Hazard Mitigation Plan Update

Maui County

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TETRA TECH

Maui County

HAZARD MITIGATION PLAN UPDATE

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EXECUTIVE SUMMARY

Executive Summary

Hazard mitigation is the use of long-term and short-term policies, programs, projects, and other activities to alleviate the death, injury, and property damage that can result from a disaster. Maui County has developed and maintained a multi-hazard mitigation plan (HMP) to reduce risks from natural disasters. The plan complies with hazard mitigation planning requirements to maintain eligibility for funding under Federal Emergency Management Agency (FEMA) grant programs.

PREVIOUS HAZARD MITIGATION PLANNING IN Maui COUNTY

Federal regulations require periodic updates of hazard mitigation plans to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies. A jurisdiction covered by a plan that has expired is no longer in compliance with the federal requirements for hazard mitigation planning.

Maui County prepared an initial FEMA in 2005. This document represents the second comprehensive update (the first update was made in 2010). Maui County has made progress on implementing mitigation measures identified in its 2010 plan. Though some actions have been completed, others still require the identification of a funding source to support implementation. Therefore, if appropriate, these actions have been carried over into the 2015 update.

PLAN UPDATE PROCESS

The plan update was carried out in the following phases:

- **Phase 1, Organize and Review**—A planning team was assembled for the plan update, consisting of staff from Maui County Civil Defense and a technical consultant. The team conducted outreach to establish the planning partnership. A 16-member steering committee was assembled to oversee the plan update, consisting of County staff, citizens, and other stakeholders in the planning area. Coordination with other county, state, and federal agencies involved in hazard mitigation occurred throughout the plan update process. This phase included a review of the existing HMP, the Hawaii State Hazard Mitigation Plan, and existing programs that may support hazard mitigation actions.
- **Phase 2, Update the Risk Assessment**—Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. This process assesses the vulnerability of people, buildings, and infrastructure to natural hazards. Risk assessment models were enhanced with new data and technologies that have become available since 2010. The risk assessment included the following:
    - Hazard identification and profiling
    - Assessment of the impact of hazards on physical, social, and economic assets
    - Vulnerability identification
    - Estimates of the cost of potential damage.

The Steering Committee used the risk assessment to rank risk and to gauge the potential impacts of each hazard of concern on the islands of Maui, Molokai, and Lanai.

- **Phase 3, Engage the Public**—The planning team implemented a public involvement strategy developed by the Steering Committee. The strategy included public meetings to present the risk assessment and the draft plan, a hazard mitigation survey, a County-sponsored website, and multiple media releases.
- **Phase 4, Assemble the Updated Plan**—The planning team and Steering Committee assembled a document to meet federal hazard mitigation planning requirements. A completed local mitigation plan review crosswalk has been included in Appendix G. This completed crosswalk provides a comparative analysis between the content within the Maui County HMP and the federal hazard mitigation planning requirements.
- **Phase 5, Plan Adoption/Implementation**—Once the State of Hawaii Emergency Management Agency and FEMA Region IX have granted pre-adoption approval, the final adoption phase will begin. The plan maintenance process includes a schedule for monitoring and evaluating the plan's progress periodically and producing a revised plan every 5 years. This plan maintenance strategy also includes processes for continuing public involvement and integration with other programs that can support or enhance hazard mitigation.

RISK ASSESSMENT RESULTS

Based on the risk assessment, hazards were ranked as follows for the level of risk they pose to the overall planning area. The volcanic hazards of Lava Flow and Volcanic Gas (VOG) were ranked separately due to their difference in frequency and likelihood.

1. Tsunami (High)
2. Earthquake (High
3. High Wind Storm (High)
4. Tropical Cyclone (Medium)
5. Flood (Medium)
6. Wildfire (Medium)
7. Coastal Erosion (Medium)
8. Volcanic Hazards—Volcanic Gas (VOG) (Low)
9. Drought (Low)
10. High Surf (Low)
11. Landslide, Debris Flow and Rock Fall (Low)
12. Dam and Reservoir Failure (Low)
13. Volcanic Hazards—Lava Flow (Low)

MITIGATION GUIDING PRINCIPLE, GOALS, AND OBJECTIVES

The Steering Committee and the planning partnership established the following goals for the plan update:

1. Protect the life, health, safety, and welfare of Maui County residents and visitors.
2. Develop and implement the Maui County Hazard Mitigation Plan based on a comprehensive, multi-hazard risk and vulnerability assessment.

3. Protect property, including but not limited to critical facilities and infrastructure, from the impacts of natural hazards.
4. Promote a sustainable economy and protect the livelihood of the local population.
5. Promote the protection of the County's natural, cultural, and historical resources.
6. Promote and increase public awareness on the potential impacts of natural hazards and actions to reduce those impacts.

The following objectives were identified that meet multiple goals, helping to establish priorities for recommended mitigation actions:

1. Reduce vulnerability of lifelines, infrastructure, ports of entry, and critical facilities to natural hazards (adapted from State HMP).
2. Retrofit, purchase, or relocate structures in high hazard areas, especially those known to be repetitively damaged.
3. Develop and implement appropriate protocols for data collection, information sharing and plan management to ensure the implementation and enhancement of the HMP over the next 5 years (adapted from State HMP).
4. Utilize the best available data, science, and technologies to identify and mitigate risk from natural hazards.
5. Promote awareness of the Maui County HMP and the integration of plan elements into other Maui County planning efforts (adapted from State HMP).
6. Promote the regulation of future development in high-risk, natural hazard areas.
7. Incorporate indigenous and resident knowledge into hazard mitigation planning processes (adapted from State HMP).
8. Inform private and public stakeholders on the risk exposure to natural hazards and ways to increase their capability to prepare, respond, recover and mitigate the impacts of these events (adapted from General Plan).
9. Identify and pursue mitigation opportunities and projects that protect natural and cultural resources, promote environmental and cultural stewardship, and enhance the natural environment's ability to withstand impacts from natural hazards.
10. Strengthen planning, coordination, consensus building, and personal and civic engagement in hazard mitigation planning processes (adapted from County Policy Plan).
11. Identify and obtain funding for cost-effective and sustainable projects, critical studies, and strategic programs related to the mitigation of natural hazards.
12. Promote and encourage informed, resilient, self-sufficient, and sustainable communities.
13. Integrate the impacts of climate change in mitigation planning and implementation.

MITIGATION ACTIONS

Mitigation actions presented in this update are activities designed to reduce or eliminate losses resulting from natural hazards. The update process resulted in the identification of nearly 65 mitigation actions for implementation by individual stakeholder, as presented in Section 21.2 of this plan.

IMPLEMENTATION

Full implementation of the recommendations of this plan will require time and resources. The measure of the plan's success will be its ability to adapt to changing conditions. Maui County will assume responsibility for adopting the recommendations of this plan and committing resources toward implementation. The framework established by this plan commits Maui County to pursue initiatives when the benefits of a project exceed its costs. Maui County developed this plan with extensive public input, and public support of the actions identified in this plan will help ensure the plan's success.

PART 1: PLANNING PROCESS AND COMMUNITY PROFILE

Chapter 1. Introduction to Hazard Mitigation Planning

1.1 The Big Picture

Hazard mitigation is defined as a method to reduce or alleviate the loss of life, personal injury, and property damage that can result from a disaster through long- and short-term strategies. Strategies include implementing planning approaches, policy changes, programs, projects, and other activities that can mitigate the impacts of hazards. The responsibility for hazard mitigation lies with many, including private property owners; business and industry stakeholders; and local, state, and federal government agencies.

The federal Disaster Mitigation Act (DMA) of 2000 (Public Law 106-390) requires state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. Prior to 2000, federal disaster funding focused on disaster relief and recovery, with limited funding for hazard mitigation planning. The DMA increased the emphasis on planning for disasters before they occur.

DMA encourages state and local authorities to work together on pre-disaster planning, and promotes sustainability for disaster resistance. “Sustainable hazard mitigation” includes the sound management of natural resources and the recognition that hazards and mitigation must be understood in the largest possible social and economic context. The enhanced planning network called for by the DMA helps local governments articulate accurate needs for mitigation, resulting in faster allocation of funding and more cost-effective risk reduction projects.

1.2 Local Concerns

Natural hazards impact citizens, property, the environment, and the economy of Maui County. Tropical cyclones, landslides, earthquakes, tsunamis, flooding, and high surf have exposed Maui County residents and businesses to the financial and emotional costs of recovering after natural disasters. The risk associated with natural hazards increases as more people move to or visit areas affected by those hazards.

The inevitability of natural hazards and the growing population and activity within Maui County create an urgent need to develop strategies, coordinate resources, and increase public awareness to reduce risk and prevent loss from future hazard events. Identifying risks posed by hazards and developing strategies to reduce the impact of a hazard event can assist in protecting life and property of citizens, communities, and visitors. Local residents and businesses can work together with the County to create a hazard mitigation plan (HMP) that addresses the potential impacts of hazard events.

1.3 Purposes for Planning

DMA compliance is only one of multiple objectives driving this planning effort. Elements and strategies in this plan were selected because they meet a program requirement, as well as the needs of Maui County and its citizens. This HMP identifies resources, information, and strategies for reducing risk from natural hazards identified as a concern in Maui County, and will help guide and coordinate mitigation activities. The plan was developed to meet the following objectives:

- Meet or exceed program requirements specified under the DMA.
- Enable Maui County to continue using federal grant funding to reduce risk through mitigation.
- Meet the needs of Maui County as well as state and federal requirements.
- Create a risk assessment that focuses on Maui County hazards of concern.
- Meet the planning requirements of the Federal Emergency Management Agency's (FEMA) Community Rating System (CRS), allowing Maui County to maintain or enhance its CRS classification.
- Coordinate existing plans and programs so that high-priority initiatives and projects to mitigate possible disaster impacts are funded and implemented.

1.4 Who Will Benefit From This Plan?

All residents and businesses of Maui County are the ultimate beneficiaries of this HMP update. The plan identifies strategies and actions to reduce risk for those who live in, work in, and visit Maui County. It provides a viable planning framework for all foreseeable natural hazards. Key stakeholders' participation in development of the plan helped ensure that outcomes will be mutually beneficial. The plan's goals and recommendations can lay groundwork for the development and implementation of local mitigation activities and partnerships.

1.5 Contents of This Plan

This hazard mitigation plan is organized into three primary parts:

- Part 1—Planning Process and Community Profile
- Part 2—Risk Assessment
- Part 3—Mitigation Strategy.

Each part includes elements required under federal guidelines. DMA compliance requirements are cited at the beginning of subsections as appropriate to illustrate compliance.

The following appendices provided at the end of the plan include information or explanations to support the main content of the plan:

- Appendix A—List of acronyms and definitions
- Appendix B—Hazard mitigation public survey results
- Appendix C—Data sources for hazard mapping
- Appendix D—Strengths, weaknesses, obstacles, and opportunities brainstorming session notes
- Appendix E—Summary of mitigation initiative action plan funding sources
- Appendix F—Progress reports template
- Appendix G—FEMA crosswalks.

Chapter 2. Plan Update—What Has Changed

2.1 The Previous Plan

Maui County prepared a hazard mitigation plan (HMP) that was adopted and approved in 2005. The initial plan was updated in 2010, and is now undergoing its second comprehensive update in accordance with federal requirements. The following factors initiated the first hazard mitigation planning effort for Maui County:

- The Maui County area has significant exposure to numerous natural hazards that resulted in millions of dollars of damage in the past.
- Limited local resources make it difficult to be pre-emptive in risk reduction initiatives. Being able to leverage federal financial assistance is paramount to successful hazard mitigation in the area.
- Maui County wanted to be proactive in its preparedness for the probable impacts of natural hazards.

With these factors in mind, Maui County committed to the preparation of its initial plan by securing technical assistance to facilitate a planning process that would comply with all program requirements. Five years later, the County adopted its first update (County of Maui, 2010a). The 2010 County of Maui Multi-Hazard Mitigation Plan identified the following key hazards of concern (County of Maui, 2010a):

- High wind storms
- Tropical cyclones
- Landslides, debris flows, and rockfalls
- Earthquakes
- Lava and volcanic gas
- Tsunamis
- Floods
- Dam and reservoir failures
- High surf
- Coastal erosion
- Droughts
- Wildfires
- Hazardous materials.

Based on the assessment of these risks, the 2010 plan identified 38 mitigation actions, under the following categories:

- Policy
- Building facilities
- Public outreach
- Hurricane
- Earthquake
- Tsunami

- Flooding
- Drought and wildfire
- Others

2.2 Why Update?

2.2.1 Federal Eligibility

Title 44 of the Code of Federal Regulations (44 CFR) stipulates that hazard mitigation plans must present a schedule for monitoring, evaluating, and updating the plan. This provides an opportunity to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies. The Robert T. Stafford Act requires jurisdictions have current HMPs to pursue and receive federal funding.

2.2.2 Changes in Development

HMP updates must be revised to reflect changes in development within the planning area during the previous performance period of the plan, as stated in 44 CFR Section 201.6(d)(3). The plan must describe changes in development in hazard-prone areas that increased or decreased vulnerability since the last plan was approved. If no changes in development impacted overall vulnerability, then plan updates may validate the information in the previously approved plan. The intent of this requirement is to ensure that the mitigation strategy continues to address the risk and vulnerability of existing and potential development, and takes into consideration possible future conditions that could impact vulnerability.

The Maui County planning area experienced a 20.7 percent increase in population between 2000 and 2010, an average annual growth rate of 2.1 percent per year (County of Maui, 2010b; U.S. Census, 2015). Since 2010, the population is estimated to have grown an additional 5.3 percent to 163,019 (U.S. Census, 2015). Maui County has adopted a Countywide Policy Plan to guide development through 2030 (County of Maui, 2010b). That plan serves as the basis for updates to numerous individual regional and community plans. Together, this bundle of plans acts as a General Plan that guides future growth and policy-making in the County. It also provides a building code and specialty ordinances based on state and federal mandates. This HMP update assumes that some new development triggered by increased population occurred in hazard areas. Because all such new development would have been regulated pursuant to local programs and codes, it is assumed that hazard vulnerability did not increase, although it is possible that an increase in hazard exposure has occurred.

2.2.3 New Analysis Capabilities

The risk assessment for the previous Maui County HMP used both quantitative and qualitative analyses. Building count data and annualized average loss estimates were provided for some, but not all hazards of concern. These estimates were predominantly reported at the countywide scale. The updated risk assessment provides more detailed information on exposed population and building counts for each hazard of concern. This update also expands the level of detail in the loss estimate modeling for dam and reservoir failure, earthquake, flood, and tropical cyclone. Exposure and vulnerability estimates are presented at the community planning area level. This enhanced risk assessment allows for a more detailed understanding of the ways in which risk in the County is changing over time.

2.3 The Updated Plan—What Is Different?

Maui County Civil Defense used the current update process to make significant changes to the format and content of the hazard mitigation plan. The plan was re-packaged to improve readability and to more readily align with the Disaster Mitigation Act of 2000 (DMA) and Community Rating System (CRS) requirements for HMPs. The plan update process included a greater focus on public involvement. A renewed effort was made to establish a plan maintenance and implementation protocol that clearly defines Maui County's commitment to the plan's ongoing success. Some of the major differences between the current and previous plans are as follows:

- New goals, objectives and mitigation initiatives were developed for the updated plan to more readily align with existing County plans and programs and identified state priorities.
- An overview of climate change is provided with this update, along with information on how climate change may impact each identified hazard of concern.
- Discussion on the onshore and offshore environment was included in hazard profiles as appropriate.
- A review of relevant existing plans and programs relevant for hazard mitigation was conducted.
- The risk assessment was updated using the best available data, including updated general building stock and critical facility databases.
- Discussion on community shelters and hazardous materials was folded into the hazard profiles.
- Discussion on existing land uses was included for each hazard of concern with defined extents and locations.
- A new risk ranking protocol was employed to assist in establishing mitigation priorities.
- The protocol for prioritizing actions was updated and included an anecdotal benefit-cost review.
- The plan maintenance and implementation strategy was revised and updated to encourage greater coordination and planning for hazard mitigation funding opportunities.

Table 2-1 indicates the major changes between the two plans as they relate to 44 CFR planning requirements.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(b): In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include: (1) An opportunity for the public to comment on the plan during the drafting stage and prior to plan approval; (2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and (3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.	At the start of the 2010 planning process, a mobilization and scoping meeting was held with relevant local, state, and federal agencies. Maui County Civil Defense Agency, the lead agency, then established a working committee composed of representatives from local stakeholder groups to oversee the plan update process. Throughout the planning and update process, the County of Maui engaged the general public through newsletters, a survey, and web postings. A draft of the plan was made available for public review and comment on the State's hazard mitigation website.	The plan update was facilitated through a Steering Committee made up of stakeholders within the planning area. The Steering Committee was responsible for review of relevant plans and programs, agency coordination, review and identification of goals and objectives, confirmation of a public involvement strategy, development of a plan implementation maintenance strategy, and review and approval of the draft plan. All Steering Committee meetings were open to the public. Additional public input was received through several public meetings held early and late in the planning process and through a public survey. A 30-day public comment period was held before the draft plan was submitted for review. Agency coordination occurred through several avenues including the development of the risk assessment and mitigation initiative action plan, the composition of the Steering Committee and the dissemination of the draft plan for public comment.
§201.6(c)(2): The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.	The plan update risk assessment was based on the working committee's research and data collection. Geographic information system (GIS) and Hazards U.S.-Multi Hazard (Hazus-MH) analysis was performed as data and resources permitted. The number of hazards profiled increased from 9 in 2005, to 13 in 2010. Hazards assessed included high wind storms, tropical cyclones, drought, landslides, debris flows and rockfalls, earthquakes, volcanic hazards (lava and volcanic gas), tsunami, floods, dam and reservoir failures, high surf, and coastal erosion. The plan also included separate chapters on hazardous materials and emergency shelters.	A comprehensive risk assessment for the planning area that looks at 12 natural hazards of concern: coastal erosion, dam and reservoir failure, drought, earthquake, flood, high surf, high wind, landslide, tropical cyclone, tsunami, volcanic hazards, and wildfire. This assessment used the best available data and science with the Hazus-MH (version 2.1) risk assessment software and GIS analysis.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(c)(2)(i): [The risk assessment shall include a] description of the … location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.	A profile was provided including maps that illustrate the extent and location of each identified hazard of concern. These profiles included information on previous occurrences of hazard events and on the probability of future hazard events.	Comprehensive risk assessments of each hazard of concern are presented in Chapters 7 through 18. Each chapter includes the following: • Hazard profile, including maps of extent and location, historical occurrences, frequency, severity and warning time • Secondary hazards • Exposure of people, property, critical facilities and environment • Vulnerability of people, property, critical facilities and natural environment • Future trends in development • Scenarios • Issues. Each hazard is compared to each other via a risk ranking methodology described in Chapter 19.
§201.6(c)(2)(ii): [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i). This description shall include an overall summary of each hazard and its impact on the community.	Vulnerability was described for most hazards of concern in a subjective context. Updated Maui County construction cost information was used in Hazus-MH analyses to produce annualized average loss estimates for the tropical cyclone, earthquake, tsunami, and flood hazards. Each profile included a discussion on impacts and previous/current mitigation efforts.	Vulnerability was assessed for all hazards of concern. The Hazus-MH computer model was used for the dam failure, earthquake, flood, and tropical cyclone hazards. These were Level-2 (user-defined) analyses using coordinating agency and County data. Critical facilities and assets were defined and inventoried using the Hazus Comprehensive Data Management System and other available datasets. Outputs were generated for other hazards by applying an estimated damage function to affected assets when available. The asset inventory was extracted from the Hazus-MH model. Best available data were used for all analyses.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(c)(2)(ii): [The risk assessment] must also address National Flood Insurance Program insured structures that have been repetitively damaged floods.	The plan described the National Flood Insurance Program and special flood hazard areas in Maui County in the flood hazard profile. Repetitive loss structures were addressed and mapped in this section.	The description of the National Flood Insurance Program and repetitive loss discussion was enhanced to meet new DMA and CRS planning requirements. The update includes a comprehensive analysis of repetitive loss properties. For these properties the type of structure was determined and causes of flooding were cited, and the information was reflected on maps. National Flood Insurance Program capability is also assessed.
§201.6(c)(2)(ii)(A): The plan should describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area.	A detailed vulnerability analysis that included building counts and annualized average loss estimates was provided for the tropical cyclone and lava hazards. Annualized average losses were included for tsunami, earthquake, coastal erosion, floods, debris flows and rockfalls. This level of detail was not provided for the other hazards of concern. Infrastructure and facilities were discussed in hazard profiles as well as the risk assessment chapter.	A complete inventory of the numbers and types of buildings exposed was generated for each hazard of concern. The Steering Committee defined "critical facilities" as they pertained to the planning area, and these facilities were inventoried by exposure. Each hazard chapter provides a discussion of future development trends as they pertain to the hazard.
§201.6(c)(2)(ii)(B): [The plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) and a description of the methodology used to prepare the estimate.	Annualized average loss estimates were calculated at the Countywide scale for tropical cyclone, tsunami, coastal erosion, floods, debris flows and rockfalls, and earthquake. Annualized average loss was calculated at both the Countywide and census tract level for lava flow. This level of detail was not provided for the other hazards of concern.	Dollar loss estimations were generated for all hazards of concern. These were generated by Hazus for the dam failure, earthquake, flood, and tropical cyclone hazards. For the other hazards, loss estimates were generated by applying a regionally relevant damage function to the exposed inventory. In all cases, a damage function was applied to an asset inventory. The asset inventory was the same for all hazards and was generated in the Hazus-MH model.
§201.6(c)(2)(ii)(C): [The plan should describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land-use decisions.	The plan included an overall description of land use in the planning area, but did not detail that discussion by hazard. The plan included no discussion on future land use or development trends, although the plan did discuss population projections for both residents and visitors.	There is a discussion on future development trends as they pertain to each hazard of concern. This discussion looks predominantly at the existing land use and the current regulatory environment that dictates this land use.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(c)(3): The plan shall include a mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs, and resources, and its ability to expand on and improve these existing tools.	Detailed descriptions of future mitigation projects by hazard were included in each hazard profile as well as the mitigation strategy and projects chapter. Identified projects were prioritized using the STAPLEE (social, technical, administrative, political, legal, environmental and economic) criteria, and projects that passed were subjected to a second set of criteria. Projects were prioritized as high, medium, or low.	An initiative action plan was developed for Maui County (Chapter 21) via a facilitated process that includes: • Risk ranking • Capability assessment • Initiative alternative review • Initiative selection • Initiative prioritization • Initiative category analysis.
§201.6(c)(3)(i): [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.	The plan identified 8 goals and 20 objectives that were subsets of the goals.	The plan identifies 6 goals and 13 objectives, found in Section 20.1 and 20.2. Objectives were selected that meet multiple goals, and initiatives were selected and prioritized based on meeting multiple objectives.
§201.6(c)(3)(ii): [The mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.	The plan identified a range of future mitigation projects for each hazard. Projects were summarized by hazard type and policy type. The categories of mitigation (prevention, property protection, public education, natural resource protection, emergency services and capital projects) were discussed, but projects were not sorted using these categories.	A hazard mitigation catalog was developed through a facilitated process that looks at strengths, weaknesses, obstacles, and opportunities in the planning area. A table in the initiative action plan section analyzes each action by mitigation type to illustrate the range of actions selected. This is detailed in Section 21.2.4.
§201.6(c)(3)(ii): [The mitigation strategy] must also address the jurisdiction's participation in the National Flood Insurance Program, and continued compliance with the program's requirements, as appropriate.	A brief discussion on the National Flood Insurance Program was provided in the flood hazard profile. Jurisdiction-specific existing flood hazard studies were discussed. Projects related to compliance with the National Flood Insurance Program were identified, but not explicitly.	Maui County was asked to assess their National Flood Insurance Program capability. The County identified actions supporting continued compliance and good standing under the program, found in Section 21.2.4.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(c)(3)(iii): [The mitigation strategy shall describe] how the actions identified in section (c)(3)(ii) will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.	Descriptions of future mitigation projects by hazard were included in each hazard profile as well as the mitigation strategy and projects chapter. Identified projects were prioritized using the STAPLEE criteria, and projects that passed were subjected to a second set of criteria. Projects were prioritized as high, medium or low. Implementation was discussed in a generalized way. Lead agencies were identified for some projects, but not all. Cost-benefit review was discussed in terms of annualized average losses. However, cost-benefit review was only peripherally tied to identified projects.	Each of the recommended initiatives is prioritized using a qualitative methodology that looked at the objectives the project will meet, the timeline for completion, how the project will be funded, the impact of the project, the benefits of the project and the costs of the project. This prioritization scheme is detailed in Section 21.3.2.
§201.6(c)(4)(i): [The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a 5-year cycle.	The plan included a plan maintenance protocol that recommended an ongoing hazard mitigation planning committee intended to meet and produce reports on a quarterly basis to support an annual review.	A detailed plan maintenance strategy, found in Chapter 23, is provided that includes the following: • Annual review and progress reporting • Defined role for Steering Committee • Plan update triggers • Plan incorporation guidelines • Strategy for continuing public involvement • Grant coordination protocol.
§201.6(c)(4)(ii): [The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.	The plan did not include this discussion.	This is contained in the detailed plan maintenance and implementation strategy in Section 23.1.1.
§201.6(c)(4)(iii): [The plan maintenance process shall include a] discussion on how the community will continue public participation in the plan maintenance process.	The plan maintenance section included discussion of continued public involvement through community-based workshops and symposia. The executive summary stated that the plan would be reviewed annually with input from an organized network of community groups in each district.	This is contained in the detailed plan maintenance and implementation strategy in Section 23.1.4.

