particularly serious because the runoff is dramatically increased.

The greatest risk involved in flash floods is that there is little to no warning to people who may be located in the path high velocity waters, debris and/or mudflow. The major factors in predicting potential damage are the intensity and duration of rainfall and the steepness of watershed and stream gradients. Additionally, the amount of watershed vegetation, the natural and artificial flood storage areas, and the configuration of the streambed and floodplain are also important.

Precipitation, which sometimes equals the average annual rainfall, has occurred throughout the historical record. Flooding in areas around Kihei and Lahaina on Maui is partially due to the fact that the topography is characterized by an abrupt transition in slope at the coastline. Many historic floods in these two areas occurred after heavy precipitation in higher elevations, which fed to narrow stream channels and drainage channels near an arid coast to the point of overflow. (Fletcher May 2000, p.2). Flash flooding is a common occurrence in the Lahaina area. This is caused by a couple of things; the steep slope of the foothills on the westside of the West Maui Mountains, and the lack of vegetation because sugar cane is no longer planted in this area.

Damage



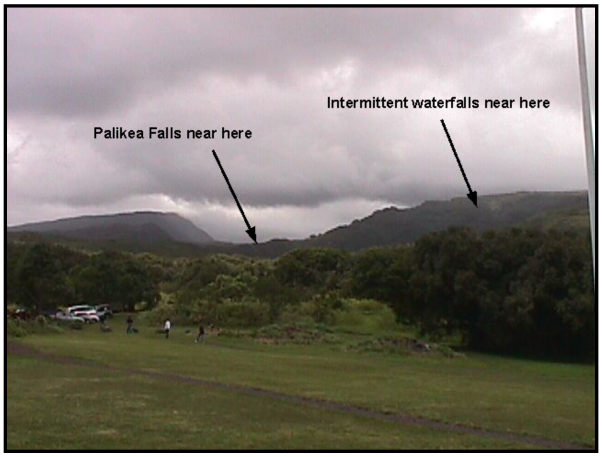
Provided by Dr Charles Fletcher UH

According to the May 2002 version of the *Atlas of the Natural Hazards in the Hawaiian Coastal Zones,* a number of flash flood events resulting in significant damage have occurred since 1900. Since 1879, 19 damaging floods have occurred in Lahaina. (Fletcher 2000) Wailuku, Maui's county seat, also experiences serious sheet flow and flash flooding events. Historically, flash flooding has been a serious problem in the Kahului and Wailuku areas, due to large amounts of water discharge from the steep hillsides of the Iao Valley cumulatively collecting when encountering a coastal lowland area. Flash flooding also poses serious threats in this low-lying coastal terraced near Waihee Point and Waihee Beach Park. The Waihee stream area is popular with visitors for hiking. However, the high potential, and past flash flooding events poses serious concerns in this area, as visitors are unaware of these risks. An additional concern is debris flow. High velocity flows from the streams within the Iao Valley area, bring rocks and boulders to the beaches near Waihee. (See May 2002 *Atlas of the Natural Hazards in the Hawaiian Coastal Zones* for complete historical listing of these events)

Sheet flow

Sheet flow is more prevalent in those areas characterized by steep grades and sudden high precipitation events. In west Maui, sheet flow flooding tends to be a problem. This area of Maui encompasses two major watersheds – Lahaina Watershed and Honoloa Watershed. The Honoloa Watershed spans the area north of the Ka'anapali Resort to Honoloa Bay, approximately 24,800 acres in size. The highest point of the watershed is the Puu Kukui peak in the West Maui Mountains

(Mauna Kahalawai). Deep valleys and narrow winding channels draining to the ocean incise the watershed. Grades begin at about 16% and flatten to 6% towards the ocean. Defined channels exist in the major valleys, varying from 5 to 10 feet deep and 10 to 20 feet wide. The Lahaina watershed is approximately 4,920 acres encompassing Lahaina Town and Pomona subdivision. (Maui Community Plan Infrastructure Assessment 1992) The remaining upper area of the watershed is mountainous with deeply incised canyons and is part of the West Maui Forest Reserve.



On Moloka'i, sheet flooding occurs along the eastern limits of Wailua Valley. This is caused by water flowing rapidly down the steep hillside onto level areas causing the water to collect in ponds. Sheet flow also occurs at east Kawela and west Wawaia valleys when water rushes over cleared portions of the flood plain after intense rainfall.

Damage

Heavy precipitation from past storm events on Maui (such as April 15-16, 1968), creates serious storm water runoff problems from the high velocities of water flowing down the pasturelands. In downtown Hana, this high velocity sheet flow has caused road damage. (Kevin Kodama, NOAA National Weather Service) During the Storm of 1968, drainage ditches in Hana town including its bedding, and sections of the earth banks were washed downstream into the ocean. (Corps of Engineers, 1968) Additionally, road shoulders, retaining walls and pavement were also severely damaged. Holoinawawae Stream was also damaged. (Corps, 1968)

Storm water runoff

Drainage refers to the system or area where rainfall and storm water runoff travels to waterways or bodies of water. Drainage presents itself as a problem in the form of flooding due to the development or alteration of natural areas and drainage patterns. Geology and rainfall are the major influences on drainage systems. Runoff is a function of infiltration capacity (soil type), relief, vegetal cover, and type and extent of development (amount of impermeable surface).

Sediment erosion is a naturally occurring process that is accelerated by human activities (West Maui Watershed Owners Manual, November 1997) There are watersheds on Maui that are high producers of sediment as a result of Maui's erodible soil, steep slopes and periodic rainfall, particularly at high elevations. Heavy precipitation events cause soil and sediment erosion and storm water runoff conditions that significantly alters river channels carrying large amounts of sediment downstream, plugging drainage systems and causing flooding and damage to homes and roads. Soil erosion also becomes a serious problem for public infrastructure when high velocity streams cause scouring to occur at the base of bridge supports. Flooding and high wave conditions erode coastal lands supporting roads.

Abandoned sugarcane fields, Lahaina

Rapidly developing downstream communities are often overwhelmed by the large amounts and high peaks of storm water and sediment flowing from upstream areas down normally dry or minimally flowing streams and irrigation channels (Lahainaluna area). Environmental degradation can occur when debris flows and storm water runoff occurs. Once flooding occurs, sediment particles are quickly transported downstream to the ocean where the suspended sediments and debris creates turbid conditions that are harmful to coral reefs when particles abrade and smother coral reefs. This is particularly true on Moloka'i. Because of the limited development in the coastal zone on Moloka'i, the hazards caused by storm water runoff affects the natural environment more so than coastal development. Some of the most expansive reefs in the state occur along the southern coast of Moloka'i. On rainy days plums of red-brown sediment can be seen lining the entire south shore. Where the shoreline progrades seaward, the reef flat becomes buried in mud. Storm water runoff and debris flows carry trash, motor oils, landscape chemicals, pet ands livestock feces and other pollutants to streams and into the ocean.

In terms of urban land use, construction sites and roadsides expose large areas of bare soils that are highly susceptible to runoff and erosion. Construction sites can contribute significantly to storm water runoff and sediment erosion because Maui's soils are so fine and the close proximity of new development to the shoreline. Construction and development within the watershed contributes sediments and pollutants to storm water runoff during the grading and construction phase. After construction is completed, the paved or impermeable surfaces create increased volume and peak rates of storm water runoff flow. Because, major sediment retention basins are mauka of urban areas, urban runoff is transported directly to the ocean through streams, gulches and some storm drains.

Studies conducted by researchers in conjunction with the West Maui Watershed project showed that pineapple and sugar cane fields generate higher loads of runoff (West Maui Watershed Owners Manual, December 1997). Pineapple fields generate the most runoff immediately before planting and for the first 8 – 12 months after planting, before the plant canopy cover is complete. (Marty Stevenson, 1997) Sugarcane fields were found to be highly vulnerable to erosion and runoff for a period of roughly 4 – 6 months after being planted (Stevenson, 1997) Cane roads are also susceptible to erosion. On Moloka'i, much of the red-brown mud or silt comes from excessive soil erosion in watersheds that have been denuded by deforestation and feral ungulates.

Damage

Historically, the Iao Stream has caused the major flood problem in the Wailuku-Kahului area. Due to the steep ground gradient, flooding from high velocity and large flow quantities has caused considerable property damage and loss of life. Another flood problem in the Wailuku area has been the overtopping of the irrigation ditches. During periods of heavy rainfall, the irrigation ditches are incapable of carrying the irrigation water and storm water runoff that is intercepted by the ditches. Flooding in Wells Park area and along Main Street has occurred during periods of heavy rainfall. Secondary areas of flooding occur in the low-lying sections of Kahului. The flooding primarily consists of the inundation of the streets and low-lying residential areas. The lack of adequate storm drainage facilities and the inability of local dry wells to accommodate the overtopping gulches and ditches cause such flooding.

Records for flooding on Moloka'i are not as good as on Maui but the observational data shows flooding does occur in both the arid and wetter regions of Moloka'i. There are only a few places where flooding has much of an impact on the developed areas of the coastal zone. The primary causes of flood damages are overflow of the watercourse, inadequate highway openings and periodical accumulation of deposits on the streambeds, which result in the reduction of flow capacity.

At least two coral species that are rare throughout the Hawaiian Archipelago can be found in the shallow water at Palaau on Moloka'i. A third rare coral species is found at Pukoo. Impact of land-derived sedimentation on the coral reefs of south Moloka'i has been and continues to be a major environmental concern. Unchecked, this can be a causative factor in the destruction and death of the coral.

Ponding

Storm water runoff and debris flows also negatively impact public infrastructure such as roads and bridges as water collects. This is typically the result of inadequate drainage systems in the immediate area, creating ponding conditions oftentimes making roads impassible. Standing surface water develops after intense

Suda Store, Kihei, October, 1999

rainfall events where poor soil permeability and urbanization prevent adequate water drainage. This may interrupt road transportation and damage low elevation buildings. Road closures can be a critical issue in Maui when these events have the potential to isolate communities.

Damage

The direct cause of flooding in Kihei is the inadequate capacity of existing channels. Between Kihei Road and Pi'ilani Highway, there are four gulches (Waiakoa, Kulanihakoi, Waipuilani and Keokea) that flow in an east-west direction and drain approximately 65% of the watershed. Storm runoff flows at high velocities above the coastal plain because of the steep ground gradient at upper elevations. Gradual slopes in this area approximate 4-5 percent with elevations ranging from 5 to 90 feet.

These slopes establish little or no well-defined surface drainage pattern. The drainage ways do not maintain stabilized channels and are generally narrow and poorly defined because of intermittent rainfall and minimal runoff throughout most of the year. As the floodwaters approach the coastline, ponding occurs because of inadequate outlets to the sea, which is frequently plugged with ocean-deposited sand. The high volumes and velocities of the flood waters of these streams, on their approach to the Kihei flood plain, cause overtopping of existing drainage structures crossing Kihei Road. (Maui Community Plan Update Infrastructures Assessment, 1992) This flat low-lying coastal area is the recipient of all of this surface runoff and contributes to the flood problems in the Kihei area.

In Kihei, the transportation and even evacuation problems are particularly severe due to the North/South Kihei Road that runs parallel, and perilously close, to the coastline. This road has been flooded on many occasions by low magnitude coastal flood inducing events such as south swells, Kona storms and heavy rains.

Rain Gages/Flood Forecasting Systems

Hydronet

The Hydronet system is a statewide network of NWS maintained and operated tipping bucket rain gages whose primary purpose is to support the flash flood forecast and warning operations of the Honolulu Forecast Office. Network communications are handled via commercial telephone lines or cellular phones that contact data loggers attached to each rain gage. Each data logger records rainfall to a resolution of 0.01 inches every 15 minutes and contains enough memory to hold several days of data.

The Hydronet computers are programmed to automatically interrogate each gage every three hours during benign weather conditions. This frequency can be increased to automatically interrogate every hour when heavy rain is anticipated or is already occurring. Each gage is also programmed to call the Hydronet computers when rainfall intensities reach or exceed one of four pre-selected thresholds. These threshold values are currently set for 0.25, 0.50, 0.75, and 1.00 inches per 15 minute period, or 1.00, 2.00, 3.00, and 4.00 inches per hour, respectively. After receipt of a heavy rain data message from the gage, the Hydronet workstation notifies the forecasters of the event via printed message, on-screen computer terminal message, and audible and visual signals in the office. Alarm messages are also sent to participating county warning points for intensities of 2.00 inches per hour or greater.

All Hydronet gages are visited routinely for maintenance and calibration purposes. The Hydronet alarm system at the Maui County Warning Point is tested quarterly to ensure receipt of messages.

Areal Mean Basin Estimated Rainfall (AMBER)

AMBER is a product derived from WSR-88D weather radar data that is used for flash flood forecasting and detection purposes. The AMBER system utilizes the maximum spatial and temporal resolution radar data available to produce specific basin averaged rainfall estimates. Output includes hourly basin accumulation rates as well as basin accumulation totals over user-specified periods. Basins have been delineated using 30-meter digital elevation model data processed through a software extension from a Geographic Information System (GIS).

For the State of Hawai'i, AMBER output is currently available from the WSR-88D radar on Moloka'i with basins delineated over the island of O'ahu and the islands in Maui County. Flash Flood Guidance (FFG) values are also tied to AMBER data to assist forecasters in the warning and advisory decision making process. FFG values indicate the amount of basin averaged rainfall needed to produce small stream flooding over different time periods.

Coastal Flooding

Storm Surge

One of the most dangerous aspects of a hurricane is a general rise in sea level called storm surge. It begins over the deep ocean; low pressure and strong winds around the hurricane's center ("eye") raise the ocean surface a foot or two higher than the surrounding ocean surface forming a dome of water as much as 50 miles across. (National Science Foundation, 1980) As the storm moves into shallow coastal waters, decreasing water depth transforms the dome of water into a storm surge that can rise 20 feet or more above normal sea level and cause massive flooding and destruction along the shoreline in its path. This problem is even more critical in the event when there is additional impact caused by high, battering waves that occur on top of the surge.

Storm surge floods and erodes coastal areas, salinizes land and groundwater, contaminates the water supply, causes agricultural losses, results in loss of life, and damages structures and public infrastructure. Maui has 149 miles of coastal

shoreline. Moloka'i has 106 miles. (Maui County Data Book, 2002). Flooding from storm surge in the immediate coastal areas occurs primarily as a result of tropical storms, hurricanes and seasonal high waves. During these events, high winds and surf can push water several feet and even hundreds of yards inland Conditions can be exacerbated by large waves that form on top of rising water. The degree of damage caused by storm surge depends on the tidal cycle occurring at the time of the event. During high tides, water levels can be significantly higher than low tide recede further inland and cause more extensive damage. The area of impact of storm surge flooding is confined to regions along the immediate coastline and typically extends to a few hundred feet inland.

Those areas most susceptible to storm surge are coastlines that are uniformly flat or only a few feet above mean sea level, the storm surge will spread water rapidly inland. Typically, storm surge diminishes one to two feet for every mile it moves inland. For example, a 20 foot surge in a relatively flat coastal area, where the land may only be 4 to 6 feet above mean sea level, would be felt 7 to 10 miles or more inland.

Damage

On Maui, the areas of Waiehu and Waihee, located in coastal embayment, the risk of coastal flooding is particularly higher due to the exposure to annual wave heights measuring as much as 20 feet during the winter, in addition to hurricanes approaching from an easterly direction. (Fletcher, May 2000). Ponding from heavy precipitation and poor storm water designs in Kahului and Wailuku is a common problem. (Pers. Comm., Cerizo, Kawasaki) Landslide, debris flow and storm water runoff may also impact the Wailuku Heights area. Built within the high slopes and valley regions of the backside of Iao Valley, this densely developed residential area is at risk to flooding sheeting down from the steep slopes.

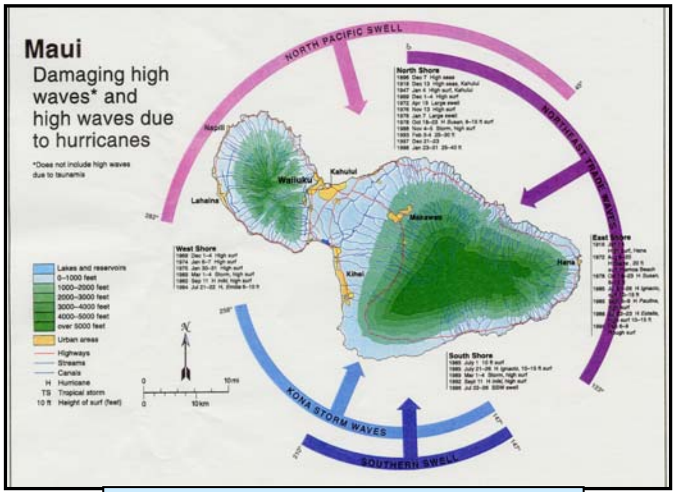
The Kihei watershed is on the western slope of Mount Haleakala on a curved band that extends approximately 8 miles south from Mokulele Junction to Wailea and approximately 15 miles east fro the shore to the summit of Haleakala. The coastal area is relatively flat and characterized by sandy beaches of varying widths. Thirty-two gulches, ravines, and gullies drain the mountain slopes above the Kihei coastal lowland. Where there are small beaches that coincide with stream mouths near Wailea, and in the south at Poolenalena the threat from stream flooding is high. The coast of Kihei and Maalaea is heavily developed. Therefore, because of the close proximity of coastal development to the ocean, coastal flooding from storm surge is a potential threat in the areas of Maalaea, Kihei, and Makena. Kealia Pond and surrounding coastal lowlands can also be inundated by storm waves and stream flooding.

Between Laniupoko Point and Ukumehame Park, the coast is relatively undeveloped except for the small recreational area at Olowalu Point. A low-lying coastal terrace that parallels the long and narrow sandy beach characterizes this area. Numerous larger stream channels cut through this region draining the wetter West Maui Mountains. While the streambeds are generally dry year round, they are known to quickly flood during extreme rainfall events in the immediate area and in the West Maui Mountains, just inland of the coastal zone. (Pers. Comm. Roger Kawasaki, NOAA National Weather Service) The only road connecting West Maui to the rest of the Island frequently bears the brunt of flooding events as the road gets closed from flooding as well as mud and landslides resulting from heavy rains in this mountainous area. Olowalu, including Ukumehame Park and Valley area is particularly susceptible to coastal flooding from more frequent events caused by south swells. In the events where there have been significant amounts of precipitation, up to Launiupoko Point and Ukumehame Park area is vulnerable to rock slides from rock outcrops hugging the only coastal road from South Maui to West Maui.

In areas characterized by low coastal slopes at the bays and stream mouths, the risks from coastal and stream flooding is greatest in the Keanae and Nahiku Coast areas (e.g. Nuaailua Bay, Kauwalu Bay, Wailuanui Bay, and Wailuaiki Bay, southeast of Papiha Point, Waiohue Bay, Honolulunui Bay, Kipakaone Bay, and Opuhano Bay). The stream flooding threat is also ranked high at Hana Bay and between Hokuula and Mokae Cove and Waiaama Bay and Kauakio Bay where the coastal slope is low and wide stream mouths coincide with coastal embayment and empty into the sea.

High Surf

The most predictable and frequent coastal hazard in Hawaii is sudden high waves combined with strong near shore currents. (Fletcher 2000) The greatest number of deaths, injuries and rescues are from the high surf breaking at the shoreline. High surf, resulting from dangerous and damaging waves, is defined by the Oahu Civil Defense as waves ranging in height from 10 feet to 20 feet or more. (Fletcher 2000) These waves



Provided by Dr. Charles Fletcher, UH SOEST result from storms passing across the higher latitudes of the Northern and Southern Hemispheres in addition to storms passing across the Pacific in close proximity to the Islands. These high wave events threaten lives and coastal property. When combined with high tides and storm surges, high waves can inundate farther inland disturbing property and infrastructure.

Waves from the north and northwest tend to be the highest on an annual basis and generally occur several days at a time, most frequently between the months of October and March. (Fletcher 2000) These swells range between 5 and 10 feet in the vicinity of Ka’anapali and 10 to 20 feet near Honolua Bay in northwest Maui and along the North Shore between Waihee and Paia. Occasionally waves of 25 feet and greater occur over the deep offshore reefs of the North Shore making them popular for big wave surfing.

Fortunately for Maui, much of its coastline has wide fringing reefs that dissipate wave energy offshore of its northern and western shores, where wave heights are the highest. However, areas important for tourism and commerce such as Lahaina, Ka’anapali, Honokowai, Olowalu, Kihei, and Kahului are sited on low coastal plains, and therefore experience wave over wash, which causes rapid erosion and temporarily disrupts transportation along Honoapi’ilani Highway. (Fletcher 2000)

Wave heights along Maui’s southern coast range between 4 to 10 feet. (Fletcher) Trade wind waves impact the eastern shores 70% of the time. (Fletcher 2000) During winter storm months, kona storm waves can reach 5 feet along the southern shore while in the summer months, tropical storms and hurricanes can generate wave heights of 10 to 20 feet along any portion of the Maui coast (Fletcher 2000).

High waves from winter North Pacific swell; trade wind swell, summer South Pacific swell, tropical storms and hurricanes, and Kona storms all affect the shoreline of Moloka’i. Steep sea cliffs east of Kalaupapa Peninsula dominate the north shore. High waves from north swell, ranging 15-20 feet, are a greater threat to the more accessible and frequented areas along the north facing shores between Moomoomi and Halawa. High waves from the trade wind swell range 3-5 feet along the Eastern Shore. Winter Kona storms create winds and waves from the south and southwest. These waves can reach heights of 3-6 feet along the south-facing shores.

Damage

Data on high waves and surf in Maui dates as far back as 1896. Much of the high waves and surf in Maui is attributable to passing hurricanes and tropical storms. Each year, however, storms passing through the northern Pacific generate wave heights reaching 15 to 20 feet in the north shore and sometimes up to 30 to 40 feet. Of the largest wave events occurred February 2-4, 1993 and January 23-31, 1998 when waves reached heights of 30 and 40 feet respectively. (Fletcher 2000) Wave heights ranging between 10 and 15 feet reached the north and east shores of Maui as Hurricanes Susan, Ignacio, and Estelle traveled through the Hawaiian waters.

(Fletcher 2000) Along the west shore, wave heights of 6 to 10 feet were recorded as a result of the passing of Hurricane Emilia to the west in July of 1994.

The most significant amount of losses to Maui occurred during a kona storm, occurring, January 8-10, 1980. Maui sustained damages over $12.9 million dollars. Twelve years earlier in April 15 – 16, 1968, the Hana District was declared a disaster area by the State of Hawaii, a result of 17 inches of heavy rains. Of this total, nearly 16 inches fell within 15 hours, and 1.8 inches fell within 15 minutes. This intensity categorized this event as a 100-year storm. (Army Corps of Engineers, Storm of 15 – 16 April 1968, Island of Maui, December 1968)

The highest waves that have impacted Moloka'i's shoreline were generated by tropical storms and hurricanes that passed by the Islands. Since the 1970's, several hurricanes have visited Hawaii; Kate in 1976, Fico in 1978, Pauline in 1985, Iniki in 1992, and Fernanda in 1993. One hurricane of note, Raymond in 1983, passed over Moloka'i as a tropical depression.

Most recently, Hurricane Fernanda generated high waves ranging 8-10 feet that damaged one house on East Moloka'i. While no damage was sustained by Hurricane Iniki, high surf was observed on the east, south and west facing shores. Hurricane Pauline generated waves of 10-15 feet along eastern shorelines. Hurricane Fico caused waves of 8-12 feet and Hurricane Kate produced waves of 8-15 feet. Tropical depression Raymond dropped two inches of rain on the island and generated 10-15 foot surf.

Dam Breaks

A dam is defined as a barrier constructed across a watercourse for the purpose of storage, control, or diversion of water. (DAM SAFETY MANUAL) A dam impounds water in the upstream area, or reservoir. The amount of water impounded is measured in acre-feet referring to the volume of water that covers an acre of land to a depth of one foot. (FEMA, Multi-Hazards 1997) Two factors influence the potential severity of a full or partial dam failure: the amount of water impounded, and the density, type, and value of development and infrastructure located downstream.

There are three types of dams: detention; storage and diversion. Detention dams are constructed to retard and minimize the effects of flood runoff. These types of dams are used to store all or a portion of an anticipated flood runoff. The floodwater stored by the dam is released at a rate that does not exceed the carrying capacity of the channel downstream. Storage dams are constructed to impound water during periods of surplus supply for use during periods of drought. This water is critical for crop irrigation, livestock watering, municipal and industrial water supply and electricity generation. Diversion dams are constructed to provide hydraulic head for diverting water from streams and rivers into ditches, canals, or other water conveyance.

Maui County has fifty dams. Of these, twenty-one have been rated to be “high” hazard potential, two is “significant” hazard potential, and four are rated as having a “low” hazard potential. Of the 50 dams, twenty-three have not been rated. All of Maui’s dams are made of earth.

Disastrous floods caused by dam failures, may cause great loss of life and property damage, primarily due to their unexpected nature and release of a high velocity wall of debris-laden water rushing downstream destroying everything in its path.

Dam Hazard Potential Classification

Category	Loss of Life	Property Damage
Low	None expected	Minimal (undeveloped to occasional structures or agriculture)
Significant	Few (no urban structures) or inhabitable	Appreciable (notable developments and no more than a small number of inhabitable structures, agriculture, industry
High	More than a five	Excessive (extensive community, industry, or agriculture)

The 1997 FEMA Multi-hazards Identification and Risk Assessment Publication reports that dam failures can result from anyone or a combination of factors:

- Prolonged periods of rainfall and flooding;
- Inadequate spillway capacity;
- Internal erosion resulting in structural failure
- Improper maintenance
- Improper design;
- Negligent operation;
- Failure of upstream dams on the same waterway;
- Landslides into reservoirs which may cause surges resulting in overtopping;
- High winds which can cause significant wave action resulting in substantial erosion; and
- Earthquakes, which cause longitudinal cracks and weaken the entire structure.

Land Slides/Debris Flows

A landslide happens when gravity forces land downward, often due to precipitation, runoff, or ground saturation. Debris flows, sometimes referred to as mudslides, mudflows, lahars, or debris avalanches, are common types of fast-moving landslides and occur in a wide variety of environments. These flows generally occur during periods of intense rainfall, but can also be triggered by seismic activity or prolonged dry periods.

The consistency of debris flow ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars. Debris can also include larger rocks and even boulders causing extensive damage. Debris flows from many different sources can combine in channels where their destructive power may be greatly increased. They continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials in its path. When the flows reach flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can wreak havoc in developed areas. Once started, however, debris flows can travel even over gently sloping ground. The most hazardous areas are canyon bottoms, stream channels, areas near the outlets of canyons, and slopes excavated for buildings and roads.

Several features on land may be noticeable prior to a landslide. These features include:

- Springs, seeps, or saturated ground appears in areas usually not wet
- New cracks or unusual bulges in the ground, street pavements, or sidewalks
- Soil moves away from foundations
- Ancillary structures (e.g. decks, lanai) tilt or move relative to the house
- Concrete floors or foundations tilt or crack
- Water lines and other underground utilities break
- Telephone poles, trees, retaining walls, or fences tilt
- Road beds sink, or drop down

They are particularly dangerous to life and property because of their high speeds and the sheer destructive force of their flow that is capable of destroying objects in their paths, and often strike without warning. Landslides usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 mph, but can exceed 35 miles per hour. These flows are capable of destroying homes, washing out roads and bridges, sweeping away vehicles, knocking down trees, and obstructing streams and roadways with thick deposits of mud and rocks.

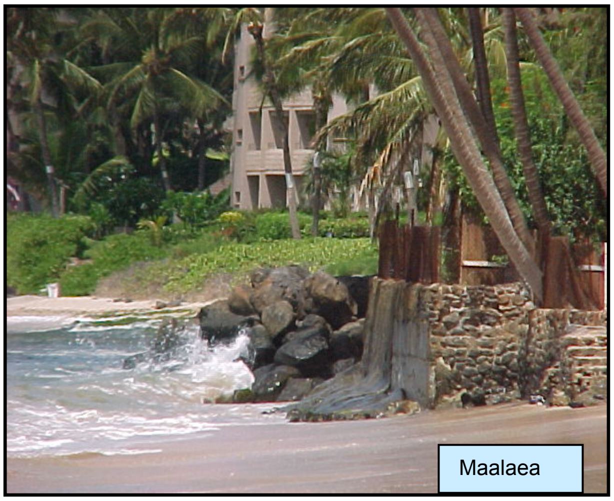
Coastal Erosion

> *"Today's coastline is of economical, social, cultural, and environmental value to communities and to nations. However, shorelines are dynamic and ephemeral places where erosion trends tend to dominate. Development along the shore places the desires of man (to have a safe and stable home) in direct opposition to the natural trends of nature (to erode, transport, and deposit coastal lands)."*
>
> *Joan Pope, U.S. Army Corps of Engineers*

The Natural Course of a Beach Life Cycle

Coastal zones are dynamic areas that are constantly undergoing change in response to a multitude of factors including sea level rise, wave and current patterns, hurricanes, and human influences. Despite the fact that Hawaii appears to have a well-developed and comprehensive governmental system in place to respond to coastal erosion and beach loss, beach loss still occurs in great proportions in Maui.

High winds and associated marine flooding from storm events such as Kona Storms and hurricanes, flooding, tsunami flooding, sea level rise, seasonal high surf, stream flooding on coastal plains, landslides, and seismic and volcanic hazard all increase the risk exposure along developed coastal lands. Storm impacts and long-term erosion threatens developed areas with potential loss of life and billions of dollars in property damage. In addition to the natural processes that cause erosion, human alterations are affecting erosion rates. Human interference with sand transport processes underlies much of the chronic erosion impacting portions of the Maui shoreline.



Maalaea

Erosion has been wearing away beaches and bluffs along the U.S. coastal and Great Lakes shores from the powers of flooding, storm surge, rising sea levels, and high surf. As shorelines retreat inland, waterfront homes, public infrastructure such as roads, bridges, wastewater treatment facilities, and storm water drainage systems eventually may become severely damaged beyond use, uninhabitable, or surrender to the powers of the sea. The Heinz Center Report on "Evaluation of Erosion Hazards" predicts that over the next 60 years erosion may claim one out of four houses within 500 feet of the U.S. shoreline. Most of the damage will occur in low-lying areas also subject to the highest risk of flooding. Some additional damage will also occur along eroding coastal bluffs.

The beaches of Hawaii are vital economic, environmental, and cultural resources. A healthy, wide sandy beach provides protection against the effects of storm surge, tsunami flooding, and high surf impacts. The beach environment provides habitat for marine and terrestrial organisms with beach dependent life stages and is home to species of indigenous and endemic Hawaiian plants. Beaches are also the basis for the visitor industry, exceeding by a factor of three all other industries combined when providing direct income to the State. (DLNR, Coastal Erosion Management Plan, 2000)

Beaches change their shape, depth, and slope in response to wind, wave, and current forces, and the availability of sand. The sources and sinks of sand within a particular beach system and the mechanisms by which they affect the beach morphology are often cumulatively referred to as the sediment budget of the beach. Seaward sources of sand to the sediment budget of a beach include long shore currents moving sand along the coast and cross shore currents moving sand onshore. Landward sources of beach sand include dunes, ancient shorelines, and other onshore sand deposits that release sand to the beach by the forces of the wind and waves. High waves will cause a beach to change its shape, or profile by redistributing sand across the shoreline.