TABLE 2-1.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2010 Plan update	2015 Updated Plan
§201.6(c)(5): [The local hazard mitigation plan shall include] documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., City Council, County Commission, Tribal Council).	The plan included a letter of adoption dated March 31, 2010, signed by the County of Maui Mayor.	Maui County will seek DMA compliance with this plan update. Chapter 22 contains the adoption resolution.

Chapter 3. Plan Methodology

The process followed to develop this Maui County Hazard Mitigation Plan Update had the following primary objectives:

- Form a planning team
- Define the planning area
- Establish a steering committee
- Coordinate with other agencies
- Review existing programs
- Engage the public.

These objectives are discussed in the following sections.

3.1 Formation of the Planning Team

Maui County hired Tetra Tech, Inc. to assist with development and implementation of the plan. The Tetra Tech project manager assumed the role of the lead planner, reporting directly to the Maui County project manager. A planning team was formed to lead the planning effort, made up of the following members:

- Robert Collum, County of Maui Civil Defense Agency, Civil Defense Staff Specialist
- Anna Foust, County of Maui Civil Defense Agency, Emergency Management Officer
- Caitlin Kelly, Tetra Tech, Project Manager
- Rob Flaner, Tetra Tech, Principal in Charge
- Jason Geneau, Tetra Tech, Corporate Liaison
- Kristen Gelino, Tetra Tech, Planner.

3.2 Defining the Planning Area

The planning area was defined as the County of Maui, which consists of four islands: Maui, Molokai (excluding the Kalaupapa peninsula, which constitutes the County of Kalawao), Lanai, and Kahoolawe. The Island of Kahoolawe, though a part of Maui County, will only be peripherally included in the planning process due to its status as a nature reserve with no permanent residents.

3.3 The Steering Committee

Hazard mitigation planning enhances collaboration and support among diverse parties whose interests can be affected by hazard losses. A steering committee was formed to oversee all phases of the plan. The members of this committee included key Maui County staff, citizens, and other stakeholders from within the planning area. The planning team assembled a list of candidates representing interests within the planning area that could have recommendations for the plan or be impacted by its recommendations. The team confirmed a committee of 16 members. Some members chose to designate alternates to attend on their behalf. Table 3-1 lists the committee members.

TABLE 3-1.
STEERING COMMITTEE MEMBERS

Jurisdiction/Agency	Name	Title
Maui County Civil Defense		
Primary Member	Bob Collum (Chairperson)	Civil Defense Staff Specialist
Alternate Member	Anna Foust (Spokesperson)	Emergency Management Officer
Pacific Disaster Center		
Primary Member	Sharon Mielbrecht (Vice Chairperson)	Hazard Mitigation Specialist
Alternate Member	Andrea Chatman	Disaster Management Applications Analyst
Maui County Planning Department – Current Planning Division		
Primary Member	Jim Buika	Coastal Resource Manager
Alternate Member	Jeff Dack	Current Planning Division Supervisor
Maui County Public Works, Development Services Administration		
Primary Member	Jarvis Chun	Supervisor, Building Plans Review Section
Alternate Member	N/A	N/A
Maui County Planning Department – Zoning Administration and Enforcement Division		
Primary Member	Carolyn Cortez	Floodplain Manager
Alternate Member	Paul Critchlow	Senior Planner
Maui County Public Works		
Primary Member	Rowena Dagdag-Andaya	Deputy Director
Alternate Member	Brian Hashiro	Highways Division Chief of Field of Operations
Hawaii State Department of Education		
Primary Member	Bruce Moore	ASA/Lahainaluna
Alternate Member	Kevin Drake	Complex Area Business Manager
Maui County GIS		
Primary Member	Rebecca King	GIS Analyst
Alternate Member	Walle Landenberger	GIS Analyst
Maui Visitor Bureau		
Primary Member	Janet Kuwahara	Director of Visitor Aloha Society of Hawaii
Alternate Member	Terryl Vencl	Executive Director
American Red Cross		
Primary Member	Michele Liberty	Maui County Director
Alternate Member	Paul Wickman	Please provide
Molokai Representative		
Primary Member	Sybil Lopez	Resident
Alternate Member	N/A	N/A
Maui Electric Company		
Primary Member	Mahina Martin	Director, Government and Community Relations
Alternate Member	N/A	N/A
Alliance of Maui Community Associations		
Primary Member	Dick Mayer	Facilitator
Alternate Member	N/A	N/A
Maui County Department of Environmental Management		
Primary Member	Mike Miyamoto	Deputy Director
Alternate Member	Kyle Ginoza	Director

TABLE 3-1.
STEERING COMMITTEE MEMBERS

Jurisdiction/Agency	Name	Title
University of Hawaii Sea Grant College Program – Coastal Zone Management		
Primary Member	Tara Owens	Coastal Processes and Hazards Specialist
Alternate Member	Dennis Hwang, JD	Coastal Hazard Mitigation Specialist
Maui County Planning Department – Long Range Planning Division		
Primary Member	Pam Pogue	Planning Program Administrator
Alternate Member	Jennifer Maydan	Planner

Note: 56 percent of Steering Committee members represent governmental agencies; 44 percent represent non-governmental interests or groups.

Leadership roles and ground rules were established during the Steering Committee's initial meeting on December 5, 2014. The Steering Committee agreed to meet monthly as needed throughout the course of the plan's development and more frequently during the mitigation initiative development phase. The planning team facilitated each Steering Committee meeting, which addressed a set of objectives based on the work plan established for the plan update. The Steering Committee met nine times from December 2014 through June 2015. Meeting agendas, notes, and attendance logs are available for review upon request. All Steering Committee meetings were open to the public and agendas and meeting notes were posted to the hazard mitigation plan website.

3.4 Coordination with Other Agencies

Opportunities for involvement in the planning process must be provided to neighboring communities, local and regional agencies involved in hazard mitigation, agencies with authority to regulate development, businesses, academia, and other private and nonprofit interests (44 CFR, Section 201.6(b)(2)). The planning team accomplished this task as follows:

- **Steering Committee Involvement**—Agency representatives were invited to participate on the Steering Committee as indicated above. Additionally, the following agencies were contacted but were unable to send representatives for the committee: Hawaiian Telcom and East Maui Irrigation Company.
- **Public Outreach and Requested Data**—The following agencies assisted with public outreach efforts, provided data that supported the risk assessment portion of the plan, or reviewed the mitigation catalog used for the development of the mitigation initiative action plan:
  - FEMA Region IX
  - Hawaii State Department of Land and Natural Resources
  - Hawaii Wildfire Management Organization
  - Maui County Department of Health
  - Maui County Department of Parks and Recreation
  - Maui County Department of Water Supply
  - Maui County Fire Department
  - U.S. Forest Service Department of Agriculture, Pacific Southwest Region.
- **Pre-Adoption Review**— The following agencies, as well as those listed above, were provided an opportunity to review and comment on this plan, primarily through the hazard mitigation plan website (see Section 3.6):

- Hawaii State Department of Agriculture
- Hawaii State Department of Forestry and Wildlife
- Hawaii State Department of Land and Natural Resources
- Hawaii State Department of Transportation
- Maui County Drought Commission
- Maui Farm Bureau
- National Oceanic and Atmospheric Association
- National Park Service
- National Weather Service
- U.S. Geological Survey.

Each agency was sent an e-mail message informing them of draft portions of the plan available for review. The complete draft plan was sent to Hawaii Emergency Management Agency, Federal Emergency Management Agency Region IX, and the Insurance Services Office for pre-adoption reviews to ensure program compliance for both DMA and CRS.

3.5 Review of Existing Programs

Hazard mitigation planning must include review and incorporation, if appropriate, of existing plans, studies, reports and technical information (44 CFR, Section 201.6(b)(3)). The following plans and programs can affect mitigation within the planning area:

- Hawaii Hazards Awareness and Resilience Program
- Hawaii State General Plan
- Hawaii State Grants-in-Aid Capital Improvement Projects Program\
- Hawaii State Hazard Mitigation Forum
- Maui County Capital Improvement Program
- Maui County Emergency Operations Plan
- Maui County General Plan
  - Maui Countywide Policy Plan
  - Maui Island Plan and Community Plans.
- Maui County Municipal Code
- Maui County Zoning Ordinance.

An assessment of all Maui County regulatory, technical and financial capabilities to implement hazard mitigation initiatives is presented in Section 4.10.3. Many of these relevant plans, studies and regulations are cited in the capability assessment.

3.6 Public Involvement

Broad public participation in the planning process helps ensure that diverse points of view about the planning area's needs are considered and addressed. The public must have opportunities to comment on disaster mitigation plans

during the drafting stages and prior to plan approval (44 CFR, Section 201.6(b)(1)). The Community Rating System expands on these requirements by making CRS credits available for optional public involvement activities.

3.6.1 Strategy

The strategy for involving the public in this plan emphasized the following elements:

- Identify and involve planning area stakeholders.
- Include members of the public on the Steering Committee.
- Use a survey to determine if the public's perception of risk and support of hazard mitigation has changed since the initial planning process.
- Invite public participation at open-house public meetings
- Attempt to reach as many planning area citizens as possible using multiple media.

Stakeholders and the Steering Committee

Stakeholders are the individuals, agencies and jurisdictions that have a vested interest in the recommendations of the hazard mitigation plan. The effort to include stakeholders in this process included stakeholder participation on the Steering Committee. Stakeholders targeted for this process included the following:

- County of Maui departments relevant for hazard mitigation planning
- Members of the academic community
- Community member representatives
- Local disaster-preparedness and relief organizations
- Local special-purpose districts and utilities
- Local business and visitor interests.

Survey

The planning team developed a hazard mitigation plan survey with guidance from the Steering Committee. The survey was used to gauge household preparedness for natural hazards and the level of knowledge of tools and techniques that assist in reducing risk and loss from natural hazards. This survey was designed to help identify areas vulnerable to one or more natural hazards. The answers to its 25 questions helped guide the Steering Committee in affirming goals and objectives and in the development of mitigation strategies. Multiple methods were used to solicit survey responses:

- A web-based version of the survey was made available on the plan website (see Figure 3-1).
- Attendees at the public meetings and open houses were asked to complete a survey.
- A press release was distributed to local media urging residents to participate.
- Maui County Civil Defense advertised the survey on social media.

Public Meetings

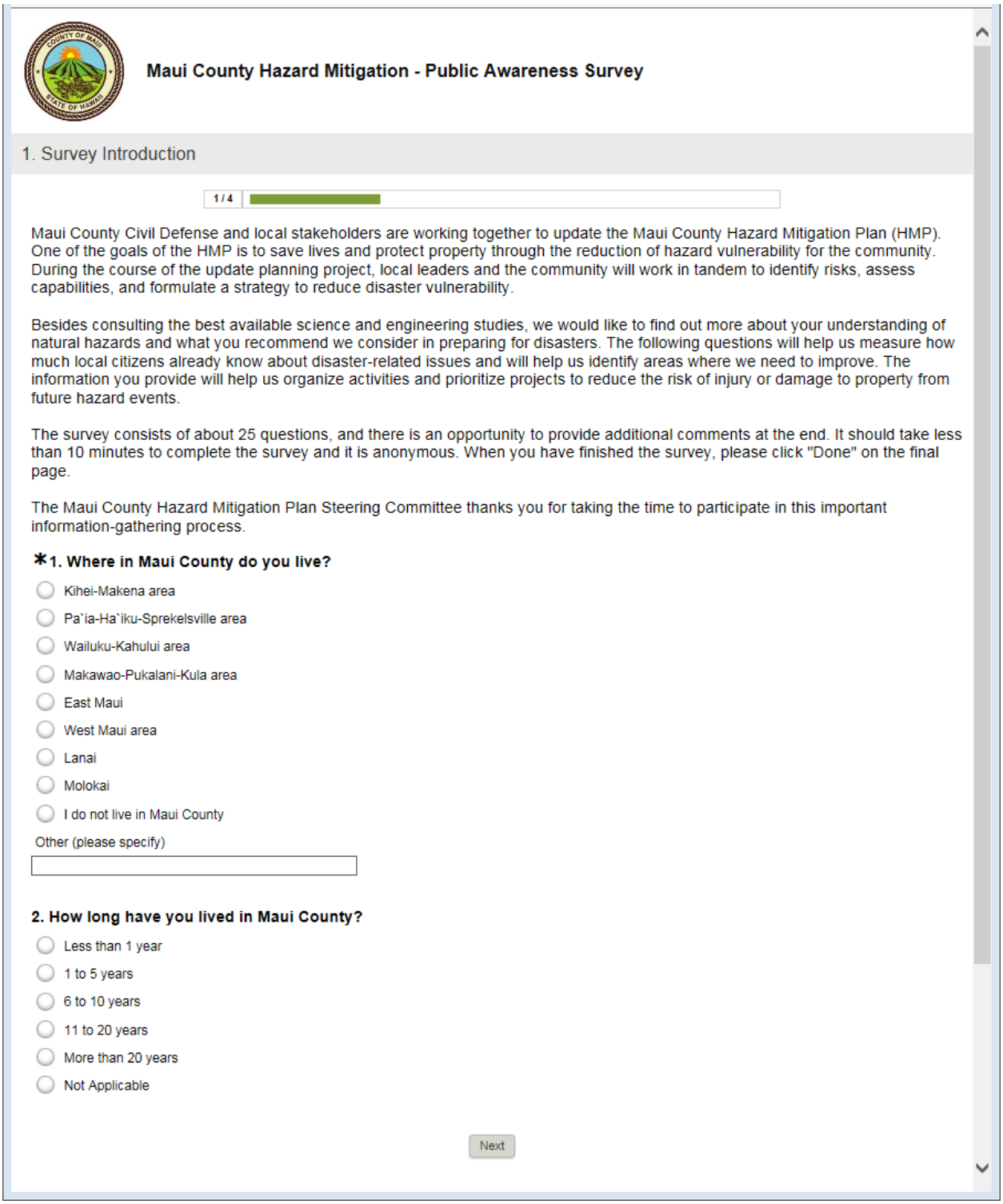
An open-house public meeting was held at the Kula Community Center in conjunction with a Community Wildfire Protection Plan community meeting, from 6:00 to 8:30 p.m. on March 3, 2015. The meeting format allowed attendees to examine maps and handouts and have direct conversations with project staff (see Figure 3-2). Reasons for planning were shared with attendees via a brief presentation. Each resident attending the open house was asked to complete a

survey, and each was given an opportunity to provide written comments to the Steering Committee. Local media outlets were informed of the open house by a press release from the planning team.

Several Steering Committee members—Anna Foust, Bob Collum, and Sharon Mielbrecht—addressed several island community associations on March 23, 2015 at the monthly Alliance of Community Associations meeting. The Steering Committee representatives discussed hazard mitigation and the Hawaii Hazards Awareness and Resilience Program with meeting attendees. Hazard maps were displayed and attendees were encouraged to participate in the survey.

Additionally, on June 8, 2015, Anna Foust presented information on hazard preparedness and the hazard mitigation plan to the Waikapu Community Association.

Finally, the public review draft of the HMP was presented to the public at a meeting held at the Cameron Center Meeting Room from 5:00 to 6:30 p.m. on June 24, 2015. The meeting included a presentation given by planning team member Caitlin Kelly and information on hazards and general preparedness. Attendees were also given the opportunity to speak with planning team members about the HMP and to provide written or verbal feedback on the draft plan. In addition, the public review draft was also presented on July 17, 2015 to the County of Maui Drought Committee, this meeting was open to the public.



Maui County Hazard Mitigation - Public Awareness Survey

1. Survey Introduction

1 / 4

Maui County Civil Defense and local stakeholders are working together to update the Maui County Hazard Mitigation Plan (HMP). One of the goals of the HMP is to save lives and protect property through the reduction of hazard vulnerability for the community. During the course of the update planning project, local leaders and the community will work in tandem to identify risks, assess capabilities, and formulate a strategy to reduce disaster vulnerability.

Besides consulting the best available science and engineering studies, we would like to find out more about your understanding of natural hazards and what you recommend we consider in preparing for disasters. The following questions will help us measure how much local citizens already know about disaster-related issues and will help us identify areas where we need to improve. The information you provide will help us organize activities and prioritize projects to reduce the risk of injury or damage to property from future hazard events.

The survey consists of about 25 questions, and there is an opportunity to provide additional comments at the end. It should take less than 10 minutes to complete the survey and it is anonymous. When you have finished the survey, please click "Done" on the final page.

The Maui County Hazard Mitigation Plan Steering Committee thanks you for taking the time to participate in this important information-gathering process.

***1. Where in Maui County do you live?**

- Kihei-Makena area
- Pa`ia-Ha`iku-Sprekelsville area
- Wailuku-Kahului area
- Makawao-Pukalani-Kula area
- East Maui
- West Maui area
- Lanai
- Molokai
- I do not live in Maui County

Other (please specify)

2. How long have you lived in Maui County?

- Less than 1 year
- 1 to 5 years
- 6 to 10 years
- 11 to 20 years
- More than 20 years
- Not Applicable

Next

FIGURE 3-1. SAMPLE PAGE FROM SURVEY DISTRIBUTED TO THE PUBLIC

FIGURE 3-2. DISPLAY OF HAZARD MAPS AT OPEN-HOUSE PUBLIC MEETING

Media Outreach

Press Releases

Press releases were distributed over the course of the plan's development as key milestones were achieved and prior to each public meeting. The planning effort received the following press coverage:

- January 8, 2015 article on Mauinow.com, "Public Input Sought on Hazard Mitigation Plan" (http://mauinow.com/2015/01/08/public-input-sought-on-hazard-mitigation-plan/)
- February 27, 2015 article on Mauinow.com, "Hazard Mitigation Plan Update to be Held in Kula" (http://mauinow.com/2015/02/27/hazard-mitigation-plan-update-to-be-held-in-kula/)
- March 24, 2015 article on Kihei Community Association website, "Alliance of Maui Community Assoc's talks Hazard Mitigation" http://gokihei.org/education-2/alliance-of-maui-community-assocs-talks-hazard-mitigation
- April 17, 2015 article on Maui TV News website, "County Wants To Know if We're Ready for 'The Big One'" http://mauitvnews.com/blog/2015/04/17/county-wants-to-know-if-were-ready-for-the-big-one/
- April 23, 2015 article on Mauinow.com. "Residents Encouraged to Complete Disaster Preparedness Survey" (http://mauinow.com/2015/04/22/residents-encouraged-to-complete-disaster-preparedness-survey/)
- May 7, 2015 article on Lahaina News, "Help Maui County Civil Defense Prepare for a Disaster" (http://www.lahainanews.com/page/content.detail/id/531529/Help-Maui-County-Civil-Defense-prepare-for-a-disaster.html?nav=9)

- June 19, 2015 article on RealEstateRama.com, "Community Meeting Set to Review Multi-Hazard Mitigation Plan" http://hawaii.realestaterama.com/2015/06/19/community-meeting-set-to-review-multi-hazard-mitigation-plan-ID0268.html
- June 20, 2015 article in Maui News "Hazard Mitigation Plan to be discussed" (picture of article below).

ghting project to
ose soccer field

eopuolani Park Soccer Field
4, the lower of the two soccer
ls in the middle of the park, will
losed from early July to Octo-
for lighting installation, the
nty Department of Parks and
reation said Friday.
Vork will begin July 6 and is
ected to run through Oct. 31.
project will include excavating
s for light pole footings,
ching to install conduits and
or demolition of asphalt and
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ing controls that will be locat-
t an existing comfort station,
ews release said.
he cost of the project is
1,049. Paul's Electrical Con-
ng LLC is the contractor.
he field and construction areas
be closed for safety. The upper

Hazard Mitigation Plan to be discussed

The Maui County Hazard Mitigation Planning Steering Committee will review the draft countywide Hazard Mitigation Plan at a community meeting from 5 to 6:30 p.m. Wednesday in the Cameron Center meeting room at 95 Mahalani St. in Wailuku.

Staff will present key components of the draft plan and answer questions. Personal hazard preparedness information will be provided and available to take home.

Maui County is updating its 2010 Hazard Mitigation Plan to ensure eligibility for future mitigation funding from the Federal Emergency Management Agency. The detailed plan addresses a variety of potential natural hazards that could affect some or all of the county's residents.