Maui's beaches serve as natural protective buffers between the ocean and the land. Waves reaching Maui from storms across the Pacific carry tremendous amounts of energy, and beaches absorb much of this energy before it reaches the shoreline and coastal properties. During storm events, a beach is able to modify its slope and overall morphology to dissipate the waves while not destroying itself. The beach profile is flattened, and the waves coming inshore shoal further out offshore, thus minimizing further erosion. Beaches recover when sand is moved back onto the shore by smaller waves, and then is blown inland to reestablish the frontal dunes. The final stage of recovery of the beach and dunes occurs when vegetation grows back over these new dunes. Hence, the narrowing of healthy beaches in response to a high wave event is often a temporary condition. (Beach Management Plan for Maui 1997, Rob Mullane and Daren Suzuki)

Coastal Erosion vs. Beach Erosion

It is important to understand the difference between coastal erosion and beach loss. Coastal lands may experience long-term erosion under some conditions. For instance, if sea level is rising, the beach must eventually migrate landward or drown. This causes coastal land behind the beach to erode. The beach then, remains wide and healthy as it moves with the eroding coastline. If sand is not available to a beach on a chronically eroding shoreline, then beach erosion will ensue, leading to narrowing and eventually beach loss. Beach narrowing and loss occurs where sand supplies are diminished or discontinued. Beaches on eroding coasts still undergo seasonal profile adjustments, but they slowly shift their position landward as the land erodes.

Chronic Erosion

Chronic erosion may also be caused by repeated episodes of high surf constantly drawing sand stores from the upland area of the beach to feed the beach profile. Along most Hawaiian shorelines, sands stored in dunes and fossil shorelines are moved onto the beach by this process. Beaches benefit from this source of sand, in order to remain wide and healthy, even as the land behind them may erode. Chronic erosion, then, causes land loss, not beach loss. Armoring, or hardening of the shoreline with seawalls and revetments to stop chronic coastal land loss, often refocuses wave forces onto the beach in front of the seawall. Beach erosion ensues, leading to a volumetric loss of sand that result in beach narrowing and eventually beach loss. (Beach Management Plan for Maui, 1997; COEMAP 2000)

Episodic Erosion

Episodic erosion is also a concern for many of Maui's beaches, especially those lacking a fringing reef and exposed to seasonally high waves. On these beaches a single unusually large wave event or high wave season can cause severe coastal erosion. The vegetation line may retreat as much as 60 or more feet, but if the erosive event is followed by a long period of normal wave conditions, the shoreline can recover, often accreting back to its pre-event location. Beaches subject to rapid erosion and accretion cycles are referred to as dynamic (Makai Ocean Engineering and Sea Engineering, 1991). There may be little or no long-term trend of shoreline erosion, but the risk of episodic erosion remains.

Effects of Local Wind and Surf Patterns

Highly variable local patterns of wind and wave dynamics can be important keys to dispelling misunderstandings of beach processes. Waves are the key factor in the process of coastal retreat because they are able to reach high onto the beach and into the dunes during certain seasons of the year when they are at their maximum height. This reach allows sand to be transported back to the beach face to "make deposits into the beach sand budget." In general, on the north shore of Maui, waves are highest in the winter because they are generated by distant storms in the northern Pacific. On the south side, waves are highest in the summer because they are generated by storms in the Southern Hemisphere. On the windward shores, waves are generated by strong trade winds and by large north swell that wraps around the coastline. Natural features such as coral reefs, offshore channels, and offshore depth variability, as well as the orientation of the coast relative to the prevailing winds and approach of distant waves, drive waves in different ways. For example, the beaches in South Maui are influenced by trade wind-driven flow so that sand typically moves to the south. But when intense "Kona" storms from the south and west occur there, sands are driven to the north in large quantities. (COEMAP 2000)

Sediment Deficiencies

There are situations that call for human interference with patterns of sand flow and accumulation. These include clearing storm drainage channel mouths, dredging harbors and boat basins, widening harbors or extending breakwaters, crossing the shoreline with outfall pipes, or cutting new channels. These and other activities that are common on the Hawaiian shoreline have the potential to cause sediment deficiencies along adjacent beaches. It is important to conduct a careful assessment of dynamics and patterns along the shoreline in question in order to minimize impacts to coastal resources. Moderate erosion trends can be exacerbated and accreting coastlines caused to erode by poorly conceived civil works projects on the coast that trap sand or alter its movement.

Sand Mining

In the past, Maui's beaches have been subjected to sand mining for lime processing. The calcareous sand ($CaCO_3$) is baked to release carbon dioxide and produce simple lime (CaO) for use as a building material. Baldwin Beach, Sugar Cove, and other beaches were past sand mining sites on Maui. Sand mining is in large part responsible for the retreat of both the vegetation line and the beach foreshore over recent decades along these beaches. Sand mining will result in obvious negative impacts to beaches by decreasing sand volumes, steepening the morphology of the shoreline, and reducing the ability of profiles to respond to seasonal wave stresses. Although presently outlawed in Hawaii, there are occasional requests to mine remote beaches that are perceived as being of low socioeconomic value and high sand volume.

Coastal Armoring

Sediment impoundment accompanies coastal armoring. Sands that would normally be released into coastal waters during high wave events and with seasonal profile fluctuations are trapped behind walls and revetments and prevented from adding to the beach sediment budget. One wall may have minimal impact, but along many Hawaiian coastlines myriad armoring types combine to reduce sand availability to nearly zero. Natural coastal erosion does not damage beaches that have access to a robust sediment budget. Beaches on chronically eroding coasts that are not armored remain healthy even during shoreline retreat because sands are released from eroding coastal lands that nourish the adjoining beach. Armoring traps those sands and a sediment deficiency develops, such that the beach does not withstand seasonal wave stresses and begins to narrow with time.

Chronic beach erosion and beach loss eventually results. Many beaches eventually disappear simply because they are starved of sand.

Dune Grading

One of the most important storage sites for sand is the frontal dune system that lines many shores and armoring traps these sands. Additionally, the leveling and grading with topsoil that accompanies housing construction on beachfront lots is one of the most destructive practices taking place along the Hawaiian coast. Dune ecologies in Maui have been decimated by common landscaping practices that do not seek enhancement of the endemic environment, do not recognize the value of salt tolerant vegetation as a tool for beach and dune preservation, and do not establish dune conservation as a goal of the landscaping effort. Soil filling to support short-grass lawns is a source of siltation to coastal waters during erosion events, and acts to compact and trap dune sands such that the adjacent beach experiences deflation, or a lowering of elevation due to sand removal by waves without replacement by dune sand. Deflated beaches fronting filled dunes provide poor erosion buffering capabilities and are themselves a degraded environment with little to offer the normal coastal ecosystem and its host of organisms with beach-dependent life stages (turtles, various marine larvae, and certain reef fishes).

Canalization

Many streams that flow intermittently from our mountains to the coast are subject to flash flooding during heavy rainfall events. To prevent coastal zone flooding, the most hazardous of these streams have been canalized into concrete canals or gutters so that flooding is contained. Where these open onto the coastal zone, the channel mouths tend to trap sand that is moving along the shoreline. The buildup of sand within the channel mouths increases the upstream flood hazard and creates a sand deficiency on the adjacent beach. Public works departments often clear these accumulations and dispose of the sand in various ways, including trucking it off-site to be used elsewhere (i.e. golf courses). Unless these sands are returned to the immediate beach area, the long-term dredging and clearing is nothing less than a sand-mining effort and it will have a similar impact on the adjacent beach. This has the potential to reduce available sand volumes and create chronic erosion where none previously existed. In placing cleared sands onto adjacent beaches it is important to be aware of prevailing sediment transport patterns so that returned sand can function in a manner that will provide nourishment. To ensure this, it will be necessary to conduct a review of the ambient littoral processes and develop schedules of transport direction around each channel mouth, with guidelines on the placement of returned sand.

Past and Recurring Damage

John Rooney at University of Hawaii SOEST has provided the following descriptions with input also from Rob Mullane and Matt Niles of Hawaii Sea Grant.

South Maui – Kihei

Along the Kihei coastline there is a general trend of erosion, but with widely varying rates and patterns of shoreline movement through time. There have also been major decreases in the width of the beach along the Kalama Park/Halama Street area where the beach has mostly disappeared in front of coastal armoring. Problems related to coastal and beach erosion has arisen along this coastline as a result of people building too close to the shoreline to accommodate natural shoreline fluctuations. The dynamic nature of shorelines is often much greater than people realize. The shoreline at the south end of Kalama Park receded a maximum of about 100 yards between 1912 and 1949, and accreted a maximum of about 115 yards between 1900 and 1949 a quarter mile south of the Whale Sanctuary Building. Beaches prone to episodic erosion include Keawakapu Beach, Mokapu Beach, Palauea, and Poolenalena; all of which suffered severe erosion during the Kona storms of 1980 and 1982.

Although most of the Kihei shoreline appears to have been much less dynamic over the past century, development and infrastructure has often been sited far too close to the ocean. For example, some of the resort hotels in the Sugar Beach area were constructed in the dynamic zone of the beach, seaward of the 1949 vegetation line. In addition to the obvious risk of property damage, Maui County may incur liability for issuing construction permits in areas that can be reasonably expected to be subject to erosion damage over the expected lifetime of the structures.

North Maui – Kanaha

Kanaha Beach, on Maui’s north shore, is part of about a 5 mile stretch of coastline between Kahului Harbor and Paia that has been experiencing severe erosion since at least 1950. Mining of beach sand for processing sugarcane in years past has undoubtedly contributed to the problem. It has been suggested that construction of Kahului Harbor in 1910 may be contributing to the problem as well. A wastewater facility serving the Kahului-Wailuku area was constructed here in the mid-1970s, despite an obvious erosion hazard, and is today protected by a rock revetment. This and the revetment built to protect the lime limn at Baldwin Beach have resulted in loss of the beach in front of these structures. Wide beaches despite severe coastal erosion, however, front adjacent, undeveloped shoreline segments. Numerous groins in the area appear to have slowed movement of sand along the shoreline in some areas, but often have led to increased erosion rates along down drift areas. A study of coastal sediment transport and the impact of Kahului Harbor may possibly suggest ways to mitigate coastal erosion here. However, the area is subject to high wind and wave energy despite the wide fringing reef offshore. The presence of what appear to be a series of beach rock ridges up to 800 feet offshore suggest that severe erosion has been occurring here for far longer than have western impacts to the coast.

West Maui

Along much of the West Maui coastline from Papalaua to a couple miles south of Lahaina, Honoapiilani Highway runs right along the ocean. Although this offers nice view planes, in several areas the highway is situated dangerously close to the ocean and interferes with active beach processes. The beaches and offshore reefs along here are valuable resources heavily used by both residents and visitors. These resources are being damaged in some cases, and threatened in others, by proximity of the highway. Revetments and seawalls armor several short segments of the highway, but nonetheless, many of these segments are still subject to coastal flooding, wave splash, and wave overtopping. Wave run-up during both moderate and large wave events floods portions of this highway, leading to occasional temporary road closures. These closures create unsafe driving conditions when traffic unexpectedly comes to a halt.

Wind Hazards

Wind is one of the most costly insured property perils, causing more damage than earthquakes, freezing, or other natural perils. (IIPLR, 1994) In most wind storms, but especially in hurricanes, windborne debris can be a major factor in causing damage. Flying objects such as tree limbs, outdoor furniture, signs, roofs, gravel, and loose building components from progressively failing adjacent buildings can impact the building envelope, creating openings that allow internal pressure to build within.

Wind Pressure

Internal pressures develop within a building when the building envelope is breached. The breakage of window glass or the failure of an overhead door commonly causes the breach in the envelope. The internal pressures add to the external pressures producing more severe pressures on the building components of the structure. (IIPLR, 1994) The roof then feels tremendous internal pressure building from inside, together with the negative wind pressures lifting the roof from outside. The resulting combined forces may be too large, even for good roofs if the roof has not been designed for them. After the roof is gone, high winds and rain destroy the inside of the structure.

Wind is defined as the horizontal component of natural air moving close to the surface of the earth. (David Ludlum1982) Wind pressure, not wind speed, causes wind damage. (IIPLR[1], 1994) There are three types of wind pressure: positive, negative, and internal.

- *Positive wind pressure* is what one feels when the wind is blowing in one's face. It is the direct pressure from the force of the wind that pushes inward against walls, doors and windows.
- *Negative wind pressure* occurs on the sides and roof of buildings. It is the same pressure that causes an airplane wing to rise. This negative pressure is also known as lift. Negative pressure causes buildings to lose all or a portion of their roofs and side walls, and pulls storm shutters off the leeward side of a building.
- *Interior pressure* increases dramatically when a building loses a door or window on its windward side. The roof fells tremendous internal pressures pushing up from inside of the building together with the negative wind pressure lifting the roof from the outside.

Wind Speed

It is often difficult to obtain accurate and consistent wind speed measurement during most storms. Wind speed measuring devices, anemometers, often become damaged from wind and airborne debris when severer wind storms occur. It is important to understand the effect of winds on buildings. Wind speeds vary with height above ground, the higher the elevation, and the stronger the wind (IIPLR, 1994)

- *The Fastest Mile Wind* is the wind speed used in the American Society of Civil Engineers (ASCE) national wind speed standard. This measurement is taken at an elevation of 33 feet in open terrain and is the highest recorded speed during a time interval in which one mile of wind passes a fixed measuring point. At 60 miles per hour this is a 1-minute average wind.

- *Sustained Wind* is the wind speed averaged over 1 minute.

- *Peak Gusts* are averaged over two to five seconds.

Wind Patterns

Trade winds are by far the most common winds over Hawaiian waters and play a major role in defining the climatology of the region. (Kodama 1998). These persistent winds, which blow from a NE to ENE direction, became known as trade winds long

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[1] IIPLR the Insurance Institute for Property Loss Reduction knows the Institute for Business and Home Safety.

ago when clipper ships carrying cargo depended on the broad belt of Easterly winds encircling the globe in the subtropics for fast passage. (Kodama 1998)

Though pleasantly brisk and refreshingly cool on land, strong, gusty trade winds can cause problems for mariners. These strong trades blowing from the NE through East funnel through the major channels between the islands--Kauai, Kaiwi, Pailolo, Kalohi, and Alenuihaha Channels--at speeds 5-20 knots faster than the speeds over the open ocean. North Pacific High-pressure systems are responsible for the majority of the gusty trade wind episodes over Hawaiian waters, which commonly persist for several days before tapering off. Mariners and beachgoers must exercise good judgment prior to entering the waters exposed to strong trades, especially in the major channels.

High winds from trade winds, which blow 70% of the time, Kona winds 30% of the time, and winds from hurricanes and tropical storms passing through Hawaiian waters all affect the Island of Maui County. (Fletcher 2000) Trade winds predominate from the northeast and generally range from 10-25 miles per hour, although occasional extreme events reach 40-50 miles per hour when the sub-tropical high-pressure cell north of the islands intensifies. (Fletcher 2000) Trade winds appear to be stronger when passing through the isthmus between West Maui and Haleakala, so that wind speeds at Maalaea and north Kihei may be higher than along the North Shore. This is the result of wind funneling which often occurs when wind passes between two mountains or into a valley.

The most damaging winds are those associated with passing tropical storms and hurricanes. East-facing coastlines in Hawaii generally receive the brunt of tropical storm winds as the storms approach the islands. The south and west facing shorelines often feel strong winds and waves derived from these storms as they pass to the west. Occasionally when such storms track to the east of the Islands, the north shores are impacted. In all cases, acceleration of wind down slope often occurs such that the highest winds may in fact be recorded on the leeward side of the wind approach.

Since 1871, at least forty-seven strong wind events have impacted the entire island of Maui. Of these, thirty-four were associated with extreme trade winds and/or Kona storm winds, while thirteen occurred during passing tropical storms and hurricanes. The strongest trade wind events hammered the north and east shores with winds of 40-60 mph. High southerly Kona storms have hit Maui with speeds of 40-50 mph on several occasions. Maui has only been brushed by a tropical depression and never hit by a hurricane. It has, however, sustained some damage from the impact of winds from both. Hurricane Nina, for example, brought gusts greater than 90 mph to parts of Maui in November 1957.

The most damaging high winds to affect either Moloka'i or Lana'i were those associated with tropical storm Sarah in 1971 and Die Deutsche Seewarte III in 1874. These both destroyed a number of houses.

History of strong winds and hurricanes on Maui

DATE	DESCRIPTION
August 9, 1871	Kohala Cyclone, gale winds
December 7, 1896	Strong winds
January 21, 1906	High winds
October 2-9, 1906	Makawao Cyclone
January 14, 1916	High winds
August 18-19, 1938	Mokupu Cyclone
January 17, 1948	High winds
January 23-26, 1948	High winds
December 21, 1955	High winds
November 30-31, 1957	Hurricane Nina, gusts to 92 mph.
August 6-9, 1958	Tropical Storm
January 17-18, 1959	Storm
August 4-7, 1959	Hurricane Dot, strong winds
January 15-17, 1963	Strong winds
January 30-31, 1963	Strong winds, gusts to 84 mph.
September 12-19, 1963	Tropical Storm Irah, strong winds
December 19-23, 1964	Strong winds
August 8-10, 1967	Tropical Storm
November 2-11, 1967	High trade winds
December 9, 1967	High winds
December 12, 1967	Strong winds
December 5-6, 1968	Storm
February 20-21, 1969	Strong winds
December 25-29, 1970	High winds, 50-60 mph.
January 5, 1971	Strong winds
November 23-27, 1975	Storm
February 5-7, 1976	Storm
January 11-19, 1979	High winds, 50+ mph.
January 8-10, 1980	High winds
July 21-22, 1982	Tropical Storm Daniel
August 1, 1982	Tropical Storm Gilma
December 19-19, 1982	Strong gusty trade winds
October 15-20,1983	Hurricane/Tropical Depression Raymond
December 24-26, 1983	Strong winds, 50 mph gusts.
December 24-25, 1984	Kona Storm
March 1-11, 1985	Gale force trade winds
July 22-23, 1986	Hurricane Estelle
November 4-5, 1988	Storm gusts 40-50 mph.
December 5-6, 1988	Storm, southerly winds to 50 mph.
December 17-18, 1988	Gusty winds
December 30-31, 1988	40-50 mph winds.

March 1-4, 1989	Storm, strong winds
December 9-11, 1989	Gusty winds
January 27, 1991	Strong winds
December 4-6, 1993	Strong trade winds 60-80 mph.
December 23-25, 1996	Southwest winds 40 mph.
January 27-28, 1997	South-southwest winds

Hurricanes

One of the most dramatic, damaging and potentially deadly events that occur in the Hawaii is a hurricane. A hurricane is defined as a large circulating windstorm covering hundreds of miles that forms over warm ocean water. To be officially classified as a hurricane, the wind speeds must exceed 74 miles per hour. The maximum winds in a hurricane occur near a calm eye and diminish with distance from the eye.

During a hurricane, high winds, marine over wash, storm surge and small scale wind bursts may damage or destroy homes, businesses, public buildings and infrastructure. Termed “microbursts” and mini-swirls, these localized winds may reach wind speeds in excess of 200 miles per hour. (Fletcher 2000) During Hurricane Iniki, damage patterns and debris indicated that there were more than 26 mircobursts (sudden intense downdrafts) and two miniswirls (a violent whirlwind, not tornado) had occurred on Kauai (Fletcher 2000).

In the northern Hemisphere, the winds circulate in a counter clockwise direction (clockwise in a southern hemisphere). A great dome of water as much as 50 miles across called the storm surge is pushed ahead of the storm by its winds. (Keillor and Miller, 1987). This can result in tides 20 feet or more higher than usual. Storm surge is responsible for many hurricane-related deaths and for coastal erosion.

In addition to severe winds, hurricanes have several other characteristics. Barometric pressure is very low, for example, usually 29 inches of mercury or less. Hurricane winds are directly related to the lowest barometric pressure reading at the center of the storm. (IIPLR, 1994) Hurricane winds are strongest near the Radius of Maximum Winds, the area within the storm path near the lowest central pressure. (IIPLR, 1994) The larger the radius, the larger the area of maximum destruction. The strongest winds are usually on the right side of the eye, as one faces the direction the storm is moving. (IIPLR, 1994) Wind speeds decrease as the distance away from the radius of maximum winds increase.

During a hurricane, high winds, storm surge and rains may damage or destroy homes, businesses, public buildings and infrastructure. Flying debris can break windows and doors, unsealing the building "envelope" and creating extensive damage inside the structure. After the roof is gone, high winds and rain destroy the inside. Roads and bridges can be washed away by flash flooding or blocked by debris. In extreme storms, such as Hurricane Iniki, the force of the wind alone caused tremendous devastation, as trees and power lines toppled and weak elements of homes and buildings failed. These losses are not limited to the coastline; they can extend hundreds of miles inland under certain conditions (FEMA,1997).

Hurricane Intensity

The Saffir-Simpson scale measures hurricane intensity. Number and range from 1 (low) to 5 (high) categorize storms. A hurricane's approximate damage potential increases as the square of the integer value for the Saffir-Simpson category. (IIPLR, 1994) The wind speed of a hurricane decreases as it moves inland for two reasons. First, the major source of storm energy (warm water) is no longer available to fuel the storm. Second, the land, vegetation, and structures offer frictional resistance to the storm winds. A hurricanes' peak wind speed distribution is a direct function of its rotational wind speed and forward speed. Storms that have a higher traveling speed do not stay in one place for long, minimizing the possibility of damaging buildings and other stationary structures. However, faster moving storms tend to be more destructive further inland. Because they travel further inland causing higher storm surge and stronger winds. (IIPLR, 1994).

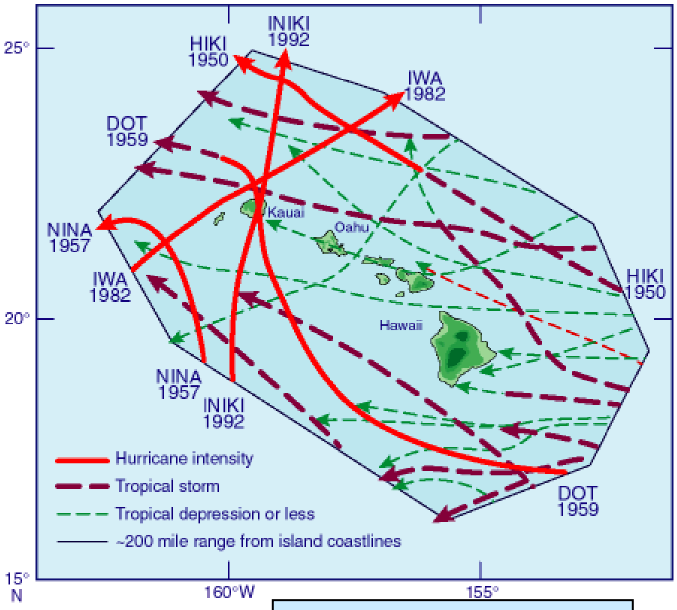
Saffir Simpson Hurricane Intensity Scale

Category	Wind Speed	Damage Potential
1	75 – 95 mph	Minimal damage to vegetation. No real damage to other structures. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.
2	96 – 110 mph	Considerable damage to vegetation; some trees blown down. Major damage to exposed mobile homes. Moderate damage to houses. Considerable damage to piers; marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation from some shoreline residences and low-lying areas required.
3	111 – 130 mph	Large trees blown down. Mobile homes destroyed. Extensive damage to small buildings. Poorly constructed signs blown down. Serious coastal flooding; larger structures near coast damaged by battering waves and floating debris
4	131 – 155 mph	All signs blown down. Complete destruction of mobile homes. Extreme structural damage.

		Major damage to lower floors of structures due to flooding and battering by waves and floating debris. Major erosion of beaches.
5	**>155 mph**	Catastrophic building failures. Devastating damage to roofs of buildings. Small buildings overturned or blown away.

Storm Tracks in Hawaiian Islands

The most typical storm track near Hawaii is toward the west/northwest. This is consistent with the large-scale winds that steer the storms. Hawaii lies at a longitude near to that of the center of the subtropical high which drives the trades. As storms pass Hawaii they will naturally curve to the northwest unless the high extends usually far to the west. In the trades, winds turn to the south with height contributing to a southeasterly steering wind. In the upper troposphere, the winds over the islands are southwesterly and contribute to north turns as well (Schroeder, 1993)



Source: Pacific Disaster Center

The Myth of Maui

A common myth in Hawaii is that the islands of Hawaii, those in Maui County, and Oahu are less vulnerable to a direct hit by a hurricane than Kauai. This myth has developed as a result of the fact that, until 1950, tropical storms hitting Hawaii were not classified as hurricanes and it was not until the advent of weather satellites that the nature of storms in this part of the world were understood to be hurricanes.

We know that since 1950 five hurricanes or tropical storms have caused serious damage in Hawaii: Hurricane Nina in 1957 produced record winds in Honolulu. Hurricane Dot did a lot of damage on Kauai in 1959. Hurricane Iwa did extensive damage on Kauai and Oahu in 1982. Hurricane Estelle produced very high surf on Hawaii and Maui and floods on Oahu in 1986. Hurricane Iniki did extensive damage on Kauai and Leeward Oahu in 1992. Since 1950, seven other tropical storms or hurricanes could have caused serious damage. These include Hurricane Fernanda in 1993 and Hurricane Emilia in 1994, the strongest to pass through our part of the Pacific.

All islands in the Main Hawaiian Islands are at the same risk of a direct hit by a hurricane. In 1871, a storm known as the Kohala Cyclone struck Maui and, from its description, was undoubtedly a hurricane. In August 1938, the Mokapu Cyclone also struck the Big Island. Both Hurricanes and Iwa in 1982 and Iniki in 1992 could have struck Hawaii, Maui, or Oahu.

Kona Storms

"Kona" is a Hawaiian term for the stormy, rain-bearing winds that blow over the islands from the SW or SSW, from the opposite direction of trade winds. The western or leeward sides of the islands, then, become windward in this case, as the predominant wind pattern is reversed. Kona winds are most likely to occur when a low pressure center is located within 500 miles NW of the islands and has an unusually low central pressure, below 1000 millibars for the subtropics. (PDC web page)

Kona winds occur as light and variable winds, most often during winter months when trade wind circulation diminishes, and as strong generally southerly winds when storm systems move across Hawaiian waters. Damaging Kona winds have reached velocities of 50 miles per hour for several days on end. Kona storms generally form in the region bounded by 15^o - 35^o N and 175^o E – 140^o W and move erratically, though with a slow tendency toward the west. (Kodama 1998). A strong Kona wind episode doesn't usually last more than a day. These storms are persistent and can last up to two weeks. During this time, however, considerable damage can be inflicted to boats caught in the open ocean or boats anchored in SW exposed anchorages. Coastal erosion can also result from the extended periods of heavy rain, strong surf and high winds.

On land, effects of strong Kona winds can be very dramatic. It is not uncommon for trees to be uprooted, branches downed, and roofs blown off houses. When reinforced by mountainous topography, down slope winds can gust to over 100 mph and can be very destructive to land in low lying areas. Pass in the Waianae Range and the Kaneohe-Kahaluu areas below the Koolau Mountains have had extensive wind damage due to strong Kona winds.

Damage

Since 1871, at least 47 strong wind events have impacted the entire island of Maui. Of these, 34 were associated with extreme trade winds and/or Kona storm winds, while 13 occurred during passing tropical storms and hurricanes. The strongest trade wind events hammered the north and east shores with winds of 40 – 60 miles per hour, as happened in the events of early December 1993, March of 1985, and December of 1982. High southerly Kona Storm associated winds have reached speeds of 40 – 50 miles per hour on several occasions including December 1988 and January 1980. (Fletcher 2000) South-facing shorelines are at greatest risk from these events, in addition to the north shore as these winds accelerate down the north slopes of Haleakala.

Some of the strongest wind events on Maui have been the result of passing hurricanes, like Hurricane Nina in November 1957, which brought gusts greater than 90 miles per hour to parts of Maui, and tropical storms like Daniel in July 1982 which caused damage along Maui's east coast. Samuel Shaw of the Central Pacific Hurricane Center writes in a comprehensive survey of documented cyclones (all intensities) that 19 storms occurred between 1832 and 1949, and 17 storms occurred between 1950 and 1959. By early 1960, satellite data became available and 34 tropical cyclones were identified between 1960 and 1969. During the next decade, 34 tropical cyclones were identified between 1970 and 1979. During the 1980s, the number of storms increased to 54. On average, between 1970 and 1992, 106 tropical cyclones have been identified in the central Pacific region at an annual average of 4.5 storms. (Shroeder, 1993)

Despite the fact that most of these storms tracking through the Pacific, have not made a direct hit on Maui, the "near misses" generate large swell and moderately high winds causing varying degrees of damage. (Fletcher 2000) Impacts from these "non-events" frequently result in beach erosion, large waves, high winds, and marine over wash. Also to consider, even though a hurricane may not actually strike one of the Hawaiian Islands, wind speeds may be significantly higher on the other side.

Seismic Hazards

Earthquakes

> *On January 22, 1938, at about 10:03 p.m. local time, a magnitude 6.8 earthquake struck the central part of the Hawaiian island chain. The submarine earthquake was located about 20 km (12 mi) northeast of Ke`anae Point (East Maui) at a depth of roughly 20 km (12 mi). For the people who lived closest, the quake might as well have been beneath their feet.*
>
> *The north coast of Maui took the brunt of the damage. Landslides blocked the road to Hana and completely severed communications for several days. Two large oil tanks near Hana shattered, and 110,000 liters (30,000 gallons) of oil flowed into the sea. Ranches in southeastern Maui suffered heavy damage as water tanks and stone walls were razed. Fortunately, no lives were lost, and injuries were few. No tsunami accompanied the shock. Central and west Maui weren't spared from damage. Concrete buildings cracked from Kahului to Lahaina. The fire station tower in Kahului shifted 13 mm (0.5 in.)*
>
> *USGS Hawaiian Volcano Observatory, Volcano Watch, April 8, 1999*

An earthquake is the sudden release of strain energy in the Earth's crust, resulting in waves of shaking that radiate outward from the earthquake source (USGS, web page). When stresses in the crust exceed the strength of the rock, it breaks along lines of weakness, either a pre-existing or new fault plane. The point where an earthquake starts is termed the focus or hypocenter and may be many kilometers deep within the earth. The point at the surface directly above the focus is called the earthquake epicenter.

The severity of these effects is dependent on the energy released from the fault or epicenter. Other factors influencing the severity of an earthquake include: magnitude, proximity to the epicenter, depth of the epicenter, duration, soil characteristics, and type of ground motion. The effects of an earthquake can be felt far from the epicenter. Unlike many other areas where a shift in tectonic plates is the sole cause of an earthquake, 95% of earthquakes in Hawaii are linked to volcanic activity. These earthquakes can occur before or during eruptions, or as molten rock travels underground.

Earthquakes are measured in terms of magnitude and intensity. The Richter Scale measures magnitude. An earthquake of 5.0 is a moderate event, 6.0 is a strong event, 7.0 is a major earthquake, and a "great quake" exceeds 8.0. For each whole number increase in magnitude, there is a 10-fold jump in seismic wave amplitude (or a 30-fold gain in energy released). For example, a 6.0 earthquake generates 30 times more energy than a 5.0 quake and 900 times greater (30 x 30) than a 4.0 earthquake.

Modified Mercalli intensity Scale

In the United States, the Modified Mercalli intensity Scale (MMI) measures intensity – the effects of an earthquake felt by people. MMI ranges from I (faintly registered by instruments to XII (nearly total destruction). Ratings decrease with increasing distance away from an earthquake's source.

Modified **M**ercalli **I**ntensity	**Felt Intensity**
I	Not felt except by a very few people under special conditions. Detected mostly by instruments.
II	Felt by a few people especially those on upper floors of buildings. Suspended objects may swing.
III	Felt noticeably indoors. Standing automobiles may rock slightly
IV	Felt by many people indoors, by a few outdoors. At night, some people are awakened. Dishes, windows, and doors rattle.
V	Felt by everyone. Many people are awakened. Some dishes and windows are broken. Unstable objects are overturned.
VI	Felt by everyone. Many People become frightened and run outdoors. Some heavy furniture is moved. Some plaster falls.
VII	Most people are alarmed and run outside. Damage is negligible in buildings of good construction, considerable in buildings of poor construction.
VIII	Damage is slight in specially damaged structures, considerable in ordinary buildings, great in poorly built structures. Heavy furniture is overturned.
IX	Damage is considerable is specially designed buildings. Buildings shift from their foundations and partly collapse. Underground pipes are broken.
X	Some well-built wooden structures are destroyed. Most masonry structures are destroyed. The ground is badly cracked. Considerable landslides occur on steep slopes.
XI	Few, if any masonry structures remain standing. Rails are bent. Broad fissures appear in the ground.
XII	Virtual total destruction. Waves are seen on the ground surface. Objects are thrown in the air.

Damage

When earthquakes occur, much of the damage is a result of structures falling under the stress created by the earth's movement. Building failure can cause damage to the building, deaths, injuries, and loss of function. Local topography and soil type also affects earthquake severity. Steep slopes composed of loose material may produce large landslides during an earthquake. The type of construction also affects the risks of damages to a property. For these reasons, earthquake hazards are highly localized and difficult to assign regional earthquake boundaries that share the same relative degree of hazard.

Each year thousands of earthquakes occur in Hawaii, with the majority of them too small to be felt except by highly sensitive instruments. The Island of Hawaii has a greater seismic hazard than any comparable area in California. (Pers. Comm Brian Yanagi, October 12, 2000) Since 1929 there have been 12 earthquakes measured at a 6.0 magnitude or greater in the Big Island. The strongest earthquakes occurred in 1868 (7.9) and 1975 (7.2). The most recent strong earthquake occurred 11 years ago in 1989. The frequency and magnitude of earthquake activity is random in the central Hawaiian Chain. Ocean bottom fracture zones and the weight of the islands flex the Pacific tectonic plate, as it inches in a northwesterly direction. (Brian Yanagi, October 12, 2000)

History of Earthquakes in Maui County

Maui's 1938 earthquake was one of the few earthquakes felt throughout the entire Hawaiian Islands. This earthquake was an example of the tectonic type, resulting from loading and bending of the earth's crust by the mass of each island. On January 22, 1938 a magnitude 6.8 earthquake struck the central part of the Hawaiian island chain. The submarine earthquake was located about 12 miles northeast of Keanae Point in East Maui, at a depth of 12 miles (USGS web site). The north coast of Maui suffered the greatest damage. Landslides blocked the roads to Hana and completely severed communications for days. Two large oil tanks near Hana shattered, and 30,000 gallons of oil flowed into the sea. Ranches in southeastern Maui suffered heavy damage as water tanks and stone walls crumbled. In Central and west Maui concrete buildings cracked from Kahului to Lahaina, and the fire station tower in Kahului shifted ½ inch. The walls of the Olinda water reservoir cracked.

History of Significant Earthquakes Affecting Maui County
1868 - present

Year	Date	Magnitude	Source
1868	March 28	6.5 – 7.0	Mauna Loa south flank
1868	April 2	7.5 – 8.1	Mauna Loa south flank
1918	November 2	6.2	Ka'oki, between Mauna Loa and Kilauea
1919	September 14	6.1	Ka'u District. Mauna Loa south flank
1926	March 19	>6.0	NW of Hawai'i Island
1927	March 20	6.0	NE of Hawai'i Island
1929	September 25	6.1	Hualalai
1938	January 22	6.9	Hualalai
1940	June 16	6.0	N of Hawaii Island
1941	September 25	6.0	Ka'oki
1950	May 29	6.4	Kona
1951	April 22	6.3	Lithospheric
1951	August 21	6.9	Lithospheric
1952	May 23	6.0	Kona
1954	March 30	6.5	Kilauea south flank
1955	August 14	6.0	Lithospheric
1962	June 27	6.1	Ka'oki
1973	April 26	6.3	Lithospheric
1975	November 29	7.2	Kilauea south flank
1983	November 16	6.6	Ka'oki

1989	June 25	6.1	Kilauea south flank

Source: Atlas of Hawaii, Third Edition, 1998

Seismic Hazard Zones in Maui County

Maui County's Uniform Building Code (UBC) seismic risk zone is currently a 2b. The UBC contains six seismic zones, ranging from 0 (no chance of severe ground shaking) to a 4 (ten percent chance of severe shaking in a fifty year period).

According to the U.S. Geological Survey, one problem in assigning seismic hazard zones to each island is that the ground shaking during a strong earthquake may vary within a small area. This variation is due to the nature of the underlying ground; for example, whether it is mainly lava bedrock or soft soil. Two homes in the same neighborhood may suffer different degrees of damage depending on the properties of the ground upon which they are built. In addition, local topography strongly affects earthquake hazards. Steep slopes composed of loose material may produce large landslides during an earthquake.

Tsunamis

“ ‘Iliki ke kai I ka ‘ope ‘ope la, lilo; I lilo no he hawawa.”

Hawaiian Proverb

“The sea snatches the bundle and it is gone, it goes when one isn’t watchful.

Tsunami is a Japanese word represented by two characters: "tsu" and "nami". The character "tsu" means harbor, while the character "nami" means wave. In the past, tsunamis were often referred to as "tidal waves" however; the term "tidal wave" is a misnomer. Tides are the result of gravitational influences of the moon, sun, and planets. Tsunamis are not caused by the tides, nor are they related to the tides, though the tide level influences a tsunami striking a coastal area at the time of impact. The scientific community referred to tsunamis as "seismic sea waves". "Seismic" implies an earthquake-related mechanism of generation.

The recorded history of tsunamis in Hawaii encompasses several phases according to the availability of recorded data. During the 19th century numerous tsunamis were reported in newspapers, weeklies, and books written by residents at the time. It was not generally known the causes of the tsunamis, nor the origin in terms of whether the tsunami was the result of a seismic event in the Aleutians or a submersive landslide in the Hawaiian Islands. Toward the end of the 19th century, seismological stations became available to record and locate earthquakes and it became easier to associate distant earthquakes with a tsunami in Hawaii. The establishment of the Volcano Observatory in 1912 on Hawaii brought the expertise needed to accurately determine the origin origins and causes of earthquakes and tsunamis in the Hawaiian Islands. After the 1946 tsunami, the Tsunami Warning system was established and a group of tsunami experts were established and began to track and document origin, wave heights and other data pertinent to tsunamis.

Tsunami-earthquake Associations

The earthquakes associated with tsunamis are referred to as “tsunamigenic earthquakes.” (Cox, 1977) The association of the earthquake and the tsunami results from the fact that both are generated by the tectonic displacement of the earth’s crust. (Cox, 1977) Earthquakes generate tsunamis when the sea floor abruptly deforms and displaces the overlying water from its equilibrium position. Waves are formed as the displaced water mass, which acts under the influence of gravity, attempts to regain its equilibrium.

The main factor that determines the initial size of a tsunami is the amount of vertical sea floor deformation. The earthquake’s magnitude, depth, fault characteristics, and coincident slumping of sediments or secondary faulting control the size of the tsunami. Other features that influence the size of a tsunami along the coast are the shoreline and bathymetric configuration, the velocity of the sea floor deformation, the water depth near the earthquake source, and the efficiency at which energy is transferred from the earth's crust to the water column.

When a tsunami approach a coastline, the wave begins to slow and increase in height; the height achieved depends on the topography of the sea floor. Often, the first sign of a tsunami is a receding water level caused by the trough of the wave. In some instances, however, the first sign of a tsunami is a small rise in the water level just before the recession. In both cases, the incoming wave approaches the shore much like the incoming tide, though much more rapidly. The maximum vertical height of the water in relation to sea level is referred to as "run-up." The maximum horizontal distance is referred to as "inundation." The most vulnerable area for tsunamis, due to the large earthquake threat there, is the Pacific Coast of the United States. Hawaii, the highest risk area in the world, averages one tsunami every year with a damaging occurrence every seven years, (FEMA, 1997).

Sometimes, tsunamis inflict severe damage to property and pose a threat to life in coastal communities. Although most people imagine a tsunami as a large, steep wave breaking on the shore, tsunamis generally appear as an advancing tide without a developed wave face and produce rapid flooding of low-lying coastal areas (Pacific Tsunami Museum, 1997). Because a tsunami typically consists of a series of waves, the danger can actually last for hours after the initial wave. A tsunami can be incredibly destructive, moving everything in its path hundreds of feet inland with great force. Buildings, automobiles, boats and massive rocks can become dangerous debris, with the potential to injure or kill those stranded in inundation areas. Tsunamis are also capable of traveling up rivers and streams that have openings into the ocean.

Tsunami-Landslide Association

The second most common cause of tsunamis in Hawaii is land sliding. A tsunami may be generated by a landslide originating above sea level but plunging into the sea, by a landslide occurring mainly beneath the sea level, or by a landslide occurring entirely beneath sea level. A sudden movement of the seafloor that generates a series of waves, traveling across the ocean until they reach a coast causes tsunamis. Seafloor movement may include faulting, land sliding, or submarine volcanic eruptions. Other geologic disturbances, such as volcanic activity and landslides occurring above or below the sea surface, can also generate tsunamis. A tsunami can be generated by ANY disturbance that displaces a large water mass from its equilibrium position.

Submarine landslides, which often occur during a large earthquake, can also create a tsunami. During a submarine landslide, the equilibrium sea level is altered by sediment moving along the sea floor. Gravitational forces then propagate the tsunami, given the initial perturbation of the sea level. Similarly, a violent marine volcanic eruption can create an impulsive force that displaces the water column and generates a tsunami. Above water (subarial) landslides and space born objects can disturb the water from above the surface. Unlike ocean-wide tsunamis caused by some earthquakes, tsunamis generated by non-seismic mechanisms usually dissipate quickly and rarely affect coastlines far from the source area.

Damage

> *"Papa's journey for the benefit o his health led to Hookena, his own land. There a ti-leaf-thatched hut was erected for healing purposes – a house of green ti leaves according to the prescribed medical treatment. While Papa was lying there in this small hut, a strange rising of the sea brought water into the house and wet the patient. Only once did this happen…*
>
> *Fragments of Hawaiian History, J.P. Ii*

Tsunamis pose a significant hazard in the Hawaiian coastal zone. Hawaii has experienced 95 tsunamis in 175 years (Dudley and Lee 1999). In fact, tsunamis have killed the greatest number of people of all of the natural hazards.

History of Significant Tsunamis Affecting Maui County

Date	Coast of max effect	Runup (ft)	Place	Known Association
1848, July	NE Maui	11+/- 5	Maliko, Kahului	ML, T
1860, Dec.	N. Molokai	12 +/-4	Maliko, Kahului	ML, T
1862, Jan.	N. Molokai	8+/-4	Waialua	ML, T
1869, Jul.	SE Maui	27+/-5	Kaupo	SL, T
1871, Feb.	Lanai	2 +/-2		E, T
1878, Jan.	NE Maui	12+/-4	Maliko, Honomanu, Halekahu	ML, T
1903, Nov.	N. Molokai	30+/-2	Pelekunu, Honokohau	ML, T
1924, May	Lanai	?	Kaumalapau	M
1946, April	N. Molokai	53	Kaupo, Nuu, S. Kihei	D
1957, March	S. Maui	8	Honaloa	D
1957, March	W. Maui	8	Maalaea	D
1960, May	S. Maui	11	Maalaea	D
1964, Mar.	N. Maui	8	Pa'uwela Point	D
1975, Nov.	SE Maui	3+/-1	Kahului	D,E

E = local earthquake
M = storm or other meteorological disturbance
D = distant earthquake
ML = submarine landslide
T = tectonic

Source: Cox, Doak, Local Tsunamis and Possible Local Tsunamis. November 1977.

Tsunamis reaching Maui and Moloka'i have exhibited tremendous variability in terms of their run-up heights, inundation distances, and the damage they have inflicted. During the 1946 tsunami, for example, run-up heights within only a few miles along the south shore of Maui varied by over 10 ft. between Haukini Bay and Mokuia Point. The same tsunami on Moloka'i had run-up heights of 6 ft. on the west side of Kalaupapa Peninsula while on the east side it was 54 ft. (Source: Fletcher III, Charles H., et. al.)

The tsunamis of April 1, 1946 and May 23, 1960 caused widespread damages on the island of Maui, as well as the rest of the state. The highest wave on Maui during the April 1946 tsunami occurred at Kahakuloa on the northern coast of the island. Thirty-three foot waves struck the shores of this community and destroyed three homes situated at about 20 feet elevation. At Honolua and Honokohau, homes, roads, and bridges were destroyed by 24 to 28 foot waves. The May 1960 tsunami was the most destructive in Kahului. The damage estimate was about $763,000 in the low coastal areas. The waves washed inland for a distance of about 3,000 feet to ground elevations of about 6 feet. The Kahului Shopping Center and immediate vicinity received most of the damage. A church was moved about twenty feet away from its foundation. (*Flood Hazard Information, Island of Maui*). A much less destructive tsunami hit Maui in March 1964 with a recorded maximum run-up at Kahului of 2.3 miles and doing an estimated $53,000 damage. (http://www.drgeorgepc.com/Tsunami1964Hawaii.html)

Large Tsunamis *(>1m, 3.3 ft) with reported damage in the Hawaiian Islands

DATE	AREA OF ORIGIN	MAGNITUDE**
April 12, 1819	N Central Chile	M=2.0
February 20, 1835	Southern Chile	M=4.0
November 7, 1837	Southern Chile	M=3.0
May 17, 1841	Kamchataka	M=2.0
April 3, 1868	SE Hawaii	M=4.1
August 13, 1868	Northern Chile	M=4.3
October 2, 1868	South Pacific	
July 24, 1869	South Pacific	
May 10, 1877	Northern Chile	M=4.0
January 20, 1878	Aleutian Is.(?)	
June 15, 1896	Japan	M=4.0
August 9, 1901	Tonga	
January 31, 1906	Columbia/Ecuador	M=1.0
August 17, 1906	Central Chile	M=2.0
September 7, 1918	Kurlis	M=3.6
October 2, 1919	Hawaii (H=14 ft.)	
November 11,1922	N Central Chile	M=3.0
February 3, 1923	Kamchataka	M=3.0

March 2, 1933	Japan	M=3.0
April 1, 1946	Eastern Aleutian Is.	M=5.0
March 17, 1952	Hawaii (H=10 ft)	
November 4, 1952	Kamchataka	M=4.0
March 9, 1957	Central Aleutian Is.	M=4.5
May 22, 1960	Chile	M=4.5
March 28, 1964	Gulf of Alaska	M=4.5
November 29, 1975	Big Is/Hawaii (H=47 ft)	

Source: Fletcher III, Charles H., E, Grossman, B. Richmond, A.E. Gibbs. 2002. Atlas of Natural Hazards in the Hawaiian Coastal Zone. U.S. Department of the Interior US Geological Survey.
*Reliability of >3 (of4) run-up 1m (3.3 ft) and reported damage (Lander and Lockridge, 1989).
**Tsunami magnitude is defined by $M=log^2H$ as revised by Iida and others (1967), where H is the maximum run-up height of amplitude on a coastline near the generating area. Other Tsunamis have occurred, such as that of October 1994, however because of their low (<1m) run-up, insignificant damage and/or uncertainty surrounding their timing and magnitude as noted in Lander and Lockridge (1989), they were not included here.

Drought Hazards

Drought

Drought is a chronic and troublesome problem in Hawaii, at one time or another affecting virtually every part of the state. These events often reduce crop yields, diminish livestock herds, desiccate streams, irrigation ditches and reservoirs, deplete groundwater supplies, and lead to forest and brush fires. Periods of drought invariably give rise to water crises, sometimes requiring imposition of emergency conservation measures.

Kualapuu Reservoir, Molokai. Agricultural reservoirs are critical during drought, but can also serve for fire suppression

Drought can be characterized from the perspectives of meteorology, agriculture, hydrology, and socio-economic impacts. For example, the meteorological perspective would describe drought as a rainfall deficit compared with some normal or expected rainfall amount. The agricultural perspective could describe drought by its impacts on the agricultural industry due to reduced rainfall and water supply (e.g., crop loss, herd culling, etc.). Hydrological descriptions of drought may compare stream flows, ground water, and reservoir levels to normal conditions. Drought can also be described from the socio-economic perspective by the direct and indirect impacts droughts have on society and the economy (e.g., increased unemployment due to failure of an industry because of drought). Lack of rainfall is not the only factor contributing to the impacts of drought. Both natural events and human activities, such as expanding populations, irrigation, and environmental needs all put pressure on water supplies. Lack of rainfall combined with the demands society place on water systems and supplies contribute to drought impacts. During the past 15 years, the most severe droughts impacting the

Hawaiian Islands have been associated with the El Niño Phenomenon and persistent zones of high pressure systems throughout the islands.

The agriculture industry is usually the first to be impacted by drought. Lack of rainfall and reduced irrigation water supplies can cause reduced yields, crop failure, and force farmers to delay planting or risk losing their crop. Drought can destroy pasture and deplete drinking water for livestock. Ranchers are forced to purchase feed and water and reduce herd sizes to cope with drought.

Another danger associated with the impacts of drought is the heightened potential of wild land fires during extended dry periods. Continued economic growth and development in the wild land/urban interface areas has increased the risk to human life and property. Other concerns include the availability of sufficient fresh water reservoirs to combat wild land fires and the looming threat of wildfire on former plantation lands no longer irrigated.

In the past, drought was addressed as a temporary emergency. Actions were taken in response to impacts in a reactionary fashion. The most important lesson learned in recent years is that the best time to reduce the impacts of drought is before they occur. It is important to develop a plan that advocates a proactive drought management approach.

Maui County's Most Severe Droughts

Droughts have impacted almost every island in Hawaii. The most severe ones have been in the past 15 years. During the El Niño years 1982/1983 and 1997/1998, droughts have occurred during the winter-spring period. The dry conditions, in general, have been associated with persistent zones of high-pressure systems ridging over the islands. This feature is typical of the larger-scale effects on atmospheric circulation in the tropical Pacific related to El Niño. Winter storms in the Pacific are prevented from brushing by Hawaii, particularly for the southern islands.

History of Most Severe Droughts[2]

YEAR	REMARKS
1953	Water rationing; Pineapple production on Moloka'i reduced by 30%. Rainfall 40% less than normal.
1962	State declared disaster. Crop damage, cattle deaths, and severe fire hazards.
1971	Irrigation and domestic water use sharply curtailed.
1976-77	Residents asked to reduce water consumption 30%
2000-02	Counties declare drought emergencies. Governor proclaims statewide

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[2] *State of Hawaii Drought and Wild land Fire Mitigation Plan,* Department of Defense, Civil Defense Division, December 1998.

emergency. Secretary of the Interior designates all counties as primary
Disaster areas due to drought.

Loss Estimates From Drought on Maui County of Maui

Losses from past droughts have, in large part, affected mostly the agricultural economy of Maui County. Good records have not been kept to determine, with any accuracy, what those losses have been. Over the years the economy has diversified, and become less reliant upon agriculture. Many of the losses can be considered opportunity cost. These are the monies spent responding to, and recovering from, a severe drought that could be spent in other, more profitable, ways. It should be the objective of Maui County to grow the economy. Spending money wisely on drought mitigation projects can help this to happen. It will also have a positive effect on the impact of wildfires. For further information on this subject please refer to the section on “Drought Risk and Vulnerability Assessment and GIS Mapping Project” found in the State Multi-hazard Mitigation Study.

Wildfire

Wildfire is one of the most destructive natural forces known to mankind. While sometimes caused by lightning, nine out of ten wildfires are human-caused. Put simply, "wildfire" is the term applied to any unwanted and unplanned fire burning in forest, shrub or grass.

The current increase in wildfires can be explained by four key factors:

1. Past fire suppression policies, including one of "total suppression," which allowed for the accumulation of fuel in the form fallen leaves, branches, and excessive plant overgrowth in forest and wild land areas.
2. Increasingly dry, hot weather.
3. Changing weather patterns.
4. Increased residential development in the wild land/urban interface.

Since the dawn of time, fires have burned regularly, consuming vegetation, accumulations of insects and diseases, and triggering a rebirth of forests. Without periodic fire, plants and animals requiring nutrients and vegetation from other parts of the cycle disappear. Fire, in places where it is a crucial part of the ecosystem, promotes vegetative and wildlife diversity, helps maintain wilderness and wild land areas, and eliminates the heavy fuel accumulations, which can ultimately lead to catastrophic wildfire. Many plants have evolved adaptations that protect them as a species against the effects of wild land fire, and some are even strengthened by it. Nearly every ecosystem in the country has some kind of fire dependent plant or tree

Wildfires destroy wilderness, property, and lives. As more homes are built in and around brushy and forested areas, and as more people take to our country's wild land areas, wildfires are also on the rise. Through discarded smoking products, sparks from equipment in operation, arced power lines, campfires, arson, debris burning and other careless means, wildfires are often ignited.

Wild land-urban interface fires tend to be more damaging than urban structural fires, are often more difficult to control, and behave differently from structural fires. When these fires erupt, people and structures must take priority, often at a devastating expense to natural resources. People who live in these areas often come directly from urban areas, and may bring with them careless habits and little understanding of wild land fire cycles and dangers. Homes and other structures are built and maintained in a manner that leaves them and their occupants vulnerable. Thus, fire becomes a significant threat to both humans and natural resources

History of wildfires in Maui County

Moloka'i seems to be the most susceptible of the islands to wildfire. There were nine years on record where 1,000 plus acres were burned. The top three were in 1981, 1991, and 1998.

In 1981, a total of 4,913 acres were burned. The eastern half of Moloka'i lost 595 acres in two fires; the western half lost 4,186 acres and three structures to fire. The month of September saw two fires destroy 1955 acres and two structures alone.

In 1991 a total of 12,656 acres were burned. This was almost entirely in one fire in June that burned 12,519 acres. This affected the south central area of Moloka'i. There were no deaths and only minor property damage; however several fire fighters did receive minor injuries. Controlling and extinguishing the fire involved ninety-two people, fourteen helicopters, numerous bulldozers and other fire fighting equipment, and cost over $500,000. This cost does not include those absorbed by the U.S. Marines and the National Guard.

In 1998, a total of 14,041 acres and one structure were burned. This, too, was mostly from one fire in August that burned for seven days and consumed 12,453 acres no reports of injuries and structures damaged. The other big fires were 643, 600, and 300 acres each. All this took place in August. This was also the second year in a row for El Nino.

Lana'i has been the safest island with only two fires of consequence in the past twenty-seven years. In January 1995, one fire burned 1204 acres and in December 1999, a fire in the Kaluanui Flats area, approximately 2 miles southeast of Lana'i City, burned over 2,000 acres.

Maui has had hundreds more fires than either Moloka'i or Lana'i but fortunately only two were of significant in size. In 1980, two fires standout. The first was in August and burned 4087 acres. The second fire was in November and burned 796 acres. Both were in the Haleakal'a National Park/Kahikinui Forest Reserve area.

In 1998, the big fire of the year was in October on West Maui in the Ma'alaea area. The Honoapi'ilani Highway was completely closed to traffic for about 12.5 hours and alternating from open-to-closed-to-one lane for another 15 hours. Many structures were threatened but none were lost. At one point all three shifts of the Maui Police Department were on the job.

Wildfires on Maui County (1975 – 2004)

Year	Number of Fires	Acres Burned Maui	Acres Burned Moloka'i	Acres Burned Lana'i	Structures Burned
1975	4	450.5	425.0	0.0	0
1976	0	0.0	1,183.0	110.0	0
1977	8	425.4	0.0	0.0	0
1978	48	360.9	501.9	0.0	7
1979	74	353.9	204.4	0.0	1
1980	44	5,778.2	230.7	0.0	2
1981	98	851.4	4,912.7	0.0	6
1982	25	693.7	46.9	0.0	3
1983	57	1,558.8	1,176.5	36.0	7
1984	53	1,991.8	2,839.7	0.0	5
1985	38	11.7	43.1	0.0	2
1986	19	134.1	13.0	0.0	4
1987	30	734.1	880.1	8.3	0
1988	21	142.1	10,735.4	0.0	1
1989	22	65.2	136.6	0.5	0
1990	43	331.4	327.4	88.1	0
1991	40	1,254.3	12,656.3	4.0	2
1992	22	88.1	460.9	0.0	0
1993	5	124.2	24.0	0.0	0
1994	23	770.9	1,395.9	0.0	1

1995	42	58.7	1,241.0	1,204.0	0
1996	37	55.5	0.5	0.0	0
1997	25	12.9	17.6	0.0	0
1998	43	4,450.1	14,041.5	0.6	2
1999	16	94.3	62.4	0.3	0
2000	44	90.8	151.8	0.0	0
2001	49	469.0	94.2	0.9	0
2002	33	276.2	0.2	0.0	0
2003	52	2,657.2	4.6	0.1	4
2004	60	384.4	626.4	0.0	1
		24,669.8	54,433.7	1,452.8	48

Maui County Fire Department is responsible for the islands of Maui, Moloka'i and Lana'i for fires in areas not covered by the Department of Fire and Wildlife. Please refer to previous information and map.

Maui. There are ten (10) fire stations on the island with a total of sixty-two (62) fire fighters on duty each day including a rescue squad. The following equipment is available:

• Engines	10
• Tankers	2
• Ladder Truck	2

Personnel and equipment from the Department of Public Works have also been dedicated for fire fighting purposes, which include tankers and bulldozers. Private construction companies have consistently assisted the County in suppressing wild land fires and can be depended on for future help. In addition, the Fire Department owns a helicopter (AirOne) that is available 24x7. There are two private helicopter companies that can be used for all three islands as needed.

Lana'i. There is one (1) fire station on the island with a five (5) person crew. The following equipment is available:

• Engines	1
• Tankers	1
• Backhoe	1

The private Lana'i Company can provide two (2) tankers, one (1) bulldozer, one (1) front-end loader and one (1) grader.

Moloka'i. There are three (3) fire stations on the island. Ten (10) to twelve (12) fire fighters are on duty daily.

There is also one (1) standby engine and one (1) tanker. Other county assets include three (3) tankers, two (2) bulldozers, one (1) grader, one (1) loader, and one (1) mower to create grass firebreaks. Two private construction companies have six (6) bulldozers available.

Chapter V Hazards Risk & Vulnerability Assessment

Natural hazards become disasters once they have resulted in the loss of lives and injuries, caused damage to property and interrupted the normal operations of government, community and businesses within those communities.

Heinz Center, The Hidden Cost of Coastal Hazards

What is Risk and Vulnerability?

The impacts of natural hazard events are measured in terms of the costs that result from the impacts on society. The potential for future costs can be measured through risk and vulnerability assessments. In the Maui Hazard Mitigation Strategy, *risk* refers to the predicted impact that a hazard would have on people, services, specific facilities and structures in the community. For example, in the event of episodic or chronic coastal erosion, a specific coastal road might be at risk. The predicted impact of coastal erosion on that road could be collapse leading to the lack of access from one area of the Island to another.

Vulnerability refers to the characteristics of the society or environment affected by the event that resulted in the costs from damages. (*The Hidden Costs of Coastal Hazards*, Heinz Center Report, 1999, p. 105) For example, coastal roads on Maui are very vulnerable because often a particular road is the only access available to travel from one area of the Island to the other, and certain roads are the only means of access within specific communities.

Risk assessment is the determination of the likelihood of adverse impacts associated with specific natural hazards to the built, natural, business, and social environments. (Heinz Coastal Hazards Panel Report, 1999, p.110)

Vulnerability assessment is concerned with the qualitative or quantitative examination of the exposure of some component of society, economy or the environment to natural hazards. There are several factors to consider when assessing vulnerability, and these include: the frequency of the hazard, the size of the area affected by the disaster, and the severity or amount of damages that has resulted.

Frequency

In order to assess Maui's vulnerability to the hazards previously identified, the National Oceanic and Atmospheric Administration's Community Vulnerability Assessment Tool was used to determine the frequency, area of impact and potential damage magnitude of each hazard. Evaluating the number of times that the natural hazard has impacted Maui or a region within Maui in the past provides a measure of the likelihood of the event occurring again in the future. This rating is derived from an investigation of trends in the long-term (30 years at least) data. Examination of past events helps to determine the likelihood of similar events occurring in the future.

FREOUENCY SCORE

Approx. Recurrence (years)	Approx. Annual Probability	Subjective Description	Frequency Score
1	100.0%	Frequently recurring hazards, multiple recurrences in one lifetime	**5**
50	2.0%	Typically occurs at least once in lifetime of average building	**4**
250	0.40%	25% chance of occurring at least once in lifetime of average building	**3**
500	0.20%	10% chance of occurring at least once in lifetime of average building	**2**
1000	0.10%	Highly infrequent events, like maximum considered earthquake	**1**
2500	0.04%	Unlikely event	**0**

Area of Impact

A second criteria used in evaluating Maui's vulnerability to natural hazards is to determine the impact, or size of the area affected by the disaster. Some hazard events impact only a small region, while others can affect the entire area. The area of impact determination indicates how much of the immediate area is impounded by a single event. Again, historical data is used to investigate damage and loss records of previous hazard events to develop an estimate of where expected impacts or the amount of property damage may occur from future events.

AREA OF IMPACT SCORE

Mean Affected Area (sq. miles)/event	Subjective Description	Area Impact Score
0	No affected area	**0**
1	Highly localized (city block scale)	**1**
10	Single zip code impact	**2**
50	City scale impact	**3**
100	County scale impact	**4**
500	Regional impact (e.g. statewide)	**5**

Severity

Severity, or magnitude criteria, is used to determine the range of the severity of damage (from minor to devastating) expected from a single event. Previous damage reports and other historical data (e.g. newspaper articles, personal accountings, video clips, etc,) are used.