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FIGURE 3-3. DISPLAY OF JUNE PRESS RELEASE IN MAUI NEWS

Internet

At the beginning of the plan update process, the County's hazard mitigation website (http://www.co.maui.hi.us/index.aspx?NID=1832) was modified to include information about the update process (see Figure 3-3). Throughout the process, the website was used to keep the public informed on milestones and to solicit relevant input:

FIGURE 3-4. SAMPLE PAGE FROM HAZARD MITIGATION PLAN WEBSITE

The site's address was publicized in all press releases, mailings, surveys and public meetings. Information on the plan development process, the Steering Committee, the survey and phased drafts of the plan was made available to the public on the site throughout the process. Maui County intends to keep a website active after the plan's completion to keep the public informed about successful mitigation projects and future plan updates.

3.6.2 Public Involvement Results

Survey Outreach

A total of 243 respondents (240 of whom identified as being residents of the County of Maui and 3 of whom identified as non-residents) completed the online survey for this plan. Detailed survey results are provided in Appendix B. Key results are summarized as follows:

- High wind storms (84 respondents), floods (30 respondents), earthquakes (21 respondents), and tropical cyclones (17 respondents) are the primary hazards to have caused property damage in the past 20 years. These results correspond similarly to survey results from the 2010 HMP, where respondents identified high winds/hurricanes, earthquakes, and flooding as the hazards causing the most historic property damage.
- Lava/Volcanic gas (VOG) is identified as the hazard with the greatest historical threat to life safety, as 26 respondents indicated personal injury to themselves or a member of their household from this hazard. The planning team has assumed that the vast majority of respondents that indicated injury were referring to VOG, as lava flows have not occurred on the islands in recent history.
- Respondents indicated they were most concerned (i.e., concerned, very concerned, or extremely concerned) about high wind storms (84.5 percent), tsunamis (82.1 percent), floods (79.5 percent), and tropical cyclones

(78.7 percent). This is in contrast to the results from the 2010 HMP survey, which identified high winds/hurricanes, earthquakes, and VOG as the most likely hazards to negatively impact property in the future.

- Respondents also indicated concern for hazards not profiled in this plan update. These include fire ants, pandemics, mosquitos, cane smoke, sea level rise/climate change, and human-caused disasters.
- The majority of respondents consider themselves somewhat prepared (45.7 percent), with an additional 23.6 percent feeling adequately prepared and 15.1 percent feeling well-prepared.
- The most common steps that residents have taken to prepare for a hazard event include the following:
  - Stored flashlights and batteries (86.3 percent)
  - Stored medical supplies (first aid kit, medications) (74.0 percent)
  - Installed smoke detectors on each level of the house (70.6 percent)
  - Stored food and water (67.2 percent)
  - Stored a battery-powered radio (62.8 percent).
- Respondents believe that locally-provided news or other media information (82.5 percent) is the best way for the County to share preparedness and response information. Social media (68.5 percent) and automated messages from the Maui County Civil Defense Agency (MCDA) (66.5 percent) are the next most popular outreach methods.
- Maui County residents would prefer more preparedness and awareness information distributed on the following hazards, in order of preference: tsunami, high winds/storm damage, earthquake, tropical cyclone, and flood. This is a slight change from the 2010 HMP survey results, which showed VOG, tsunami, high winds/hurricanes, and earthquakes as the hazards the public would like to learn more about.
- Most respondents indicated that they do not live in a hazard-prone area; however, of the respondents that do, the following hazard-prone areas were the most frequently identified:
  - Tsunami evacuation zone (26.6 percent)
  - Floodplain or coastal flood zone (16.6 percent)
  - Earthquake hazard zone (15.6 percent)
  - Wildfire risk area (11.1 percent).
- The majority of respondents (61.5 percent) indicated that a real estate agent, landlord, or seller did not indicate whether their home was in a hazard zone. Approximately the same number of people (60.3 percent) believes this would have influenced their decision to buy or rent a property.
- The most common type of specialty insurance purchased by residents in the County is flood insurance (23.5 percent). Earthquake insurance is more common than wildfire insurance, and some residents have also purchased hurricane insurance.
- Respondents indicated that insurance premium discounts would be the strongest motivational incentive for taking additional steps to prepare their homes against a hazard. A rebate program, grant funding for retrofits, and mortgage discounts were also popular incentives.
- Respondents cited cost and lack of knowledge (44.3 percent for each response) as the most common obstacles preventing them from taking further preparedness steps. Although percentages differ, these were the same primary obstacles noted in the 2010 HMP survey.
- Respondents' ranked government-sponsored risk reduction projects in the following order of preference.

- Infrastructure retrofits
- Retrofits to essential facilities
- Better public information about risk
- Projects to restore natural functions in the environment
- Projects focused on reducing climate change impacts.

- Respondent demographic information correlates to the 2010 HMP survey results, wherein approximately two-thirds of respondents own their home and most respondents live in a single-family home (73.4 percent). Approximately 14.1 percent of respondents live in a condominium, while 8.3 percent live in an apartment. One respondent identified their home as an illegal, not-to-code shack and expressed concern that such residences were common for some low-to-moderate income populations in the County, making it difficult for many residents to afford preparedness measures.

Public Meetings

By engaging the public through the public involvement strategy, the concept of mitigation was introduced to the public and the Steering Committee received feedback that was used in developing the components of the plan. Details of attendance and comments received are summarized in Table 3-2.

FIGURE 3-5. QUESTIONS ANSWERED AT OPEN-HOUSE PUBLIC MEETING #2

TABLE 3-2.
SUMMARY OF PUBLIC MEETINGS

Date	Location	Number of Citizens in Attendance
3/3/15	Kula Community Center, Maui	3
3/23/15	Alliance of Community Associations Meeting	23
6/8/15	Waikapu Community Association	12
6/24/15	Cameron Community Meeting Room	1
7/17/15	Maui County Drought Commission Meeting	14
Total		**53**

3.7 Plan Development Chronology/Milestones

Table 3-3 summarizes important milestones in the development of the plan.

TABLE 3-3.
PLAN DEVELOPMENT MILESTONES

Date	Event	Description	Attendance
2014			
07/29	Initiate consultant procurement	Seek a planning expert to facilitate the process	N/A
10/13	Select Tetra Tech to facilitate plan development	Facilitation contractor secured	N/A
Nov.	Identify planning team	Formation of the planning team	N/A
Nov.	Steering Committee formed	Potential committee members identified and contacted.	N/A
12/05	Steering Committee Meeting #1	• Introduce potential Steering Committee members to planning process • Discuss the role of the Steering Committee • Review and discuss proposed charter for Steering Committee • Review update process and schedule • Introduce and discuss public involvement strategy	20
2015			
1/07	Public Outreach	Press release announcing process distributed, website updated	N/A
1/09	Steering Committee meeting #2	• Confirm Steering Committee charter • Discuss previous plan review • Discuss public involvement strategy	19
2/06	Steering Committee meeting #3	• Discuss public involvement strategy • Discuss previous plan review • Discuss results of vision statement and goal setting exercise • Review and discuss critical facilities definition	11

TABLE 3-3.
PLAN DEVELOPMENT MILESTONES

Date	Event	Description	Attendance
3/03	Public Outreach	Public Open House at Kula Community Center	3
3/06	Steering Committee meeting #4	• Discuss goals and objectives • Review and confirm critical facilities definition • Discuss risk maps and data dictionary • Discuss plan maintenance and implementation • Discuss planning schedule • Discuss public involvement strategy	17
3/23	Public Outreach	Presentation to Alliance of Community Associations	9
4/10	Steering Committee meeting #5	• Discuss and confirm objectives • Review and confirm critical facilities definition • Discuss public involvement strategy • Discuss planning schedule	17
5/01	Draft Plan	Internal review draft of Part 1 provided by planning team to Steering Committee	N/A
5/08	Steering Committee meeting #6	• Review Part 1 of the plan • Discus risk assessment update • Confirm plan implementation and maintenance strategy • Strengths, weaknesses, obstacles, and opportunities brainstorming session	15
5/28	Mitigation Initiative Development meeting	Stakeholder discussion of mitigation catalog	6
6/05	Mitigation Initiative Development meeting	Stakeholder discussion of mitigation catalog	9
6/08	Steering Committee meeting #7	• Discuss mitigation action catalog	9
6/08	Public Outreach	Waikapu Community Association	12
6/10	Draft Plan	Internal review draft of Part 2 provided by planning team to Steering Committee	N/A
6/16	Steering Committee #8	• Discuss plan schedule • Review Part 2 of the plan • Discus risk ranking results • Confirm plan implementation and maintenance strategy • Discuss mitigation action catalog	10
6/19	Steering Committee meeting #9	• Review Part 3 of the plan • Finalize mitigation initiative action plan	14
6/23	Public Comment Period	Initial public comment period of draft plan opens. Draft plan posted on plan website with press release notifying public of plan availability.	N/A
6/24	Public Outreach	Public meeting on draft plan	1
7/17	Public Outreach	Presentation to the County of Maui Drought Committee	14

TABLE 3-3.
PLAN DEVELOPMENT MILESTONES

Date	Event	Description	Attendance
X/X	Plan Approval	Final draft plan submitted to the Hawaii Emergency Management Agency, FEMA Region IX, and the Insurance Services Office for review and approval.	N/A
X/X	Adoption	Plan adopted by Maui County	N/A
X/X	Final Plan Approval	Final plan approved by FEMA	N/A

Chapter 4. Maui County Profile

4.1 Geographic Overview

The County of Maui is one of five counties in the State of Hawaii. It consists of the islands of Maui, Lanai, Kahoolawe and Molokai (excluding the Kalaupapa peninsula, which constitutes the County of Kalawao). The County boundaries encompass 1,162 square miles of land and 1,237 square miles of water. The Island of Maui is divided into four districts: Lahaina, Wailuku, Makawao, and Hana. The Makawao district also includes the Island of Kahoolawe. The islands of Molokai and Lanai are each separate districts. Even though a separate county, the County of Kalawao is typically treated as a district of the County of Maui for statistical purposes. The Maui County seat is Wailuku. For planning purposes, the County of Maui has defined nine community planning areas that make up the entire County (County of Maui, 2010b):

- Hana
- Kahoolawe
- Lanai
- Molokai
- Kihei-Makena
- Makawao-Pukalani-Kula
- Paia- Haiku
- Wailuku-Kahului
- West Maui.

The planning area is shown in Figure 4-1.

4.2 Historical Overview

The first inhabitants of the islands that make up the County of Maui arrived from the southern islands of Polynesia, approximately 800 to 1,000 years ago. These original inhabitants formed societies across the islands, but detailed historical information is limited. European settlers arrived in the late 1700s. From that point, the islands of Maui County saw development that was similar but distinctive for each island.

The following is a summary of key points in the history of the Island of Maui (County of Maui, 2006):

- The towns of Hana, Makawao, Wailuku, and Lahaina housed most of the native and arriving population in the early years after European contact.
- In 1848, Kamehameha III proclaimed the Great Mahele, or land division, establishing private ownership of lands in Hawaii.
- Sugar planting and refining throughout Hawaii was established between 1836 and 1861.
- In 1876, the Hawaiian Reciprocity Treaty with the United States allowed for duty-free admission of Hawaiian sugar to the U.S., resulting in a substantial increase of profits for island growers. With massive growth of the sugar industry, the need for labor grew, resulting in the importation of workers from other countries.

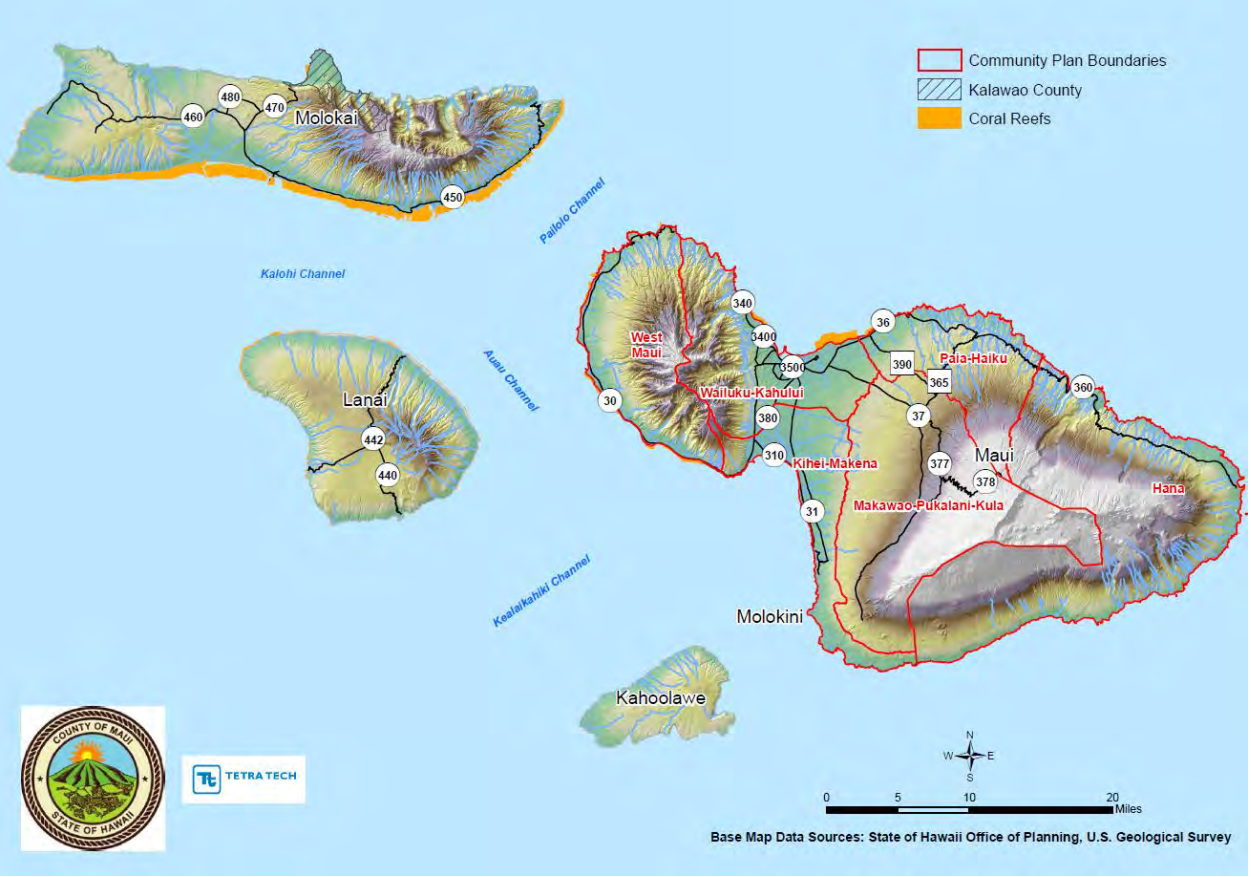


FIGURE 4-1. PLANNING AREA MAIN FEATURES

Note1: Community Plan boundaries are not delineated for Molokai and Lanai because the Community Plan boundary and the Islands' geographic boundary are conterminous.

Note2: Due to geographic location, coral reef and Community Plan boundaries data have overlapping boundaries.

- The pineapple industry began on Maui in 1890. By 1930, over 28 percent of Maui's cultivated lands were dedicated to pineapple.
- During World War II, the military population on Maui reached approximately 200,000, outnumbering local residents four to one.
- With a decline of the sugar and pineapple industries after World War II and bourgeoning economies in Oahu and the mainland U.S., Maui lost 24 percent of its population from 1940 to 1960. In 1959, the Report of Land Use for the Island of Maui proposed that, to reverse the trend, Maui could work to capture a greater share of Hawaii's tourist industry. The need for additional visitor facilities gave birth to the concept of the resort destination area, and in 1961 Kaanapali became the first of its kind in Hawaii.
- As Maui's population grew, settlement patterns expanded rapidly, spreading out from existing population centers. Central, South, and West Maui have grown significantly in the last three decades with the birth of new subdivisions and visitor accommodations. The rapidly increasing population also impacted upcountry Maui, experiencing a large growth in the residential market beginning in the 1970s.

The following is a summary of key points in the history of the Island of Molokai (Visit Molokai Dot Com, 2011; Wikipedia, 2014):

- The oldest known Hawaiian settlement on Molokai was in Halawa Valley.
- In 1832, a Protestant mission was established at Kaluaaha on the east end of the island.
- Kalaupapa, was the site of a leper settlement from 1866 to 1969.
- In the late 1800s, King Kamehameha V built a vacation home in Kaunakakai and was responsible for the planting of over 1,000 coconut trees in Kapuaiwa Coconut Grove.
- Beginning in 1897 much of the western end of the island was purchased by Molokai Ranch to operate a cattle ranch. From 1923 to 1985 thousands of acres of that land was leased to pineapple producers.
- In 2008, community members successfully opposed Molokai Ranch's attempt to expand, and what was then the island's largest employer shut down all operations including hotels, movie theater, restaurants and golf course, and dismissed 120 workers.
- Tourism is not as large an industry on Molokai as it is on other islands in Hawaii, as accommodations are limited; residents have resisted attempts to dramatically increase tourism. As of 2014, the largest industry on the island was seed production.

The following is a summary of key points in the history of the Island of Lanai (waimea.com, 2014):

- In his campaign to unify the Hawaiian Islands under one ruler in the 1700s, Kamehameha I killed much of Lanai's population, leaving few settlements or inhabitants.
- In 1922, James Dole, president of the Hawaiian Pineapple Company, purchased the entire island, and much of the land was used for pineapple plantations. When the pineapple industry started to plateau in the 1980s, the company, by that time called Dole Food Company, was reformed into a new company named Castle & Cooke.
- When David H. Murdock bought Castle & Cooke, he gained control over Lanai Island and began developing it as a tourist destination.
- In 2012, Larry Ellison purchased 97 percent of the island from Murdock. The island's focus on tourism remains.

The following is a summary of key points in the history of the Island of Kahoolawe (ProtectKahoolaweOhana.org, 2013):

- Kahoolawe was home to a school from 1828 to 1837 and a penal colony from 1832 to 1853.
- In 1858, the government issued the first of many ranch leases for the island. Ranching remained a primary use until 1952.
- The island was ceded to the United States in 1898, and was taken over by the U.S. military following the bombing of Pearl Harbor in 1941.
- Military use of the island remained significant until 1993, when the island was transferred to the State of Hawaii under a federal act that called for clearance or removal of unexploded ordnance and environmental restoration of the island. The state designated the island as the Kahoolawe Island Reserve, to be used solely for preservation of native Hawaiian culture, preservation of historical and environmental resources, rehabilitation of habitat, and education.

4.3 Major Past Hazard Events

Presidential disaster declarations are typically issued for hazard events that cause more damage than state and local governments can handle without assistance from the federal government, although no specific dollar loss threshold has been established for these declarations. A presidential disaster declaration puts federal recovery programs into motion to help disaster victims, businesses and public entities. Some of the programs are matched by state programs. The planning area has experienced 20 events since 1955 for which presidential disaster declarations were issued. These events are listed in Table 4-1.

TABLE 4-1.
PRESIDENTIAL DISASTER DECLARATIONS FOR HAZARD EVENTS IN PLANNING AREA

Type of Event	Disaster Declaration #	Date
Volcano	DR-32	4/1/1955
Tidal Wave	DR-71	3/16/1957
Hurricane Dot	DR-94	8/16/1959
Earthquakes and Volcanic Disturbances	DR-96	1/21/1960
Tidal Waves	DR-101	5/25/1960
Heavy Rains and Flooding	DR-152	4/24/1963
Heavy Rains and Flooding	DR-251	9/13/1968
Severe Storms, High Surf and Flooding	DR-613	2/6/1980
Heavy Rains and Flooding	DR-656	4/22/1982
Hurricane Iniki	DR-961	9/11/1992
Severe Storms And Flooding	DR-1348	10/28 – 11/2/2000
Maalaea Fire	FM-2673	9/1 – 9/6/2006
Earthquake	DR-1664	10/15/2006
Olowalu Fire	FM-2701	6/27 – 7/4/2007
Severe Storms, High Surf, Flooding, and Mudslides	DR-1743	12/4/2007 – 12/7/2007
Kaunakakai Fire	FM-2834	8/29 – 9/7/2009
Maalaea Fire	FM-2844	6/8 – 6/13/2010
Tsunami Waves	DR-1967	3/11/2011
Severe Storms, Flooding, and Landslides	DR-4062	3/3 – 3/11/2012
Tropical Storm Iselle	DR-4194	8/7 – 8/9/2014

a. Prior to 1964, federal disaster declaration were not issued specific to counties; pre-1964 declarations listed in this table are for the entire state of Hawaii, not Maui County specifically

Review of these events helps identify targets for risk reduction and ways to increase a community's capability to avoid large-scale events in the future. Still, many natural hazard events do not trigger federal disaster declaration protocol but have significant impacts on Maui County's communities. These events are also important to consider in establishing recurrence intervals for hazards of concern.

4.4 Physical Setting

The Hawaiian Archipelago consists of 132 volcanic islands, atolls, reef, and shoals in the North Pacific Ocean. The islands that make up Maui County are among the eight main islands at the southeastern end of the island chain. The

archipelago beyond those eight islands are known as the Northwestern Hawaiian Islands and forms part of the Papahanaumokuakea Marine National Monument created in 2006 (County of Maui, 2010a).

4.4.1 Geology and Topography

The Island of Maui is the second largest island in the Hawaiian Archipelago, covering 727 square miles. It was formed 1.3 million to 0.7 million years ago by two volcanic cones: Haleakala on the east side of the island, with a current elevation of 10,023 feet; and Puu Kukui (Mauna Kahalawai) on the west side, with a current elevation of 5,788 feet. Haleakala, which last erupted in 1790, is a dormant volcano that could erupt in the next 100 years. A relatively flat isthmus of sand 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 southwestern 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 (County of Maui, 2010a). The Island of Molokai is the fifth largest of the main Hawaiian Islands, covering approximately 260 square miles. It is 38 miles long and 10 miles wide and has approximately 100 miles of shoreline. It was formed primarily by the coalescence of two shield volcanoes 1.8 million to 1.3 million years ago: the East Molokai volcano (also known as Kamakou) and the West Molokai volcano (also known as Mauna Loa). The island's geology and topography vary east to west (County of Maui, 2010a):

- The east side of Molokai has a range of mountains whose highest peak, Kamakou, has an elevation of 4,970 feet. The Kamakou Preserve (2,774 acres of rainforest) is located on this side of the island. Stream erosion has cut large amphitheater-headed valleys into its northern coast. Near the end of the shield stage of the East Molokai volcano, its northern flank slid into the ocean, leaving behind the towering cliffs that dominate the northeast coast of the island. At more than 3,000 feet above sea level, these cliffs are the tallest sea cliffs in the world. Smaller and narrower valleys are found on the southern side of East Molokai. The southeastern edge of the island is bordered by an alluvial plain produced from a series of semi-contiguous alluvial fans associated with upland gulches.
- An East Molokai volcanic episode approximately 300,000 years ago formed a 2,500-acre peninsula in the sea below the steep cliffs of the north side of Molokai Island proper. This is the Kalaupapa peninsula, which is virtually isolated from the rest of the island by cliffs 1,600 to 2,000 feet high. The island's broad Hoolehua Saddle forms a low-lying coastal plain along the south shore at the island's center.
- On the west side of Molokai, the sloping West Molokai volcano reaches an altitude of 1,380 feet. This is the only Hawaiian volcano with no clear evidence of a summit caldera. The west side of the island has rolling arid land rather than valleys and is considerably drier than the east side. It is home to plantations, ranches, and small farms.