SEVERITY SCORING

Severity Score	Earthquake MMI	Hurricane SSI	Average Flood Elevation
0	3	0	0
1	4	1	1
2	5	2	8
3	7	3	12
4	9	4	14
5	12	5	24

Maui County Multi-hazard Risk Assessment Scores

Based on the results of the cumulative scores, the following formula is used to prioritize the potential threat each hazard poses to Maui: **(FREQUENCY + AREA OF IMPACT) X POTENTIAL DAMAGE MAGNITUDE = TOTAL SCORE**

RISK SCORE FOR MAUI COUNTY, HAWAII

Hazard	Frequency	Area Impact	Severity	Total
Tsunami	3	4	4	28
Hurricane	4	4	3	24
Coastal Erosion	5	3	3	24
Inland Flooding	5	2	3	21
Kona Storm	5	4	2	18
Storm Surge	5	3	2	16
Earthquake	1	4	4	16

The vulnerability of the built environment on Maui to hazards, combined with trends in population growth and the value of insured property, suggests that there is a potential problem of a first order magnitude. Obviously one cannot prevent the storm from occurring, therefore the forces accompanying the hazard – storm surge, wind, coastal erosion and flooding—will result in significant damage and destruction. However, much of the multi-hazard vulnerability can be attributed to inappropriately designed, built and located communities—often the result of not using the best available knowledge and practices. (Heinz, 1999) Almost every planning and development decision made at the local level has implications for the vulnerability to, and impact of, a natural hazard event.

Recognizing the importance of balancing all of these factors: public safety and well being; development and the built environment; social institutions and natural ecosystems; the Maui County Natural Hazard Mitigation Strategy will identify the risk and vulnerability potential of these components as well as balance the relationships among them.

A critical first step in assessing the risk and vulnerability of Maui County to natural hazards is to identify the links between the built environment vulnerability and the community's vulnerability to hazard-related business interruptions, disruptions of social structure and institutions, and damage to the natural environment and the flow of economic goods and services.

Social Vulnerability

Hurricanes, storms, and other natural events become "hazards" when they affect human society in adverse ways. Communities are vulnerable to these hazards to the extent that they are subject to potential damage to, or disruption of, normal activities. Societal conditions reflect human settlement patterns, the built environment, and day-to-day activities. These conditions include the institutions established to deal with natural hazards during both preparations and response. The impact of hazards on the social environment includes the damages on a human scale" such as injuries, deaths, long-term health related problems and emotional issues arising from the event itself and the subsequent damages. Losses such as baby books, mementos, and photo albums cannot be measured in dollars.

The vulnerability of a community includes the potential for direct damage to residential, commercial, and industrial property as well as schools, government, and critical facilities. It also includes the potential for disruption of communication and transportation following disasters. Any disruption of the infrastructure, such as a loss of electric power or break in gas lines, can interrupt business activity and cause stress to affected families, particularly if they are forced to evacuate their residences and are subject to shortages of basic supplies. If the destruction of the infrastructure causes additional damage (e.g., property destroyed by fires caused by breaks in the gas lines), then this vulnerability needs to be taken into account. One also has to consider the exposure of the population to each hazard type and the potential number of fatalities and injuries to different socioeconomic groups.

Other obstacles are typically communication barriers. How do people who do not speak English or have a lower literacy rate handle the complicated paperwork that needs to be completed in order to receive financial compensation? What happens to those living in low-income housing, and/or public assistance that have not purchased flood/hurricane insurance? What happens to those living in rental housing with owners who are off-island and/or who cannot afford to rebuild?

Not just the immediate impact of the disaster creates serious hardship; there are also serious issues and problems with rebuilding after the disaster. Examples include, disreputable contractors either not paying workers, or taking down payments on roof repairs from home owners and either not completing the job, or doing very shoddy work. How can people be protected from being taken advantage? How do people who do not speak English or have a lower literacy rate handle the complicated paperwork that needs to be completed in order to receive financial compensation? What happens to those living in low- income housing, and/or public assistance that have not purchased flood/hurricane insurance? What happens to those living in rental housing or those who cannot afford to rebuild?

Then there are the critical complications resulting from the interruption of governmental and social services. What happens if the locations where these services took place is damaged or destroyed and no alternative location had been identified ahead of time? What happens when the centers damaged beyond repair? Or if clients receiving these services do not know where the new location is? What if the paperwork, files, database or box of information on the casework or clients has been destroyed? What happens when public shelters for the homeless have been destroyed-where do the homeless go? What happens to congregations/parishes whose churches and places of worship have been destroyed?

State Shelter Program

Hawaii is vulnerable to a wide-range of emergencies and disasters ranging from Hurricanes tsunamis and floods, to hazardous material accidents and volcanic eruptions. Hurricanes, above all others, are clearly the most dangerous and capable of inflicting enormous damage and loss of life. Hurricanes provide the greatest challenge to Civil Defense and emergency management agencies at all levels of government.

In the Caribbean, Hawaii, and other geographically isolated areas around the world, residents and visitors cannot move away from a storm, as they do on the U.S. mainland, to reduce the life-threatening effects of a hurricane. They must remain in-place and have immediately available hurricane resistant homes, businesses, hotels, public shelters, etc., in which to seek refuge. In that regard, government has a distinct responsibility to provide for the health, safety and welfare of its citizens. Two important aspects of this responsibility as it pertains to the hurricane hazard is the adoption of building codes that afford hurricane protection to both public and private sector property, and the provision of sufficient, reasonably provisioned hurricane-resistant public shelters.

Hana High School

The State Civil Defense and the County Civil Defense are responsible for opening shelters in the event of a hurricane Maui County Civil Defense works with the American Red Cross to survey, inventory and then develop recommendations for the upgrade and retrofit public shelter safety standards. Hawaii State Civil Defense spearheaded a comprehensive effort by completing an inventory analysis of public shelter needs for all of Hawaii’s counties. The shelter inventory was completed in Maui County under the direction of Norman Ishikawa from Hawaii State Civil Defense and Kyle Watanabe the Maui County Civil Defense Administrator in 1997, and was updated September 2000.

Maui County Shelter Inventory

This technical manual describes selected public sheltering facilities on the county of Maui. It is to be used only as a guide for civil defense planning in determining recommended upgrading needs. The tropical cyclone (hurricane/tropical storm) hazard was used as a modification yardstick because of the stringent requirements needed to combat the damaging wind, wave and flooding associated with these storms. The shelters listed in the manual were selected by Maui County Civil Defense and the American Red Cross (Maui Chapter) personnel as having the best potential for enhancing the safety of individuals or families displaced by the various hazards that could affect Maui County. In most cases, the listed facilities require mitigation measures prior to use and/or formal agreements with their owners, for even further structural analysis.

Emphasis was also placed on identifying the simplest and most cost-effective means for retrofitting the facilities. In that regard, where the need for "heavy" plywood is identified, the use of 3/4-inch plywood is essential if minimum safety levels are to be achieved. The alternative to heavy plywood (while not always identified) is often described as either debris impact resistant or impact resistant. It should also be noted that the facility surveys were indeed surveys, not detailed studies. They were quite general and limited in that window measurements, where listed, were rounded to the nearest full or half foot. Roofing inspections were cursory, identifying only those roofs that were obviously unsatisfactory or those that needed some type of additional work. Floor measurements were made using what was perceived to be serviceable interior space rather than wall-to-wall footage. As a result, the building or room upgrading requirements reported should be used only for developing modification estimates. Evacuee space availability should also be treated as approximate, subject to the many variables present in any "real world” sheltering environment.

State Civil Defense's intent is to ensure that sufficient public hurricane shelters spaces are available for both residents and visitors to the State of Hawaii seeking hurricane sheltering. An essential component of the State Civil Defense's strategy to minimize the statewide shelter space deficit is by retrofitting existing structures. The retrofit effort has been hampered by the lack of dedicated funding sources.

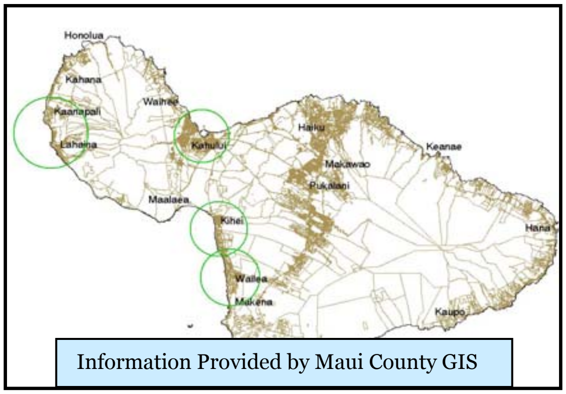
Shelter Capacity Analysis

Public Shelter Space Requirements for Maui Residents
Weak and Strong Storms

Res Pop.	Res. Evac Weak Storm	Res Evac. Strong Storm	Shelter Space Needs Weak Storm	Shelter Space Needs Strong Storm
117,644	70,586	105,880	53,836	65,182

Source: Hawaii Civil Defense Survey, 1998 Updated.

According to the 1997 Technical Manual, the island of Maui as 32,266 shelter spaces (Hawaii Civil Defense Shelter Survey, 1997 updated). The same survey indicates a residential population of 117,644 and assumes a tourist population on any given day of 35,164. The study assumes that 80% of the tourists (28,131) and 60% of the residents (70,586) will evacuate their locations during a category 1-2 event. Of these, 35% of the residents (24,705) and 100% of the tourists (28,131) or a total of 53,836 will seek a shelter space. This is a short fall of 20,570 shelter spaces.



Information Provided by Maui County GIS

During a category 3-5 event it is assumed that 90% of the residents (105,880) will evacuate. Using the same assumptions otherwise, there will be 65,182 people seeking shelter in 32,266 spaces or a shortfall of 32,922 spaces.

Moloka'i has an overage of 138 spaces during a category 1-2 event and a shortage of 639 spaces during a category 3-5 event.

Lana'i has a shortage of 854 spaces during a category 1-2 event and a shortage of 1188 spaces during a category 3-5 event.

State of Hawaii's Hurricane Resistant Shelter Criteria

In Hawaii, there is legislation that enables private facilities to house the public with relief for negligence liability. Hawaii Revised Statutes (HRS) 128-19 provides relief for negligence liability to private sector owners who volunteer the use of their facilities as an emergency shelter. The immunity protection that may be provided applies when an owner or controller of the facility meets the following criteria:

(1) Their actions relating to the sheltering of people are voluntary;
(2) They receive no compensation for the use of the property as a shelter;
(3) They grant a license or privilege, or permit the property to be used to shelter people;

(4) The Director of Civil Defense, or delegated agency or person, has designated the whole or any part of the property to be used as a shelter;
(5) The property is used to shelter persons; and
(6) The use occurs during an actual impending mock or practice disaster or attack.

The State Attorney General's Office, in a written opinion, further states that I-IRS 128-19 does not have an indemnification provision and that the immunity protection provided does not extend to intentional negligence. (Note: HRS 128-19 has been used to encourage hotel and condominium owners to participate in a County emergency hurricane sheltering programs.)

State and County Civil Defense planners have, for several years, assisted hotel and resort managers to identify, within their own facilities, hurricane-resistant shelter space for their guests. As an incentive, liability coverage private shelters, as outlined in Hawaii Revised Statute 128-19, was offered to those facilities that either had created suitable guest shelter space, or agreed to mitigate portions of their facilities to make them hurricane- resistant. This was and continues to be an important initiative. Based on the assumption that private facilities receive no additional compensation for the use of their property as a shelter, the table below estimates the additional visitor shelter space Maui should plan for. The formula for determining the added shelter space is Number of Units (multiplied by) Average Number of Tourists/Unit (equals) Nominal Tourist Population (multiplied by) Average Occupancy Rate (equals) Estimated Tourist Public Shelter needs.

Estimates of Hotels/Resort Populations Needing Public Shelter Space (1998)

Units*	Average. # Tourists/Unit	Nominal Tourist Population.	Average Occupancy Rate	Est. # of Tour. Pub. Shelter Needs
17,582	2	35,164	80%	28,131

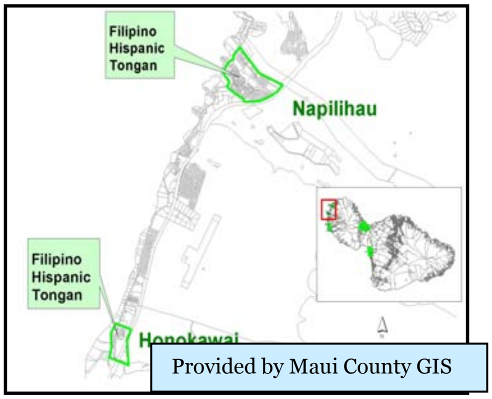
*Excludes Hotels/resorts which have identified they will either retain guests within their facilities or move them to hurricane resistant properties under their purview.

Source: Hawaii Civil Defense Survey, 1998.

Communication Barriers

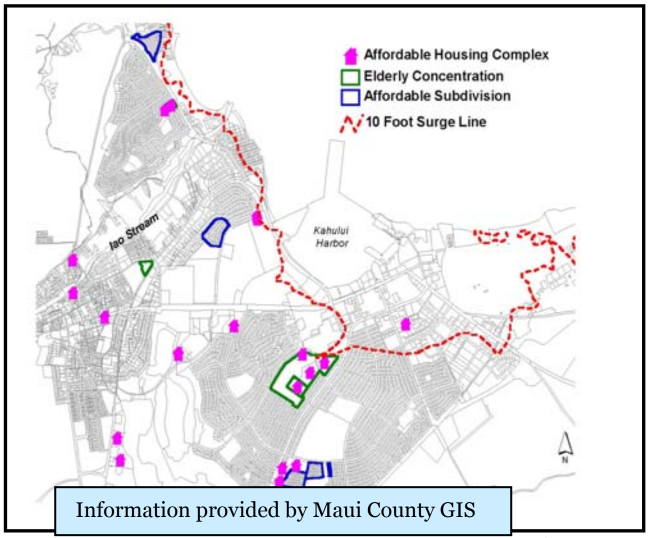
A very real concern in terms of the Maui citizenry being prepared for a storm event is the ability to reach all of its community in order to assist them in everything including preparedness, evacuation and recovery after the disaster. Not only can these events be filled with panic, emotion and confusion, but facing these situations with an additional impediment such as a language barrier or other handicaps related to communication (non-English speaking, hearing impaired) or the ability to receive and understand (building owners located off-island, mentally challenged, illiterate) can make a very difficult situation even more unbearable. The consequences can hinder recovery in every aspect-structural, emotional and financial.

In Maui, three general areas have been identified by the Maui County Department of Human Services as the primary locations of non-English speaking/English as a second language. These locations include: Central Maui (Kahului, Wailuku) for Filipino immigrants; West Maui (Lahaina) for Filipino, Tongan and Hispanic immigrants; and South Maui (Kihei) for Tongan immigrants. (Memo from Roger L. Cachola, Maui County Department of Human Services)



Provided by Maui County GIS

An effective disaster mitigation program begins at the community level with the development of a community vulnerability inventory (Cutter, 1998). Examples of useful sources of information to include in this profile would be the locations and/or concentrations of:

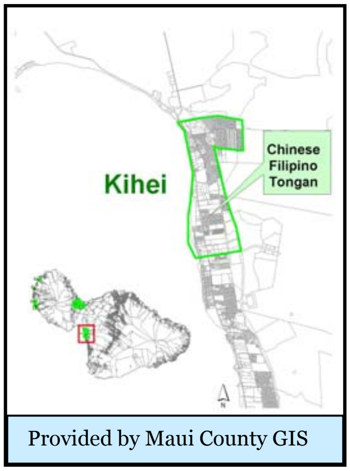


Information provided by Maui County GIS

- poor households
- elderly; particularly frail elderly
- physically or mentally handicapped
- children and youth
- woman-headed households
- large households
- ethnic minorities
- renters
- recent residents, immigrants, migrants
- the homeless
- tourists and transients

While it is unrealistic to gather this information for individual households, it should be feasible for planners to maintain databases reflecting the extent to which highly vulnerable groups are represented in each neighborhood. (Heinz Study, 2000).

The most effective means of addressing these potential problems would be to establish and implement an aggressive public outreach program. A number of measures can be taken prior to a disaster to enable a community to respond to the health and social needs of disaster victims. Public service announcements can be prepared ahead of time to discourage the influx of unneeded people and supplies into an affected region. Aggressive outreach programs are needed to reach isolated populations as soon as possible. Non-English speaking populations should be identified and workshops, pamphlets and flyers, and meetings should be held in those locations where these populations live. (Please see GIS maps identifying these locations) Shelters should be evaluated to determine their capability to



Provided by Maui County GIS

withstand various storm events. The need for mental health programs should be assessed and pre-planning should be undertaken by local, state and federal responders. FEMA employees responsible for administering Public Assistance grants should hold workshops and target those populations, prior to the disaster, where more assistance may be needed completing the myriad of paperwork forms. If possible, those assisting during the disaster should have the capability to speak the foreign language spoken in those smaller non-English speaking communities (or at least have a translator).

County Social Services

Kaunoa Senior Center, Sprecklesville, Maui – this property is located in a tsunami evacuation zone, FEMA FIRM Zone C and is also subject to storm surge from hurricanes and various storms. The facility is comprised of four buildings: cafetorium, administrative office, classroom building and a visual arts/computer building. The Kaunoa is the only senior center on Maui and thus serves as a focal point where Maui Seniors, especially economically disadvantaged seniors gather to take part in a broad range of activities and services. (Pers. Comm. Priscilla Mikell, Deputy Director, Maui County Human Services Department)

As the only center of its kind on Maui, this center serves as a catalyst for bringing together the elderly in an environment where they can pursue meaningful and interesting activities. The Kaunoa Center houses six senior programs: Nutrition Congregate Program; Assisted Transportation Program, Meals on Wheels Program; Senior Companion Program, Leisure Program, and the Retired Senior Volunteer Program. Additionally, this location serves as the base yard where 23 vehicles for the Meals on Wheels and Assisted Transportation Programs are located.

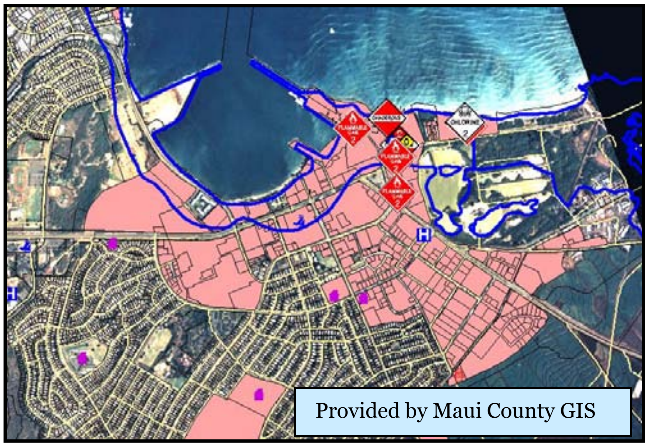
Pre-planning activities should include relocating vehicles prior to the approaching disaster (if time warrants). Emergency schedules, drivers and needed food supplies and services should be pre-arranged in the event of a disaster.

Environmental Vulnerability

Hurricanes, earthquakes, tsunamis, flash floods, coastal erosion, or any weather-related hazard event will have unique impacts on the natural environment. Differences in storm size, speed of movement, wind speeds, storm surge heights, timing with respect to tides, and landfall location relative to vulnerable natural resources make for high variability in impacts and costs. (Heinz Center, 1999) Major climatic events, such as severe storms, are part of the natural cal and ecological processes that constantly shape coastal lands and vegetation. According to the 2000 Heinz Center Study on the costs of coastal hazards, the extent of the risk that coastal hazards pose to natural systems and the built environment is related directly to the degree that land uses alter and degrade the environment.

Direct and Indirect Costs

When the natural environment is impacted, there are both direct and indirect costs. Some of the direct costs may include the erosion of recreational beaches, loss of buffering dunes and upland property; destruction of agricultural crops due to flooding, winds and salt water intrusion; and loss of urban landscaping due to high winds and water damage.



Provided by Maui County GIS

Indirect costs, as described by the 1999 Heinz Center Study, include the widespread distribution of debris, accidental spills of fuel, sewage and industrial waste, household chemicals, or other contaminants onto the land or into the marine environment; in addition to environmental damage associated with storm debris or material cleanup, including illegal filling of wetlands in low-lying areas and the loss of landfill capacity. As experienced after Hurricane Inkiki in Kauai, post-storm debris management can be another problem. This occurs when vast amounts of vegetation, including potentially toxic, treated building materials from destroyed buildings, as well as other materials are burned at different sites with little management. Even with the burning, vast amounts of landfill capacity was used up with storm debris, meaning new sites would need to be developed at significant expense

To analyze this risk, it is necessary to assess the characteristics and resilience of the natural environment. More specifically, natural features such as soils, elevations above sea level, and vegetative cover need to be inventoried. The intensity of land use, and the extent that hydrology, water quality, and habitats are altered, must all be evaluated. Land uses that extensively modify natural systems make these systems much more vulnerable to coastal hazards than do those that preserve and perpetuate natural ecological processes. The natural environment may be affected adversely immediately after the disaster as well as over the long term. Some of the damage may be irreversible, whereas other adverse impacts may be only temporary.

Beach and Dune Loss

Hurricanes, Kona storms, other Pacific storms (particularly during El Ninos), and chronic erosion can, and often do, cause extreme damage along the shoreline, including a loss of beach sand offshore or down drift, undermining or over washing of the dunes that protect uplands, or, in extreme cases, the cutting of new ocean inlets. Once a beach or dune is lost, its capacity to buffer the next storm is reduced dramatically. Following major erosion events, the recreational value of beaches declines sharply, because of both reduced beach area and loss of aesthetic appeal. Local tourist dollars are lost altogether or transferred elsewhere.

Water Quality and Other Pollution Impacts and Costs

Weather-related storm events have the potential to affect water quality in a number of ways and, thus, also affect human and ecosystem health. Hazardous materials discharges to standing water bodies and ground- water are another threat during disasters. For example, accidental spills of sewage and propane tanks and torches, failures of treatment plants and household septic systems are other major water-quality and health concerns associated with natural disasters. The location of the Kahului Treatment plant, pumping stations and the various chemical storage facilities in Kahului Port pose a serious threat to the densely developed residential areas in close proximity to these facilities. Additionally, saltwater inundation associated with storm surge can contaminate wells, particularly shallow ones.

Wildlife and Habitats

In South Carolina, Hurricane Hugo dramatically altered the coastal forests, beaches, wetlands, and estuaries. Some changes were relatively short-lived, such as lowered salinity and increased freshwater flows into estuaries. Other changes in fish and wildlife habitat were more permanent and resulted in dramatic losses of local flora and fauna. Loss of these habitats severely impacted the species populations dependent on these areas. Many of the species populations might be more significantly impacted, principally because of continuing human alteration of coastal and forest ecosystems. The effects of hurricanes, tsunamis, and kona storms on wildlife and fishery resources may also adversely affect the economy of Maui County by impeding several forms of outdoor recreation. Access to fishing, boating, and hunting sites may be eliminated in – a direct impact on the tourist economy of Maui County. Support facilities and the cottage businesses associated with these activities take a direct hit.

Critical Facilities Vulnerability

Public Infrastructure

The damage to and destruction of the built environment, particularly public infrastructure such as transportation, utilities, and communications often represents enormous economic, social, and general functional costs to a community, while also impeding emergency response and recovery activities. More and more people live in the areas most vulnerable to hurricanes, within 50 miles of the Gulf of Mexico or the Atlantic Ocean. It is here where, for many coastal states, tremendous amounts of valuable infrastructure exist, especially transportation lifelines. A nonfunctional road can have major implications for a community: general loss of productivity; disruption of physical access preventing residents from getting to work or other daily activities, prevention of emergency vehicles from reaching their destinations, with the associated health and safety implications and the potential access difficulties causing the disruption of important lifeline supplies such as food and other deliveries to the community. (Heinz Report, 2000)

Specific Items to address:
Public Safety and Security
Maui County Civil Defense Emergency Operations Center
Fire Stations – Hana
Police Stations – Hana
Hospitals/medical
Mass Emergency Shelters
Facilities – Wastewater treatment/pump stations/MECO
Port in Kahului (to be covered under economic implications)

Utilities

Damaged or destroyed utility lines and facilities – including electricity, computer and satellite links, gas sewer, and water services – can cripple a region after a disaster. Power lines are often badly damaged or destroyed resulting in the loss of power for days, weeks or even months. This is particularly critical considering modern societies' dependence on electricity. In addition to basic modern households appliances being affected, public water supplies, water treatment and sewage facilities can also be impacted. Electric pumps cannot pump drinking water into an area without power, and even if they could, the water delivery system could be breached in several areas. The loss of even elevated water tanks also results in a lack of safe drinking water. Even disaster victims who do get water may have to boil it to eliminate waterborne pathogens introduced to the supply in breached areas.

Nonfunctional sewer systems also prevent a unique set of problems. Most systems need pumps to deliver the effluent to the treatment facilities. If there is a loss of power, and if many of the sewer lines are broken, a very serious health problem can rapidly develop. This problem, combined with the interruption of the public water supply could potentially cripple a community’s recovery effort. Both the Maui Electric Company Power plant and the Kahului Wastewater Treatment Plant are located in the FEMA Special Flood Hazard Area.

Roads and Transportation

Maui’s regional highway network is primarily made up of two-lane highways, connecting the high growth areas on the island. These two-lane facilities are generally high quality arterials, such as Piilani Highway in Kihei, Honoapiilani Highway in Lahaina, Kuihelani Highway in Wailkuku, and Kula Highway in Kula.

Honoapiilani Highway provides the only access between West Maui and the rest of the Island. The two-lane Honoapiilani Highway continues around the north end of the island to Kahekili Highway, which passes through the communities of Honokohau and Kahauloa before reaching Wailuku.

Specific Flood Risks and Vulnerabilities

			FLOODING RISKS AND VULNERABILITIES			
Vulnerable Area	**Location**	**Ownership**	**Natural Hazards**	**Primary Problems/Effects**	**Mitigation Benefits**	**Risk**
building damage-repet. loss	Lahaina, Kihei, Napili	private	flooding	damage to structure & contents,	Public safety, well being,	H/P
roads	Lower Honoapiilani, Oluwalu, N.Kihei, see GIS map, Hana	county, state	flood, overwash, erosion, landslide	disruption to evacuation,inter-island transportation interuption, business disruption,property damage	public safety, prevent costly road repair & debris cleanup	H/P
business district, tourist area	Lahaina, Kihei	private	flood, overwash	damage to property, business interup. decrease in tourism	prevent business disruption (jobs) minimize costly cleanup	H/P
hiking, touring sites-parks	Oheo Gulch, Iao Wainee	county, federal state	flash flood	no warning injury, loss of life	Public safety	H/P
bridges	Hana	county, state	landslide, damage from debris flow	evacuation &transportation disruption, community isolation, visitor strandings	Public safety	H/P
historical buildings	Lahaina	county,state, private	sheetflow, flooding	economic hardship, loss of cultural resources	Preserve/protect cultural resources	H/P
schools	Lahainaluna, Hana	county,state,	sheetflow, flash flood	damage to structure & contents, social hardship	Public safety, maintain shelter protect social/economic well being	P
pumping stations	Kahului, Kihei	county	flood, high waves	loss of service, contamination, threat to public health	Public safety & well being	P
County baseyard	Lahaina	county	flooding	loss of resources for recovery, costly & time consuming to replace	Public safety, protect county resources	P

Flood prone Areas

A Special Flood Hazard Area is known as the 100-year floodplain. It is more precisely defined as the floodplain associated with a flood that has a 1-percent annual chance of being equaled or exceeded in any given year. Therefore the SFHA is not a flood event that happens once in a hundred years, rather a flood event that has a one percent chance of occurring every year. It is delineated as such on a Flood Insurance Rate Map (FIRM) as Zone A. In coastal situations, Zone V is also part of the SFHA. The SFHA may or may not encompass all of the community's flood problems.

The following are located within the FEMA designated Special Flood Hazard Area (SFHA):

- Maui has 465,846 acres, which has a total assessed value of $684,272,600.
- Moloka'i has 167,030 acres, which has a total assessed value of $ 17,661,600.

Maui's FEMA FIRMs were created in 1981. The last time Maui had amended these maps was May 15, 2002. Maps are amended periodically based on new development and requests to the Corp of Engineers as needed.

MAUI FEMA FIRM FLOOD HAZARD RISK CATEGORIES

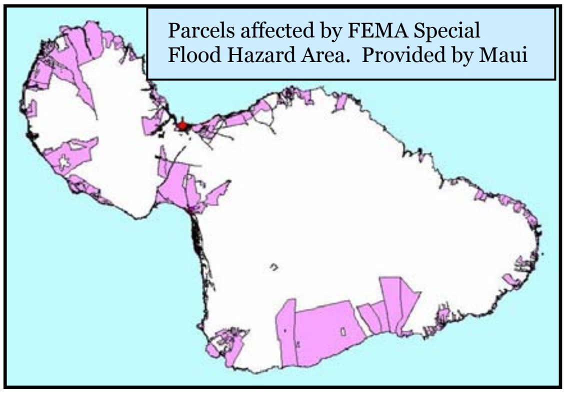
FEMA FIRM	Acres of Land		
Category	Maui	Moloka'i	Risk Score
A zones	6,536	4,701	**5**
X500 zones	227	278	**4**
X zones	459,083	162,051	**3**
Total	465,846	167,030	

Maui County National Flood Insurance Program Data (March 2000)

Structural value in SFHA	NFIP Policies	Average Premiums	Total Premiums
$684M	**10,864**	**$257.00**	**$2.7 M**

Repetitive Losses

Repetitive loss structure is a term that is usually associated with the National Flood Insurance Program (NFIP). For Flood Mitigation Assistance (FMA) programs purposes, this is a structure, covered by a contract of flood insurance under the NFIP that has suffered flood damage on two or more occasions over a ten-year period. This period ends on the date when a second claim is made. The cost to repair the flood damage, on average, must exceed twenty-five percent of the market value of the structure at the time of each flood loss event.



Parcels affected by FEMA Special Flood Hazard Area. Provided by Maui

For the Community Rating System (CRS) of the NFIP, a repetitive loss property is any property, which the NFIP has paid two or more claims of $1,000 or more in any given ten-year period since 1978. A repetitive loss structure is important to the NFIP. Structures that flood frequently put a strain on the flood insurance fund. It should also be important to the community because residents' lives are disrupted and may be threatened by the continual flooding. (FEMA Quarterly Newsletter).

There have been thirty claims on twelve properties on Maui as of January 1, 2003. These claims total $669,272 of which $529,787 is for building losses and $139,485 is for the loss of contents. The average amount per property was $55,773. The average amount per claim was $22,309. Of these properties, 1 was in zone A4, 1 was in zone A5, 2 were in zone AO, 2 were in zone V24, and 8 were in zone C. This is more than twelve as some properties changed in classification over time**.**

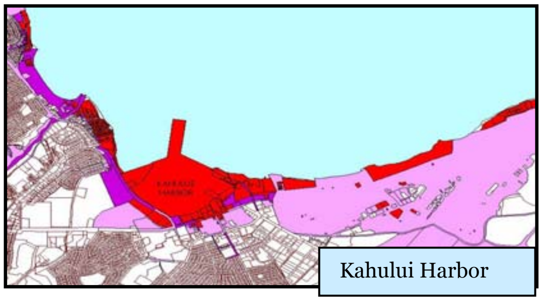
Repetitive Loss Data for Maui

AREA	BUILDING	ZONE	TOTAL COSTS
Lahaina	Single Family	A4	$12,424
Lahaina	Single Family	A4	$5,059
Lahaina	Non-Resident	C	$13,280
Lahaina	Non-Resident	C	$57,993
Lahaina	Non-Resident	C	$1,973
Lahaina	Other Resident	C	$2,299
Lahaina	Other Resident	C	$3,724
Lahaina	Single Family	A5	$9,548
Lahaina	Single Family	A5	$45,386
Lahaina	Single Family	V24	$38,627
Lahaina	Single Family	V24	$13,632
Lahaina	Non-Resident	C	$3,904
Lahaina	Single Family	V24	$1,318
Kihei	2-4 Family	A0	$3,796
Kihei	2-4 Family	A0	$3,094
Lahaina	Single Family	C	$60,046
Lahaina	Single Family	C	$101,320
Lahaina	Single Family	C	$30,561
Lahaina	Single Family	C	$5,498
Lahaina	Single Family	C	$3,836
Lahaina	Single Family	C	$3,921
Lahaina	Single Family	C	$172,730
Lahaina	2-4 Family	C	$11,142
Lahaina	2-4 Family	C	$3,829
Lahaina	Single Family	C	$21,693

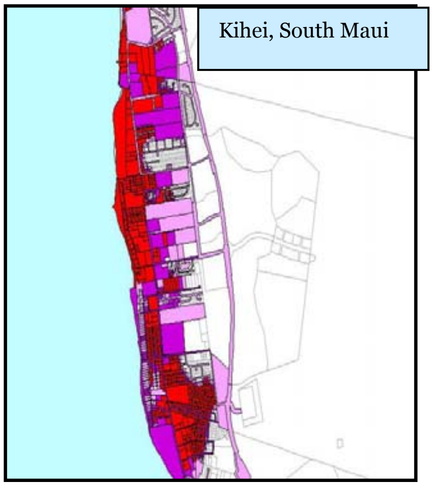
Lahaina	Single Family	C	$15,533
Lahaina	Single Family	C	$6,599
Lahaina	Single Family	C	$12,223
Kihei	Single Family	C	$1,389
Kihei	Single Family	A0	$2,895
Grand Total			**$669,272**

Structures at Risk

During the summer of 2000, a risk and analysis study was done, the objective of which was to determine the dollar amount and number of properties at risk to some amount of flooding. Three risk categories were identified:



- Greatest risk: shaded in red, this delineates those properties that lay 50% to 100% within the FEMA Special Flood Hazard Area, and will most likely sustain at least 75% in damages.
- Moderate risk: shaded in purple, this category delineates those properties that lay 50% to 75% within the FEMA Special Flood Hazard Area, and will most likely sustain at least 50% in damages.
- Minimal Risk: shaded in pink, this delineates those properties that lay less than 50% within the FEMA Special Flood Hazard Area, and will most likely sustain at least less than 35% in damages.



It is important to remember for this analysis that the figures are fairly conservative in that they do not reflect the costs associated with replacing the structure, its contents or the true market value. All of the numbers used in the analysis were derived from the Maui County Tax Assessors' Map Key (TMK data).

Due to time constraints, these areas were analyzed: Kahului, Lipoa Gulch area in Kihei, Lahaina, and a few areas in Wailuku. For the Island of Maui the damages that could result from a 100 year storm event are the following:

- Greatest risk: $684 million dollars
- Moderate risk: $291 million dollars
- Minimal Risk: $83 million

Out of Date FEMA FIRMs

Another factor to point out is that the following was based on FEMA flood data (Q3data) that is very outdated and does not represent current conditions of development within and in proximity to the floodplain.

Storm Water Runoff

Flood damage resulting from stormwater runoff is a frequent problem on Maui. It is a timely issue that needs to be addressed in light of the intense development pressure on Maui. If this is not addressed, it will only exacerbate stormwater runoff and sediment erosion problems. There is a need for a more comprehensive approach to floodplain management specifically to address issues related to stormwater runoff and sediment erosion. Most stormwater management and land use planning in the State of Hawaii and County of Maui is based on political boundaries with responsibilities divided between political jurisdictions rather than on watersheds. Development of roads, subdivisions, driveways and other impermeable surfaces continue without a comprehensive approach between jurisdictions, communities and County agency departments. The effect of this pattern of development is the exacerbation of stormwater runoff as a subdivision deflects their stormwater runoff to developments downhill. As this development pattern continues without a comprehensive strategy, runoff accumulates, velocities increase and the costs of damage to properties and areas of exposure to this risk to residential and urban areas (such as the Lahaina and the Lahainaluna Ditch complex area) becomes incrementally greater.

Although stormwater runoff and sediment erosion, both the result of flooding, are serious issues for most areas on Maui, particularly as development continues, only one community, West Maui, has addressed these issues through the development of the West Maui Watershed Owners Manual.

This inter-jurisdictional approach should be used to address stormwater management, floodplain management and land use planning issues. State and County department representatives from Department of Transportation, Planning, Public Works, Land Use and Building, and the NFIP Coordinator should be involved at a minimum. To best address these issues, future development should address erosion, runoff, and other potential impacts caused by flooding. Areas more vulnerable to erosion, debris flows, and sediment transport such as: unstable slopes, floodplains, floodways, wetlands, slide areas, and alluvial fans should be identified with specific recommendations developed to mitigate soil erosion and sediment transport from flooding and stormwater. Regional Master Stormwater Management Plans should be developed between jurisdictions lying within the same watershed (Recommendation from State Flood Hazard Mitigation Plan) Remaining areas should be prioritized and then regional stormwater management plans developed. Some of these areas should include: Kahakuloa, Wailuku, Makawao, Koolau, Kipahulu, and Kihei-Makena area.

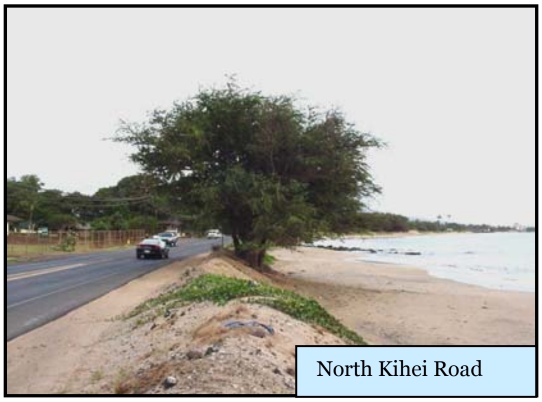
Flood forecasting, early warning, and emergency preparedness measures are an integral part of a well-balanced flood management system. All flash flood forecasts, watches, warnings, and advisories are produced by the National Weather Service. Upon issuance, these products are sent immediately to emergency management agencies and the media for public notification. The information is also broadcast immediately via NOAA Weather Radio (NWR). Due to the mountainous terrain on Maui, there are several areas with gaps in NWR coverage. One critical gap is in the Hana-Kipahulu area which includes the Ohe'o Gulch in eastern portion of Haleakala National Park. This gulch is popular with tourists and is also prone to flash flooding. Additional funding is needed to place new NWR transmitters for more complete broadcast coverage on Maui.

Flood Loss in Maui County

In 1983 the Department of Land and Natural Resources reported that floods in Hawaii, from 1860 to 1962, caused more than 350 deaths and over $475,000,000 in damages. Damages from floods from 1963 through 1982 totaled about $395,000,000. From January 1983 to July 1992, twelve deaths have been attributed to flooding. The 1987 New Year's Flood caused an estimated $35,000,000 in damages. Floods in March 1991 resulted in damage estimated at $10-15,000,000. In December 1991, floods damaged an estimated $7,000,000 in property.

Specific Coastal Erosion Vulnerabilities

Beach Loss


North Kihei Road

Within the Kihei area there are private homes, resorts, and portions of North and South Kihei Road that are vulnerable to damage from chronic and episodic erosion and major Kona storms, hurricanes, and tsunamis. In some cases, developments sited unwisely close to the ocean interfere with active sandy beach processes. Beach loss in front of armored segments of coast is common, and longshore sediment transport has been interrupted.

Adequate setbacks that take into account local shoreline behavior, and maintenance of healthy beach and dune systems, will help reduce risks associated with these hazards. Construction of coastal armoring structures should only be permitted after a full analysis of all the costs involved, including cumulative and long-term impacts to the beach system, have been considered. Some threatened areas of the Kihei coast may be suitable sites for mitigation by beach nourishment, and this option should be pursued further. In addition to their storm damage and erosion buffering properties, healthy beaches are a major attraction driving the visitor industry. As an economic engine of vital importance to Maui's economy and a significant feature of island living, their protection must be a priority.

Setbacks

Obviously, future construction in erosion-prone areas, if allowed at all, must be situated far enough inland to allow for continued coastal erosion. The wastewater facility should be relocated further inland to avoid public health concerns during tsunamis, major storms, or other events that are likely to damage or inundate it. For existing residential areas such as Sprecklesville, erosion control measures such as beach restoration should be considered. Sugar Cove in Sprecklesville has successfully implemented periodic beach nourishment, and similar projects are tentatively planned for the Stable Road beachfront and Laulea Place beachfront.

Roads at Risk

Honoapiilani Highway is a heavily traveled major artery linking West Maui with the rest of the island. A tsunami or major storm could damage one area of the island and render Honoapi'ilani Highway impassable, making it impossible for emergency services to be provided by less damaged areas. In addition to more protection from coastal erosion and storm impacts, the highway also needs widening. Land on the ocean side of the highway is primarily agricultural at this time and therefore available for relatively modest sums. As sugarcane gives way to other land uses the cost of land acquisition to move the highway will increase tremendously.

Relocating the highway further inland appears to be the most logical course of action at this time. By taking advantage of funds available to the Department of Transportation to protect and widen the road, the county will be able to economically acquire a tremendously valuable coastal resource. They also have the opportunity here, while backshore development is minor and the highway sits on land bordering the ocean, to create a model of progressive and sustainable coastal development by establishing zoning that includes generous setbacks to allow for natural fluctuations of the shoreline.

Resorts at Risk

The Upper West Side of Maui includes the resort developments of Kaanapali, Honokowai, Kahana, Napili, and Kapalua. Kaanapali Beach is a seasonally dynamic shoreline, and episodic shoreline retreat on the order of 50 feet is not uncommon. Although major structures such as parking lots and hotel buildings have relatively deep setbacks, other amenities such as beach activity centers, concrete walkways, and swimming pools are sited closer to the shoreline, and hence are vulnerable to episodic coastal erosion. A beach management plan was developed to help guide future development and activities along Kaanapali Beach. (Kaanapali Beach Management Plan, 2000)

Honokowai, Kahana, and Napili, while less dynamic than Kaanapali, were developed with minimal setbacks, often 40 feet or less. Coastal erosion has threatened many of the numerous condominiums and other multi-story buildings, and seawalls and revetments are common. Beach loss is widespread, especially in Honokowai and Kahana. The majority of threatened structures are multi-story, concrete masonry buildings, so strategic retreat is probably not a feasible option, but recently, some condos and other developments have expressed interest in beach restoration.

Erosion Loss Estimates

Beach loss affects Hawaii residents by seriously impacting the visitor economy. In 1997, tourism accounted for 171,900 jobs in the state, $13,000,000 in tourism expenditures and supported a payroll of $3,500,000. Beach loss and shoreline hardening restricts public access to ocean recreation areas and natural resources. It causes environmental and ecological damage to natural resources and habitats. Coastal hardening can also produce coastal water quality problems through increased Turbulence and turbidity. (DLNR Coastal Lands Program and University of Hawaii School of Ocean, Earth Sciences and Technology, Coastal Geology Group, 1998. SOEST Coastal Erosion Management Plan).

Specific Wind Event Hazard Vulnerabilities

Windborne Debris

Until recently, wind had not received as much attention as other hazards, like fire and earthquake. However, the overwhelming extent and magnitude of wind damage from Hurricane Andrew in 1992 revealed the serious nature of buildings and structures at risk along the US coastline. In extreme storms, such as Hurricane Andrew, the force of the wind alone can cause tremendous devastation, as trees and power lines topple and weak elements of homes and buildings fail. These losses are not limited to the coastline; they can extend hundreds of miles inland under certain conditions (FEMA, 1997). This lack of attention by the general public, building code officials, developers and even the insurance community, is in part responsible for the proliferation of structures along the shore that could not survive even a moderate hurricane.

In addition to placing more property in harm's way, coastal population growth has created life-threatening problems associated with storm warnings and evacuation. It is becoming more and more difficult to ensure that ever-rising numbers of residents and summer visitors can be evacuated and transported to adequate shelters during storm events. In some locations, hurricane evacuation decisions must be made long before hurricane warnings can be issued. Further, a significant percentage of the coastal population has not experienced a hurricane and may be less likely to prepare and respond properly before, during and after such an event. Even the best organized governmental response may be unable to meet the large demands for emergency shelter, food and water in many heavily populated areas.

HURRICANES RISKS & VULNERABILITIES					
Vulnerable Area	**Location**	**Ownership**	**Natural Hazards**	**Primary Problems/Effects**	**Mitigation Benefits**
power lines, traffic signals, power substations, highway signs	Islandwide,high elevations	MECO	High winds, Kona storms Hurricanes	utility and transportation disruption, navigation impeded, business interruption; social/family stress	Public safety, well-being minimize power outages,
residential homes	coastal, high elevations	private	High winds, Kona storms Hurricanes, erosion	Damage, loss of property	Public safety, reduce costs of recovery, rebuilding & repair
schools		public/private	high winds, hurricane	loss of life, damage to building and contents, disruption of social well being, shelter facilities at risk	Public safety, protect structure
coastal hotels/resorts	Wailea, Kaanapali, Kihei, Napili, Maalea	private	coastal erosion, storm surge, high wind & surf	erosion removes sand and compromises structural integrity, damage to lower floors, social/economic disrupt.	Prevent costly damage, prevent impact of erosion on beaches/ dune systems
public beaches and facilities	coastal areas	Federal, county state	coastal erosion, storm surge, high wind & surf	flood debris deposited on beach, coastal erosion	minimize social disruption, protect beaches and dunes
port/harbor damage	Kahului Port, Maalaea Harbor	public/private	storm surge,high surf, erosion, overwash	facility flood inundation, hazardous materials released, foundation/ structural damage, waterborne debris, interrupted intermodal comerce, loss of supplies to Island, business interruption, natural resource damage	maximize social wellbeing, minimize business disruption, prevent costly damage, protect natural resources
coastal roads	Oluwalu, N. Kihei, Lower Honoapiilani	County, State	overwash, erosion, storm surge, high surf	evacuation difficulties, inter-island access difficulties, loss of safety/health services	prevent costly road repair, business interruption, protect beaches and dunes
downed trees	Lahaina,Kula, Hana Kahului, Wailuku	county, private	high winds, hurricanes, Kona Storms	damage to buildings, cars, power outages, business interruption, transport ation disrution,debris cleanup	Public safety, prevent costly debris cleanup, business interruption
Historical buildings	Lahaina	county, state, private	high winds, storm surge	economic & social hardship, loss of cultural resources	Protect cultural resources,
Kahului Treatment Plant	Kahului	county	storm surge,high surf	environmental damage, economic & social hardship	Public safety, avoid environmenta damage

Potential Losses from Future Hurricanes in Maui County

If a Category 1 storm as strong as Hurricane Iwa, with winds gusting as 74 mph, strikes any of the islands in the state, we can guess from past experience that about 12% of the houses and apartments could be destroyed or heavily damaged and about 18% would probably experience minor damages.

If a Category 3 storm strikes any island with the same force as Iniki, with winds raging at 130 mph, we can guess that about 38% of the homes will be heavily damaged or destroyed. An additional 40% will probably have minor damages.

The following information was extrapolated from Kauai damages in 1982 and 1992.

	Oahu	Maui	Hawaii	Kauai
Iwa-strength storm	$ 4.5 - 7.5	$0.8-1.4	$0.8-1.4	$0.3-0.6
Iniki-strength storm	$13.9-23.3	$2.7-4.5	$2.6-4.4	$1.1-1.9

Source: Hawaii Coastal Hazard Mitigation Planning Project, Office of Planning, December 1993.

The Hurricane Advisory Council has identified the following model for understanding and developing hurricane loss estimates (Hurricane Hazard Advisory from the Hawaii Multihazard Science Advisory Committee [MSAC] to the State Hazard Forum, 2002).

> State-of-the-art hurricane loss estimation requires regionally-validated storm windfield modeling and tracking, topographic speedup modeling, terrain category and building inventory databases defined with detailed spatial resolution, and regional building damage and loss functions. The two NASA-sponsored projects have developed the core computational components of what could be developed into Hurricane Loss Estimation Model (HLEM) software available for Hawaii State and County planning.
>
> Expected hurricane risk levels (i.e., expected loss as a function of return period) could be determined for a geocoded building inventory database using the wind hazard analysis by Peterka combined with the Chock topographic wind and building damage model. The Average Annualized Losses due to could be then calculated windstorms for individual communities to determine their risk relativity factors. This would allow an objective ranking of hurricane risk for regions or areas (such as census tract groupings), taking into account hurricane probabilities, site-specific wind environment, and the building inventory existent in each study region.
>
> The HLEM could provide technically validated input on hurricane hazard and vulnerability pertinent to State and County agencies. For example, all other proprietary and “black box” catastrophic hurricane loss models (principally those used by insurance companies for hurricane rate filings) could then be evaluated by comparisons of defined scenarios with the results of the Hurricane Estimation Model.

Stronger Wind Provisions Needed in Building Code

In 1993, the University of Hawaii Social Science Research Institute estimated losses that could be expected from an Iwa-strength storm and an Iniki-strength storm for all four counties based on the impact of Hurricane Iwa in 1982 and Iniki in 1992. Iwa had winds just below hurricane strength at 74 mph and Iniki had winds of about 130 mph.

Total losses for Maui County were estimated at $1.1 billion for an Iwa-strength storm and $ 3.6 billion for an Iniki-strength storm (see table, below). This estimate is in 1992 dollars and 1992 development on Maui. These figures are derived from actual loss figures for Hurricanes Iwa and Iniki on Kauai using ratios of number of structures (property), population (public utilities), or production (e.g. agriculture) on Kauai as compared to Maui in 1992.

Damage Estimate for Maui if a Category 4 Storm Hits

The same SSRI study estimated that following an Iwa-Strength storm on Maui in 1992 the loss of visitor expenditures would have been almost $655 million in the first quarter following the storm. For an Iniki-strength storm on Maui in 1992 would have been a little over $1.6 billion in the first quarter following the storm (D. Kennard 1993).

1992 Estimate of Asset Damage for Maui from Hurricane Iwa- and Iniki-Strength Storms

Category of Asset	Iwa-Strength Storm	Iniki-Strength Storm
Chapter VI Residential		
Structures	$385 million	$1,121 million
Personal Property	$173 million	$504 million
Sub-total	$559 million	$1,625 million
Commercial		
Tourism Accommodations	$273 million	$798 million
Other Visitor Facilities	$99 million	$460 million
Public Utilities	$ 43 million	$282 million
Sub-total	$415 million	$1,540 million
Non-Federal Public Property	$81 million	$124 million
Clean-up	$35 million	$110 million
Sub-total	$116 million	$234 million
Agriculture	$46 million	$200 million
TOTAL	**$1,135 million**	**$3,599 million**

Source: David Kennard, “Modeling Future Hawaiian Hurricanes: Damage Assessment and Economic Impact Scenarios.” In M.P. Hamnett et al, *Hawaii Coastal Hazard Mitigation Planning Project.* Hawaii Office of State Planning, Coastal Zone Management Program, December 1993, pp 75-103.

Specific Seismic Hazard Vulnerabilities

	SEISMIC RISKS AND VULNERABILITIES					
Vulnerable Area	**Location**	**Ownership**	**Natural Hazards**	**Primary Problems/Effects**	**Mitigation Benefits**	**Risk**
roads, bridges	coastal, near steep slopes, mountains Hana, West Maui	county, state	tsunami inundation, landslide, earthquake	transportation disruption, costly repair business interuption, social disruption	Public safety & well being protection of public infrastructure	H/P
MECO Powerplant	Maalaea	private	tsunami inundation	loss of power, destruction to refuge	Public well being, minimize ecoconomic/social disruption	P
Kahului Treatment Plant	Kahaului	county	tsunami inundation	social/ econmic disruption, environ mental degradation to refuge, water quality damage to harbor	Public safety & well being, min. social/economic hardship	P
Business & retail district	Lahaina, Wailuku Kihei	private	tsunami inundation	damage to structures, loss of jobs, business interuption, social hardship	protect jobs, tourist revenues	H/P
Community Centers	Kaunoa Sr. Center	county	tsunami inundation	only facility of its kind on island, high use by senior population, houses many social programs	Social well being, critical social services protected	
masonry buildings	Islandwide	public, private	earthquake	structural damage	Public safety & well being	P
critical support equipment, generators, elevators, chillers, medical equip., computers	hospitals, fire/police	county, private	earthquake	structural damage, loss of critical services	Public safety, critical response services protected	P
gas, electric, water lines water towers, pump stations	Islandwide	county, private	earthquake, tsunami inundation	loss of water, sanitary problems, fires from gas leaks, hazardous spills, social/economic hardship	Public safety,minimize economic disruption, socail well being, prevent environmental damage	

Earthquakes

In the risk and vulnerability assessment, the areas in which the community is vulnerable need to be identified and what damages are expected if an earthquake occurs. Much of the risk from earthquakes is related to life safety; therefore, the occupancy of buildings is an important factor in determining risk. Other factors to consider when evaluating Maui's vulnerability to earthquakes are:

- The kind of structures in the community
- Contents of the structures
- Structure use and occupancy

Earthquake Prediction

Although it is known that most global earthquakes will concentrate at the plate boundaries, there is no reliable method of accurately predicting the time, place, and magnitude of an earthquake. Most current research is concerned with minimizing the risk associated with earthquakes by assessing the combination of seismic hazard and the vulnerability of a given area. Many seismic countries, however, have research programs based on identifying possible precursors to major earthquakes. This includes the study of dilatancy, how rocks crack and expand under the increased stress associated with the earthquake. Some major earthquakes, but not all, are heralded by the occurrence of foreshocks, which can be detected by dense local monitoring networks. Other instruments can measure changes in the levels of radon gas, electrical and magnetic properties, velocity changes of seismic waves, and changes in topography. Long term monitoring and examination by these sensors is required as some or all of these factors may change due to the opening of cracks prior to the earthquake.

All attempts to predict earthquakes have, however, generally been considered failures and is unlikely that accurate prediction will occur in the near future. Efforts will, instead, be channeled into hazard mitigation. Earthquakes are difficult or impossible to predict because of their inherent random element and their near-chaotic behavior

FEMA HAZUS Loss Estimation Model

As part of its efforts to mitigate hazards and protect lives and property from the devastating effects of natural disasters, FEMA aims to provide individuals, businesses, and communities with information and tools to work proactively to mitigate hazards and prevent losses resulting from disasters. One of these tools is HAZUS or Hazards U.S., a natural hazard loss estimation methodology developed by FEMA under contract with the National Institute of Building Sciences. Using Geographic Information Systems (GIS) technology, HAZUS allows users to compute estimates of damage and losses that could result from an earthquake.

HAZUS estimates the violence of ground shaking, the number of buildings and residential units damaged, and the number of casualties. It also estimates the amount of damage to transportation systems, disruption to the electrical and water utilities, the number of people displaced from their homes, and the estimated cost of repairing projected damage and economic losses.

Hawaii State Civil Defense (SCD) and the Hawaii State Earthquake Advisory Committee (HSEAC) have been working with the Pacific Disaster Center (PDC) to operationally implement HAZUS Earthquake Loss Estimation Methodology in the State of Hawaii. HSEAC spent several years compiling a more accurate building inventory database for Maui to yield more comprehensive loss estimations. The model is in the final phase of completion. The data is loaded into the model and PDC is developing the final presentation portion of the model.

HAZUS will be expanded to include multi-hazard modules (i.e. wind, flood, and hurricane) which will broaden its user base in Hawaii and throughout the nation. The hazard component of the HAZUS Hurricane Model will make use of an existing state-of-the-art windfield model, which has been calibrated and validated using full-scale hurricane data. The model incorporates sea surface temperature in the boundary layer analysis, and calculates wind speed as a function of central pressure, translation speed, and surface roughness.

Tsunamis

Tsunamis can be induced “locally” by such events as volcanic eruptions, earthquakes or surface and submarine landslides on neighbor islands such as the big island of Hawaii. This could cause a tsunami wave to hit the Maui County coastline in a matter of minutes. The Coast of Maui County is also vulnerable to tsunamis generated at locations that are considerably distant such as Alaska, Japan or Chile. In this case it could take many hours before a wave would hit the Maui coastline.

A tsunami can flood inland hundreds of feet or more and cause much damage and loss of life. These waves are not simply large wind-generated waves. They can have very long wavelengths, sometimes with distances as much as 60 miles between crests. Large Pacific Ocean tsunamis can travel at 500 – 600 miles per hour in the open ocean. As the waves reach shallow water of the coast, the waves are slowed down, forcing the water to form walls of 30 feet or more. Tsunamis have considerable energy to run up and flood the coast and the ability to inundate much farther inland than ordinary wind-generated waves.

A tsunami's effect at the shoreline can be considerably different within very short distances. The only general rule is that runup heights tend to be greatest near where the offshore bathymetry is steeper. Along gentle-sloping coasts, wave energy is dissipated upon shoaling. Even so, inundation can be significant and is usually greatest along low-lying coastal plains.

Tsunamis can cause death and major damage to port facilities and public utilities. It can damage breakwaters and piers because of the wave impact and scoring action. Ships and smaller craft moored in harbors may be swamped, sunk or left stranded on shore. Oil tank farms near the waterfront are particularly vulnerable to damage, which can result in spreading of hazardous materials or fire. Any resulting oil fire could be spread by the wave. Communities may be disrupted due to tsunami damage until debris can be cleared, wharves and piers rebuilt, and utilities restored.

Specific Drought Hazard Vulnerabilities

Drought

A drought is a period of abnormally dry weather. Drought diminishes natural stream flow and depletes soil moisture, which can cause social, environmental and economic impacts. In general, the term "drought" should be reserved for periods of moisture deficiency that are relatively extensive in both space and time.

A drought is caused by a deficiency of rainfall and can be increased by other factors such as high temperatures, high winds, and low relative humidity. Drought can also result from human activities that increase demand for water. Expanding populations, irrigation, and environmental awareness all put pressure on water supplies. The severity of the drought depends not only on the duration, intensity, and geographic range, but also on the regional water supply demands made by human activities and vegetation.

Lack of rainfall is not the only factor contributing to the impacts of drought. Both natural events and human activities, such as expanding populations, irrigation, and environmental needs all puts pressure on water supplies. Lack of rainfall combined with the demand society place on water systems and supplies contribute to drought impacts. During the past 15 years, the most severe droughts impacting the Hawaiian Islands have been associated with the El Niño Phenomenon and persistent zones of high pressure systems throughout the islands.

Drought is a chronic and troublesome problem in Hawaii, at one time or another affecting virtually every part of the state. These events often reduce crop yields, diminish livestock, desiccate streams, irrigation ditches and reservoirs, deplete groundwater supplies, and lead to forest and brush fires. Periods of drought invariably give rise to water crises, sometimes requiring imposition of emergency conservation measures.

Drought can be characterized from the perspectives of meteorology, agriculture, hydrology, and socio-economic impacts. For example, the meteorological perspective would describe drought as a rainfall deficit compared with some normal or expected rainfall amount. The agricultural perspective could describe drought by its impacts on the agricultural industry due to reduced rainfall and water supply (e.g., crop loss, herd culling, etc.). Hydrological descriptions of drought may compare stream flows, ground water, and reservoir levels to normal conditions. Drought can also be described from the souci-economic perspective by the direct and indirect impacts droughts have on society and the economy (e.g., increased unemployment due to failure of an industry because of drought).

Droughts increase the potential for wildland fires. Farmers, cattle ranchers, and people using water catchment systems are the most severely affected by drought. Drought exacerbates the problem of ensuring a sustainable yield of potable water. Since Hawaii is an island state, this is particularly critical. Failure to take appropriate action could result in Hawaii not having sufficient quantity and quality of water resources to sustain future population and industry. (Drought and Wildland Fire Mitigation Plan. December 1998. Department of Defense, Civil Defense Division, http://www.hawaii.gov/dlnr/cwrm/drought/drought.htm).

Wildfires

All the Hawaiian Islands are susceptible to wildland fires, especially during prolonged drought and high winds. For the past 15 years, the average annual cost to suppress wildland fires in Hawaii is about $1,100,000 - making it a statewide risk. The greatest danger of fire is where the wildland borders the urban areas. The amount of natural fuel (trees and brush) in close proximity to human populations contributes to increasing the risk to life and property. Other threatened locations include agricultural areas that are adjacent to wildland where downed trees and flammable brush are prevalent.

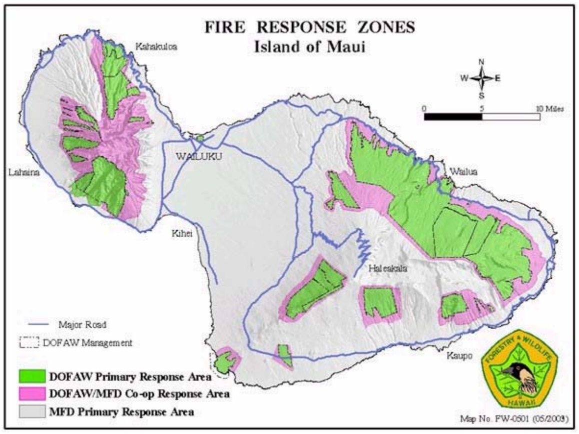
Each year, the State of Hawaii is endangered by hundreds of wildland fires. Wildland fires are associated with periods of little or no rainfall and are typically the highest with the months associated with severe drought conditions in Hawaii.

Humans have historically directly caused the majority of these fires. This is done either on purpose or by negligence. The risks of these fires are varied, but the greatest risk to property is that the majority of wildland brush fires are in areas that traditional fire fighting equipment cannot be used, (i.e. mountaintops, steep pali ridges and valleys). Expensive equipment like airborne helicopters and other aircraft are usually needed just to keep these fires in check, but can do very little in the prevention of brush and grass fires

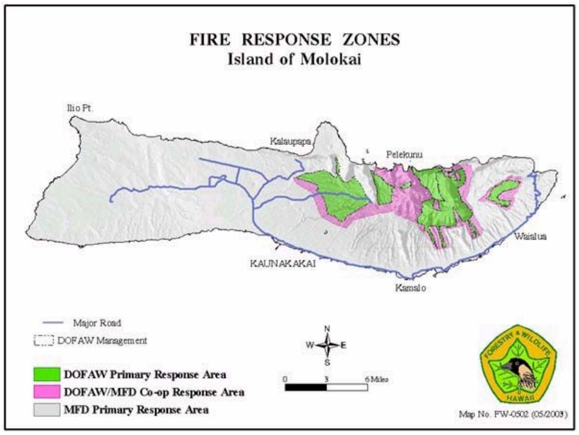
Fortunately, wildland fires have not caused extensive damage or destruction to buildings nor injury to people. However, as residential development expands or encroaches into relatively untouched wildland, people living in these communities will be at greater risk of encountering a wildland fire.