The Island of Lanai is the sixth largest of the main Hawaiian Islands, with an area of 141 square miles. The island was formed from a single shield volcano that last erupted about 1.3 million years ago. A low-lying basin in the center of the island is what is left of the volcano's caldera (County of Maui, 2010a).

The smallest of the main Hawaiian Islands, Kahoolawe has a land area of 45 square miles. It was formed by a single volcano that underwent shield and post-shield stages. The highest point on the island is Puu Moaulanui at 1,483 feet above sea level (County of Maui, 2010a).

4.4.2 Onshore and Offshore Natural Resources

Maui County's natural resources range from tropical rain forests and jagged-peaked mountains to the near-shore environment and coral reefs. The islands are home to flora, fauna and ecological communities that can be found nowhere else in the world (County of Maui, 2012a). These natural resources face pressure from development, invasive species, natural hazards and climate change. Forty species on the islands —37 plant species and 3 animal species—have been given protection under the Endangered Species Act (see Section 4.10.1; U.S. Fish and Wildlife Service, 2013).

These resources are an integral part of the economy, sense of place and traditional culture of the island communities. They need to be considered in hazard mitigation planning, because they are impacted by natural hazards and can influence the way that hazards impact the built environment.

4.4.3 Climate

Rainfall varies considerably across the Island of Maui, with windward areas experiencing much heavier rainfall than leeward areas. The slopes of Haleakala and Puu Kukui force moist northeasterly trade wind air upwards, causing the formation of clouds and showers. Subsiding air over the leeward slopes suppresses cloud and shower development, leaving these areas dry. Median annual rainfall is 200 to 300 inches on the windward side of Haleakala and about 350 inches near the summit of Puu Kukui; but leeward locations in central Maui such as Kihei have a mean annual rainfall of only 10 inches. Trade winds are also deflected around the volcanic masses and funneled through gaps and valleys, causing local accelerations and eddies. A notable example is a feature known as the "Maui vortex," a persistent circulation that usually occurs during trade wind conditions over the western slopes of Haleakala (County of Maui, 2010a).

Similarly, the eastern portion of Molokai receives much more rain than the western portion. Trade-wind rains throughout the year come in from the northeast and drop most of their moisture in the northern windward highlands, seldom on the southern or lee side of the island. The average annual rainfall is 20 inches in West Molokai and at the Molokai airport in the middle of the island. The eastern slopes of Kamakou (East Molokai) receive an average of 150 plus inches a year. Kona storms are major storms that come from the south once or twice a year, normally between October and April, and may drop 8 to 10 inches of rain in a short time. Molokai is warm year-round, with an average yearly temperature of 74ºF. During winter (December through March), the nighttime temperatures may drop to the lower 60s with more rain and stronger water currents (County of Maui, 2010a).

The Island of Lanai is sheltered from the prevailing northeasterly trade winds by the mountains of West Maui. Because of its protected location, Lanai has a much dryer climate than the other main Hawaiian Islands. Average annual rainfall at the summit of the island's highest peak, Lanaihale, is 30 to 40 inches. Lower-lying areas of the island have an average annual rainfall of 10 to 20 inches (County of Maui, 2010a).

Kahoolawe has a very dry climate because of its low relief and its sheltered location in the shadow of Haleakala on the Island of Maui. Annual mean precipitation throughout the island is 10 to 20 inches (County of Maui, 2010a).

Table 4-2 summarizes normal climate date from 1981 through 2010 at National Climatic Data Center (NCDC) weather stations across the planning area.

TABLE 4-2.
NORMAL PRECIPITATION AND TEMPERATURES, 1981 – 2010

	Precipitation (inches)	Temperature (°F) Minimum	Average	Maximum
Weather Station: Haleakala Ranger Station 338				
Annual	49.74	45.7	54.2	62.8
Winter	18.93	43.4	52.0	60.5
Summer	6.07	48.3	57.0	65.7
Spring	13.97	43.7	52.4	61.0
Autumn	10.77	47.2	55.6	64.0
Weather Station: Kahoolawe 499.6				
Annual	17.24	66.5	70.9	75.3
Winter	7.08	64.4	68.9	73.4
Summer	2.46	68.2	72.5	76.9
Spring	3.33	64.9	69.3	73.7
Autumn	4.37	68.5	72.8	77.1
Weather Station: Kahului Airport				
Annual	17.83	67.4	75.9	84.3
Winter	8.11	63.9	72.4	81.0
Summer	1.20	70.7	78.9	87.2
Spring	4.74	65.7	74.2	82.7
Autumn	3.78	69.3	77.8	86.3
Weather Station: Kapalua W Maui Airport 462				
Annual	29.01	69.1	75.5	81.9
Winter	11.16	66.5	72.5	78.6
Summer	3.75	71.3	78.0	84.7
Spring	7.89	67.6	74.0	80.4
Autumn	6.21	71.0	77.4	83.8
Weather Station: Lanai Airport 656				
Annual	15.59	63.3	71.5	79.7
Winter	6.31	60.1	68.3	76.4
Summer	1.52	65.8	74.2	82.7
Spring	3.02	61.6	69.9	78.2
Autumn	4.74	65.5	73.4	81.4
Weather Station: Molokai Kaunakakai Molokai Airport				
Annual	24.68	67.3	74.5	81.6
Winter	11.42	63.8	71.0	78.1
Summer	1.72	70.6	77.6	84.6
Spring	5.65	65.2	72.6	80.0
Autumn	5.89	69.7	76.8	83.8

Source: NCDC, 2015a.

4.5 Land Use

Table 4-3 summarizes the area of current land uses on each island in Maui County. As of 2012, Hawaii's Land Use Commission has classified the County of Maui as urban, rural, agricultural, and conservation as shown on Figure 4-2 (see Section 4.10.3 for description of land use districts).

TABLE 4-3.
LAND USE IN THE COUNTY OF MAUI

Land Class Description	Area (acres)	Land Class Description	Area (acres)
Lanai		**Molokai**	
Agricultural	356.6	Agricultural	126,793.4
Apartment	71.8	Apartment	51.2
Commercial	621.1	Commercial	121.6
Conservation	943.4	Commercialized Res	4.7
Hotel/Resort	80.1	Conservation	28,708.6
Industrial	45.7	Hotel/Resort	216.3
Residential	88,116.0[a]	Industrial	1,306.9
Not Classified	72.2	Residential	1,024.4
Total	**90,306.8**	Not Classified	1,161.7
		Total	**159,388.7**
Maui			
Agricultural	250,322.4		
Apartment	1,537.2		
Commercial	2,121.6		
Commercialized Res	120.1	**Kahoolawe**	
Conservation	193,047.9	Conservation	28,560.4
Hotel/Resort	1,057.0	**Total**	**28,560.4**
Industrial	3,455.3		
Residential	9,145.6		
Time Share	16.2		
Not Classified	5,717.9		
Total	**466,541.2**		

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified."

Note[a]: Residential estimates are derived from parcel data. A vast acreage in Lanai is assigned to one parcel, which is identified as residential.

4.6 Critical Facilities, Infrastructure, and Assets

Critical facilities and infrastructure are those that are essential to the health and welfare of the population. These become especially important after a hazard event. Critical facilities typically include police and fire stations, schools and emergency operations centers. Critical infrastructure can include the roads and bridges that provide ingress and egress

and allow emergency vehicles access to those in need, and the utilities that provide water, electricity and communication services to the community.

Source: State of Hawaii Land Use Commission, 2015

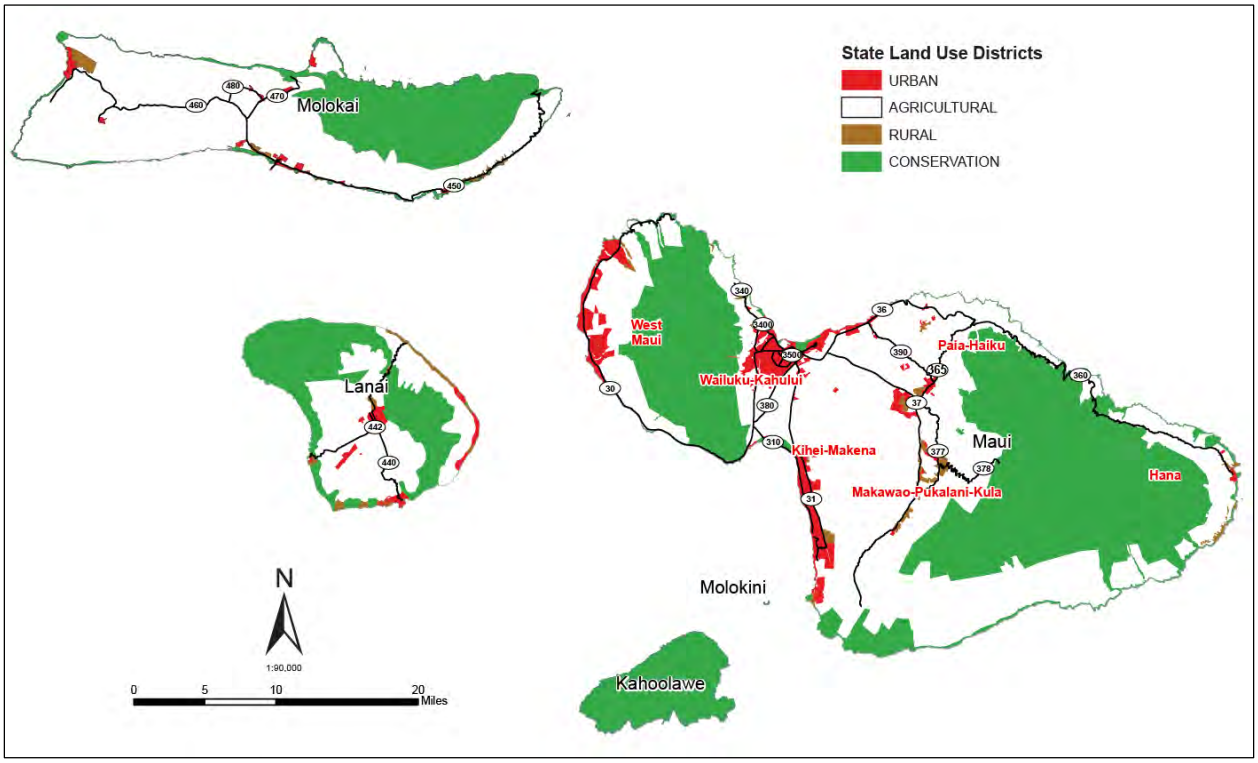


FIGURE 4-2. STATE OF HAWAII LAND USE CLASSIFICATIONS IN THE PLANNING AREA

Critical facilities identified in this plan were selected, mapped and included in geographic information system (GIS) databases based on information provided through the Steering Committee meetings, the previous Maui County Hazard Mitigation Plan (2010) and the State of Hawaii Multi-Hazard Mitigation Plan (2013). Although many facilities and assets of Maui County are important to the quality of life in Maui, this plan focuses on those whose loss would result in the greatest impacts on life and safety in the event of a natural hazard. These critical facilities and assets are considered imperative to the sustainability of Maui County. As updates to this plan are pursued in the future, additional information and detail will be incorporated. As defined for this hazard mitigation plan update, critical facilities include but are not limited to the following:

- **Emergency Services Infrastructure**—These are critical facilities required during a disaster and first response units capable of addressing any type of disaster. They include the emergency operations center, police stations, fire stations, hospitals, emergency medical service stations, medical centers, and community shelters.
- **Government Facilities and Services**—Government facilities and services including schools are all important for maintaining daily operations and preserving the economy. Facilities for all governmental departments of Maui County and schools are identified as critical in the GIS databases.
- **Critical Infrastructure and Lifelines**—Critical infrastructure covers a wide range of activities and lifelines that support daily activities and operations and are essential in emergency situations. These include transportation and points of entry, water infrastructure, energy, telecommunications, and solid and hazardous waste disposal.

- **Other Important Assets**—Maui County relies heavily on the tourism industry and depends on the beauty of the natural resources to support this industry as well as facilities to house tourists. The viability of financial institutions is also critical. The GIS databases include information on economically important assets throughout the County, including financial institutions (banks), hotels and tourism facilities. GIS data also include information on nursing facilities and assisted living facilities. This allows Maui County to identify areas where more assistance is likely to be needed after a disaster.

Table 4-4 provides summaries of the general types of critical facilities. General locations of critical facilities and assets in the planning area are shown in Figure 4-3 through Figure 4-8. Due to the sensitivity of this information, a detailed list of facilities is not provided. The list is on file with Maui County. All critical facilities and point-based structures were analyzed in Hazards U.S. (Hazus) to help rank risk and identify mitigation actions. The risk assessment for each hazard qualitatively discusses critical facilities with regard to that hazard.

TABLE 4-4.
CRITICAL FACILITIES AND ASSETS IN THE PLANNING AREA

Facility Type	Number in Planning Area	Comment
Emergency Services		
Emergency Operations	1	Emergency operations centers
Police & Fire	30	Police stations and fire stations
Community Shelter[a]	8	Community shelters other than schools
Medical & Health	5	Hospitals, emergency medical service stations and medical centers
Government and Services		
Government[b]	--	Government buildings
Schools[a]	92	Schools
Critical Infrastructure and Lifelines		
Transportation	175	Airports, bridges and highway bridges, and ferry, port and rail facilities
Water Supply	176	Potable water treatment plants and tanks
Wastewater	98	Wastewater treatment facilities and pump stations
Dams	48	Dams and reservoirs
Energy	7	Electric power and oil facilities
Telecommunications	21	Television and radio stations
Hazardous Materials	7	EPA Toxic Release Inventory (TRI) facilities
Other Important Assets		
Financial	54	Banks
Tourist Lodging	181[c]	Hotels and other tourist lodging accommodations
Early Assistance	3	Nursing and assisted living facilities
Total	**906**	

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.

b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

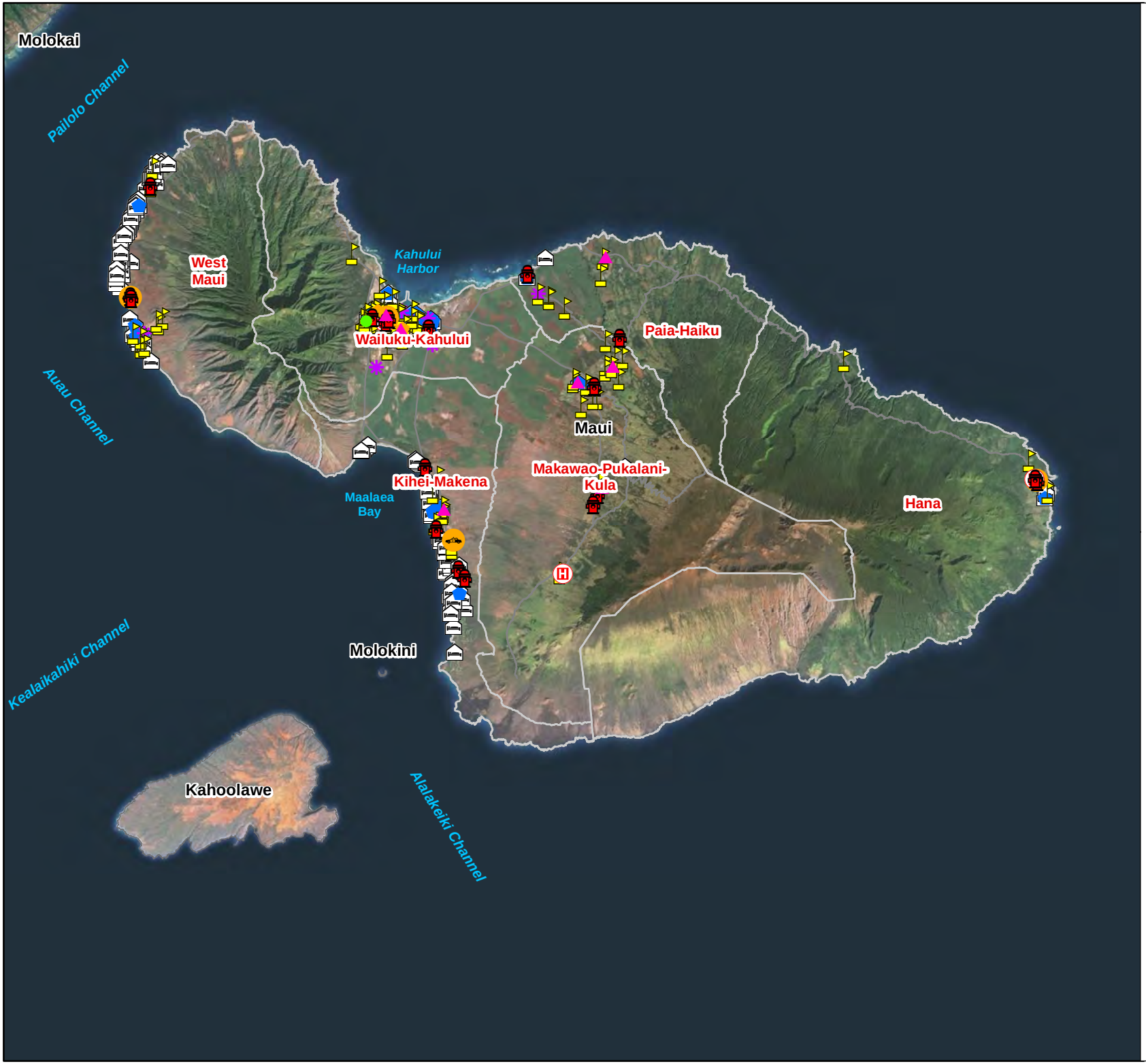
c. Hotel data was downloaded from the Hawaii State Office of Planning website in April 2015. The hotel data set includes hotels, condominium hotels, individual vacation units, apartment hotels, bed & breakfasts, timeshares, and hostels; hotels with fewer than 10 units are not included.

Note: School data set includes pre-schools, elementary and high schools for both public and private institutions. Totals for schools may appear high due to the inclusion of pre-schools.

Data sources: See Table 5-2

Maui County Islands of Maui and Kahoolawe

Critical Facilities



Legend

- Community Plan Boundaries
- EOC Facilities
- Shelters
- Fire Stations
- Early Assistance Facilities
- Medical Care Facilities
- Police Stations
- Schools
- Hazardous Materials
- Financial
- Tourist Lodging

Base Map Data Sources:
Maui County, Hazus, ESRI
HI Office of Planning

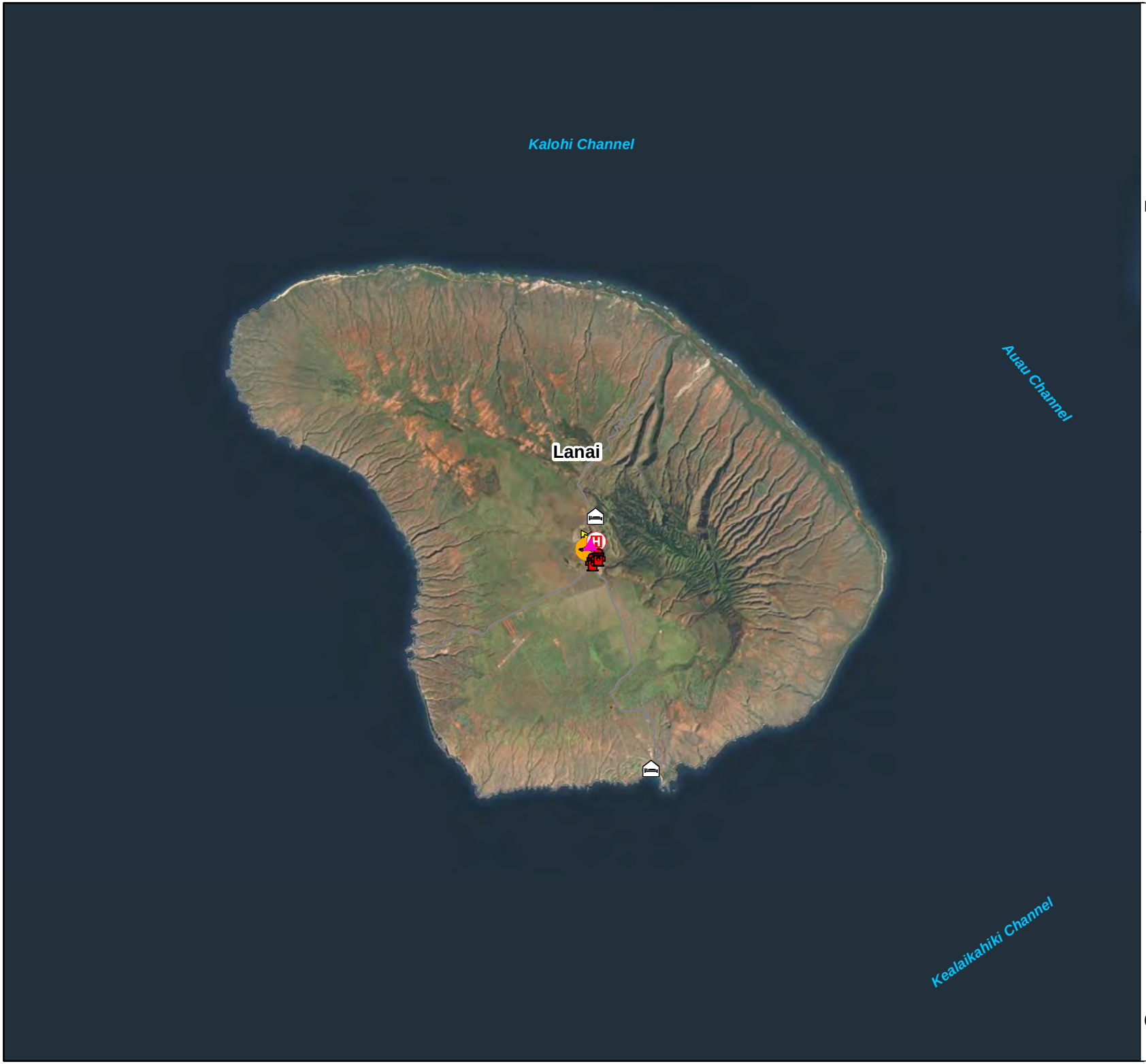
TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Critical Facilities