Department of Forestry and Wildlife Management

The mission of the Division of Forestry and Wildlife Management (DOFAW) Fire Management Program is to provide protection to forest reserves, natural area reserves, wildlife and plant sanctuaries and public hunting areas. DOFAW will cooperate with established fire control agencies for the protection of other wildland not within department protection areas to the extent needed to provide for public safety. DOFAW will hold environmental damage below the level at which it would interfere with the high level, sustained yield of services and commodities from these lands.



By virtue of its core mission, DOFAW plays a pivotal role in protecting the state's watersheds and unique forest resources, i.e. forest products, and threatened and endangered species. Because wildfire is a threat to Hawaii’s economy, society, and natural resources, all levels of government have established fire services to guard against the ravages of uncontrolled conflagration.



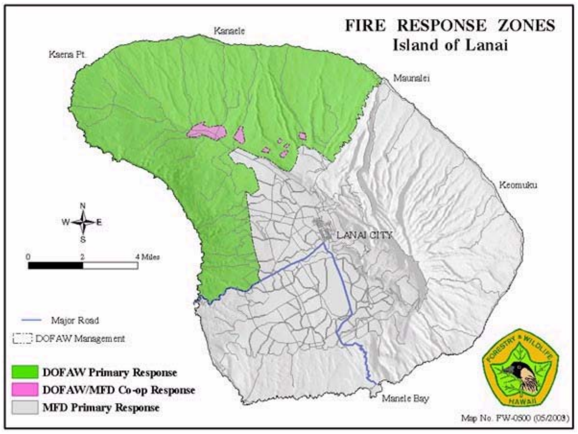
Combined with cooperative zones, DOFAW is involved with each of the four counties in the protection of 3,360,000 acres statewide, which are approximately 81% of the state's land area. The remainder is managed by various military fire departments and Department of Interior (National Park Service and the Fish & Wildlife Service) and The Nature Conservancy of Hawaii.

In the early 1980s, a map of each county was delineated to depict areas where DOFAW has primary fire responsibility (color-coded green), areas where it could respond mutually with other firefighting agencies (color-coded pink), and areas totally out of its jurisdiction (color-coded white). DOFAW would automatically respond to fires in the green area. The pink areas generally are those areas that are adjacent to the green areas. If fires were in these areas, DOFAW would respond mutually if the request came directly from the county fire department.

It was agreed that DOFAW would be able to respond to fires in the white areas only under specific conditions, i.e. extreme threats to public safety, local resources fully committed, extreme fire behavior, etc., and through the appropriate channels and only if its resources are available.

To respond to fires in the white area, the following must occur:

- The request for assistance must come from the County Fire Department through the County Civil Defense to State Civil Defense that DOFAW assistance is needed.
- State Civil Defense will then contact the DOFAW Administrator or the State Protection Forester that DOFAW assistance is needed.
- State Civil Defense will notify the Adjutant General as soon as possible of the request made to DOFAW. The Adjutant General will notify the Governor as soon as possible and keep him periodically informed of the situation.
- The DOFAW Administrator or State Protection Forester will then contact the respective DOFAW Branch Manager who will then mobilize his resources to assist the County Fire Department.
- The DOFAW Administrator will notify the DLNR Chair as soon as possible of the request made by State Civil Defense.



Risk and vulnerabilities

The fire season runs from April through October. Dry periods can extend the season. The possibility of a wildland fire depends on fuel availability, topography, the time of year, weather, and activities such as debris burning, land clearing, camping, and recreation. In Maui County, wildland fires start most often in fields, or open areas, transportation areas, and wooded wildland areGas. They are usually extinguished while less than one acre, but can spread to over thousands of acres. Wildland fires responded to by the County Fire Department and the Department of Land and Natural Resources fire fighters were largely started by human causes. The highest percentage of number of fires was caused by arson. Debris burning, smoking and campfires follow this. Wildland fires started by arson caused the largest acreage loss, followed by equipment, debris burning and cigarettes. Loss per incident for arson fires is three and a half time higher than any other fire cause.

The effects of wildland fires vary with intensity, area, and time of year. Factors affecting the degree of risk include rainfall, type of vegetation, and proximity to firefighting agencies. Short-term loss is the complete destruction of valuable resources, such as watersheds, wildlife habitat, scenic vistas, and trees. Vulnerability to flooding increases due to the destruction of watersheds. Long-term effects are erosion, loss of wildlife habitat and an environmentally friendly place for people to relax and have fun.

Wildland Fire Costs and Losses

The “wildland urban interface” area is anywhere houses and a wooded or wildland area are in close proximity with to each other. On Maui County that could be almost every where. From 1975-2002 there were 44 structures burned and 1430 fires covering approximately 65,341 acres. This cost millions of dollars of both direct and indirect expense.

Wildfire doesn’t need to happen in your backyard to affect you. People all over Maui were impacted in some manner during a 1998 3,340-acre wildfire in Maalaea that jumped across Honoapiilani Highway, causing evacuation of nearby residents. Traffic to Lahaina was disrupted for days affecting locals and tourists alike. People weren’t able to get to and from work; tourists weren’t able to get to their hotels or the airport.

The cost of wildfires goes beyond the economic aspects. It also has environmental, social and cultural impacts as well. These costs include such things as impacts on soil and vegetation, the degradation or loss of wildlife habitat and forage, impacts related to range resources and agriculture (i.e. loss of forage, range and grazing management complications), impacts on cultural recourses (i.e. trampling, crushing, exposing and covering of cultural resources, disturbance of archeological sites, damage or degradation of sacred sites). Intangible economic impact is found in areas such as loss of tourism and visitation revenues, diminished real property values and thus tax revenues, loss of retail sales, and relocation expenses of temporarily or permanently displaced residents.

Chapter VI Mitigation Actions and Projects

Risk management is the process by which the results of an assessment are integrated with political, economic, and engineering information to establish programs, projects and policies for reducing future losses and dealing with the damage after it occurs. (Heinz Center, 1999) Managing risk involves selecting various approaches that, when applied to the risk area, will reduce the vulnerability. In order to effectively evaluate the true costs associated with natural hazards, the vulnerability of the built environment, social, health and safety, business and natural resources, and ecosystems' vulnerability must be determined.

Once all the possible actions are on the table, there must be a way to determine if there are appropriate measures to solve the identified problems. Using some basic evaluation criteria can help to decide which actions will work best. The most important criteria are whether the proposed action mitigates the particular hazards or potential loss. Each action should also be examined for conflict with other community programs or goals. For example, how does this action impact the environment? It is very important to consider whether the proposed action will meet state and local environmental regulations. Does the mitigation action affect historic structures or archeological areas? Does it help achieve multiple community objectives? Another important issue is timing. For example, how quickly does the action have to take place to be effective? Which actions will produce quick results? It is particularly important to consider if funding sources have application time limits; if it is the beginning of storm season; if the community is in the post-disaster phase, where everyone wants to recover at maximum speed.

The County Planning Department develops the General Plan in concert with the Communities Plans. These plans shall be internally consistent, with compatible vision, principles, goals, policies, implementing actions, and land use maps. "The General Plan shall be developed after input from State and County agencies and the general public, and shall be based on sound policy and information. The General Plan shall: indicate desired population and physical development patterns for each island and region within the County; address the unique problems and needs of each island and region; and environmental consequences related to potential developments; and set forth the desired sequence, patterns, and characteristics of future developments" (Ordinance No. 3166. Chapter 2.80.030.E)

The Maui County Civil Defense Agency will be able to influence the planning process via this Multi-Hazard Mitigation Strategy. This plan will endeavor to influence the regulation of urban growth and development, building permitting and codes, shoreline setbacks and other mitigation priorities.

STAPLEE

STAPLEE Criteria is an acronym for a general set of criteria common to public administration officials and planners. It stands for the Social, Technical, Administrative, Political, Legal and Economic & Environmental criteria for making planning decisions. These criteria were used for each project considered and a work sheet is provided with each project to indicate how the project measures up to the STAPLEE criteria. This will help to prioritize each project.

STAPLEE criteria for selecting mitigation measures

Social: Is the purposed action socially acceptable to the community? Is there equity issues involved that would mean that one segment of the community is treated unfairly? Will the action cause social disruption?

Technical: Will the proposed action work? Will it create more problems than it solves? Does it solve a problem or only a symptom? Is it the most useful action in light of the other community goals?

Administrative: Can the community implement the action? Is there someone to coordinate and lead the effort? Is there sufficient funding, staff and technical support available? Are there ongoing administrative requirements that need to be met?

Political: Is the action politically acceptable? Is there public support to implement and to maintain the project? Will the Mayor, his Cabinet, County Council and other decision making political bodies support the mitigation measure?

Legal: Is the community authorized to implement the proposed action? Is there a clear legal basis or precedent for this activity? Is enabling legislation necessary? Are there any legal side effects? Will the community be liable for action or lack of action? Will the activity be challenged?

Economic: What are the costs and benefits of this action? Does the cost seem reasonable for the size of the problem and the likely expenses? How will this action affect the fiscal capability of the community? What burden will this action place on the tax base or local economy? What are budget and revenue effects of this activity? Does the action contribute to other community goals, such as capital improvements or economic development? What benefits will the action provide?

Environmental: How will the action impact the environments? Will the action need environmental regulatory approvals? If the action requires construction, will it meet local inland wetlands and/or Conservation Commission and State

DEP regulatory requirements? Are endangered or threatened species likely to be affected?

Hazard Mitigation Benefits and Cost for the Community

OMB Circular No. A-94 (Sections 6 and 6a) indicates that:

> Analyses should include comprehensive estimates of the expected benefits and costs to society based on established definitions and practices for program and policy evaluation. Social net benefits, and not the benefits and costs to the Federal Government, should be the basis for evaluating government programs or policies that have effects on private citizens or other levels of government. Social benefits and costs can differ from private benefits and costs as measured in the marketplace because of imperfections arising from…external diseconomies…monopoly power…and taxes or subsides. Both intangible benefits and costs should be recognized.

Final implementation of these mitigation measures can be prioritized based on some form of cost-benefit analysis. The purpose of the cost-benefit analysis is to evaluate the tradeoffs about reaching goals concerned with protection of the built and natural environments.

The costs for mitigation will include FEMA, other federal agency, state, local and private dollars spent on the mitigation activities. This “dollars-spent” assessment should include administrative and maintenance costs and indirect costs. Costs also should include relevant opportunity costs, i.e. the value of alternatives forgone to achieve the mitigation activity. The costs of mitigation include:

- Direct expenditures on relocation, construction and transportation.
- Costs generated by rules and regulations setup in the name of hazard mitigation (e.g. possibly lower property values due to new zoning restrictions).
- Denial of access to economic resources due to zoning.
- Increased business costs from mitigation-related safety regulations.

The benefits of mitigation activities are estimated. Expected benefits are the losses avoided because of a mitigation activity for hazard events of different intensities, multiplied by the probability of each of these events occurring. Losses avoided include, but are not limited to: reduced loss of life, injury, and damage to property (including historic properties); reduced impacts on environmental, social and recreational values; reduced community disruption and business interruption; and future expenditures on disaster relief. Most benefits of mitigation are costs and losses avoided through the reduction in loss probabilities and a reduction in loss amounts/value, such as reduced:

- Loss of life, injury and pain.

- Property destruction and damage.
- Community disruption, personal and local infrastructure.
- Business interruption, including closures, shutdowns, un- (and under) employment.
- Loss of culturally and historically important items.
- Expenditure on disaster relief by both governments and private organizations.

Benefits may also include increased awareness by communities of hazards, their impacts and avoidance, leading to better decisions and future actions.

Categories of Mitigation Actions

There are several types of mitigation actions that Maui County has planned. Some of the plans will require long-term strategies for implementation, but will reduce the future impacts of disasters in the County of Maui. The following are listed in order of priority.

Mitigation Planning and Policy Development

- Mapping hazards and incorporating them into planning documents, potential loss estimates, and zone considerations.
- Assessing inventories of public facilities.
- Refining and updating building codes and zoning requirements.
- Education, training & public awareness.
- Developing loss mitigation incentives to the public.
- Implement existing policies, ordinances and statutes.
- Revise regulations.
- Leveraging grants with other agencies.
- Providing technical assistance.
- Conducting research to improve knowledge, develop standards, map & identify hazards.

Mitigation Actions for Flooding

1. Enforce existing floodplain regulations and shoreline setback requirements, i.e. tsunami inundation zone.
2. Designate coastal high hazard areas on all county planning, zoning, and land use maps and establish a hazard mitigation review process.
3. Review FEMA FIRMS and evaluate their accuracy in depicting special flood hazard areas and effects of new development.
4. Prohibit floodplain/floodway development.
5. Acquire, when possible, land in floodway/floodplain.
6. Storm water runoff and sediment erosion.
7. Collection of flood damage data.
8. Maintenance of flood control facilities/structures.
9. Forecasting/warning/stream gauging.

10. Public education/awareness/information for flooding via tsunami, hurricane, or heavy storms.

Mitigation Actions for Wind Events

1. Provide higher grade poles for electrical distribution.
2. Provide emergency back-up power to critical facilities: emergency generators, secondary feeds, portable generators with standard camlock connections.
3. Analyze communications lines on power poles. If they cause unacceptable loads, remove when possible.
4. Protect traffic lights and other traffic controls from high winds.
5. Prune trees and tree branches to reduce wind damages and plant species of plants that are more resistant to wind damage.
6. Analyze all public shelters, buildings or rooms and strengthen as necessary.
7. Install shutters on windows or doors or otherwise protect building openings from wind damage.
8. Ensure that roof-mounted equipment, including cowlings and flashing, is securely mounted.
9. Install additional connections such as hurricane straps and tie downs to resist wind loads.
10. When re-roofing a critical facility, provide extra protection from water damage; check and refasten the roof sheathing.

Mitigation Actions for Drought and Wildfire Events

1. Further refinement and/or delineation of areas of drought risk.
2. Application, receipt and administration of funds for the implementation of identified projects.
3. Provision of oversight and management of project implementation.
4. Improve and expand fire education programs, i.e. Firewise Communities™.
5. Examine and expand the use of fuel breaks.
6. Form a committee to examine the issue of emerging wildland fire risk due to changes in land uses (former agriculture lands) and make recommendations for wildland fire mitigation.

Mitigation Actions for Coastal Erosion

1. Build and support an on-going, Comprehensive Public Education and Awareness Campaign.
2. Develop a Technical Guidance Manual that provides direction for coastal development. This could become a standard for the safe, economical, and sustainable utilization of the coastline through common usage.
3. Enhance inter-agency coordination and cooperation.
4. Develop and support a continuous data stream to coastal managers.
5. Implement a pilot Shoreline Hazard Mitigation Project using beach and dune restoration.

6. Establish decision-making criteria for coastal land use.
7. Define statewide erosion hazard zones and map base flood elevations.
8. Numerical Wave Run-up and Storm Surge Models should be developed.

Mitigation Actions for Seismic Events

1. Replace brittle equipment in electric substations.
2. Retrofit bridges/overpasses and other critical transportation links.
3. Provide shutoff valves in water and gas distribution lines.
4. Add additional seismic connections through methods such as bolting.
5. Brace equipment such as mechanical equipment, chillers, emergency generators, and elevators, where failure may disrupt the operation of a critical facility, such as a hospital.
6. Reinforce at-risk masonry buildings.
7. Brace parapet walls on buildings, brace or demolish outdoor shelters that pose collapse hazards.
8. Harden critical wireless emergency communications systems.
9. Brace equipment that could block building exits or injure people.
10. Brace high value equipment, such as computers and medical equipment that could topple and be damaged.
11. Install flexible connections on gas lines.
12. Install flexible connections on water sprinkler systems.
13. Bolt houses to their foundations.

The mitigation actions and measures that could be placed in the project proposal format are included in the following section for the County of Maui. Full cost-benefit analyses have not been conducted for these projects. This will be done for the next iteration.

The following ten projects are all wildland fire, agriculture and drought related, in that order. The Hawaii State Commission on Water Resource Management (CWRM) conducted a series of workshops on Maui on June 30 and July 19, 2004, in order to develop a drought mitigation strategy for Maui County. Workshops were undertaken to compile an inventory of existing drought mitigation programs, identify data gaps, identify drought risk areas, and recommend and prioritize drought mitigation projects. The drought committee consisted of representatives from various agencies and entities. A list of names can be found in the appendices.

The Maui Drought Committee will serve as a focal point for the exchange of information between Federal, State, and County agencies, local stakeholders, and the Hawaii Drought Council. The Maui Drought Committee will be responsible for monitoring drought conditions, gathering data, and forwarding information to the Hawaii Drought Council via the State Drought Coordinator. In turn, the State Drought Coordinator will provide data gathered by the Water Resources Committee to the Maui Drought Committee for distribution to local agencies and stakeholders.

Methodology for Project Prioritization

A prioritization process was undertaken by the Maui Drought Committee to categorize the proposed mitigation projects. This resulted in lists of “high” and “other” priority projects for each impact sector.

Some general guidelines were discussed for consideration during the project prioritization discussion, and are listed below:

- Potential impacts to people;
- Potential impacts to critical natural resources (endangered species habitat, watersheds, cultural resources, erosive soils, etc.);
- Potential impacts to economic resources (jobs, agriculture sector, tax revenues, etc.); and
- Impacts to critical government services (emergency services, water supply, health & human safety).

Generalized timelines were also agreed upon for high priority projects to indicate whether the projects were intended for immediate and/or long-term implementation.

For high priority projects, the Committee members developed detailed project descriptions, utilizing a form developed by the Hawaii Hazard Mitigation Forum. These forms provide project justification and estimated cost information to support the future pursuit of funding and implementation activities.

Project implementation will be focused on those projects that have been identified as having an immediate need and which are most easily achieved. The Maui Drought Committee will seek planning or project funding opportunities through existing government programs, private foundation grants, and county, State, or federal appropriations. Forming partnerships with existing groups (i.e., watershed partnerships, water user cooperatives, etc.) and coordinating mitigation projects will help leverage any funding opportunities or cost-sharing requirements.

PROJECT 1: Improve vehicular access in mauka Kalamaula-Makakupaia and Kula Forest

Jurisdiction: Maui County

Agency/Organization: DOFAW, the Nature Conservancy, County Fire Dept.

Project Title: Improve vehicular access in mauka Kalamaula-Makakupaia (2 miles) & Kula Forest (1 mile).

Contact Person: Glenn Shishido

Phone: 808-873-3501

e-mail: mafire@aloha.net

Hazard(s): High Fire Risk

Flood Zone: NA

Base Flood Elevation: NA

Erosion Rate: NA

Critical Facility/Population/Asset at Risk:
Endangered species, prevention of erosion and flooding

Environmental Impact:
[✓ High] Medium Low

Historical Preservation Impact:
[✓ High] Medium Low

Risk of Hazard Impact:
[✓ High] Medium Low

Importance to Protection of Life and Property and Recovery from Disaster:
[✓ High] Medium Low

Estimated Cost of Project: $100,000 to $300,000

Project Period (duration): Annual maintenance

Estimated Value of Structure or Facility:

Sources of Financial Support: Various sources

Project Objectives:

To improve vehicular access to for fire suppression and to create a fire break for protection of natural resources.

Project Description:

Improve approximately 1-mile of existing road in the Kula Forest (Waipoli Road). This is an existing public access. The road needs to be maintained at least annually, and possibly more frequently depending on erosion and vegetation growth. Cost estimate for this project is approximately $100,000. Annual cost would be significantly less once initial improvements are completed.

Improve approximately 2-miles of road in the Kalamaula-Makakupaia area. Access would be restricted by landowners and used by DOFAW/the Nature Conservancy/Maui Fire Department for fire suppression and natural resources management. The project needs to be maintained at least annually, and possibly more frequently depending on erosion and vegetation growth. Cost estimate for this project is approximately $200,000. Annual cost would be significantly less once initial improvements are completed.

Proposal Date:

PROJECT 1: Improve vehicular access in mauka Kalamaula-Makakupaia and Kula Forest

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	?
	Funding Allocated	Yes (Grant monies)
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	DOFAW, MFD
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit	Access & Fire Break Road
	Cost of Action	$100,000 - 300,000
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	No-existing roads
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 2: Conservation Management plan.

Jurisdiction: Maui County

Agency/Organization: DOFAW, NRCS, FSA, DHHL, SWCD

Project Title: Conservation Management plan and implementation for Makakupaia to Kalamaula, portion of Ukumehame and Kahikinui, and Kula Forest Road.

Contact Person: Glenn Shishido and
Ranae Ganske -

Phone: Glenn Shishido 873-3501;
Ranae Ganske - 244-3100 ext. 3

e-mail: mafire@aloha.net (Glenn Shishido)
ranae.ganske@hi.usda.gov (Ranae Ganske)

Hazard(s): Fire, mudslides, loss of electricity, road closures

Flood Zone:

Base Flood Elevation:

Erosion Rate:

Critical Facility/Population/Asset at Risk:
Highway, Electrical Power Line/ Homeowners, Tourists/ Natural resources and wildlife including endangered species.

Environmental Impact:

[✓ High] Medium Low

Historical Preservation Impact:
Questionable due to lack of knowledge regarding the archaeological sites. Bulldozing may alter sites.

[✓ High] Medium Low

Risk of Hazard Impact:

[✓ High] Medium Low

Importance to Protection of Life and Property and Recovery from Disaster:

[✓ High] Medium Low

Estimated Cost of Project: $2 to $3 million for planning and implementation

Project Period (duration): Year round

Estimated Value of Structure or Facility: There are power lines, reservoirs and delivery system. No estimate of total value.

Sources of Financial Support: County, USDA, USFWS, EPA, DOH, DLNR, DHHL

Project Objectives:

This Management Plan will identify mitigation measures which will reduce the impact of wild land fires through best management practices within Maalaea to Ukumehame Area, Kahikinui, and Kula Forest.

Project Description:

Division of Forestry and Wildlife(DOFAW), Maui Fire Department (MFD), and Department of Transportation (DOT) will provide technical assistance through the following:

- Fuel Reduction by grazing management
- Partner with MECO and other landowners to implement vegetation management, i.e. 10 foot buffers around all power poles, etc...
- Proposed Subdivision fire mitigation plans through Firewise
- Fire prevention Education such as signage and brochures
- Maintaining and utilizing and access road firebreaks.
- Operation and maintenance for highway Fire Prevention

- Develop Conservation Plan for landowners and operators.
- Install conservation practices according to NRCS specifications such as Prescribed Grazing, Brush Management, Firebreaks, Fencing Water Facilities, Access Road, Upland Wildlife Habitat which includes Threatened and Endangered species.
- Cost share may be available through NRCS and FSA
- Emergency Watershed Protection (EWP) which responds to emergencies created by natural disasters

Proposal Date: July 13, 2004

PROJECT 2: Conservation Management plan and implementation for Makakupaia to Kalamaula, portion of Ukumehame and Kahikinui, and Kula Forest Road.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	DOFAW, MFD, DOT, MECO
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit Cost of Action	Reduction of wildland fires. $2-3M for plng & Impl.
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	May
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 3: Maui Fire Prevention Education Campaign.

<table>
<tr><td colspan="3">Jurisdiction: Maui County</td><td colspan="3">Agency/Organization: Maui Fire Dept., DOFAW, Community Organizations</td></tr>
<tr><td colspan="3" rowspan="3">Project Title: Maui Fire Prevention Education Campaign</td><td colspan="3">Contact Person: County Fire Chief</td></tr>
<tr><td colspan="3">Phone: 808-270-7361</td></tr>
<tr><td colspan="3">e-mail: mafire@aloha.net</td></tr>
<tr><td colspan="6">Hazard(s): Fire</td></tr>
<tr><td colspan="2">Flood Zone:</td><td colspan="2">Base Flood Elevation:</td><td colspan="2">Erosion Rate:</td></tr>
<tr><td colspan="6">Critical Facility/Population/Asset at Risk:
All of Maui County</td></tr>
<tr><td colspan="3">Environmental Impact:
[✓ High] Medium Low</td><td colspan="3">Historical Preservation Impact:
High Medium [✓ Low]</td></tr>
<tr><td colspan="3">Risk of Hazard Impact:
[✓ High] Medium Low</td><td colspan="3">Importance to Protection of Life and Property and Recovery from Disaster:
[✓ High] Medium Low</td></tr>
<tr><td colspan="3">Estimated Cost of Project:</td><td colspan="3">Project Period (duration): On-going</td></tr>
<tr><td colspan="6">Estimated Value of Structure or Facility:</td></tr>
<tr><td colspan="6">Sources of Financial Support: County Fire Dept, DOFAW, other fire organizations, community groups</td></tr>
<tr><td colspan="6">Project Objectives:
Create an educated and informed public concerning Maui County fire risk and personal responsibilities to reduce such risk.</td></tr>
<tr><td colspan="6">Project Description:
Invigorate current fire education and outreach program to reach a greater number of Maui County residents through a more disciplined and organized fashion. During fire seasons and periods of drought, the campaign should be customized to represent the risk and threat to residents.</td></tr>
<tr><td colspan="6">Proposal Date:</td></tr>
</table>

PROJECT 3: Maui Fire Prevention Education Campaign.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	MFD, DOFAW
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No No
Economic	Benefit	Better educated & motivated Public.
	Cost of Action	
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	No
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 4: Wildland fire suppression.

<table>
<tr><td colspan="3">Jurisdiction: County of Maui</td><td colspan="3">Agency/Organization: DOFAW, DHHL, Ulupalakua Ranch</td></tr>
<tr><td colspan="3" rowspan="3">Project Title: Procure, construct and provide access to open water storage facilities (reservoirs) for wildland fire suppression areas in the West Maui (former cane lands), west Molokai, Kahikinui, and other high risk areas</td><td colspan="3">Contact Person: Sumner Erdman, Glenn Shishido</td></tr>
<tr><td colspan="3">Phone: Glenn Shishido 873-3501</td></tr>
<tr><td colspan="3">e-mail: : mafire@aloha.net (Glenn Shishido)</td></tr>
<tr><td colspan="6">Hazard(s): Wildland fire suppression</td></tr>
<tr><td colspan="2">Flood Zone:</td><td colspan="2">Base Flood Elevation:</td><td colspan="2">Erosion Rate:</td></tr>
<tr><td colspan="6">Critical Facility/Population/Asset at Risk:
Residences, telecommunication towers, power lines, natural resources</td></tr>
<tr><td colspan="3">Environmental Impact:
High [✓ Medium] Low</td><td colspan="3">Historical Preservation Impact:
High [✓ Medium] Low</td></tr>
<tr><td colspan="3">Risk of Hazard Impact:
[✓ High] Medium Low</td><td colspan="3">Importance to Protection of Life and Property and Recovery from Disaster:
[✓ High] Medium Low</td></tr>
<tr><td colspan="3">Estimated Cost of Project: (to be provided by contacts)</td><td colspan="3">Project Period (duration): (to be provided by contacts)</td></tr>
<tr><td colspan="6">Estimated Value of Structure or Facility:</td></tr>
<tr><td colspan="6">Sources of Financial Support: grants, Tri-Isle RC&D, County funds, OHA</td></tr>
<tr><td colspan="6">Project Objectives:
Develop new water storage facilities and reservoirs for wildland fire suppression activities.</td></tr>
<tr><td colspan="6">Project Description:
Inventory sites for possible reservoir development suitable for helicopter and/or vehicle access. After the inventory has been completed, develop sites based upon accessibility for fire equipment access.</td></tr>
<tr><td colspan="6">Proposal Date:</td></tr>
</table>

PROJECT 4: Wildland fire suppression.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	DOFAW, DHHL, Ulapalakua Ranch
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit	Wildland fire suppression.
	Cost of Action	
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 5: Moloka'i Irrigation System Improvements.

Jurisdiction: Maui County (Moloka'i)	**Agency/Organization:** HDOA/ARMD
Project Title: Moloka'i Irrigation System Improvements	**Contact Person:** Robert Lum **Phone:** 808-973-1123 **e-mail:** robert.b.lum@hawaii.gov

Hazard(s): Drought

Flood Zone:	**Base Flood Elevation:**	**Erosion Rate:**

Critical Facility/Population/Asset at Risk:
Irrigation water to the farmers of the Moloka'i Irrigation System. This is the largest state-owned water irrigation system. Supplies a significant portion of irrigation water on Moloka'i.

Environmental Impact: High Medium [✓ Low]	**Historical Preservation Impact:** High Medium [✓ Low]
Risk of Hazard Impact: [✓ High] Medium Low	**Importance to Protection of Life and Property and Recovery from Disaster:** [✓ High] Medium Low
Estimated Cost of Project: $3 Million	**Project Period (duration):** 2 years (estimate)

Estimated Value of Structure or Facility: $120,000,000

Sources of Financial Support: State of Hawaii

Project Objectives:

Improve the Moloka'i Irrigation System with respect to emergency, life/safety, reliability, and maintenance issues.

Project Description:

Conduct various initiatives and projects related to restoring the Moloka'i Irrigation System to full operation and ensuring its long-term reliability. Some initiatives will address immediate operational deficiencies such as recent electrical malfunctions that have led to pump failures. Another sub-project may improve maintenance infrastructure and equipment, such as access roads, tunnel lighting, etc. Life/safety issues, such as exposed high voltage power lines and warning signs, must also be addressed. Finally, an ongoing repair and maintenance program must be developed and implemented to reduce the likelihood of future catastrophic system failures.

Proposal Date: 7/19/2004

PROJECT 5: Moloka'i Irrigation System Improvements.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes-High
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	HDOA/ARMD
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit	Improve the Moloka'i irrigation system
	Cost of Action	$3M
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 6: Upcountry Maui Agriculture Pipeline Extension.

Jurisdiction: Maui County

Agency/Organization: HDOA/ARMD

Project Title: Upcountry Maui Agriculture Pipeline Extension

Contact Person: Robert Lum

Phone: 808-973-1123

e-mail: robert.b.lum@hawaii.gov

Hazard(s): Drought

Flood Zone:

Base Flood Elevation:

Erosion Rate:

Critical Facility/Population/Asset at Risk:

Reduce the risk of drought to farmland, reduce treatment cost, and reduce potable water demand in Upcountry Maui.

Environmental Impact:

High Medium [✓ **Low**]

Historical Preservation Impact:

High Medium [✓ **Low**]

Risk of Hazard Impact:

High [✓ **Medium**] Low

Importance to Protection of Life and Property and Recovery fromDisaster:

[✓ **High**] Medium Low

Estimated Cost of Project: $5 to $8 Million

Project Period (duration) 3 years

Estimated Value of Structure or Facility: $20,000,000

Sources of Financial Support: NRCS, State of Hawaii

Project Objectives:

Provide affordable irrigation water to the Lower Kula Farmers and increase irrigation water availability and reliability.

Project Description:

This project proposes the installation of a separate agricultural water distribution system to supply untreated water for irrigation purposes to farmers in the Lower Kula area. The water source will be Kahakapao Reservoir. The main distribution pipeline will extend from Olinda to Keokea with nine lateral systems serving the areas of Olinda, Crater Road, Kimo Road, Pulehuiki/Kamehameiki, Kealahou, Waiakoa, Kaonoulu, Waiohuli, Keokea/DHHL.

Proposal Date:

PROJECT 6: Upcountry Maui Agriculture Pipeline Extension.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes-High
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	HDOA/ARMD
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit	Reduce: risk of drought, treatment cost, potable water demand in upcountry Maui
	Cost of Action	$5-8M
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes-minimal
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 7: Construct a new 100 – 200 MG storage reservoir.

Jurisdiction: Maui County

Agency/Organization: Department of Water Supply

Project Title: Construct new 100 – 200 MG storage reservoir

Contact Person: Larry Winter

Phone: 270-7835

e-mail: larry.winter@maui.co.hi.us

Hazard(s): Drought

Flood Zone:

Base Flood Elevation:

Erosion Rate:

Critical Facility/Population/Asset at Risk:
Upcountry water using population (about 25,000+ people)

Environmental Impact:
[✓ High] [✓ Medium] Low

Historical Preservation Impact:
[✓ High] Medium Low

Risk of Hazard Impact:
[✓ High] Medium Low

Importance to Protection of Life and Property and Recovery from Disaster:
High [✓ Medium] Low

Estimated Cost of Project: $30 to $60 Million

Project Period (duration): 10+ years

Estimated Value of Structure or Facility:

Sources of Financial Support: Federal grants/state loans/County funds

Project Objectives:

To reduce the impacts of drought on upcountry farmers and residents.

Project Description:

Construct an open lined reservoir after the intakes for the Piiholo WTP. This reservoir would be sized to minimize drought and provide continuous supply to DWS customers in times of drought. The transmission line to feed the reservoir is an existing line and the reservoir would be along that alignment. A Preliminary Engineering Study for the project is being prepared.

Proposal Date:

PROJECT 7: Construct a new 100 – 200 MG storage reservoir.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	Yes-minimal
Technical	Technical Feasibility	Yes-High
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No-grants needed
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	County of Maui Water Dept.
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	Yes
Economic	Benefit	Reduction of impact of Drought on upcountry farmers and residents.
	Cost of Action	$30-60M
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes-minimal
	Affects Endangered Species	Unk (potentially high)
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 8: Improve surface water sources in upcountry Maui.

<table>
<tr><td colspan="2">Jurisdiction: Maui County</td><td colspan="2">Agency/Organization: Department of Water Supply</td></tr>
<tr><td colspan="2" rowspan="3">Project Title: Improve surface water sources in upcountry Maui</td><td colspan="2">Contact Person: Jeff Pearson</td></tr>
<tr><td colspan="2">Phone: 270-7834</td></tr>
<tr><td colspan="2">e-mail: jeff.pearson@co.maui.hi.us</td></tr>
<tr><td colspan="4">Hazard(s): Drought</td></tr>
<tr><td>Flood Zone:</td><td colspan="2">Base Flood Elevation:</td><td>Erosion Rate:</td></tr>
<tr><td colspan="4"><i>Critical Facility/Population/Asset at Risk:</i>
Upcountry water system, resident population of 25,000+</td></tr>
<tr><td colspan="2">Environmental Impact:
[✓ High] [✓ Medium] Low</td><td colspan="2">Historical Preservation Impact:
[✓ High] Medium Low</td></tr>
<tr><td colspan="2">Risk of Hazard Impact:
[✓ High] Medium Low</td><td colspan="2">Importance to Protection of Life and Property and Recovery from Disaster:
High [✓ Medium] Low</td></tr>
<tr><td colspan="2">Estimated Cost of Project: $5 to $10 Million</td><td colspan="2">Project Period (duration): continuous</td></tr>
<tr><td colspan="4">Estimated Value of Structure or Facility:</td></tr>
<tr><td colspan="4">Sources of Financial Support: Fed. Loans/State loans/County funds</td></tr>
<tr><td colspan="4">Project Objectives:
To increase or improve source water (surface) for the upcountry system. This will increase the available water to minimize drought impacts</td></tr>
<tr><td colspan="4">Project Description:
Improve existing intakes to capture a higher percentage of surface water. This may involve adding intakes at known surface sources. The intakes must also be maintained to enable optimal operational efficiency. A preliminary project assessment will be prepared to develop project costs and specifications.</td></tr>
<tr><td colspan="4">Proposal Date:</td></tr>
</table>

PROJECT 8: Improve surface water sources in upcountry Maui.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	Yes
Administrative	Staffing	Yes
	Funding Allocated	
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	County of Maui Water Dept.
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	Yes
Economic	Benefit	Increase the water available to upcountry residents.
	Cost of Action	$5-10M
	Contributes to Economic Goals	Yes
	Outside Funding Required	
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 9: Improve surface water transmission system in upcountry Maui.

Jurisdiction: Maui County

Agency/Organization: Department of Water Supply

Project Title: Improve surface water transmission system in Upcountry Maui

Contact Person: Jeff Pearson

Phone: 270-7834

e-mail: jeff.pearson@co.maui.hi.us

Hazard(s): Drought

Flood Zone:

Base Flood Elevation:

Erosion Rate:

Critical Facility/Population/Asset at Risk:
Upcountry system and population, farming and water supply, 25,000+ population.

Environmental Impact:
[✓ High] [✓ Medium] Low

Historical Preservation Impact:
[✓ High] Medium Low

Risk of Hazard Impact:
[✓ High] Medium Low

Importance to Protection of Life and Property and Recovery from Disaster:
High [✓ Medium] Low

Estimated Cost of Project: $5,000,000 to $10,000,000

Project Period (duration): Ongoing CIP projects

Estimated Value of Structure or Facility:

Sources of Financial Support: State loans/ County loans and funds

Project Objectives:

To improve the surface water transmission system to improve the flow of water for agriculture, domestic supplies, and fire protection.

Project Description:

Systematically improve the existing surface water transmission system by replacing existing lines or installing new lines.

Proposal Date:

PROJECT 9: Improve surface water transmission system in upcountry Maui.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Yes
	Long-term Solution	Yes
	Secondary Impacts	Yes
Administrative	Staffing	Yes
	Funding Allocated	
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	County of Maui Water Dept.
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	Yes
Economic	Benefit	Increase the water available to upcountry residents.
	Cost of Action	$5-10M
	Contributes to Economic Goals	Yes
	Outside Funding Required	
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	No
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

PROJECT 10: Alternate water sources for non-agriculture irrigation on Lana'i.

Jurisdiction: Maui County (Lanai)

Agency/Organization: Castle & Cooke Resorts (Lanai Co.)

Project Title: Alternate water sources for non-agriculture irrigation on Lanai

Contact Person: Collins Lam

Phone: (808) 565-3352

e-mail: collinsl@lanai-resorts.com

Hazard(s): Drought

Flood Zone: N/A

Base Flood Elevation: N/A

Erosion Rate: N/A

Critical Facility/Population/Asset at Risk:
Manele Golf Course, Manele Project District

Environmental Impact:
High [✓ Medium] Low

Historical Preservation Impact:
High Medium [✓ Low]

Risk of Hazard Impact:
High [✓ Medium] Low

Importance to Protection of Life and Property and Recovery from Disaster:
[✓ High] Medium Low

Estimated Cost of Project: $3,000,000 to $6,000,000

Project Period (duration) 3 - 5 years

Estimated Value of Structure or Facility:

Sources of Financial Support: Private and government grants

Project Objectives:

To sustain irrigation water supply for Manele Project District as housing development increases in order to mitigate drought impacts to the irrigated landscape areas. This would reduce the demand placed on potable water supply.

Project Description:

As housing development increases at the Manele Project District, more water is required for irrigation of lawn and common areas. The Manele Project District cannot use potable water for landscape irrigation. Alternate sources will need to be evaluated in order to sustain development. Among the alternatives are desalination using reverse osmosis units and electrodialysis (EDR). A feasibility study is required to determine the most logical technology to select.

Proposal Date: July 2004

PROJECT 10: Alternate water sources for non-agriculture irrigation on Lana'i.

Evaluation Category	Considerations	Comments
Social	Community Acceptance	Yes
	Adversely Affects Segments of the Population	No
Technical	Technical Feasibility	Unk
	Long-term Solution	Yes
	Secondary Impacts	
Administrative	Staffing	Yes
	Funding Allocated	No
	Maintenance/Operations	Yes
Political	Political Support	Yes
	Plan Proponent	Castle & Cook Resorts
	Public Support	Yes
Legal	Authority	Yes
	Action Subject to Legal Challenge	No
Economic	Benefit	Reduce the demand placed on potable water supply.
	Cost of Action	$3-6M
	Contributes to Economic Goals	Yes
	Outside Funding Required	Yes
Environmental	Affects Land/Water Bodies	Yes
	Affects Endangered Species	Unk
	Affects Hazardous Materials and Waste Sites	No
	Consistent w/Community Environmental Goals	Yes
	Consistent w/Federal Laws	Yes

Projects under consideration

1. The relocation or renovation of the Civil Defense Agency Emergency Operating Center.
2. Upgrade, retrofit and harden schools as hurricane shelters. Haiku Elementary, Paia Elementary and Kula Elementary should be considered first. Kula Elementary is considering implementing retrofit and hardening measures in the school's scheduled maintenance upgrade program.
3. Survey and assess the possible use of other County and State government, business, and hotel and private facilities as hurricane shelters.
4. Identify and prioritize essential government facilities and operations that require hardening or retrofitting against hurricane.
5. Assess the feasibility of retrofitting and hardening County of Maui Community Centers for hurricane shelters.
6. Harden various Maui County Police Department communications sites.
7. Develop and maintain hazard mitigation principles and ideas in the Geographical Information System (GIS). GIS can provide a basis for the hazard, risk and vulnerability assessments that should improve the data and information used to determine and decide hazard mitigation concepts, principles and measures
8. Survey and assess essential government facilities, operations and resources in tsunami evacuation zones.

During the next iteration of the Multi-hazard Mitigation Plan the above projects will be further developed indicating such items as are noted in the evaluation form. They will also include a cost-benefit analysis.

Project Description	Hazards	Lead Agency	Funding Source	Priority
Relocation or renovation of the Civil Defense Agency Emergency Operations Room.	All Hazards	Maui County Civil Defense Agency	FEMA & County	HIGH
Upgrade, retrofit and harden schools as shelters. Haiku, Paia and Kula Elementary should be considered first. Kula Elementary is considering implementing retrofit and hardening measures in the school's scheduled maintenance upgrade program.	Hurricane, Earthquake	Maui County	FEMA, State County	HIGH
Survey and assess the possible use of other County and State government, business, and hotel and private facilities as hurricane shelters.	Hurricane	Maui County Civil Defense Agency	State & County	HIGH
Identify and prioritize essential government facilities and operations that require hardening or retrofitting against hurricanes.	Hurricane Earthquake	Maui County Civil Defense Agency	County	HIGH

Assess the feasibility of retrofitting and hardening County of Maui Community Centers for hurricane shelters.	Hurricane Earthquake	Maui County Civil Defense Agency	County	HIGH
Harden various Maui County Police Department Communications sites. Develop and maintain hazard mitigation principles and ideas in the Geographical Information System (GIS). GIS can provide a basis for the hazard, risk and vulnerability assessments that should improve the data and information used to determine and decide hazard mitigation concepts, principles and measures.	All Hazards All Hazards	Maui County Dept of Public Safety Maui County Department of Planning	FEMA & County State & County	HIGH HIGH
Survey and assess essential government facilities, operations and resources in tsunami evacuation zones.	Tsunami	Maui County Civil Defense Agency	State & County	HIGH
Improve vehicular access in mauka Kalamaula-Makakupaia (2 Miles) and Kula forest (1 mile) Conservation Management.	Wildland fire risk	DOFAW, MFD, The Nature Conservancy	Various	HIGH
Create an educated and informed public concerning Maui County fire risk and personal responsibilities to reduce such risk.	Wildland fire risk	MFD, DOFAW	MFD, DOFAW	MED
Develop new water storage facilities and reservoirs for wildland fire suppression activities.	Wildland fire risk	DOFAW, DHHL, Ulupalakua Ranch	Maui County, OHA, grants, Tri-Isle RC&D	High
Improve the Molokai Irrigation System with respect to emergency, life/safety, reliability, and maintenance issues.	Wildland fire risk, & drought	HDOA/ARMD	State of Hawaii	HIGH
Provide affordable irrigation water to the lower Kula farmers and increase irrigation water availability and reliability.	Drought	HDOA/ARMD	NRCS, State of Hawaii	HIGH
Construct an open lined reservoir after the intakes for the Piiholo WTP. This would be a 100 - 200 MG storage reservoir.	Drought	Dept. of Water	Federal grants, State loans, County funds	MED
Improve existing intakes to capture a higher percentage of surface water.	Drought	Dept. of Water	Federal grants, State loans, County funds	MED
Systematically improve the existing surface water transmission system by replacing existing lines or installing new lines.	Drought	Dept. of Water	Federal grants, State loans, County funds	MED
Sustain irrigation water supply for Manele Project District as housing development increases.	Drought	Castle & Cooke Resorts on Lanai	Private and Government grants	MED
Harden a yet-to-be-built facilities that will be used as a church, private school, community center, pre-school, youth recreation center, and an emergency shelter.	Hurricane Earthquake	Maui County	Private and FEMA	MED

Evaluation, ranking, and approval of future mitigation projects

The County of Maui Civil Defense Agency will establish a special committee to evaluate, screen, and prioritize eligible hazard mitigation projects submitted by County government agencies and private nonprofit agencies. The County committee will use a scoring system that emphasizes projects that addresses repetitive losses, high risk to public safety, cost-effective, State and local priorities, and environmentally and technically sound. Committee members will be selected from the following organizations: (Note: The Administrator of the County Civil Defense Agency will act as chair of the committee)

Fire Department
Police Department
Office of the Mayor
Data Systems Management
Department of Environmental Management
Department of Planning
Department of Public Works
Department of Research and Development
Department of Water Supply

According to State mitigation priorities all of the four counties will receive equal priority for the following natural hazards because all jurisdictions are vulnerable: hurricane and high winds, floods, drought, wildland fire, landslides, coastal erosion, and tsunamis. Priorities (in order) for earthquake projects are: (1) County of Hawaii; (2) County of Maui; (3) City and County of Honolulu; and (4) County of Kauai.

The County & State will use FEMA's cost-benefit models to include HAZUS-MH. Also, EPA standards and State Historical Preservation Guidelines will supplement the cost-effectiveness review of each project. State Civil Defense will train appropriate county personnel in the cost-benefit models. The State Mitigation Forum will also be developing a program to better assess potential losses especially with wind events. This will involve wind speed maps for all counties and a customized hurricane simulation model with geo-coded building inventory, user-defined damage functions, and other variables into a GIS-based hurricane loss estimation software package.

All mitigation projects must also meet all appropriate Federal, State, and county laws and regulations.

The Committee will score and rank each project. These recommendations will be forwarded to the Mayor for final selection of projects.

The State Civil Defense Mitigation staff will provide technical assistance to the applicants in the preparation of the applications, cost-benefit analysis to include training, acquisition of environmental data.

The following are the County priorities regarding hazard mitigation projects:

1. Hardening and Retrofitting of Critical Facilities

   Facilities include emergency shelters, fire stations, police stations, hospitals, sewage treatment plants, water systems, communications sites, power plants, schools, harbors, airports, key transportation nodes, and other facilities/buildings providing critical services.

2. Flood Control

   Flood proofing of critical facilities and improvement of drainage systems

3. Mapping/Assessments/Studies

   Re-mapping of existing flood prone areas and mapping of unmapped areas.
   Analysis of high hazard areas and studies to develop mitigation measures
   Enhancement of GIS Capability (Hardware, Software, and Personnel)

   Mapping of All Major Natural Hazards

4. Public Awareness/Education

5. Upgrading of Warning Systems

6. Buy-Out/Acquisition/Relocation Program

7. Safe Room/Homeowners Retrofit Grant Programs

8. Prevention of Coastal Erosion

9. Prevention of Land/Rock Slides in Residential Areas and Highway Corridors

Chapter VII Implementation of Mitigation Measures

As in all aspects of emergency management, the hazard mitigation program will require planning, Collaboration and coordination among various organizations and departments. The successes of each action or project will require commitment and cooperation from all participating entities involved in hazard mitigation. Initially, The Civil Defense Agency will be the overall coordinator for the implementation of Mitigation's Actions and Projects.

A Local Hazard Mitigation Committee will need to be established to assist with the implementation and management of the hazard mitigation program. This committee will consist of representatives from all levels of government and the private sector. Selection of representatives and formulation of committee by-laws will need to be developed as the hazard mitigation program progresses and expands. In general terms, the committee will need to involve the public in the planning process, coordination with other agencies, assessing hazards and their vulnerabilities, setting goals and objectives, adopting new initiatives, implementing actions and revising or updating the strategy. The committee will need to seriously consider intergrating hazard mitigation planning and implantation actions into existing County of Maui programs and planning efforts.

The County of Maui will seek assistance from various Federal, State and local agencies involved in the planning and implementation of hazard mitigation concepts. Maui Civil Defense Agency will continue to work closely with the other County Civil Defense Agencies and the Hawaii State Hazard Mitigation Forum. The Hawaii State Hazard Mitigation Forum seeks to provide a unified and coordinated management platform for hazard mitigation and provides assistance to the various agencies and organizations.

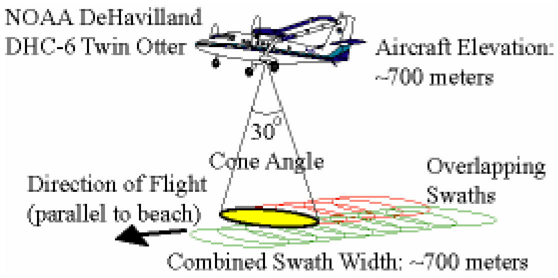
Chapter VIII Plan Maintenance Procedures

The Multi-Hazard Mitigation Plan was developed as a “living” document and will be updated and revised as new information becomes available. FEMA requires the plan to be continuously monitored and evaluated and that it is updated at least once every five years. It is the goal to review it on an annual basis and update and revise it as new information becomes available. Updates may be implemented throughout the year because of some of the following issues:

- Ongoing mitigation actions within the County of Maui.
- Development of new mitigation recommendations.
- Updates on the benefit-cost performance of current mitigation options.
- Changes necessary because of Federal, State, or County legislative acts, appropriations, mandates and recommendations.
- The integration of Homeland Security threats and issues.
- Public involvement in mitigation and other existing planning activities.
- Scientific and other technical data update recommendations based on new data, analysis, or scientific and Geographic Information System modeling capabilities.
- Events or new information on environmental conditions that indicate new mitigation needs or requirements.
- Identification and analysis of county structures with emphasis on critical facilities in the various hazard areas. Analysis will include estimation of dollar losses. The county intends to use the methodologies developed by the State Hazard Mitigation Forum.
- Analyze vulnerability of residential buildings in the various hazard areas.
- Incorporate hazard analysis in the county’s general plan process to evaluate the impact on land use, zoning, etc., issues.

Both the State of Hawaii and the County of Maui are using the State Hazard Mitigation Forum and hazard mitigation planning processes to improve the hazard-related Geographic Information System (GIS). User groups using GIS and additional networks have been developed to evaluate and update their databases. These efforts will improve the risk and vulnerability assessment of future hazards. The County of Maui is developing a GIS system that is expected to become an integral part in updating and maintaining the Multi-Hazard Mitigation Plan.

The Hawaii Statewide Hazard Mitigation Forum and the Multi-Hazard Scientific Advisory Council have currently advised the counties to assemble the best available data for this first strategy. Several programs exist across the state to gather and prepare data and information. For example, a working group has been looking at **L**ight **D**etection **A**nd **R**anging (LIDAR) to improve the Flood Insurance Rate Maps (FIRM) through the new FEMA Map Modernization Program. LIDAR is a rapidly



emerging technology for determining the shape of the ground surface plus natural and man-made features. It has also been used by the U.S. Army Corp of Engineers **S**canning **H**ydrographic **O**perational **A**irborne **L**idar **S**ystem (SHOALS) for coastal zone mapping in Hawaii. The FIRMs are currently the best available flood hazard maps, but all the counties recognize the need to improve this information. Systems such as LIDAR could help achieve that goal.

Monitoring, Evaluating, and Updating the Plan

The County will establish a Hazard Mitigation Committee that will initially be responsible for monitoring, evaluating and providing input for updating the plan. The actual plan update will reside with the Maui County Civil Defense Agency. The committee will include representatives from each County agency or department having hazard mitigation responsibilities. The committee will meet on a quarterly basis to evaluate the effectiveness of the planning process. The agency or department representatives will be required to prepare quarterly reports to be discussed during these meetings. These reports will include worksheets ("Evaluate Your Project Results Worksheet") that will help the committee determine how well the project met the objectives it was designed to achieve. This enhanced communication will enable the various agencies and departments to gain a comprehensive view of the County's hazard mitigation activities and a better understanding of the interrelationship of their actions. This is also a good opportunity to reflect on whether certain relationships developed during the process should be enhanced and to initiate new partnerships based on experiences from developing and implementing the plan. The quarterly reports will enable the Hazard Mitigation Committee to prepare an annual report which will serve as an evaluation tool measuring how effective the planning process and recommendations were and the progress that has been made toward achieving the objectives of the plan as a whole.

The public was initially involved, through Project Impact, to develop the hazard/risk analysis section of the plan. It is anticipated that, once the County's Hazard Mitigation Committee has had an opportunity to develop and become viable, the next step will be to involve the public. Seeking comment, specifically from non-profit organizations, community planning groups and various community organizations, will be important to maintaining communication and development of a network for future planning efforts. To that end, either a new committee will be organized to effectively obtain the input from the public and engage them in the mitigation process, or they will be asked to join the existing committee. The exact timing and methodology will be determined at a future date.

The revision of the plan, if needed, will take place on a five year cycle. The results of the Committee's observations and evaluations will be re-programmed back into each of the planning process which will tell them how (or whether) they should revise each section of the plan.

The Hazard Mitigation Committee will revisit the risk assessment to incorporate updated estimates of cost of living and replacement costs, new data on hazard areas, the effect of hazards on the community, changes in growth patterns and reductions in vulnerability due to completion of projects. The worksheet “Revisit Your Risk Assessment” will be used to complete this process. The Hazard Mitigation Committee, along with community involvement, will also revisit the goals, objectives and actions to determine what, if any, should be changed. The results will determine what actions should be undertaken, reconsidered, or eliminated to further the plan’s goals.

The revised plan will include an up-dated description of the planning process to include the steps taken to revise the plan document and how the community was involved. The implementation strategy will also be up-dated to identify who will be responsible for the new or revised actions, the time frame, and the funding sources.

Maui County Executive Order

The Executive Order (EO) to establish Maui County as a Disaster Resilient Community provides a framework for implementation of the policies and actions identified in this document. The inclusion of government agencies and the private sector in the committee enables hazard mitigation policies to be supported at all levels in the County.

The EO supports the hazard mitigation planning process outlined throughout this document, including periodic updates. Even though the communities in the County were consulted during the risk and vulnerability assessment and mitigation planning process, they have not developed mitigation plans for each community. The EO will provide assistance for communities to further engage in mitigation planning.

The EO encourages the continued development of partnerships. Project Impact initiated a process for partnerships to mitigate impacts from natural hazards. Project Impact demonstrated that partnerships help to maximize limited resources and build awareness throughout all sectors of the community. Although Project Impact has ended, the EO establishes a process that enables the sustainability of these partnerships.

The EO supports enforcement and improvement of building codes and standards and the promotion of hazard considerations in land use decisions. These address hazards that cause the greatest risks to Maui County.

The EO supports the maintenance of all emergency response, recovery, and mitigation plans. This includes technical assistance in communities to develop local plans.

ACRONYMS

AMBER	Areal Mean Basin Estimated Rainfall
CRS	Community Rating System
CWRM	Hawaii State Commission on Water Resource Management
DLNR	Depart of Land & Natural Resources
DOFAW	Division of Forestry & Wildlife Management
FEMA	Federal Emergency Management Agency
FFG	Flash Flood Guidance
FIRMS	Flood Insurance Rate Maps
FIS	Flood Insurance Studies
FMAP	Flood Mitigation Assistance Program
GIS	Geographic Information System
HAZUS	Hazards U.S.
HLEM	Hurricane Loss Estimation Model
HMPG	Hazard Mitigation Grant Program
HMS	Multi-Hazard Mitigation Strategy
HUD	Housing and Urban Development
LHMC	Local Hazard Mitigation Committee
LIDAR	Light Detection And Ranging
MECO	Maui Electric Company
MSAC	Multi-Hazard Science Advisory Committee
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
RACES	Radio Amateur Civil Emergency Services
RVA	Hazard Risk and Vulnerability Assessment
SFHA	Special Flood Hazard Area
SHOALS	Scanning Hydrographic Operational Airborne Lidar System
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOAD	Voluntary Organizations Active in Disasters

GLOSSARY

Accretion - the deposition of sediment, sometimes indicated by the seaward advance of a shoreline indicator such as the water line, the berm crest, or the vegetation line.

Active beach - the portion of the littoral system that is frequently (daily or at least seasonally) subject to transport by wind, waves, and currents.

Algal bloom - a sudden increase in the amount of marine algae (seaweed) often caused by high levels of phosphates, nitrates, and other nutrients in the near shore area.

Armoring - the placement of fixed engineering structures, typically rock or concrete, on or along the shoreline to reduce coastal erosion. Armoring structures include seawalls, revetments, bulkheads, and rip rap (loose boulders).

Backshore - the generally dry portion of the beach between the berm crest and the vegetation line that is submerged only during very high sea levels and eroded only during moderate to strong wave events.

Beach - an accumulation of loose sediment (usually sand or gravel) along the coast.

Beach loss - a volumetric loss of sand from the active beach.

Beach management district - a special designation for a group of neighboring coastal properties that is established to facilitate cost sharing and streamline the permitting requirements for beach restoration projects.

Beach narrowing - a decrease in the useable beach width caused by erosion.

Beach nourishment - the technique of placing sand fill along the shoreline to widen the beach.

Beach profile - a cross-sectional plot of a shore-normal topographic and geomorphic beach survey, usually in comparison to other survey dates to illustrate seasonal and longer-term changes in beach volume.

Berm - a geomorphological feature usually located at mid-beach and characterized by a sharp break in slope, separating the flatter backshore from the seaward-sloping foreshore.

Building setback - the county required seaward limit of major construction for a coastal property. Building setbacks on Maui vary from 25 feet to 150 feet landward of the certified shoreline.

Coastal dunes - dunes within the coastal upland, immediately landward of the active beach.

Coastal erosion - the wearing away of coastal lands, usually by wave attack, tidal or littoral currents, or wind. Coastal erosion is synonymous with shoreline (vegetation line) retreat.

Coastal plain - the low-lying, gently-sloping area landward of the beach often containing fossil sands deposited during previously higher sea levels.

Coastal upland - the low-lying area landward of the beach that often contains unconsolidated sediments. The coastal upland is bounded by the hinterland (the higher-elevation areas dominated by bedrock and steeper slopes).

Day-use mooring - a buoy, or other device, that boats can be secured to without anchoring.

Deflation - a lowering of the beach profile.

Downdrift - in the direction of net longshore sediment transport.

Dune - a landform characterized by an accumulation of wind-blown sand, often vegetated.

Dune restoration - the technique of rebuilding an eroded or degraded dune through one or more various methods (sand fill, drift fencing, re-vegetation, etc.).

Dune walkover - light construction that provides pedestrian access without trampling dune vegetation.

Dynamic equilibrium - a system in flux, but with influxes equal to out-fluxes.

Erosion - the loss of sediment, sometimes indicated by the landward retreat of a shoreline indicator such as the water line, the berm crest, or the vegetation line.

Erosion hotspots - areas where coastal erosion has threatened shoreline development or infrastructure. Typically, the shoreline has been armored and the beach has narrowed considerably or been lost.

Erosion watchspots - areas where the coastal environment will soon be threatened if shoreline erosion trends continue.

Foreshore - the seaward sloping portion of the beach within the normal range of tides.

Hardening - see Armoring.

Inundation – the horizontal distance traveled inland by a tsunami.

Improvement districts - a component of a beach management district established to help facilitate neighborhood-scale improvement projects (e.g., beach nourishment).

Land banking - the purchase of shoreline properties by a government, presumably to reduce development pressure or to preserve the parcel as a park or as open space.

Littoral budget - the sediment budget of the beach consisting of sources and sinks.

Littoral system - the geographical system subject to frequent or infrequent beach processes. The littoral system is the area from the landward edge of the coastal upland to the seaward edge of the near-shore zone.

Longshore transport - sediment transport down the beach (parallel to the shoreline) caused by longshore currents and/or waves approaching obliquely to the shoreline.

Lost beaches - a subset of erosion hotspots. Lost beaches lack a recreational beach, and lateral shoreline access is very difficult if not impossible.

Monitoring - periodic collection of data to study changes in an environment over time.

Nutrient loading - the input of fertilizing chemicals to the near shore marine environment, usually via non-point source runoff and sewage effluent. Nutrient loading often leads to algal blooms.

Offshore - the portion of the littoral system that is always submerged.

Overwash - transport of sediment landward of the active beach by coastal flooding during a tsunami, hurricane, or other event with extreme waves.

Revetment - a sloping type of shoreline armoring often constructed from large, interlocking boulders. Revetments tend to have a rougher (less reflective) surface than seawalls.

Risk - refers to the predicted impact that a hazard would have on people, services, specific facilities and structures in the community.

Risk management - the process by which the results of an assessment are integrated with political, economic, and engineering information to establish programs, projects and policies for reducing future losses and dealing with the damage after it occurs.

Run-up - A vertical measure of a tsunami's wave height or amplitude in a low-lying coastal area relative to mean sea level. Run-up is often determined by the height of seaweed or other debris in trees.

Scarp - a steep slope, usually along the foreshore and/or at the vegetation line, formed by wave attack.

Scarping - the erosion of a dune or berm by wave-attack during a storm or a large swell.

Sea bags - large sand-filled geotextile tubes used in coastal protection projects.

Seawall - a vertical or near-vertical type of shoreline armoring characterized by a smooth surface.

Shoreline setback - see **Building setback**.

Siltation - the input of non-calcareous fine-grained sediments to the near-shore marine environment, or the settling out of fine-grained sediments on the seafloor.

Storm surge - a temporary rise in sea level associated with a storm's low barometric pressure and onshore winds.

Tsunami – A series of ocean waves that can produce an unusual increase in sea level that floods, or inundates, low-lying coastal areas.

Urban runoff - the input of hydrocarbons, heavy metals, pesticides, and other chemicals to the near-shore marine environment from densely populated areas.

Vulnerability - the characteristics of the society or environment affected by the event that resulted in the costs from damages.

Vulnerability assessment - the qualitative or quantitative examination of the exposure of some component of society, economy or the environment to natural hazards.

REFERENCES

BRUUN, P., 1962. Sea level rise as a cause of shore erosion. *Journal of Waterways & Harbors Division, ASCE,* 88: 117-130.

CAMPBELL, J.F., ROSENDAHL, B.R., COULBOURN, W.T., AND MOBERLY, R.M., 1971. *Reconnaissance Sand Inventory: Off Leeward Molokai and Maui.* HIG-71-17. Hawaii Institute of Geophysics, University of Hawaii-Manoa.