Legend

- EOC Facilities
- Shelters
- Fire Stations
- Early Assistance Facilities
- Medical Care Facilities
- Police Stations
- Schools
- Hazardous Materials
- Financial
- Tourist Lodging

Base Map Data Sources:
Maui County, Hazus, ESRI,
HI Office of Planning

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Critical Facilities

Legend

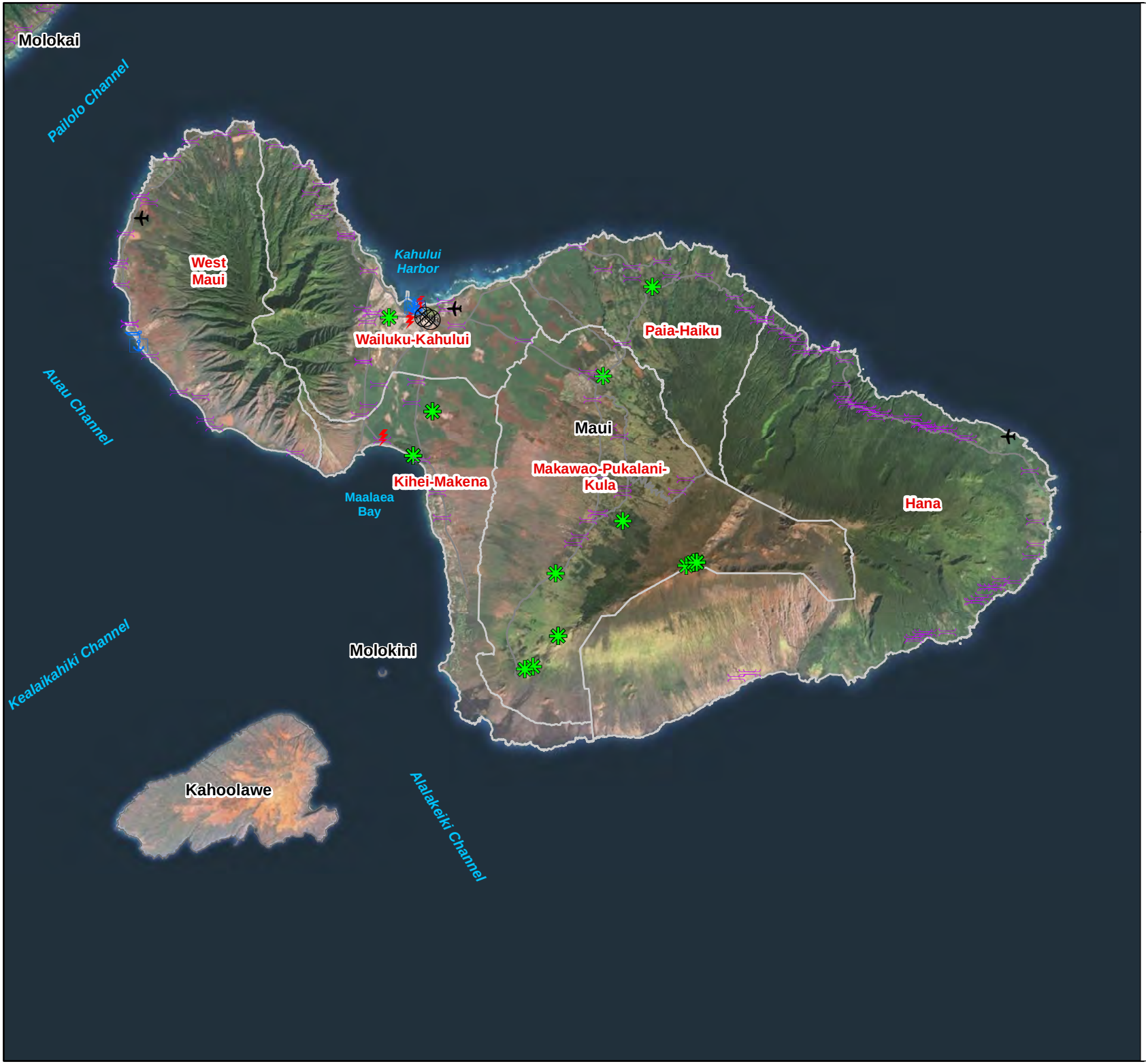
- Kalawao County
- EOC Facilities
- Shelters
- Fire Stations
- Early Assistance Facilities
- Medical Care Facilities
- Police Stations
- Schools
- Hazardous Materials
- Financial
- Tourist Lodging

Base Map Data Sources:
Maui County, Hazus, ESRI,
Hi Office of Planning

TETRA TECH

N

0 3.5 7 Miles



Maui County Islands of Maui and Kahoolawe

Critical Infrastructure

Legend

- Community Plan Boundaries
- Airports
- Rail Facilities
- Ferry Facilities
- Port Facilities
- Bridges
- Communication Facilities
- Electric Power Facilities
- Oil Facilities

Water and waste water facilities were analyzed however they are not displayed on the map for security reasons.

Base Map Data Sources:
Maui County, Hazus, ESRI
HI Office of Planning

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Critical Infrastructure

Legend

- Airports
- Rail Facilities
- Ferry Facilities
- Port Facilities
- Bridges
- Communication Facilities
- Electric Power Facilities
- Oil Facilities

Water and waste water facilities were analyzed however they are not displayed on the map for security reasons.

Base Map Data Sources:
Maui County, Hazus, ESRI,
HI Office of Planning

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Critical Infrastructure

Legend

- **Kalawao County**
- Airports
- Rail Facilities
- Ferry Facilities
- Port Facilities
- Bridges
- Communication Facilities
- Electric Power Facilities
- Oil Facilities

Water and waste water facilities were analyzed however they are not displayed on the map for security reasons.

Base Map Data Sources: Maui County, Hazus, ESRI, Hi Office of Planning

TETRA TECH

N

0 3.5 7 Miles

4.7 Demographics

Some populations are at greater risk from hazard events because of decreased resources or physical abilities. Research has shown that people living near or below the poverty line, the elderly (especially older single men), individuals with disabilities, women, children, ethnic minorities, and renters all experience, to some degree, more severe effects from disasters than the general population. These vulnerable populations may vary from the general population in risk perception, living conditions, access to information before, during and after a hazard event, capabilities during an event, and access to resources for post-disaster recovery. Indicators of vulnerability—such as disability, age, poverty, and minority race and ethnicity—often overlap spatially and often in the geographically most vulnerable locations. Detailed spatial analysis to locate areas where there are higher concentrations of vulnerable community members would help to extend focused public outreach and education to these most vulnerable citizens.

4.7.1 Population Characteristics

Resident Population

Knowledge of the composition of the population and how it has changed in the past and how it may change in the future is needed for making informed decisions about the future. Information about population is a critical part of planning because it directly relates to land needs such as housing, industry, stores, public facilities and services, and transportation. The U.S. Census Bureau estimates the County's total resident population at 154,834 as of 2010. Table 4-5 presents Maui County 2010 population estimates for the islands of Maui, Molokai and Lanai.

TABLE 4-5.
POPULATION OF MAUI COUNTY BY ISLAND

Island	Population (According to Maui County General Plan and Community Plans)
Maui[a]	144,444
Molokai[b]	7,255
Lanai[c]	3,102

Sources:

a. County of Maui, 2012a

b. County of Maui, 2015

c. County of Maui, 2012b.

Population changes are useful socio-economic indicators. A growing population generally indicates a growing economy, while a decreasing population signifies economic decline. Table 4-6 shows the population in the planning area and the State of Hawaii from 1980 through 2010. The average annual growth rate over that period, for Maui County and for the state, is shown on Figure 4-9. State of Hawaii and Maui County Population Growth. The planning area's annual average population growth of about 3.5 percent through the 1980s dropped to 1.8 percent in the late 1990s. After a brief increase in population growth between 2000 and 2005, population growth has continued to decrease to about 1.5

percent. The statewide population growth rate has been consistently lower than that of Maui County throughout this period.

TABLE 4-6.
ANNUAL POPULATION DATA

	Population	
	Maui County	State of Hawaii
1980	71,600	968,500
1985	85,147	1,039,698
1990	101,709	1,113,491
1995	117,895	1,196,854
2000	129,078	1,213,519
2005	143,448	1,292,729
2010	155,214	1,363,621

Source: Hawaii Department of Business, Economic Development & Tourism, 2012

Note: Source data for Table 4-5 and Table 4-6 differ. Therefore, variances in the 2010 annual population exist between the tables.

Source: Hawaii Department of Business, Economic Development & Tourism, 2012

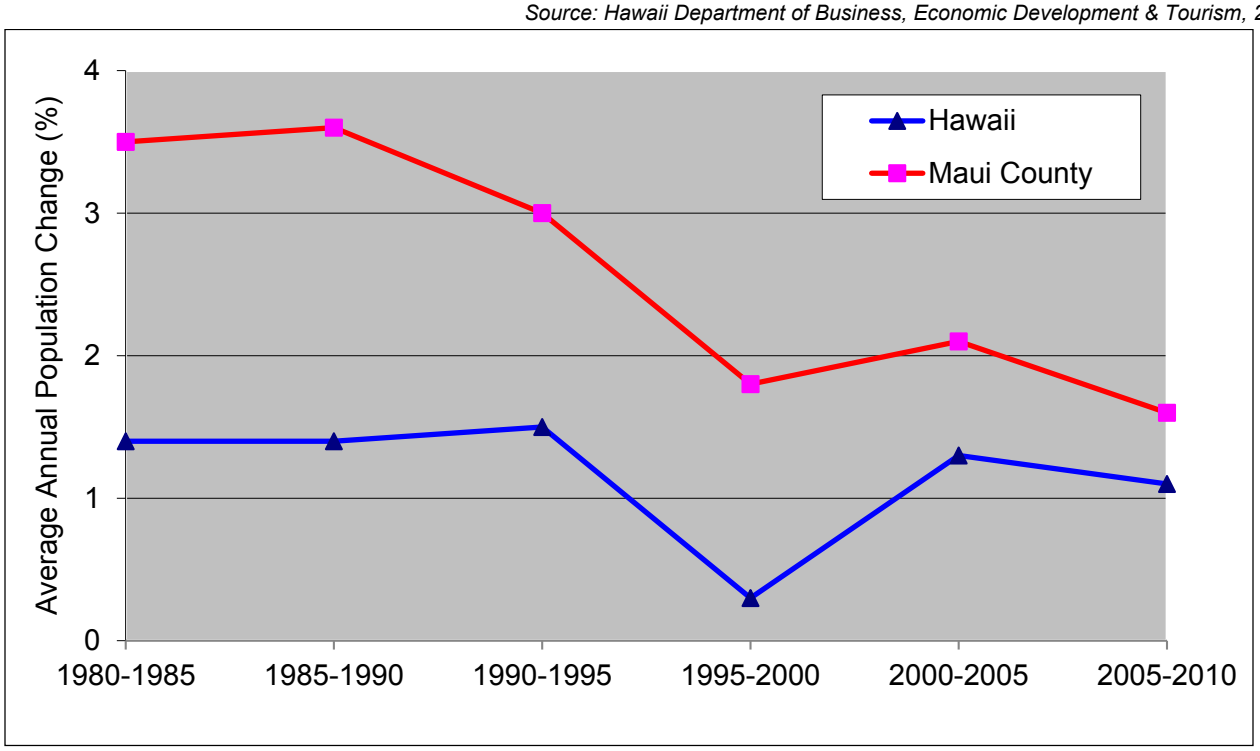


FIGURE 4-9. STATE OF HAWAII AND MAUI COUNTY POPULATION GROWTH

Visitor Population

According to the Hawaii Tourism Authority, more than 2.4 million people visited Maui County in 2013. The average daily number of visitors in the County in 2013 was 54,233, with peak population in December (Hawaii Tourism Authority, 2013). The average number of daily visitors differs substantially by island (Table 4-7). This large visitor contingent has

impacts on planning for the County's infrastructure and service needs, as well as planning for hazard mitigation and emergency management.

TABLE 4-7.
ESTIMATED AVERAGE DAILY VISITOR POPULATION OF MAUI COUNTY BY ISLAND

Island	Average Daily Number of Visitors	Peak Daily Number of Visitors
Maui	52,798	62,675
Molokai	725	1,122
Lanai	710	873

Source: Hawaii Tourism Authority, 2013.

4.7.2 Age Distribution

As a group, the elderly are more apt to lack the physical and economic resources necessary for response to hazard events and are more likely to suffer health-related consequences making recovery slower. They are more likely to be vision, hearing, and/or mobility impaired, and more likely to experience mental impairment or dementia. Additionally, the elderly are more likely to live in assisted-living facilities where emergency preparedness occurs at the discretion of facility operators. Emergency managers typically identify these facilities as "critical facilities" because they require extra notice to implement evacuation. Elderly residents living in their own homes may have more difficulty evacuating their homes and could be stranded in dangerous situations. This population group is more likely to need special medical attention, which may not be readily available during natural disasters due to isolation caused by the event. Specific planning attention for the elderly is an important consideration given the current aging of the American population.

Children under 14 are particularly vulnerable to disaster events because of their young age and dependence on others for basic necessities. Very young children may additionally be vulnerable to injury or sickness; this vulnerability can be worsened during a natural disaster because they may not understand the measures that need to be taken to protect themselves from hazards.

The overall age distribution for the planning area is illustrated in Figure 4-10. Based on U.S. Census 2013 data estimates, 13.4 percent of the planning area's population is 65 or older, compared to the state average of 14.8 percent. According to U.S. Census data, 9.9 percent of the over-65 population has disabilities of some kind and 5.1 percent have incomes below the poverty line. Children under the age of 18 account for 14.4 percent of individuals who are below the poverty line. It is also estimated that 19 percent of the population is 14 or younger, compared to the state average of 18.1 percent.

4.7.3 Race, Ethnicity and Language

Research shows that minorities are less likely to be involved in pre-disaster planning and experience higher mortality rates during a disaster event. Post-disaster recovery can be ineffective and is often characterized by cultural insensitivity. Since higher proportions of ethnic minorities live below the poverty line than the majority white population, poverty can compound vulnerability. According to the U.S. Census, the racial composition of the planning

area is predominantly white, at about 34 percent. The largest minority populations are Asian at 29 percent and Native Hawaiian or other Pacific Islander at 10 percent. Figure 4-11 shows the racial distribution in the planning area.

The planning area has a 17.2-percent foreign-born population. Other than English, the most commonly spoken languages in the planning area are Asian and Pacific Island languages. The census estimates 9.5 percent of the residents speak English "less than very well."

Source: U.S. Census – American Community Survey 5-Year Estimates

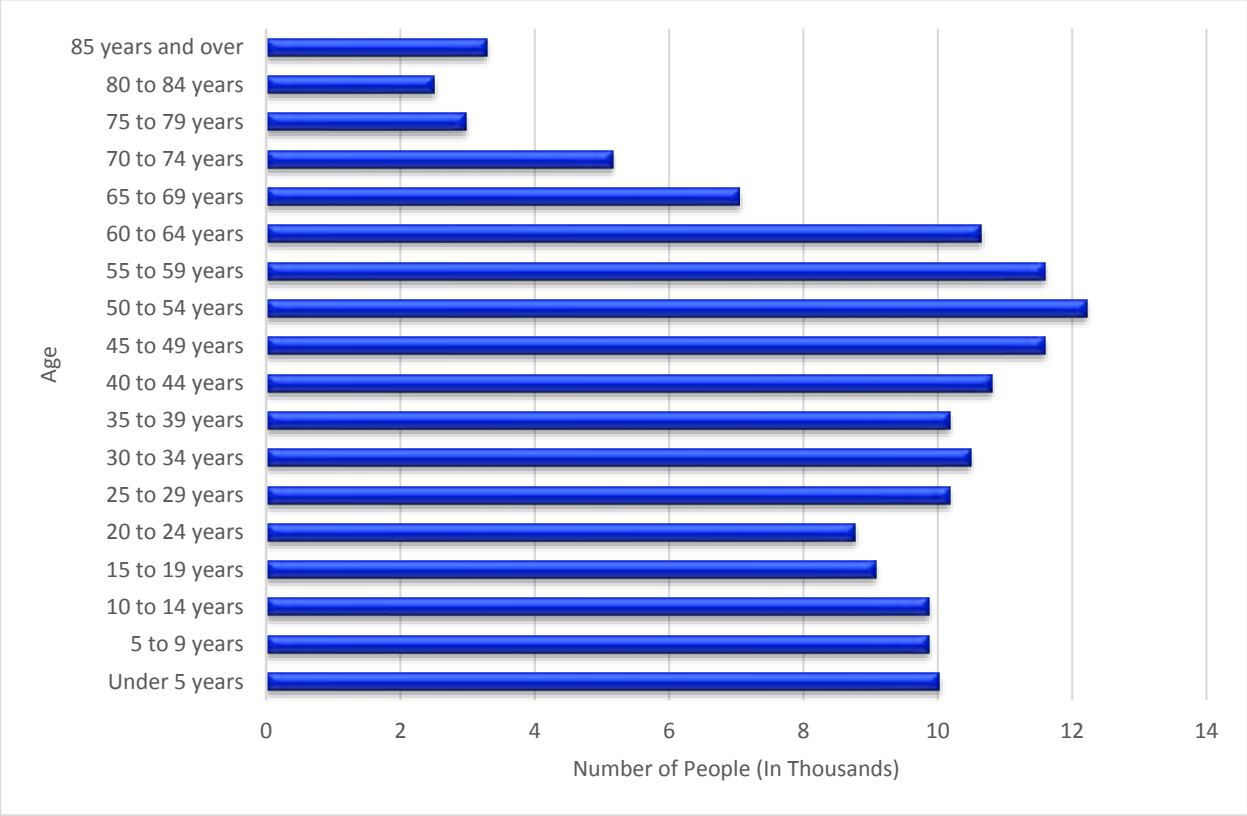


FIGURE 4-10. MAUI COUNTY AGE DISTRIBUTION

Based on U.S. Census 2010 Data

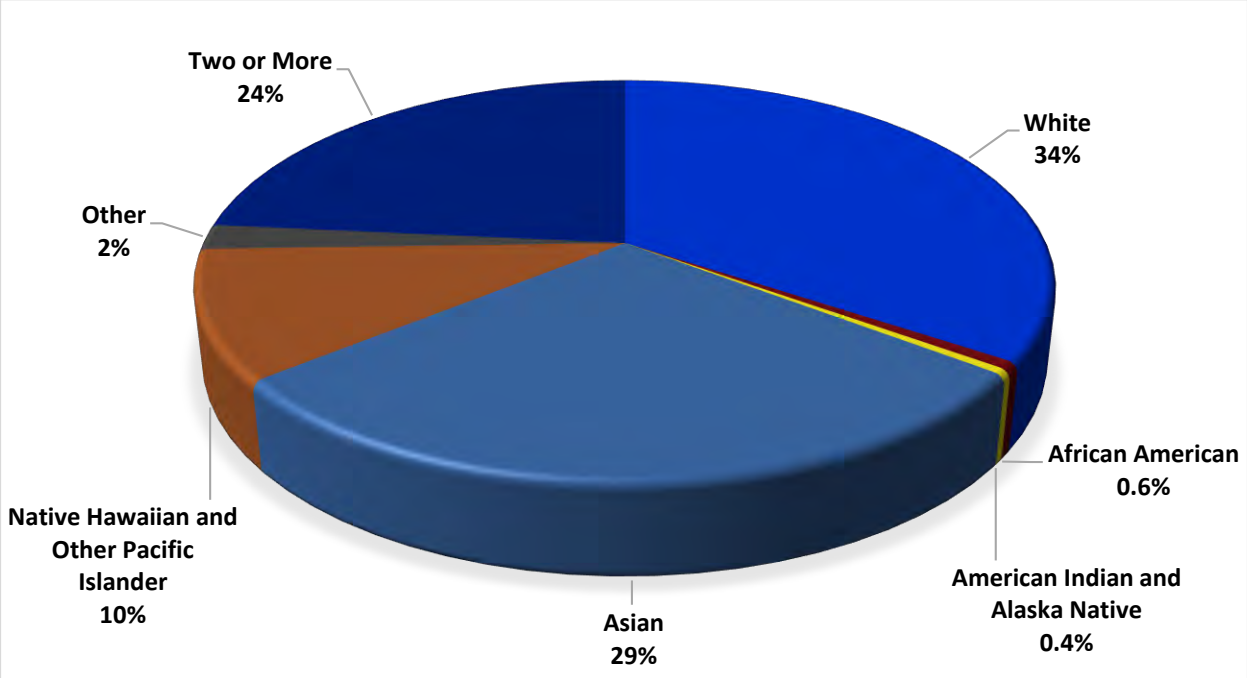


FIGURE 4-11. PLANNING AREA RACE DISTRIBUTION

4.7.4 Persons with Disabilities or with Access and Functional Needs

The 2010 U.S. Census estimates that 54 million non-institutionalized Americans with disabilities or with access and functional needs live in the U.S. This equates to about one in five persons. This population is more likely to have difficulty responding to a hazard event than the general population. Local government is the first level of response to assist these individuals, and coordination of efforts to meet their access and functional needs is paramount to life safety efforts. It is important for emergency managers to distinguish between functional and medical needs in order to plan for incidents that require evacuation and sheltering. Knowing the percentage of population with a disability will allow emergency management personnel and first responders to have personnel available who can provide services needed by those with access and functional needs.

According to the U.S. Census 2013 estimates, persons with disabilities or with access and functional needs make up nearly 10 percent of the total civilian non-institutionalized population of Maui County.

4.8 Economy

4.8.1 Income

In the United States, individual households are expected to use private resources to prepare for, respond to and recover from disasters to some extent. This means that households living in poverty are automatically disadvantaged when confronting hazards. Additionally, the poor typically occupy more poorly built and inadequately maintained housing. Mobile or modular homes, for example, are more susceptible to damage in earthquakes and floods than other types of housing. Furthermore, residents below the poverty level are less likely to have insurance to compensate for losses incurred from natural disasters. This means that residents below the poverty level have a great deal to lose during an

event and are the least prepared to deal with potential losses. The events following Hurricane Katrina in 2005 illustrated that personal household economics significantly impact people's decisions on evacuation. Individuals who cannot afford gas for their cars will likely decide not to evacuate.

Based on U.S. Census Bureau estimates, estimated per capita income in the planning area in 2013 was $29,517, and the median household income was $63,512. It is estimated that about 16.1 percent of households receive an income between $100,000 and $149,999 per year and nearly 14 percent of household incomes are above $150,000 annually. About 11 percent of the households in the planning area make less than $25,000 per year. According to the U.S. Census Bureau, 7 percent of households and 11 percent of individuals had income that fell below the poverty line. As presented in the State of Hawaii's *Self-Sufficiency Income Standard* (Hawaii Department of Business, Economic Development & Tourism, 2014), Maui County had the third lowest self-sufficiency income requirements for single-adult and two-adult couples, and the second lowest for family types with children. Table 4-8 illustrates the estimated self-sufficiency income requirements for 2013.