Clarke, C.L. and M. Munasinghe, 1995, "Economic aspects of disasters and sustainable development: an introduction." Pp 1-10 in Munasinghe, M. and C. Clarke, Eds., 1995, Disaster Prevention for Sustainable Development: Economic and Policy Issues; A report from the Yokohama World Conference on Natural Disaster Reduction, May 1994; Washington, D.C.: The World Bank.

COEMAP (1999) *The Coastal Erosion Management Plan*, Department of Land and Natural Resources, Honolulu, Hawaii.

COX, DOAK C. and JOSPEH MORGAN, 1977. *Local Tsunamis and Possible Local Tsunamis in Hawaii.* 118 p. National Science Foundation

Department of the Army, Pacific Ocean Division, Corp of Engineers and State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development. *Flood Hazard Information, Island of Maui.*

DEPARTMENT OF LAND AND NATURAL RESOURCES, 1983. *General Flood Control Plan for Hawaii*, 168 p. Division of Water and Land Development, Honolulu, HI.

Drainage Master Plan for Maui County, State of Hawaii; R. M. Towill Corporation, October 1971.

Drainage Master Plan for Kaunakakai, Moloka'i, Hawaii; Wilson Okamoto & Associates, August 1992.

DUXBURY, A.B. AND DUXBURY, A.C., 1996. *Fundamentals of Oceanography.* P. 308.

DUDLEY, W.C. and LEE, M. *Tsunami!* Honolulu: University of Hawaii Press, p.362.

Elliot, W.P., and R.K. Reed, 1984: A climatological estimate of precipitation for the world ocean. *J. Climate Appl. Meteor., 434-439.*

FLETCHER, C.H., MULLANE, R.A., AND RICHMOND, B.R., 1997. *Beach loss along armored shorelines on Oahu, Hawaiian Islands*. Journal of Coastal Research, 13, 1, 209-215.

Flood Insurance Study, Maui County, Hawaii. Federal Emergency Management Agency, Community Number – 150003, Revised: March 16, 1995.

Hamnett, Mike Professor. University of Hawaii, Director, Social Science Research Institute, Proteus Hall, Room 719, University of Hawaii, Honolulu, Hawaii 96822, USA.

HARAGUCHI, PAUL, 1980. *Storm of January 8 – 10, 1980: State of Hawaii.* Department of Land and Natural Resources, Division of Water and Land Development, Honolulu, HI, 33p.

Heintz Coastal Hazards Panel Report, 1999, p. 110. “The Hidden Costs of Coastal Hazards.”

HWANG, D.J. AND FLETCHER, C.H., 1992. *Beach Management Plan with Beach Management Districts.* Hawaii Office of State Planning, Coastal Zone Management Program, Honolulu, 192 p.

II, J.P., 1959. Fragments of Hawaiian History. M.K. Pukui, transl. D.B. Barrere, ed.; Bishop Mus. Press, 183 pp., Honolulu. (Orig. publ. In Hawaiian Newspaper, Kuokua, 1866-1870).

IIPLR. The Insurance Institute for Property Loss Reduction. http://www.ibhs.org/about/history.asp.

JOHNSTONE, H.W., 1997. *Mo'omomi, West Moloka'i: a Coastal Treasure.* University of Hawai'i at Manoa, Sea Grant Extension Service, Honolulu, 56 p.

Kapa’akea Homestead, Moloka’i, Hawaii, Detailed Project Report for Flood Control. U.S. Army Engineer District, Honolulu, December 1976.

KODAMA, KEVIN R. and BUSINGER, STEVEN, 1998. *Weather Forecasting Challenges in the Pacific Region of the National Weather Service.* American Meteorological Society,

LUDLUM, DAVID M., 1982. *The American Weather Book*, Boston, MA Houghton Mifflin Company, 1982, 57p.

MAKAI OCEAN ENGINEERING, INC. AND SEA ENGINEERING, INC., 1991. *Aerial Photograph Analysis of Coastal Erosion on the Islands of Kaua'i, Moloka'i, Lana'i, Maui, and Hawai'i.* Hawaii Office of State Planning, Coastal Zone Management Program, Honolulu, 199 p.

NATIONAL RESEARCH COUNCIL, 1995. *Beach Nourishment and Protection.* Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, Washington, DC, 334 p.

Pacific Tsunami Museum. P.O. Box 806, Hilo, HI 96721**.** tsunami@tsunami.org

R.M. TOWILL CORPORATION, August 1992. *Maui Pubic Facilities Assessment* (Final Report) Prepared for the County of Maui Planning Department.

TAIT, J.F., AND GRIGGS, G.B., 1990. Beach response to the presence of a seawall. *Shore and Beach,* 58, 11-28.

SEA ENGINEERING, INC., 1993. *Beach Nourishment Viability Study.* Hawaii Office of State Planning, Coastal Zone Management Program, Honolulu, 95 p.

SCHROEDER, Tom, December, 1993. "Hawaii Hurricanes: Their History, Causes, and the Future." *In Hawaii Coastal Hazard Planning Project*. Office of State Planning.

WEST MAUI WATERSHED MANAGEMENT ADVISORY COMMITTEE, 1997 *West Maui Watershed Owners Manual.* 92 p.
Yanagi, Brian. Earthquake - Tsunami - Volcano Program Manager, Hawaii State Civil Defense.

Maui County Hazard Mitigation Committee Bylaws

Purpose

1. Continue to support, implement and revise the Maui Multi-hazard Mitigation Strategy and to provide the support necessary for an ongoing forum for the education and awareness of multi-hazard mitigation issues, program, policies and projects

2. Assist in the provision of workshops, trainings and forums for County Government and Stakeholders that will provide information, data, and skills as needed to assist in the implementation of the Maui County Hazard Mitigation Strategy.

3. Identify and establish close coordination with county agencies responsible for implementing the sound practices of hazard mitigation through building standards and local land use development decisions and practices.

4. Establish and support partnerships between the County and private sector, local communities and non-profit organizations in order to coordinate and collaborate natural hazard mitigation programs;

5. Assist county government in obtaining funds to implement mitigation projects.

6. Develop specific goals on a biennial basis and provide status reports to the Mayor and County Council, County departments, private organizations represented on this "group."

7. Recommend policy and program changes to the County Administration, including County Council and County involved in mitigation activities.

8. Assist in the development of an on-going comprehensive public education and awareness program about the risks and losses from natural disasters, in addition to natural hazard mitigation programs, policies and projects.

9. Provide reports, as appropriate, to the Mayor and County Council on special mitigation activities addressed or completed by this "group."

10. Foster partnerships between the County and private sector, local communities and non-profit organizations in order to coordinate and collaborate natural hazard mitigation programs

Definitions

For the purpose of these Bylaws, the following definitions are derived from statutory documents, which have been accepted as functional by all levels of government involved in emergency management activities or operations:

a. **Hazard Mitigation:** Any action taken to reduce or permanently eliminate the long-term risk to human life and property loss or damage from natural hazards.

b. **Hazard Mitigation Grant Program (HMGP):** An ongoing program involving a coordinated effort of State and county agencies and private organizations to reduce risks to people and property from natural hazards. During and after periods of Presidential declared disasters, the Stafford Act makes available Federal funds up to 15 percent of the estimated aggregate amount of grants for emergencies and permanent repairs with respect to a federally declared disaster. The Federal government may contribute up to 75 percent of any cost-effective measure to be implemented while State and county governments and private nonprofit organizations must contribute the remaining 25 percent in this cost-sharing relationship.

c. **Major Disaster:** Any natural catastrophe (including hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mud slide, flood, or drought), or, regardless of cause, any fire or explosion which, in the determination of the President, causes damage of sufficient severity and magnitude to warrant major disaster assistance under the Stafford Act to supplement the efforts and available resources of State and county governments and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby.

d. **Measure/Project:** Any activity proposed to reduce risk of future damage, hardship, loss, or suffering from major disasters. The terms (measure and project) are used interchangeably in Federal regulations.

e. **Stafford Act:** Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, signed into law on November 23, 1988, amended the Disaster Relief Act of 1974, PL 93-288.

f. **State Hazard Mitigation Office**: The office designated by the Governor to coordinate and monitor all State hazard mitigation programs. For the State of Hawaii, this responsibility has been placed in the State Civil Defense Division of the Department of Defense.

Membership

County Government

- Civil Defense
- Administration (Mayor's Office)
- Planning and Zoning
- Department of Public Works (roads and facilities)
- Building Code
- GIS Specialist
- Police and/or Fire
- Project Impact
- Human Services (Housing)
- NFIP/CRS Coordinator
- Lanai Representative(s)
- Molokai Representative(s)
- Parks & Recreation

State/Federal Government

- Hawaii Civil Defense
- Earthquake Advisory Board
- FEMA Pacific Area Office
- Hawaii CZM
- Army Corps of Engineers

Private Sector

- Pacific Disaster Center
- Maui Hotel and Resort Association
- Chamber of Commerce
- Maui Electric Company
- Red Cross
- Convention & Visitors Bureau
- Environmental Organization
- Builders

NGOs

- Community/neighborhood Associations
- University of Hawaii, Social Sciences Research Institute

- Hawaii Sea Grant

Officers

The Maui County Hazard Mitigation Committee shall elect a Chairperson and Vice Chairperson from among its members.

1. The duties of the Chairperson shall be:

   a. Preside at all meetings of the Maui County Hazard Mitigation Committee;

   b. Call for approval of the minutes of the preceding meeting when a quorum Shall be present;

   c. Announce the business before the Maui County Hazard Mitigation Committee;

   d. Receive and submit all matters properly brought before the Maui County Hazard Mitigation Committee to call for votes upon the same, and to announce the results;

   e. Appoint members to all committees, subject to appeal by a majority of Maui County Hazard Mitigation Committee members;

   f. Authenticate, by signature, all acts of the Maui County Hazard Mitigation Committee as may be required;

   g. Make known all rules of orders when so requested and to decide all questions of order, subject to appeal to the Maui County Hazard Mitigation Committee;

   h. Act as spokesperson for the Maui County Hazard Mitigation Committee;

   i. Perform other duties as may be required of such office.

2. The duties of the Vice Chairperson shall be:

   a. Act as the presiding officer in the absence or disability of the Chairperson;

   b. Perform any special duties assigned by the Chairperson;

   c. In case of resignation or incapacitation of the Chairperson, the Vice Chairperson shall become Chairperson for the unexpired part of the term.

3. The duties of the Fulltime Hazard Mitigation Person shall be:

a. Keep accurate and current records of each meeting of the Maui County Hazard Mitigation Committee noting all actions taken, whether carried or lost;

b. Call the meeting to order in the absence of the Chairperson and Vice Chairperson and proceed with the election of a temporary Chairperson;

c. Prepare and disseminate correspondence as directed;

d. Send out all notices of meetings;

e. Keep an account of receipts and expenditures.

Meetings

1. Two-thirds of the entire Maui County Hazard Mitigation Committee membership shall constitute a quorum.

2. The affirmative vote of the majority of the entire Maui County Hazard Mitigation Committee membership shall be necessary to take any action. Proxy votes shall not be allowed.

3. Regular meetings of the Forum shall be held three times per year. The Maui County Hazard Mitigation Committee may also convene special meetings at any other times deemed appropriate.

4. Special meetings may be called by the officers of the Maui County Hazard Mitigation Committee.

5. Any Maui County Hazard Mitigation Committee member may request a matter be placed on the agenda by notifying the Fulltime Hazard Mitigation Person 15 days before the date of a meeting.

6. The Maui County Hazard Mitigation Committee requests prior notification of dissenting opinions when such opinions are made public. The Maui County Hazard Mitigation Committee shall not prohibit the expression of dissenting opinions.

7. The Maui County Hazard Mitigation Committee shall be notified of any solicitation of outside party review of Maui County Hazard Mitigation Committee work. The reviewer shall be notified.

8. Minutes of all meetings will be prepared by the Fulltime Hazard Mitigation Person and disseminated to all members prior to the next scheduled meeting.

Committees

1. The Maui County Hazard Mitigation Committee should utilize the work of established committees, boards, councils, etc., which are involved in mitigation affairs such as Maui Project Impact, and Project Impact Subcommittees including the Public Education and Building Standards Committees, to facilitate its own actions and to maximize available resources and expertise.

2. The Forum may establish special committees whose members are appointed by the Chairman.

Petition for Adoption, Amendment, or Repeal of Bylaws

1. Any Maui County Hazard Mitigation Committee member may petition the Maui County Hazard Mitigation Committee requesting adoption of amendment or repeal of any articles of the Bylaws. No action will be taken until the subsequent meeting of the "group."

2. Bylaws may be adopted, amended, or repealed by the vote in person of two-thirds of the membership of the "group."

Parliamentary Authority

1. Robert's Rules of Order, revised, shall govern the Maui County Hazard Mitigation Committee where the same are not inconsistent with these Bylaws.

Validity

1. If any section or part of the rules is held to be invalid for any reasons whatsoever, such invalidity shall not affect the validity of the remaining sections of the Bylaws.

Effective Date of These Rules

1. These Bylaws shall become effective upon approval of the Director of Civil Defense and filing with the State Civil Defense Division.

INVENTORY OF FLOOD INSURANCE RATE MAP (FIRM) REVISIONS, LETTERS OF MAP REVISIONS (LOMR'S), APPLICATIONS FOR LOMR'S OR CONDITIONAL LETTERS OF MAP REVISIONS (CLOMR'S), FOR THE COUNTY OF MAUI, COMMUNITY NO. 150003

Effective Date	Panel No.	Project Description
9-6-89	0040 C,0045 C, 0050 C,0080 C, 0085 C,0190 C, 0265 C	Entire Panel Changed
9-11-89	0265 C	Haleakala Gardens and Haleakala Village Subdivision
4-10-91	0190 C	Vicinity of Kahului Bay
12-6-91	0161 B, 0163 B	Vicinity of Kahoma Stream
3-11-92	0265 C	Southpointe at Waiakoa
4-3-92	0255 B	Vicinity of the Kihei coastline
6-3-92	0265 C	Lots J-1, J-2, and J-3, Waiakoa-Makai Homesteads
7-13-92	0265 C	Buildings A, B, C, D, E, F, G, H, I, J, K, and 8, Southpointe of Waiakoa Phase I
11-4-92	0265 C	Lot J-3, Southpointe at Waiakoa, Phase III
1-22-93	0265 C at Waiakoa, III	Building 31, Lot J-3, Southpointe
11-22-93	0190 C	Vicinity of Kahului Harbor
8-9-94 (A)	0330 B	Makena Surf Subd. III
8-22-94	0190 C	Vicinity of Kahului Beach Road
12-1-94	0190 C	2049 Kolo Place, Wailuku
1-3-95	0265 C	Meadowlands Subdivision, Phases I & II-CLOMR
3-16-95	0185 C, 0190 D 0195 C	Wailuku to Paia (ENTIRE PANEL REVISED)
6-30-95 (A)	0265 C	Welakahao Village, LUCA #3.1592
8-17-95	0151 B	Kahana-Kai Subdivision
3-8-96	0265 C	Kenolio Place Subd.-Lot 1, 105 Pauloa Place
3-21-96 (A)	0265C	Royal Kiawe Plaza-CLOMR
6-5-96	0153 B	Kai Ala Subdivision, LUCA NO. 4.685
6-6-96	0151 B & 153 B	Honokawai Stream Channel

7-23-96	0190 D	Kahului Airport - Revised "V" Zone
8-19-96	0265 C	Meadowlands Subdivision, Phases I only
12-16-96	0265C	1787 Halama Street-LOMA
1-31-97	0265C	156 Ho'Opili Akau Street-LOMA
2-10-97	0265C	1641 Halama Street LOMR
7-18-97	0330B	Makena Surf
9-17-97	0151C, 0153C,	Honokowai (ENTIRE PANEL REVISED)

Map Index

10-02-97	0161C, 0163C	proposed Map Revision for the entire panels
10-22-97	0160B,0160,index	Kalepa Gulch(Waihee School)LOMR
11-14-97	0265C	1795 Halama Street, LOMA
7-13-98	0153C	Kai Ala Subdivision, LOMR
8-3-98	0161C, 0163C,index	Lahaina (ENTIRE PANEL REVISED)
2-22-99	0151C firm/fldwy	Mahinahina Gulch
3-5-99	0265C	Meadowlands II-exclusions noted

Damages From Past Flood Events

Past Flooding Events In Maui County
November, 1900 – January 1997

Date	Area affected	Flood type	Damage
11/14/00	Islandwide	flash flood	NA
2/13/03	Wailuku	flash flood	NA
12/23/06	Islandwide	flash flood	NA
1/14/16	Islandwide	flash flood	NA
1/26/16	Lahaina/Olowalu/Kihei	stream flooding	NA
12/24/20	Wailuku	stream flooding	NA
1/29/30	Kulat, Kihei	flash flood	NA
8/10/30	Islandwide	flash flood	NA
11/18/30	Islandwide	flash flood	NA
1/2/46	Islandwide	stream flooding	NA
12/20/46	Islandwide	flash flood	NA
1/?/48	Iao Stream	flash flood	NA
4/2/48	Islandwide	flash flood	NA
11/30/50	Islandwide	flash flood	NA
2/22/51	Islandwide	flash flood	NA
12/21/55	Kihei	stream flooding	NA
5/12-13/60	Islandwide	stream flooding	NA
10/24/61	Islandwide	flash flood	NA
10/31-11/3/61	Kahoma Stream	stream flood	NA
11/2/61	Iao Stream, Wailuku Millstream	flooding	NA
11/2/61	Napili, Honolua	flash flooding	NA
12/19/64	NW Maui	flooding	NA
2/4/65	Sprecklesville	sheet flow	NA
4/25-28/65	Hana	flash flood	NA
3/17-18/67	West Maui	stream flooding, 7” in 5.5 hours	NA
3/24/67	Kihei	flood, 6” in 6 hours	NA
3/24/67	Napili Bay	flooding	NA
1/28/68	Kihei	flood	NA
3/13-16/68	Islandwide	stream flooding	NA
3/13-16/68	Napili Beach, Honolua, Pa’akea	24” in 48 hours	NA
4/15-16/68	E. Maui, Honoma’ele Stream	flash flooding	NA
11/28/68	Islandwide	minor flooding	NA
1/27-28/71	Islandwide	flooding	NA
1/27-28/71	Kihei	6 ft stream overflow	NA
1/27-28/71	North Central Maui	5820 cfs@ Iao Stream, 2 ft @Paia	NA
2/24/72	Lahaina	streamflooding, 5-8” in 5 hours	NA
4/19/74	Islandwide	flash flood	NA
22/12/78	Kahului	flash flood	NA
1/6-14/80	Islandwide	stream flooding	NA
8/3-4/80	Islandwide	stream flooding	NA
10/27-28/81	Islandwide	stream flooding	NA
10/27-28/81	road to Hana	sheet flow flooding	NA
3/30-31/82	Islandwide	stream flooding	NA
3/30-31/82	road to Hana	sheet flow flooding	NA
4/1-3/82	Islandwide	stream flooding	NA
7/16-17/82	Islandwide	stream flooding	NA
7/21-22/82	Haleakal	sheet flow flooding	NA
12/23-24/82	Islandwide	flooding , 3-5”rain	NA
5/23/84	Islandwide	minor flash floods	NA
5/23/84	road to Hana	minor flash floods	NA
12/24-25/84	Islandwide	flash flood	NA
10/17-18/85	Islandwide	flash flood	NA
11/18/85	Islandwide	minor flash flood	NA
2/15/86	Islandwide	flash flood	NA
11/10-11/86	Islandwide	minor flash flood	NA
2/15/87	Hana area	stream flooding, 8-10 inches	NA
3/5-6/87	North Central Maui	flash flooding, 10” rain	NA

4/21-22/87	Islandwide	minor flash flood	NA
4/26/87	Islandwide	flash flood	NA
5/5-6/87	Islandwide	flash flood, 10" rain	NA
1/28-29/88	Islandwide	flash flood	NA
3/24/88	road to Hana	sheet flow flooding	NA
11/4-5/88	Islandwide	extensive flooding	NA
12/5-6/88	Islandwide	flash flood, 10" rain	NA
2/3-5/89	Haiku	flash flooding	NA
2/10-11/89	Islandwide	flash flood	NA
3/1-4/89	Islandwide	flash flood	NA
1/14-22/90	Islandwide	stream flooding, 20 " rain	NA
1/27/90	Islandwide	stream flooding	NA
3/19-21/90	Islandwide	stream flooding	NA
3/21/91	road to Hana	flooding, mudslide	NA
11/26-27/92	windward Haleakala	severe flooding	NA
7/21-23/93	Islandwide	flooding, remnants of H. Dora	NA
10/23/93	windward Halakala	flash flood mudslide	NA
4/12-13/94	North Central Maui	flash flood, mudslide	NA
1/19-20/97	Lahaina	flooding	NA

Source: Coastal Hazard Atlas, May 2000

Maui Damages from Kona Storm
January 8-10,1980

	Estimated Cost
PRIVATE PROPERTY	
Agriculture	$4,189,000
Residential	$2,711,000
Business	$1,209,000
Utilities	$1,225,000
PUBLIC PROPERTY	
Schools/Buildings	$ 450,000
Roads	$1,468,000
Water Supply	$ 273,000
Parks (County, State and Federal)	$ 515,000
Harbors	$ 113,000
Forestry	$ 208,000
Sewers, refuse	$ 400,000
Airport	$ 52,000
Communication System	$ 56,000
TOTAL COST	**$12,869,000**

Sources: Maui Civil Defense, State Civil Defense, Department of Agricultural Services, FEMA, Parks and Recreation, State Parks Division, Maui News, ASCS??

Maui County Dams Classification

Dam	Classification	Built	Owner
50 MG Piiholo Reservoir	High		
Haiku Reservoir	High		
Hanakaoo Reservoir	High		
Happy Valley	High		
Honokawa	High		
Honokawai Reservoir	High		
Honolua	Low		
Horner Reservoir	High		
Kahana Dam	High		
Kahoma Reservoir	High		
Kapalaalaea Reservoir	Unknown		
Kaupakulua Reservoir	Unknown		
Kolea Reservoir	Unknown		
Kualapuu Reservoir	High		
Napili 2-3 Desilting	High		
Napili 4-5 Desilting	Significant		
Olinda Reservoir	High		
Papaaea Reservoir	Unknown		
Pauwela Reservoir	High		
Peahi Reservoir	Unknown		
Pukalani Reservoir	Low		
Reservoir 14	Unknown		
Reservoir 15	Unknown		
Reservoir 20	High		
Reservoir 21	High		
Reservoir 22	High		
Reservoir 24	High		
Reservoir 30	Unknown		
Reservoir 33	Unknown		
Reservoir 35	Unknown		
Reservoir 40	Unknown		
Reservoir 42	Unknown		
Reservoir 52	Unknown		
Reservoir 60	Unknown		
Reservoir 61	Unknown		
Reservoir 70	Unknown		
Reservoir 73	High		
Reservoir 74	High		
Reservoir 80	Unknown		
Reservoir 81	Low		
Reservoir 82	Low		
Reservoir 84	Unknown		
Reservoir 90	Unknown		
Reservoir 92	Unknown		
Upper Field 30	High		
Wahikuli Reservoir	High		
Waikamoi Dam No. 2	Unknown		

AUGUST 9,1871 (THE KOHALA CYCLONE)

This tropical cyclone has not been tracked by any known source. The following excerpts are quoted from the August 16 and 23 issues of The Hawaiian Gazette published in Honolulu by M. Raplee, Director of the Government Press, and leave little doubt as to the authenticity of the occurrence:

On Wednesday last (August 9) the Island of Maui was visited by one of the most severe, if not the severest, storm that has been felt on any of these islands for many years. At Lahaina the storm, which appears to have been almost violent cyclone, commenced about ten o'clock, and ranged for several hours. The following graphic description by a resident, will give our readers news of the violence there:

> 'Thursday morning - I hope you are all safe there. We, here of Lahaina, have had one of those terrific, tropical storms, hurricanes, cyclones, or if there is any harder word in the dictionary it well deserves it, which we read of in sensation paragraphs, but which few men actually witness more than two to three times in their lives.

'It commenced yesterday morning before daybreak with a fine, steady rain accompanied by a rising wind from the North and Northeast increasing in violence until about noon, when the play was at its height, and coconuts, breadfruit, branches of trees and whole trees might be seen pirouetting and gallopading down one street and up another, while the horrible roar of the gale, now shrieking like 5000 steam whistles let off at once, now becoming like magnificent thunder kept up with music to the mad performance. Add to that an inveterate rain that knew no ceasing from early morn to late at night and you may have an idea of a tropical storm in Lahaina. 'Owing to the previous dry spell of long duration, the swollen streams from the mountain did not come down till about 11 A.M. and the water in the canal in front of my house was gradually rising by the rain alone until it was full and overflowing. At that time down came the accumulated waters from the mountain sides in all directions, red, like streams of blood, roaring like wild bulls, plowing up channels of their own, inundating houses and making confusion worse confounded. The damage to fruit trees, vineyards and cane fields must be very considerable but as yet (Thursday morning) no accurate accounts have been received. The wind gradually wore round from North to Southwest and subsided at 5 P.M.' Captain Makee writes:

> "We have met with a great misfortune, but not, I hope, an irremediable one. At a quarter past ten this morning I went into the office to write letters. I had just begun to write when the wind began to blow furiously; in five minutes after, it was blowing one of the most fearful hurricanes I ever experienced. The door of the office was blown in, and took all the strength of Mr. S. and myself to close it and nail it up. Just as we had secured the door we saw the flagstaff fall. The hurricane being so terrific that trees, houses, and everything about were flying before the force of the wind.
>
> "I was of course anxious to get to the dwelling house, but could see no way of accomplishing my desire. At this time a servant who had managed to get to the office window informed me that (omitted) was sick. I got out of the lee window of the office and made a desperate attempt to get to the house. The air was literally full of branches of trees, barrels, and shingles. It seemed as though the Furies were let loose. I finally got into the garden where the trees were falling in every direction, when a gust of wind took me and threw me some ten feet, fortunately landing on a grass plot, by which good fortune I received no injury. One of the natives came with great difficulty to my rescue, when, with great exertion we succeeded in getting into the house. I found (omitted) had swooned with fright. She had been in the cottage and had in passing from there to the house narrowly escaped being crushed by the falling trees; arrived at the house, the terrible danger through which she had passed overcame her."

(Source: http://www.nws.noaa.gov/pr/hnl/cphc/summaries/1800s.html#Kohala)

Maui Drought Committee

Membership and Leadership

The Maui County/Local Drought Committee (hereafter referred to as "Maui Drought Committee") is comprised of representatives from key governmental agencies, non-governmental organizations, and major landowners with an active interest in drought-related issues. Based on participation in the drought workshops, the present membership includes the following individuals, agencies and entities:

Bob Collum, County of Maui Civil Defense Agency
John Cummings, Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife,
Lance DeSilva, DLNR Division of Forestry and Wildlife
Harold Edwards, Molokai Ranch
Sumner Erdman, Ulupalakua Ranch
Ranae Ganske, U.S. Department of Agriculture (USDA) Natural Resources Conservation Service
Robert Granger, Molokai Irrigation System Water Users' Advisory Board, and the Hawaii Farm Bureau Federation - Molokai
Garret Hew, East Maui Irrigation Company and Hawaiian Commercial & Sugar Company
Joloyce Kaia, Hana Soil & Water Conservation District
Collins Lam, Lanai Water Company
Robert Lum, Department of Agriculture
Doug MacCluer, Central Maui Soil and Water Conservation District
George Maioho, Department of Hawaiian Home Lands, Molokai District
Vanessa Medeiros, Department of Hawaiian Home Lands, Maui District
Jeff Pearson, County of Maui Department of Water Supply
James Robello, USDA Farm Services Agency
Glenn Shishido, DLNR Division of Forestry and Wildlife
Rex Takushi, County of Maui Fire Department
Warren Watanabe, Hawaii Farm Bureau Federation
Edwin Young, Nahiku-Hana Farmer
Warren Suzuki, Wailuku Agribusiness

County of Maui

Proclamation

WHEREAS, various natural hazards have caused and will continue to cause physical and financial impacts in Maui County; and

WHEREAS, these impacts also affect the environment, economy and infrastructure of Maui; and

WHEREAS, effective mitigation measures when implemented will significantly reduce the vulnerabilities and risks associated with inland and coastal flooding, high winds and surf, drought, wildland fires, tsunamis, and earthquakes; and

WHEREAS, partnerships with all levels of government, the private sector, and the citizens of Maui can effectively plan, implement, and fund mitigation projects;

NOW, THEREFORE, I, Alan M. Arakawa, Mayor of the County of Maui, by virtue of the authority vested in me under the ordinances of the County of Maui, do hereby proclaim the following actions and call upon the Maui County Council and the citizens of this County to assist in these endeavors. We will

1. *Establish a County Hazard Mitigation Committee, to be comprised of representatives from all levels of government and the private sector to further develop and implement the Maui County Hazard Mitigation Strategy and to manage the County's Hazard Mitigation Program.*

2. *Complete, with periodic updates as additional information becomes available, a countywide risk and vulnerability assessment of Natural hazards, which will include the provision of assistance to communities to identify their hazards and risks.*

3. *Develop partnerships with businesses to provide a public-private link for coordinated disaster mitigation, preparedness, response and recovery. These partnerships will start with the businesses that form the core for recovery (e.g., utilities, communications, food suppliers, medical facilities) and the core of the economy in the County.*

4. *Encourage the Maui County Council to adopt the latest version of the Uniform Building Code (UBC) and relevant wind load and seismic provisions of the latest version of the International Building Code (IBC). Administration will promote code enforcement at the appropriate levels.*

5. *Begin to address relevant hazards and the risks they pose through county-level land-use decisions, including plans for county-owned property development. The County will also encourage adoption of local land-use plans that incorporate hazards into decision-making. We will develop a simple, natural, multi-hazard disclosure checklist for all county land-use decisions.*

6. *Maintain the County's emergency response plan and develop the County's post-disaster recovery and mitigation plan that incorporates our mitigation priorities. We will provide technical assistance to local areas to develop their local recovery plans.*

7. *Secure compliance, participation, and improvement of current ratings in the National Flood Insurance Program and its Community Rating System, the Fire Suppression Rating System, the Building Code Effectiveness Grading Schedule (BCEGS) and any other such natural hazard-related rating or regulatory systems.*

8. *Incorporate disaster protection measures into public and private lifelines, infrastructure and critical facilities.*

9. *Develop and continue support of existing programs, such as Project Impact, and future programs to increase the public's awareness of natural hazards and ways to reduce or prevent damage through coordinated efforts with multiple stakeholders.*

10. *Support the incorporation of natural hazard awareness and reduction programs into school curricula through appropriate means in partnership with Maui Community College and Department of Education, Maui District.*

11. *Support the retrofit of community shelters and non-profit child care centers, through efforts such as those proposed by Project Impact and its partners.*

12. *Promote mitigation training for planners, developers, architects, engineers and surveyors, and County personnel, including the departments of planning and public works, including the land use and codes division, and encourage the participation of government, industry and professional organizations in the training process.*

IN WITNESS WHEREOF, I have hereunto set my hand and caused the seal of the County of Maui to be affixed hereto.

DONE at Wailuku, Maui, Hawaii, this 5th day of August, 2005.

Alan Arakawa

Alan M. Arakawa
Mayor, County of Maui