TABLE 4-8.
SELF-SUFFICIENCY INCOME REQUIREMENT – MAUI COUNTY (2013)

	One Adult	Two Adult Family	One Adult + One Preschooler	One Adult + One Preschooler + One School Age	Two Adult + One Preschooler + One School Age
Hourly	$16.27	$10.72	$25.64	$31.62	$17.81
Monthly	$2,864	$3,775	$4,513	$5,566	$6,268
Annual	$34,365	$45,296	$54,151	$66,791	$75,219

4.8.2 Industry, Businesses and Institutions

The Maui Economic Development Board was formed in the 1980s to assist the County of Maui in pursuing opportunities in high technology and other growing sectors. One of the achievements of the Board has been the development of the Maui Research and Technology Park in Kihei. The Economic Development Board worked with key legislators to secure State funding for this development (County of Maui, 2010a). Major educational and research institutions in the planning area today include University of Hawaii: Maui College, and the Maui Space Surveillance Site.

Maui County is also moving toward diversification of the tourism industry, including the enhancement of niche tourism. Two rapidly expanding areas include ecotourism and wellness tourism. Ecotourism emphasizes the interpretation of local ecosystems and culture and affords minimal visitation impact, commitment to local conservation issues, and direct benefits to local residents. Wellness tourism is travel for the purpose of enhancing mental, emotional, physical, and spiritual wellness. Niche tourism has potential to change the face of the tourism industry in Maui County (County of Maui, 2010a).

Maui County is dependent on off-shore sources for energy, food, construction materials, and common daily goods. The local community has expressed a desire to retool the County's economy to be more self-reliant. This would mean expanding agriculture, aquaculture, manufacturing, and renewable-energy sectors in the islands. By working toward

self-sufficiency, Maui County's economy could diversify and offer additional opportunities for employment and income (County of Maui, 2010a).

The planning area's economy today is strongly based in the entertainment/recreation industry (22.3 percent), followed by the education/health care/social assistance and retail trade industries. Information and wholesale trade make up the smallest source of the local economy. Figure 4-12 shows the breakdown of industry types in the planning area.

4.8.3 Employment Trends and Occupations

Business/science/arts occupations, service occupations, and sales/office occupations make up 28 percent, 28 percent and 25 percent of the jobs in the planning area respectively. Only about 9 percent of the employment in the planning area is in production/transportation/moving occupations (see Figure 4-13). The U.S. Census estimates that almost 71 percent of workers in the planning area commute alone (by car, truck or van) to work.

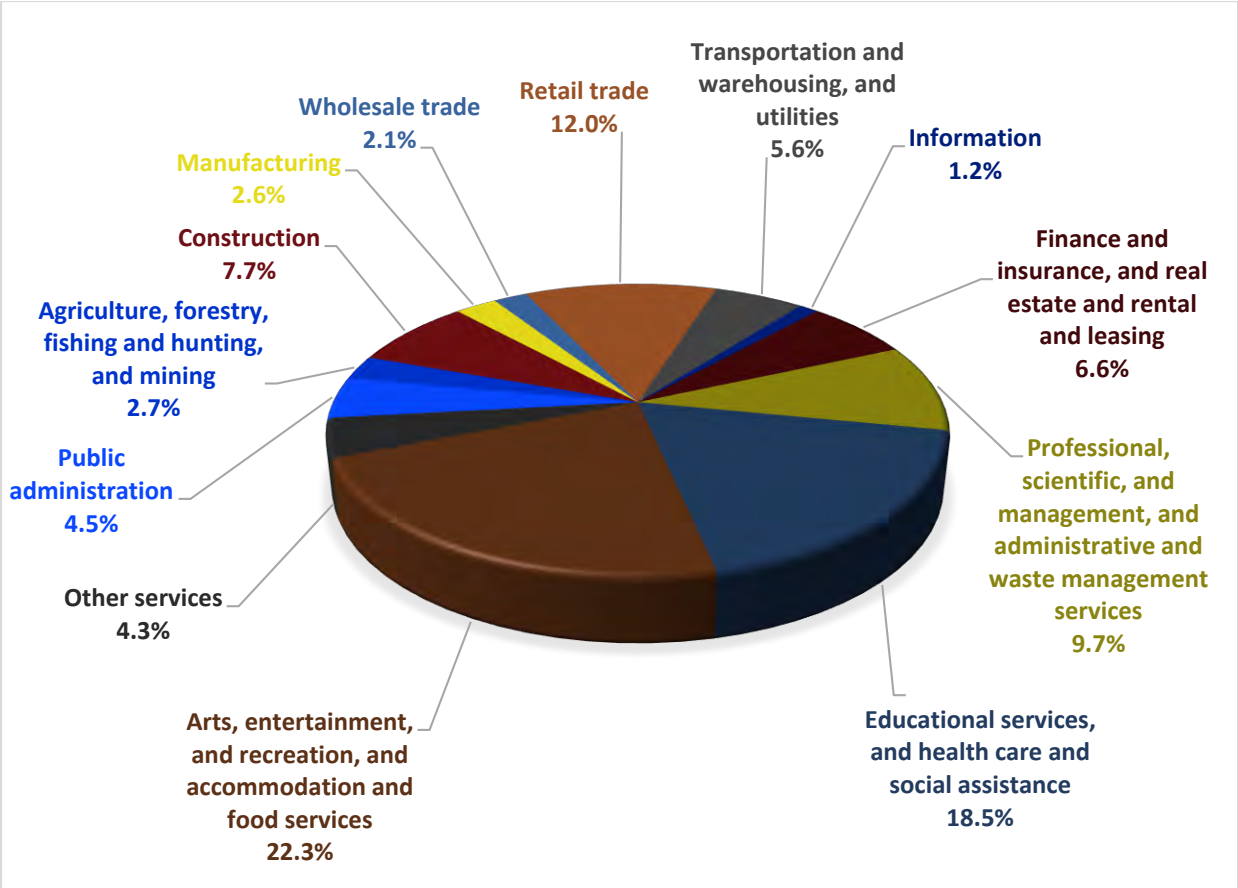


FIGURE 4-12. INDUSTRY IN THE PLANNING AREA

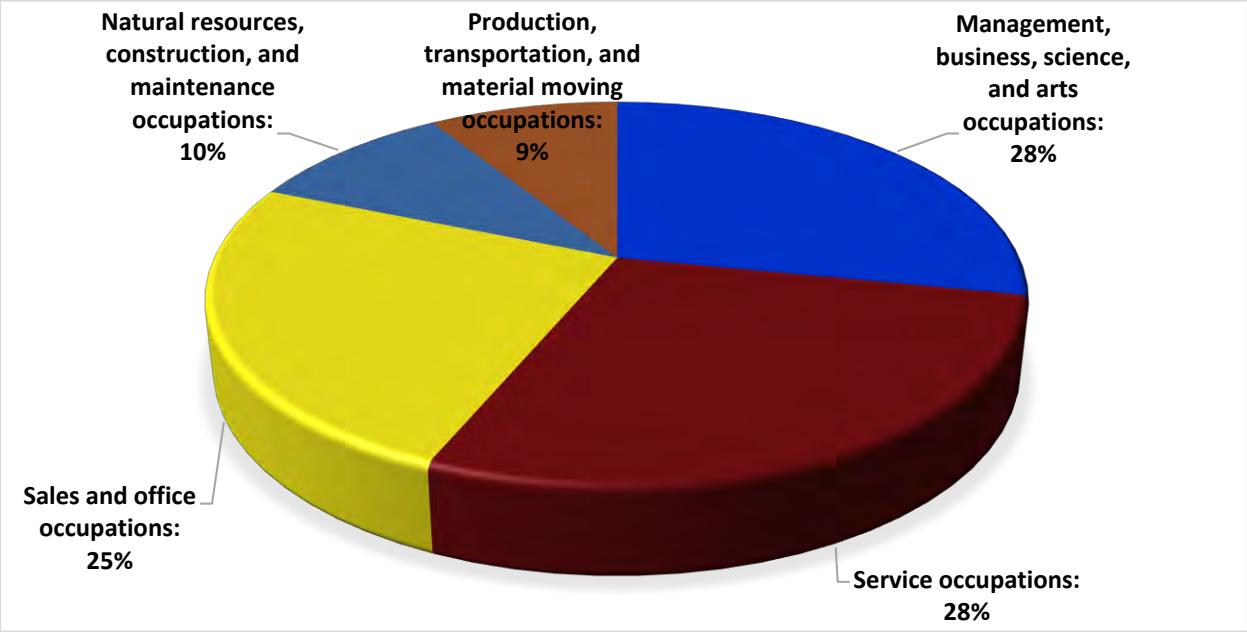


FIGURE 4-13. OCCUPATIONS IN THE PLANNING AREA (BASED ON U.S. CENSUS 5-YEAR ESTIMATES: 2009-2013)

Hawaii state data lists the following as the largest employers in Maui County (State of Hawaii, 2015a):

- Towne Realty of Hawaii
- Hale Makua
- Lodge At Koele
- Grand Wailea A Waldorf Astoria
- Tropica
- Dorvin D Leis Co. Inc.
- Ritz-Carlton-Kapalua
- Four Seasons-Lanai
- Kula Hospital
- Hyatt Regency
- Wailuku Elementary School
- Bayada Home Health Care
- Maui Brand Sugar
- Aloha Air Cargo
- PWC the People Who Clean
- Four Seasons-Maui
- Marriott-Maui Ocean Club
- Costco
- Maui Memorial Medical Center
- Sheraton-Resort & Spa
- Dole Food Co Inc.
- Westin-Maui Resort & Spa
- Kaiser Permanente
- Kaiser Permanente
- Four Seasons
- Cafe Kiowai
- Goodfellow Brothers Inc.
- Fairmont-Kea Lani
- Kaanapali Beach Hotel Hula
- Maui Canoe Club
- Makena Beach & Golf Resort
- PWC Hawaii Corp
- Aloha Mixed Plate
- Walmart
- Tiki Terrace Restaurant
- Old Lahaina Luau
- Kaanapali Beach Club
- Maui Electric Co Ltd
- Mama's Fish House Restaurant & Inn
- Royal Lahaina Resort
- Maui County Fire Department
- Baldwin High School
- Maui County Police Department
- Macy's
- Maui County Water Supply Board
- Marriott-Wailea Beach Resort
- Castle & Cooke Resorts LLC
- Home Depot
- Maui County Environmental Management
- Travaasa Hana
- Sheraton-Maui Resort & Spa
- Maui County Police Chief
- Aston Kaanapali Shores

According to the American Community Survey, about 69 percent of the planning area's population 16 and older is in the labor force. Figure 4-14 compares unemployment trends from the State of Hawaii and Maui County from 2005

through 2014. Maui County's unemployment rate was lowest in 2006, at 2.4 percent, rose to 8.7 percent in 2009, and has since fallen back, to 4.5 percent, in 2014. The state unemployment rate was slightly higher than the County's before 2007 and slightly lower after 2007.

Source: U.S. Bureau of Labor Statistics, 2015

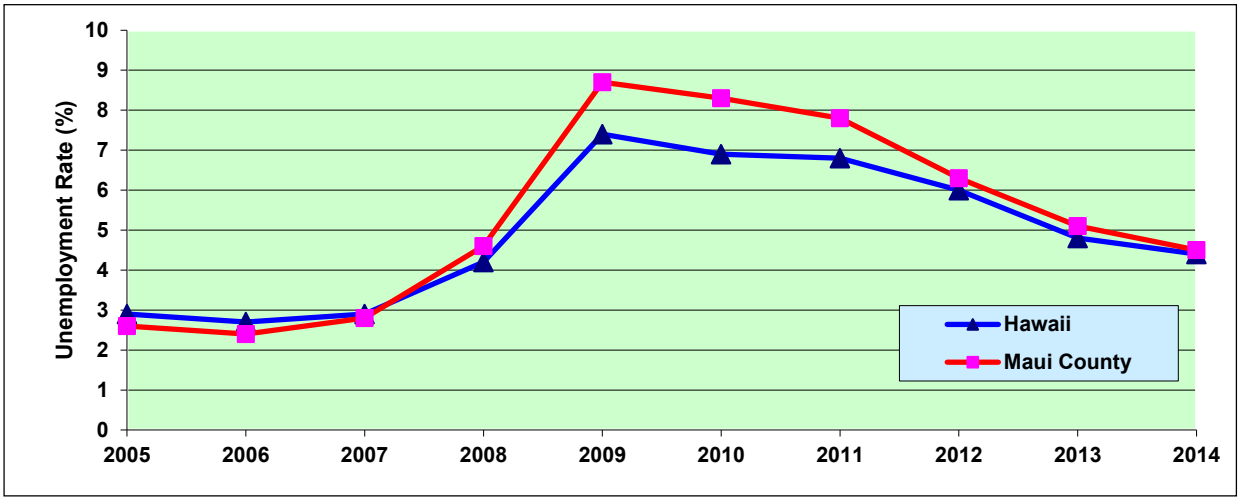


FIGURE 4-14. STATE OF HAWAII AND MAUI COUNTY UNEMPLOYMENT RATE

4.9 Future Trends in Development

The Maui County General Plan is a long-term comprehensive blueprint for the physical, economic, and environmental development and cultural identity of Maui County. The Countywide Policy Plan, adopted in 2010, provides goals, objectives, policies, and implementing actions for achieving the desired direction of the County's future. The Countywide Policy Plan provides a policy framework for the Maui Island Plan and the nine community plans (County of Maui, 2014). Decisions on land use will be governed by these planning documents. The hazard mitigation plan will work together with these programs to support wise land use in the future by providing vital information on the risk associated with natural hazards in the planning area. The results of the risk assessment will be integrated into the Natural Hazards Element of the community plans. This will ensure that all future trends in development can be established with the benefits of the information on risk and vulnerability to natural hazards identified in this plan.

4.10 Laws and Ordinances

Existing laws, ordinances and plans at the federal, state and local level can support or impact hazard mitigation initiatives identified in this plan. Hazard mitigation plans are required to include a review and incorporation, if appropriate, of existing plans, studies, reports, and technical information as part of the planning process, as stated in 44 CFR, Section 201.6(b)(3). Pertinent federal, state, and local laws are described below.

4.10.1 Federal

Disaster Mitigation Act

The DMA is the current federal legislation addressing hazard mitigation planning. It emphasizes planning for disasters before they occur. It specifically addresses planning at the local level, requiring plans to be in place before Hazard

Mitigation Grant Program funds are available to communities. This Plan is designed to meet the requirements of DMA, improving eligibility for future hazard mitigation funds.

Endangered Species Act

The federal Endangered Species Act (ESA) was enacted in 1973 to conserve species facing depletion or extinction and the ecosystems that support them. The act sets forth a process for determining which species are threatened and endangered and requires the conservation of the critical habitat in which those species live. The ESA provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The ESA outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species and contains exceptions and exemptions. It is the enabling legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Criminal and civil penalties are provided for violations of the ESA and the Convention.

Federal agencies must seek to conserve endangered and threatened species and use their authorities in furtherance of the ESA's purposes. The ESA defines three fundamental terms:

- **Endangered** means that a species of fish, animal or plant is "in danger of extinction throughout all or a significant portion of its range." (For salmon and other vertebrate species, this may include subspecies and distinct population segments.)
- **Threatened** means that a species "is likely to become endangered within the foreseeable future." Regulations may be less restrictive for threatened species than for endangered species.
- **Critical habitat** means "specific geographical areas that are essential for the conservation and management of a listed species, whether occupied by the species or not."

Five sections of the ESA are of critical importance to understanding it:

- **Section 4: Listing of a Species**—The National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) is responsible for listing marine species; the U.S. Fish and Wildlife Service is responsible for listing terrestrial and freshwater aquatic species. The agencies may initiate reviews for listings, or citizens may petition for them. A listing must be made "solely on the basis of the best scientific and commercial data available." After a listing has been proposed, agencies receive comment and conduct further scientific reviews for 12 to 18 months, after which they must decide if the listing is warranted. Economic impacts cannot be considered in this decision, but it may include an evaluation of the adequacy of local and state protections. Critical habitat for the species may be designated at the time of listing.
- **Section 7: Consultation**—Federal agencies must ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed or proposed species or adversely modify its critical habitat. This includes private and public actions that require a federal permit. Once a final listing is made, non-federal actions are subject to the same review, termed a "consultation." If the listing agency finds that an action will "take" a species, it must propose mitigations or "reasonable and prudent" alternatives to the action; if the proponent rejects these, the action cannot proceed.

- **Section 9: Prohibition of Take—**It is unlawful to "take" an endangered species, including killing or injuring it or modifying its habitat in a way that interferes with essential behavioral patterns, including breeding, feeding or sheltering.
- **Section 10: Permitted Take**—Through voluntary agreements with the federal government that provide protections to an endangered species, a non-federal applicant may commit a take that would otherwise be prohibited as long as it is incidental to an otherwise lawful activity (such as developing land or building a road). These agreements often take the form of a "Habitat Conservation Plan."
- **Section 11: Citizen Lawsuits**—Civil actions initiated by any citizen can require the listing agency to enforce the ESA's prohibition of taking or to meet the requirements of the consultation process.

The 2013 listing of 40 endangered plant and animal species in Maui County has several important implications for local plans and programs (Federal Register, 2013):

- The listing requires recovery actions, which generally require the participation of a broad range of partners, including federal and state agencies, nongovernmental organizations, businesses, and private landowners. Examples of recovery actions include habitat restoration, management of threats from predation, research, captive propagation and reintroduction, and outreach and education.
- Federal agencies must ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species or result in destruction or adverse modification of critical habitat.
- The listing establishes prohibitions that make the following illegal:
    - Unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting of the listed species
    - Activities that take or harm the three listed tree snail species by causing significant habitat modification or degradation that causes actual injury or significantly impairs essential behavioral patterns.
    - Damaging or destroying any of the 37 listed plants in violation of the Hawaii State law prohibiting the take of listed species.

The Clean Water Act

The federal Clean Water Act (CWA) employs regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's surface waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water."

Evolution of CWA programs over the last decade has included a shift from a program-by-program, source-by-source, and pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach, equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining water quality and other environmental goals is a hallmark of this approach.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) provides federally backed flood insurance in exchange for communities enacting floodplain regulations. Participation and good standing under NFIP are prerequisites to grant funding eligibility under the Robert T. Stafford Act. Maui County participates in the NFIP and has adopted regulations that meet the NFIP requirements. At the time of the preparation of this plan, Maui County was in good standing with NFIP requirements.

Coastal Zone Management Act

The national Coastal Zone Management Act requires federal agencies to conduct their planning, management, development, and regulatory activities in a manner consistent to the maximum extent practicable with the policies of state Coastal Zone Management (CZM) programs. State CZM lead agencies have the authority to review federal actions for consistency with their federally approved CZM programs. In Hawaii, the Office of Planning is the state CZM lead agency empowered to conduct federal consistency reviews. The informational and procedural requirements for CZM federal consistency reviews are prescribed by federal regulations (15 CFR 930).

Because there is a significant federal presence in Hawaii, CZM federal consistency is a valuable state management tool. Federal planning, regulatory, and construction activities have direct and significant effects on land and water uses throughout the state. Federal agencies issue permits for a number of coastal activities and developments, and they control vast tracts of land. The range of federal activities and permits reviewed is extensive and includes harbor projects, beach nourishment projects, military facilities and training exercises, fisheries management plans and regulations, open ocean aquaculture, and dredge and fill operations.

National Incident Management System

The National Incident Management System (NIMS) is a systematic approach for government, nongovernmental organizations, and the private sector to work together to manage incidents involving hazards. The NIMS provides a flexible but standardized set of incident management practices. Incidents typically begin and end locally, and they are managed at the lowest possible geographical, organizational, and jurisdictional level. In other instances, success depends on the involvement of multiple jurisdictions, levels of government, functional agencies, and emergency-responder disciplines. These instances necessitate coordination across this spectrum of organizations. Communities using NIMS follow a comprehensive national approach that improves the effectiveness of emergency management and response personnel across the full spectrum of potential hazards (including natural hazards, terrorist activities, and other human-caused disasters) regardless of size or complexity.

Americans with Disabilities Act and Amendments

The Americans with Disabilities Act (ADA) seeks to prevent discrimination against people with disabilities in employment, transportation, public accommodation, communications, and government activities. The most recent amendments became effective in January 2009 (P.L. 110-325). Title II of the ADA deals with compliance with the Act in emergency management and disaster-related programs, services, and activities. It applies to state and local governments as well as third parties, including religious entities and private nonprofit organizations.

The ADA has implications for sheltering requirements and public notifications. During an emergency alert, officials must use a combination of warning methods to ensure that all residents have any necessary information. Those with hearing impairments may not hear radio, television, sirens, or other audible alerts, while those with visual impairments may

not see flashing lights or visual alerts. Two stand-alone technical documents have been issued for shelter operators to meet the needs of people with disabilities. These documents address physical accessibility as well as medical needs and service animals.

The ADA also intersects with disaster preparedness programs in regards to transportation, social services, temporary housing, and rebuilding. Persons with disabilities may require additional assistance in evacuation and transit (e.g., vehicles with wheelchair lifts or paratransit buses). Evacuation and other response plans should address the unique needs of residents. Local governments may be interested in implementing a special-needs registry to identify the home addresses, contact information, and needs for residents who may require more assistance.

4.10.2 State

State of Hawaii Land Use Law

The Hawaii State Legislature adopted the State Land Use Law (Chapter 205, Hawaii Revised Statutes) in 1961. The Land Use Commission administers statewide zoning established in the State Land Use law. The law classifies lands throughout the state into one of four districts:

- The Urban District generally includes lands characterized by "city-like" concentrations of people, structures and services. This district also includes vacant areas for future development. Jurisdiction of this district lies primarily with counties.
- The Rural District consists primarily of small farms intermixed with low-density residential lots with a minimum size of 0.5-acre. The Land Use Commission and County governments share jurisdiction over rural districts. Permitted uses include those relating or compatible with agricultural use and low-density residential lots.
- The Agricultural District includes land with significant potential for agriculture uses as well as lands used for the cultivation of crops, aquaculture, raising livestock, wind energy generation, timber cultivation, and agriculture-support (mills, employee quarters, etc.). Uses permitted in the highest productivity agricultural categories (A or B) are governed by statute. Uses in lower-productivity categories (C, D, E, or U) include those allowed on A or B lands as well as uses stated under Section 205-4.5, Hawaii Revised Statutes.
- The Conservation District consists primarily of lands in existing forest and water reserve zones. These include areas necessary for protecting watersheds and water sources; scenic and historic areas; parks, wilderness, open space and recreational areas; habitats of endemic plants, fish and wildlife; submerged lands seaward of the shoreline; and lands subject to flooding and soil erosion. The State Board of Land and Natural Resources administrates conservation districts.

State Building Code and Design Standards

In 2007, the State Legislature created State Building Code Council with the authority to establish codes applicable to all construction in the state of Hawaii (Chapter 107, Hawaii Revised Statues). The State Building Code Council evaluates model building codes and develops amendments necessary to make the codes appropriate for Hawaii conditions. Once the Council develops and approves a Hawaii code, it is legally adopted into the Hawaii Administrative Rules (HAR). Counties have 2 years from the date of establishment of the HAR State Building Code to adopt the Hawaii State Building Code as local county code, with the addition of any locally approved county amendments. The process has successfully enabled a unified set of nearly comprehensive building codes to be adopted by the state and the counties.

Ocean Resources Management Plan

The Ocean Resources Management Plan is a comprehensive plan for conservation and sustainability of ocean and coastal resources (Chapters 205A and 225M, Hawaii Revised Statues). Hawaii is facing pressures that will have a significant impact on ocean and coastal environments, including urbanization, tourism, recreational and commercial ocean uses, sea level rise and other natural hazards to include beach erosion, inundation of land, increased flood and storm damage, saltwater intrusion into the freshwater lens aquifer, the rising of the water table, and more frequent or more powerful weather events, marine debris, and invasive species. The Ocean Resources Management Plan was updated in 2013 to address these issues.

Hawaii Coastal Zone Management Program

In response to the federal Coastal Zone Management Act, the State of Hawaii established its coastal zone management program in 1977 (Chapter 205A, Hawaii Revised Statutes). Managed by the State Office of Planning, Hawaii's CZM program provides a common focus for state and county actions dealing with land and water uses and activities. Under the CZM program, agencies must look at resources from a broader ecosystem perspective instead of individual species or resources. The CZM law builds upon the authorities and responsibilities of state and county agencies to form a network based on legal and operational compliance with the law's objectives and policies. All agencies must ensure that their statutes, ordinances, rules, and actions comply with the CZM objectives and policies (State of Hawaii Office of Planning, 2015).

The CZM area encompasses the entire state because there is no point of land more than 30 miles from the ocean. What occurs on land, even on the mountains, impacts and influences the quality of coastal waters and marine resources. The CZM area extends seaward to the limit of the State's police power and management authority, to include the territorial sea. This legal seaward boundary definition is consistent with Hawaii's historical claims over the Hawaiian archipelagic waters, based on ancient transportation routes and submerged lands.

State General Flood Control Plan

As authorized by the Hawaii Revised Statutes Chapter 179 Flood Control and Flood Water Conservation, the State General Flood Control Plan (SGFCP) serves as a guide for linking partnering agencies and community groups. The plan provides these stakeholders with the data and tools required to strategize flood improvement needs and goals.

The SGFCP is currently being revised as of July 2015. A key benefit of the updated SGFCP will be the ability for all stakeholders to view and analyze flood-prone areas and/or flood mitigation needs. The updated SGFCP will also enable users to locate project partners and build on current or previously completed flood improvement efforts. A goal of the plan update is to increase each stakeholder's ability to complete projects by integrating best practices and lessons learned from other partner agencies and through resource sharing.

4.10.3 Local

General Plan 2030

The Maui County General Plan is a long-term comprehensive blueprint for the physical, economic, environmental development and cultural identity of Maui County. The Countywide Policy Plan, adopted in 2010, provides goals, objectives, policies, and implementing actions for achieving the desired direction of the County's future. The

Countywide Policy Plan provides a policy framework for the Maui Island Plan and the nine community plans (County of Maui, 2014):

- The Maui Island Plan, adopted in 2012, establishes urban and rural growth areas that indicate where development is intended and will be supported on the Island of Maui. Growth areas will provide for less costly services, reduced commuting, protection of community character and the preservation of agriculture, open space and cultural and natural resources. The plan outlines goals, policies, programs and actions based on an assessment of current and future needs and available resources. It is the principal tool for the County and its citizens to use when evaluating public and private projects on the Island of Maui and their impacts on land use, the economy, environment, infrastructure and cultural resources.
- Each of nine community plans provides recommendations concerning land use, density and design, transportation, community facilities, infrastructure, visitor accommodations, commercial and residential areas and other matters related to development that are specific to the region of the plan. The following community plans have been prepared:
    - Kihei – Makena (1998)
    - Paia – Haiku (1995)
    - Wailuku – Kahului (2002)
    - Makawao - Pukalani – Kula (1996)
    - Hana (1994)
    - West Maui (1996)
    - Lanai (1998)
    - Molokai (2001)
    - Kahoolawe (1995).

Comprehensive Zoning Ordinance

The County of Maui Code of Ordinances (Title 19 – Zoning) establishes a Comprehensive Zoning Ordinance (Article II) to regulate land use in a manner encouraging orderly development. The ordinance intends to promote the health, safety, and welfare of the people of the County through the following:

- Guiding, controlling and regulating future growth and development in accordance with the general plan and community plans of the County.
- Regulating the location and use of buildings and land adjacent to streets and thoroughfares to lessen the danger and inconvenience to the public caused by undue interference with existing or prospective traffic movements on streets and thoroughfares;
- Regulating the location, use or design of sites and structures in order to minimize adverse effects on surrounding uses, prevent undue concentrations of people, provide for adequate air, light, privacy, and the convenience of access to property, and secure the safety of the public from fire and other dangers;
- Encouraging designs which enhance the physical form of the various communities of the County;
- Stabilizing the value of property;
- Encouraging economic development, which provides desirable employment and enlarges the tax base.

- Promoting the protection of historic areas, cultural resources and the natural environment;
- Encouraging the timeliness of development in conjunction with the provision of public services which include, but are not limited to, police, fire, flood protection, transportation, water, sewerage, drainage, schools, recreational facilities, health facilities and airports.

The Comprehensive Zoning Ordinance divides the lands in the County into the following 13 Use Zone Districts:

- Residential
- Multiple-Family
- Hotel
- Business
- Industrial
- Airport
- Agricultural
- Off-Street Parking and Loading
- Planned Development
- Civic Improvement
- Park
- Rural
- Open Space.

Some Use Zone Districts are further subdivided into subzones according to parameters specific to each zone. The different Use Zone Districts and their boundaries are specified in maps entitled "Land Zoning Maps" on file in the office of the County clerk with certified copies on file with the County Planning Department. To complement the maps, the Comprehensive Zoning Ordinance delineates the permitted uses, special uses, area regulations, height regulations, setback lines, etc. for each Use Zone Districts.

To complement the Comprehensive Zoning Ordinance, Title 19 – Zoning of the County of Maui Code also includes and Ordinance for the Maui County Historic Districts (Article III) and for the Regulation of Miscellaneous Areas (Article IV). The purpose of the Maui County Historic Districts Ordinance is to promote the preservation of the County's history and culture by regulating the demolition and movement of existing structures and the architectural styles of new structures. The ordinance establishes three historic districts numbered from 1 to 3. Historic Districts 1 and 2 include areas of the town of Lahaina on the Island of Maui. Similarly, Historic District 3 encompasses areas of the town of Wailuku, also on the Island of Maui.

The Regulation of Miscellaneous Areas Ordinance, on the other hand, aims at regulating special areas and conditions such as areas with significant vistas, areas within flood or tsunami inundation zones, and areas within specific project districts (i.e. Lahaina, Wailuku- Kahului, Kihei-Makena, and Kapalua on the Island of Maui and Manele and Koele on the Island of Lanai).

Capability Assessment

The planning team performed an inventory and analysis of existing authorities and capabilities called a "capability assessment." A capability assessment creates an inventory of an agency's mission, programs and policies, and evaluates its capacity to carry them out. An assessment of legal and regulatory capabilities is presented in Table 4 9. An assessment of fiscal capabilities is presented in Table 4 10. An assessment of administrative and technical capabilities is presented in Table 4 11. Information on National Flood Insurance Program (NFIP) compliance is presented in Table 4 12. Classifications under various community mitigation programs are presented in Table 4 13.

TABLE 4-9.
LEGAL AND REGULATORY CAPABILITY

	Local Authority	State or Federal Prohibitions	Other Jurisdiction Authority	State Mandated
Codes, Ordinances & Requirements				
Building Code	Yes	No	No	Yes
Comments: Maui County Code, Title 16: Buildings and Construction – Chapter 16.26B – Building Code, International Building Code 2006 as amended (last updated Ord. No. 3928, § 3, 2012)				
Zoning Code	Yes	No	No	Yes
Comments: Maui County Code, Title 19 – Zoning, Article 1. Interim Zoning Provisions (Ord. No. 3661, § 2, 2009), Article II. Comprehensive Zoning Provisions (last updated Ord. No. 4088, §§ 1—6, 2013)				
Subdivisions	Yes	No	No	No
Comments: Maui County Code Title 18 – Subdivisions (last updated Ord. No. 4053, § 1, 2013)				
Stormwater Management	Yes	No	No	Yes
Comments: Maui County Code, Title 18, Chapter 20.135 – Post-construction stormwater quality best management practices (Last updated Ord. No. 4053, § 34, 2013); Title 16, Chapter 26B.3900 – Post-construction Stormwater Quality Best Management Practices (last updated Ord. No. 3928, § 3, 2012)				
Post-Disaster Recovery	Yes	No	No	No
Comments: Hawaii Revised Statues Title 10. Public Safety and Internal Security, 127; Title 13. Planning and Economic Development, 209				
Real Estate Disclosure				
Comments: Hawaii Revised Statues Title 28. Property, 508D; Special Flood Hazard Area and Tsunami Inundation Area Disclosure				
Growth Management	Yes	No	No	Yes
Comments: Hawaii Revised Statues Title 13. Planning and Economic Development, 223 and 226				
Site Plan Review	Yes	No	No	No
Comments: Maui County Code, Title 12 – Landscape Planting and Beautification (last updated Ord. 2268 § 2, 1993); Title 16 – Buildings and Construction, Chapter 16.26B Building Code (last updated Ord. No. 3928, § 3, 2012)				
Public Health and Safety	Yes	No	No	Yes
Comments: Maui County Code, Title 8 – Health and Safety				
Environmental Protection	Yes	No	No	Yes
Comments: Maui County Code, Title 20 – Environmental Protection; Hawaii Revised Statues Title 19. Health, 344				
Climate Change Adaptation	No	No	Yes	Yes
Comments: Hawaii State Legislature, Act 286, 2012; Act 234, 2007				
Planning Documents				
General or Comprehensive Plan	Yes	No	No	Yes
Is the plan equipped to provide linkage to this mitigation plan? Yes, Natural Hazard Elements				
Comments: General Plan 2030: Countywide Policy Plan, Maui Island Plan, Community Plans				
Capital Improvement Plan	Yes	No	Yes	
What types of capital facilities does the plan address? All public infrastructure meeting the criteria: a permanent improvement or betterment as distinguished from ordinary repair or current maintenance				
How often is the plan updated? Annually, 6-year timeframe				
Comments: Maui County Code Title 3, Chapter 3.04.040 – Capital Program (last updated Ord. 1731 § 1 (part), 1988: Ord. 1438 § 2 (part), 1984)				

TABLE 4-9.
LEGAL AND REGULATORY CAPABILITY

	Local Authority	State or Federal Prohibitions	Other Jurisdiction Authority	State Mandated
Floodplain Management Plan	Yes	No	No	No
Comments: Maui County Multi-Hazard Mitigation Plan 2015 will serve as a CRS-credited Floodplain Management Plan				
Stormwater Plan	Yes	Yes	No	Yes
Comments: *Maui Storm Water Management Program Plan; prepared in accordance with Hawaii Administrative Rules, Chapter 11-55 Appendix K for Kahului, Maui – File No. HI 14KE352*				
Habitat Conservation Plan	Yes	No	Yes	Yes
Comments: Approved Habitat Conservation Plans online at: http://dlnr.hawaii.gov/wildlife/hcp/approved-hcps/ Draft Habitat Conservation Plans online at: http://dlnr.hawaii.gov/wildlife/hcp/draft-hcps/				
Economic Development Plan	Yes	No	No	
Comments: Maui General Plan 2030, Economic Development Elements; Hawaii Comprehensive Economic Development Strategy, 2010				
Shoreline Management Plan	Yes	No	Yes	Yes
Comments: Hawaii Coastal Zone Management Program; Ocean Resources Management Plan, July 2013; Shoreline Access Inventory Update, March 2005; Beach Management Plan, June 2008				
Community Wildfire Protection Plan	Yes	No	No	No
Comments: West Maui Community Wildfire Protection Plan, June 2014; Upcountry/Central Maui and South Maui plans in development				
Climate Change	No	No	Yes	No
Comments: Climate Change Impacts in Hawaii: A summary of Climate Change and Its Impacts to Hawaii Ecosystems and Communities, 2014				
Response/Recovery Planning				
Emergency Operations Plan	Yes	No	No	Yes
Comments: County of Maui Emergency Operations Plan, 2009				
Threat & Hazard Identification & Risk Assessment	Yes	No	No	Yes
Comments: Maui County THIRA				
Catastrophic Hurricane Framework	Yes	No	No	No
Comments: County of Maui Catastrophic Hurricane Response Framework, 2014				
Post-Disaster Recovery Plan	Yes	No	No	No
Comments: Post-Disaster Reconstruction Guidelines and Protocols for Conservation of Coastal Resources and Protection of Coastal Communities; Natural Disaster Economic Recovery Strategy, December 2014				

TABLE 4-10.
FISCAL CAPABILITY

Financial Resources	Accessible or Eligible to Use?
Community Development Block Grants	Yes
Capital Improvements Project Funding	Yes
Authority to Levy Taxes for Specific Purposes	Yes
User Fees for Water, Sewer, Gas or Electric Service	Yes: Sewer, Water
Incur Debt through General Obligation Bonds	Yes
Incur Debt through Special Tax Bonds	Yes

TABLE 4-10.
FISCAL CAPABILITY

Financial Resources	Accessible or Eligible to Use?
Incur Debt through Private Activity Bonds	No
Withhold Public Expenditures in Hazard-Prone Areas	**No**
State-Sponsored Grant Programs	**Yes**
Development Impact Fees for Homebuyers or Developers	**Yes**
Other	**NA**

TABLE 4-11.
ADMINISTRATIVE AND TECHNICAL CAPABILITY

Staff/Personnel Resources	Available?	Department/Agency/Position
Planners or engineers with knowledge of land development and land management practices	Yes	Maui County Planning Department; Development Services Administration, Maui County Department of Public Works
Engineers or professionals trained in building or infrastructure construction practices	Yes	Development Services Administration, Maui County Department of Public Works
Planners or engineers with an understanding of natural hazards	Yes	Maui County Planning Department
Staff with training in benefit/cost analysis	Yes	Maui County Civil Defense
Surveyors	Yes	Engineering Division, Maui County Department of Public Works
Personnel skilled or trained in GIS applications	Yes	Maui County GIS Program – Geographic Analysis and Cartographic Services Pacific Disaster Center
Scientist familiar with natural hazards in local area	Yes	Pacific Disaster Center
Emergency manager	Yes	Emergency Management Officer, Maui County Civil Defense Agency
Grant writers	Yes	Grants Management Division, Housing and Human Concerns

TABLE 4-12.
NATIONAL FLOOD INSURANCE PROGRAM COMPLIANCE

What local department is responsible for floodplain management?	Department of Planning
Who is your floodplain administrator? (Department/position)	Planning/Floodplain Manager
Are any certified floodplain managers on staff in your jurisdiction?	Yes
What is the date of adoption of your flood damage prevention ordinance?	Title 19, Chapter 19.62 (Ord. 2223 § 1 (part), 1993: Ord. 1145 § 2 (part), 1981)
When was the most recent Community Assistance Visit or Community Assistance Contact?	6/15/2015
Does your jurisdiction have any outstanding NFIP compliance violations that need to be addressed?	No

TABLE 4-12. NATIONAL FLOOD INSURANCE PROGRAM COMPLIANCE	
• If so, please state what they are.	NA
Do your flood hazard maps adequately address the flood risk within your jurisdiction?	Yes
• If no, please state why.	NA
Does your floodplain management staff need any assistance or training to support its floodplain management program?	No
• If so, what type of assistance/training is needed?	NA
Does your jurisdiction participate in the Community Rating System (CRS)?	Yes
• If so, is your jurisdiction seeking to improve its CRS Classification?	Yes
• If not, is your jurisdiction interested in joining the CRS program?	N/A

TABLE 4-13.
COMMUNITY CLASSIFICATIONS

	Participating?	Classification	Date Classified
Community Rating System	Yes	8	10/1/2000
Building Code Effectiveness Grading Schedule	No	99/99	N/A
Public Protection	No	99/99	N/A
StormReady	Yes	StormReady	11/29/2001
TsunamiReady	Yes	TsunamiReady	11/29/2004
Firewise	No	N/A	N/A

PART 2 – RISK ASSESSMENT

Chapter 5. Identified Hazards of Concern and Risk Assessment Methodology

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. It allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets. The process focuses on the following elements:

- **Hazard identification**—Use all available information to determine what types of disasters may affect a jurisdiction, how often they can occur, and their potential severity.
- **Vulnerability identification**—Determine the impact of natural hazard events on the people, property, environment, economy and lands of the region.
- **Cost evaluation**—Estimate the cost of potential damage or cost that can be avoided by mitigation.

The risk assessment for this hazard mitigation plan update evaluates the risk of natural hazards prevalent in the planning area and meets requirements of the DMA (44 CFR, Section 201.6(c)(2)).

5.1 Identified Hazards of Concern

For this plan, the Steering Committee considered the full range of natural hazards that could impact the planning area and then listed hazards that present the greatest concern. The process incorporated review of state and local hazard planning documents, as well as information on the frequency, magnitude and costs associated with hazards that have impacted or could impact the planning area. Anecdotal information regarding natural hazards and the perceived vulnerability of the planning area's assets to them was also used. Based on the review, this plan addresses the following hazards of concern (hazards were profiled in alphabetical order, therefore the listing of the hazard has no relevance on the hazard's severity or level of concern):

- Coastal erosion
- Dam and reservoir failure
- Drought
- Earthquake
- Flood
- High surf
- High wind storm
- Landslide, debris flow, and rockfall
- Tropical cyclone
- Tsunami
- Volcanic hazards
    - Lava
    - VOG.
- Wildfire

With the exception of dam failure, technological hazards (e.g., nuclear radiation) and human-caused hazards (e.g., terrorist acts) are not addressed as stand-alone hazards in this plan. Where appropriate, discussion on the location of hazardous material facilities and the potential for releases as a secondary impact of natural hazard events in included in each hazard profile.

5.2 Risk Assessment Tools

5.2.1 Mapping

A review of national, state, and county databases was performed to locate available spatially based data relevant to this planning effort. Maps were produced using GIS software to show the spatial extent and location of identified hazards when such data were available. These maps are included in the hazard profile chapters of this document. Information regarding the data sources and methodologies employed in these mapping efforts is located in Appendix D.

5.2.2 Hazus-MH

Overview

In 1997, the Federal Emergency Management Agency (FEMA) developed the standardized Hazards U.S.-Multi-Hazard (Hazus-MH) model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. Hazus-MH was later expanded into a multi-hazard methodology, Hazus-MH, with new models for estimating potential losses from hurricanes and floods.

Hazus-MH is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facility, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- Provides a consistent methodology for assessing risk across geographic and political entities.
- Provides a way to save data so that it can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
- Facilitates the review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
- Supports grant applications by calculating benefits using FEMA definitions and terminology.
- Produces hazard data and loss estimates that can be used in communication with local stakeholders.
- Is administered by the local government and can be used to manage and update a hazard mitigation plan throughout its implementation.

Levels of Detail for Evaluation

Hazus-MH provides default data for inventory, vulnerability and hazards; this default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about the planning area:

- **Level 1**—All of the information needed to produce an estimate of losses is included in the software's default data. This data is derived from national databases and describes in general terms the characteristic parameters of the planning area.
- **Level 2**—More accurate estimates of losses require more detailed information about the planning area. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics and building inventory, as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3**—This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical information to customize it for the planning area.

5.3 Overall Risk Assessment Approach

The risk assessments in Chapter 8 through Chapter 18 describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and probable event scenarios. The following steps were used to define the risk of each hazard:

- Identify and profile each hazard—The following information is given for each hazard:
  - Geographic areas most affected by the hazard
  - Event frequency estimates
  - Severity estimates
  - Warning time likely to be available for response.
- Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with an inventory of structures, facilities, and systems to determine which of them would be exposed to each hazard.
- Assess the vulnerability of exposed facilities—Vulnerability of exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and assessing structures, facilities, and systems that are exposed to each hazard. Tools such as geographic information systems (GIS) and FEMA's hazard-modeling program called Hazus-MH (Hazus-MH) were used to perform this assessment for the dam failure, flood, earthquake and tropical cyclone hazards. Outputs similar to those from Hazus-MH were generated for other hazards, using maps generated through GIS.

5.3.1 Dam and Reservoir Failure, Earthquake, Flood and Tropical Cyclone

The following hazards were evaluated using Hazus-MH:

- **Dam and Reservoir Failure**—A Level 2 general building stock analysis of mapped dam failure evacuation areas was run. The building exposure for each evacuation area was analyzed, and the evacuation areas with the highest, non-overlapping exposure values were selected for further analysis in Hazus-MH (two on Maui and one on Molokai). Depth grids for the evacuation area were generated and integrated into the Hazus-MH model. It is important to note that the level of analysis for this hazard was assessed at the evacuation, rather than inundation, level. This is likely to have overstated the risk for any singular dam or reservoir failure event.
- **Earthquake**—A Level 2 analysis was performed to assess earthquake exposure and vulnerability for two scenario events and two probabilistic events:

- A Magnitude-7.0 event approximately 5 miles north of the Island of Lanai in the Kalohi Channel (Scenario Earthquake 1)
- A Magnitude-7.0 event approximately 32 miles northeast east of Kahului (Scenario Earthquake 2)
- The standard Hazus-MH 100- and 500-year probabilistic events.

- **Flood**—A Level 2, general building stock analysis was performed. Depth grids were generated from the Flood Insurance Study dated August 8, 2014. This study incorporated data relevant for the flood, high surf, tsunami, and tropical cyclone hazards. Additional discussion is available in each respective chapter.
- **Tropical Cyclone**—A Level 2 analysis was performed to assess tropical cyclone exposure and vulnerability for the 50-, 100- and 500-year probabilistic events. The probabilistic scenarios available in Hazus-MH assess wind only scenarios. It is likely that damages are underestimated as a result of the lack of flood-related damage available for these probabilistic events.

5.3.2 Landslide, Tsunami, Volcano, Coastal Erosion, High Wind Storm, and Wildfire

For most of the hazards of concern, historical data were not adequate to model future losses. However, areas and inventory susceptible to some of the hazards of concern were mapped by other means and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment.

5.3.3 Drought

The risk assessment methodologies used for this plan focus on damage to structures. Because drought does not impact structures, the risk assessment for drought was more limited and qualitative than the assessment for the other hazards of concern.

5.4 Sources of Data Used in Hazus-MH Modeling

5.4.1 Building Counts

GIS building and assessor data (replacement cost values and detailed structure information) were loaded into Hazus-MH, along with structure dates of construction. When available, an updated inventory was used in place of the Hazus-MH defaults for critical facilities and assets.

There were about 24,000 records in the available data that had a unique assessor value but used the same map key as other records. The assumption was made that these records are multi-family or multi-use complexes, including time shares. Rather than load them as individual buildings, a frequency analysis was run on the map key and summaries were developed of square footage, building value, and content value. For example, the data included 459 records for the Lahaina Marriott Resort, but these records were merged and loaded into Hazus-MH as a single building. Using this approach, the 24,000 records were reduced to 273 buildings.

5.4.2 Hazus-MH Data Inputs

The following data sources were used to update the Hazus-MH inventory for the Level 2 analysis conducted for the risk assessment

- **Flood**—GIS building and assessor data (replacement cost values derived from RS Means and detailed structure information) provided by Maui County were loaded into Hazus-MH. An updated inventory was used in place of the Hazus-MH defaults for essential facilities, transportation and utilities. Current planning area digital Flood Insurance Rate Maps (DFIRMs) were used to delineate flood hazard areas and estimate potential losses from the 100-year flood event. Using the DFIRM floodplain boundaries, NOAA 3-meter coastal digital elevation model (DEM), and USGS 10-meter DEM data, flood depth grids were generated and integrated into the Hazus-MH model.
- **Dam and Reservoir Failure**—Dam failure evacuation area mapping for the planning area was collected where available. USGS 10-meter DEM data were used to develop depth grids. The updated building stock and facilities data were the same as used for the flood risk assessment.
- **Earthquake**—Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. An updated general building stock inventory was developed using replacement cost values and detailed structure information from assessor tables. An updated inventory of essential facilities, transportation and utility features was used in place of the Hazus-MH defaults. A National Earthquake Hazard Reduction Program (NEHRP) soils map was also integrated into the Hazus-MH model.
- **Tropical Cyclone**—Probabilistic data contained in Hazus-MH was used for the analysis of this hazard. An updated general building stock inventory was developed using replacement cost values and detailed structure information from assessor tables. An updated inventory of essential facilities, transportation and utility features was used in place of the Hazus-MH defaults.

5.4.3 Other Local Hazard Data

Locally relevant information on hazards was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, emergency management specialists and others. Data sources for specific hazards were as follows:

- **Landslide**—A dataset for landslide probability areas was created by intersecting slope data with NEHRP soils data. Three landslide probability classifications were created: high (greater than 30 percent slope, D type soils), moderate (15-30 percent slope, D type soils), and low (0-15 percent slope, D type soils). The slope data were generated from the USGS 10-meter DEM. The NEHRP soils data were generated using the USGS Geologic Map of the State of Hawaii data and the County of Maui Probable Site Classes map in the 2013 Hawaii State Mitigation Plan. This cursory assessment of landslide risk areas was conducted at an extremely coarse resolution. It is likely that this assessment either greatly over- or understates risk in each classification and is only valid for planning purposes.
- **Tsunami**—Tsunami evacuation zone data were provided by Maui County GIS.
- **Volcano Hazards**—Lava inundation zones data were obtained from the USGS Cascade Volcano Observatory.
- **Coastal Erosion**—No GIS format coastal erosion area data were identified for Maui County.
- **High Wind Storm**—No GIS format high wind storm area data were identified for Maui County.
- **High Surf**—No GIS format data were identified that exclusively addressed the high surf hazard. FEMA mapped coastal V and VE zones were used as a proxy to estimate exposure. It is likely that this method has exaggerated exposure.

- **Wildfire**—The Hawaii Wildfire Management Organization's (HWMO) Community Wildfire Hazard Assessments data were identified as a source for wildfire hazard area data. However this GIS data is not available from HWMO at this time.

5.4.4 Cost Data

Replacement cost is the cost to replace the entire structure with one of equal quality and utility. Replacement cost is based on industry-standard cost-estimation models published in *RS Means Square Foot Costs* (RS Means, 2014). It is calculated using the RS Means square foot cost for a structure, which is based on the Hazus-MH occupancy class (e.g., multi-family residential, commercial retail trade), multiplied by the square footage of the structure from the tax assessor data. For single-family residential, the construction class and number of stories also factor into determining the square foot costs.

5.4.5 Visitor Population Distribution

The 2013 visitor population estimates presented in Section 4.7.1 break down the average daily numbers of visitors on the islands of Maui, Molokai and Lanai, as taken from the 2013 Hawaii Tourism Authority Annual Visitor Research report. Because the risk assessment for this plan is based on community planning areas, a methodology was developed to distribute the visitor population estimates for the Island of Maui among that island's six community planning areas. The islands of Molokai and Lanai are each single community planning areas, so the Hawaii Tourism Authority estimates for those islands apply directly to the community planning areas. No visitors stay on Kahoolawe.

TABLE 5-1.
MAUI COUNTY VISITOR POPULATION DISTRIBUTION

Community Planning Area	Daily Average Occupied Units	2013 Daily Average Visitor Population[a]	Average Visitors per Occupied Unit	Calculated Daily Average Visitor Population[b]
Island of Maui Total	14,810	52,798	3.57	52,798
Kihei - Makena	6,000	—	3.57	21,390
Paia - Haiku	9	—	3.57	32
Wailuku - Kahului	275	—	3.57	980
Makawao - Pukalani - Kula	40	—	3.57	143
Hana	63	—	3.57	225
West Maui	8,423	—	3.57	30,028

a. Estimate from 2013 Hawaii Tourism Authority Annual Visitor Research report

b. Calculated based on number of occupied units and average visitors per occupied unit

The analysis for community planning areas on the Island of Maui used the 2013 Hawaii Tourism Authority Annual Visitor Research report and a hotel data set downloaded from the Hawaii State Office of Planning website in April 2015. The hotel data set includes hotels, condominium hotels, individual vacation units, apartment hotels, bed & breakfasts, timeshares, and hostels; hotels with fewer than 10 units are not included. Bed & breakfasts are not required to register with the County and therefore, may be underestimated in the data set. Hotel units were assigned to each community

planning area, and the number of occupied units in each was estimated assuming an average occupancy rate of 72 percent (Hawaii Tourism Authority, 2013). The daily visitor average for the Island of Maui was then divided by the island's total number of occupied units to determine the average number of occupants per unit. The average occupants per unit were multiplied by the number of occupied units in each community planning area for the visitor distribution (See Table 5-1).

5.4.6 Data Source Summary

Table 5-2 summarizes the data sources used for the risk assessment for this project.

TABLE 5-2.
HAZUS-MH MODEL DATA DOCUMENTATION

Data	Source	Date	Format
Property parcel data	State of Hawaii Office of Planning GIS data website	2014	Digital (GIS) format
Building information such as area, occupancy, date of construction, stories, and foundation type (used to estimate finished floor elevations)	Maui County public information download website	2015	Digital (text) format
Building replacement cost	RS Means	2014	Paper format. Updated RS Means values
Population data	State of Hawaii Office of Planning GIS data website	2010	Digital (GIS and tabular) format
Visitor population	State of Hawaii Office of Planning GIS data website, Hawaii Tourism Authority	2010, 2013	Digital (GIS and tabular) format and text
Flood hazard data	FEMA	1/2015	Digital (GIS) format
Dam evacuation areas	Pacific Disaster Center	2015	Digital (GIS) format
Earthquake shake maps	USGS Earthquake Hazards Program website	2013	Digital (GIS) format
NEHRP Soils	Tetra Tech	2015	Digital (GIS) format
Critical Facilities and Assets			
Hospitals, airports, emergency operation centers, emergency medical stations, fire stations, police stations, shelters	Maui County GIS	2015	Digital (GIS) format
Schools, dams, banks, hotels, assisted living facilities, skilled nursing facilities	State of Hawaii Office of Planning GIS data website	2015	Digital (GIS) format
Potable water system facilities	Maui County Department of Water Supply	2015	Digital (GIS) format
Wastewater system facilities	Maui County Wastewater Division	2015	Digital (GIS) format
Hazardous material facilities	U.S. Environmental Protection Agency website Toxic Release Inventory data	2014	Digital (GIS) format
Ferry facilities, highway bridges, port facilities, rail facilities, communications facilities, oil facilities	FEMA-Hazus-MH version 2.1 default Comprehensive Data Management System	2012	Digital (GIS) format

5.5 Limitations

Loss estimates, exposure assessments and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic or economic parameter data
- The unique nature, geographic extent and severity of each hazard
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event.

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate and should be used only to understand relative risk. Over the long term, Maui County will collect additional data to assist in estimating potential losses associated with other hazards.

The visitor population distributions by community planning area used for the risk assessment present the following limitations:

- The numbers of occupants per occupied unit used for the distribution of visitor population on the Island of Maui are likely overestimated because the visitor count estimates used include not only those staying in hotels but also visitors staying on cruise ships, with relatives or friends or in less formal rental arrangements.
- The distribution of visitor population by community planning area on the Island of Maui assumes that all community planning areas have the same occupancy rate, but this assumption may not be correct.
- Visitor population exposure is based on accommodation location, but over the course of each day, visitors may be in areas of the County other than where their accommodations are located.

Chapter 6. Climate Change Considerations for Hazard Mitigation

6.1 What is Climate Change?

Climate, consisting of patterns of temperature, precipitation, humidity, wind and seasons, plays a fundamental role in shaping natural ecosystems and the human economies and cultures that depend on them. "Climate change" refers to changes over a long period of time. Worldwide, average temperatures have increased more than 1.4ºF over the last 100 years (NRC, 2010). In Hawaii, the rate of warming temperature has quadrupled in the last 40 years to over 0.3ºF per decade (University of Hawaii, 2014). Although this change may seem small, it can lead to large changes in climate and weather.

The warming trend and its related impacts are caused by increasing concentrations of carbon dioxide and other greenhouse gases in the earth's atmosphere. Greenhouse gases are gases that trap heat in the atmosphere, resulting in a warming effect. Carbon dioxide is the most commonly known greenhouse gas; however, methane, nitrous oxide and fluorinated gases also contribute to warming. Emissions of these gases come from a variety of sources, such as the combustion of fossil fuels, agricultural production and changes in land use. According to the U.S. Environmental Protection Agency (EPA), carbon dioxide concentrations measured about 280 parts per million (ppm) before the industrial era began in the late 1700s and have risen 41 percent since then, reaching 394 ppm in 2012 (see Figure 6-1. Global Carbon Dioxide Concentrations Over Time). The EPA attributes almost all of this increase to human activities (EPA, 2013a).

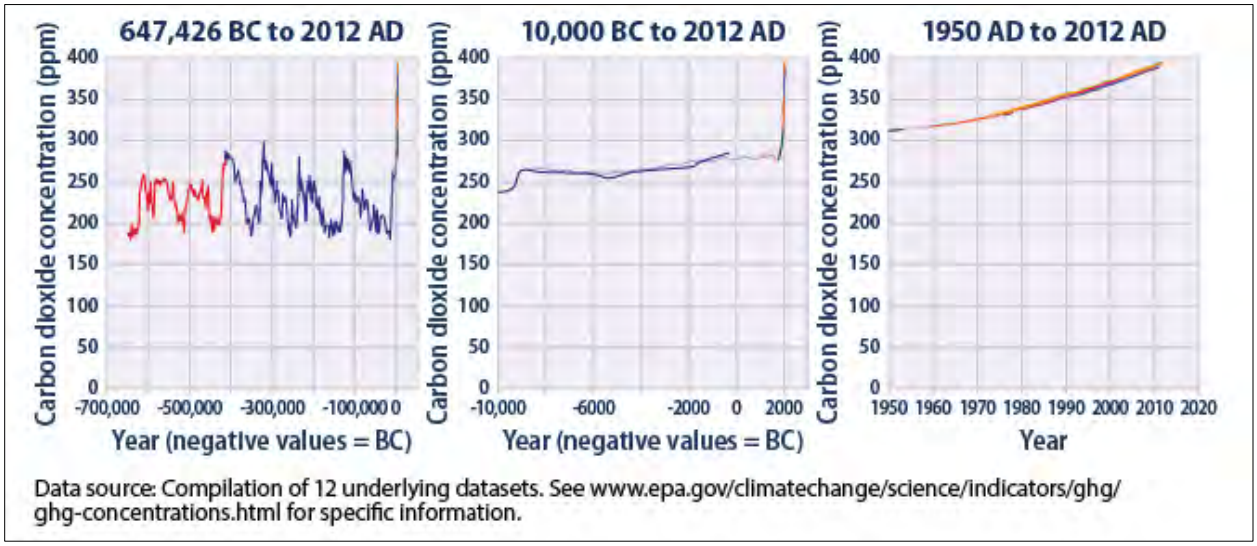


FIGURE 6-1. GLOBAL CARBON DIOXIDE CONCENTRATIONS OVER TIME

Temperature increases are not the only indication of climate change in Hawaii. The state has also recorded a decrease of prevailing northeasterly trade winds in the last 40 years; these winds drive orographic precipitation on windward coasts. There has also been an overall decline in rainfall in the last 30 years, leading scientists to expect droughts and heavy rains more frequently leading to flash flooding, infrastructure damage, runoff and sedimentation. In addition,

the decrease in rainfall levels has also led to a decline in stream base flow over the last 70 years, influencing aquatic and riparian ecosystems, local agriculture, and aquifer recharge and freshwater supplies. Global ocean acidification has also been noted, with a 30 percent increase of marine uptake of CO_2 or pH change of 0.1. Scientists expect this trend to continue, with pH levels increasing up to 0.4 by 2100. Higher levels of ocean acidity can negatively impact marine animals, such as by inhibiting shell and skeleton growth in corals, shellfish, and plankton (University of Hawaii, 2014).

Climate change will affect the people, property, economy and ecosystems of Maui County in a variety of ways. Climate change impacts are most frequently associated with negative consequences, such as increased flood vulnerability or increased heat-related illnesses/public health concerns; however, other changes may present opportunities. The most important effect for the development of this plan is that climate change will have a measurable impact on the occurrence and severity of natural hazards.

6.2 How Climate Change Affects Hazard Mitigation

An essential aspect of hazard mitigation is predicting the likelihood of hazard events in a planning area. Typically, predictions are based on statistical projections from records of past events. This approach assumes that the likelihood of hazard events remains essentially unchanged over time. Thus, averages based on the past frequencies of, for example, floods are used to estimate future frequencies: if a river has flooded an average of once every 5 years for the past 100 years, then it can be expected to continue to flood an average of once every 5 years.

For hazards that are affected by climate conditions, the assumption that future behavior will be equivalent to past behavior is not valid if climate conditions are changing. As flooding is generally associated with precipitation frequency and quantity, for example, the frequency of flooding will not remain constant if broad precipitation patterns change over time. Specifically, as hydrology changes, storms currently considered to be the 100-year flood might strike more often, leaving many communities at greater risk. The risks of, landslide, severe storms, and wildfire are all affected by climate patterns as well. For this reason, an understanding of climate change is pertinent to efforts to mitigate natural hazards. Information about how climate patterns are changing provides insight on the reliability of future hazard projections used in mitigation analysis. This chapter summarizes current understandings about climate change in order to provide a context for the recommendation and implementation of hazard mitigation measures.

6.3 Current Indications of Climate Change

The major scientific agencies of the United States—including the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA)—agree that climate change is occurring (EPA, 2013b). Multiple temperature records from all over the world have shown a warming trend (EPA, 2011). According to NOAA, the decade from 2000 to 2010 was the warmest on record, and 2010 was tied with 2005 as the warmest year on record (NOAA, 2011). Worldwide, average temperatures have increased more than 1.4ºF over the last 100 years (NRC, 2010). Many of the extreme precipitation and heat events of recent years are consistent with projections based on that amount of warming (USGCRP, 2009).

Rising global temperatures have been accompanied by other changes in weather and climate. Many places have experienced changes in rainfall resulting in more intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced changes: oceans are warming and becoming more acidic, ice caps

are melting, and sea levels are rising (EPA, 2010). Global sea level has risen approximately 9 inches, on average, in the last 140 years (EPA, 2010). This has already put some coastal homes, beaches, roads, bridges, and wildlife at risk (USGCRP, 2009).

In Hawaii specifically, 70 percent of the beaches have eroded and over 13 miles of beach have been completely lost to erosion in the last century. Additionally, many of the State's coastlines are experiencing shoreline retreat, with an average of 1 foot lost per year, wetland migration, and cliff collapse. Low coastal areas have experienced more frequent flooding due to elevated groundwater tables, which have increased partially due to sea-level rise. Tropical cyclones are occurring more frequently, with more having developed from Pacific storms between 1991 and 2010 than in the last century (University of Hawaii, 2014).

6.4 Projected Future Impacts

6.4.1 Global Projections

Scientists project that Earth's average temperatures will raise between 2ºF and 12ºF by 2100 (NRC, 2011a). Some research has concluded that every increase of 2ºF in average global average temperature can have the following impacts (NRC, 2011b):

- 3 to 10 percent increases in the amount of rain falling during the heaviest precipitation events, which can increase flooding risks
- 200 to 400 percent increases in the area burned by wildfire in parts of the western United States
- 5 to 10 percent decreases in stream flow in some river basins
- 5 to 15 percent reductions in the yields of crops as currently grown.

6.4.2 Projections for Hawaii

In 2014, the University of Hawaii released a 2014 report summarizing the major expected impacts of climate change in Hawaii. These impacts concern five primary areas: the marine ecosystems (both open ocean and coral reefs/near-shore habitats), coasts and the built environment, terrestrial eco-systems, freshwater resources, and public health. The study noted that the most likely changes to Hawaii include accelerated sea level rise, ocean and atmospheric warming, increased flooding, ocean acidification, changing distributions of terrestrial and marine biota, and changing intensity and frequency of storms. Specific projected changes include some of the following. The impacts listed were cited due to their relevance to this HMP, but the original study includes a more comprehensive summary:

- Sea surface temperatures will continue warming, increasing between 2.3ºF and 4.9ºF in the Pacific by 2100.
- Sea-level rise estimates by 2100 range from a mean of 1 foot and 3 feet for low and high emission concentration scenarios, respectively.
- Portions of low-lying coastal areas may become submerged. In addition to Kahului, Maui, this would also include Hilo, Hawaii; Waikiki Beach, Oahu; and Hanalei, Kauai.
- Maui and Hawaii are expected to become wetter closer to 2100, while northern islands are expected to become slightly drier. This can lead to increased public health concerns. In 2001 and 2002, Maui experienced an outbreak of dengue fever because of warmer and wetter conditions.

Climate change impacts are not limited to just physical impacts, however; they can also create social, cultural, and economic impacts. The residents of Maui need to implement climate change mitigation actions not just to prevent increased risk to hazards but also to prevent any negative impacts to the tourism economy or a coastal culture (University of Hawaii, 2014). Threats to food and water security, infrastructure, health, and safety will lead to increased human migration away from the islands or towards higher land, decreasing tourism and making it more difficult for unique regional customs, beliefs and languages to endure. Additionally, native plants and animals, particularly those in high-elevation ecosystems or experiencing increased exposure to invasive species, face higher stresses and a greater risk of extinction (Leong et al., 2014).

6.5 Responses to Climate Change

6.5.1 Mitigation and Adaptation

Communities and governments worldwide are working to address, evaluate and prepare for climate changes that are likely to impact communities in coming decades. Generally, climate change discussions encompass two separate but inter-related considerations: mitigation and adaptation. The term "mitigation" can be confusing, because it's meaning changes across disciplines:

- Mitigation in restoration ecology and related fields generally refers to policies, programs or actions that are intended to reduce or to offset the negative impacts of human activities on natural systems. Generally, mitigation can be understood as avoiding, minimizing, rectifying, reducing or eliminating, or compensating for known impacts (CEQ, 1978).
- Mitigation in climate change discussions is defined as "a human intervention to reduce the impact on the climate system." It includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks (EPA, 2013c).
- Mitigation in emergency management is typically defined as the effort to reduce loss of life and property by lessening the impact of disasters (FEMA, 2013).

In this chapter, mitigation is used as defined by the climate change community. In the other chapters of this plan, mitigation is primarily used in an emergency management context.

Adaptation refers to adjustments in natural or human systems in response to the actual or anticipated effects of climate change and associated impacts. These adjustments may moderate harm or exploit beneficial opportunities (EPA, 2013c).

Mitigation and adaptation are related, as the world's ability to reduce greenhouse gas emissions will affect the degree of adaptation that will be necessary. Some initiatives and actions can both reduce greenhouse gas emissions and support adaptation to likely future conditions.

Societies across the world are facing the need to adapt to changing conditions associated with natural disasters and climate change. Farmers are altering crops and agricultural methods to deal with changing rainfall and rising temperature; architects and engineers are redesigning buildings; planners are looking at managing water supplies to deal with droughts or flooding.

Most ecosystems show a remarkable ability to adapt to change and to buffer surrounding areas from the impacts of change. Forests can bind soils and hold large volumes of water during times of plenty, releasing it through the year; floodplains can absorb vast volumes of water during peak flows; coastal ecosystems can hold out against storms, attenuating waves and reducing erosion. Other ecosystem services—such as food provision, timber, materials, medicines and recreation—can provide a buffer to societies in the face of changing conditions.

Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change. This includes the sustainable management, conservation and restoration of specific ecosystems that provide key services.

The County of Maui and the State of Hawaii have already begun implementing progressive mitigation actions, and this plan is one way in which the County intends to identify and achieve more mitigation projects. Because coastal erosion in a significant concern in Hawaii and because near-shore development has been known to exacerbate coastal erosion rates, the state requires that developments must be built 20 to 40 feet away from the shoreline. Maui has adopted even more stringent rules than the state requirements, wherein the required setbacks (distance between the ocean and development) are based on measured rates of erosion. These rates are calculated by multiplying the current rate of erosion by a number of years. Such requirements are some of the most restrictive in the region and will ideally help protect life, property, and coastal resources (EPA, 2013d).

6.5.2 Future Modeling Efforts

Current modeling efforts are unable to assess climate change at a resolution small enough to determine specific impacts for individual communities. However, generalized assessments of larger climatic regions can be used to determine impacts that are most likely to affect these communities. As these models are developed in the future, the risk assessment presented in this plan may be enhanced to better measure these impacts. The Pacific Islands Regional Climate Assessment (PIRCA), released in 2012, does contain some regional models and estimates. Since these data are not focused on the specific impacts to the County of Maui, it has been included as a reference and was not utilized in overall vulnerability assessment ratings (Keener et al., 2012).

Sea Level Rise Estimates

One such example of future and current modeling is estimated sea level rise. Data that was created by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center to depict potential sea level rise and its associated impacts on the nation's coastal areas included areas of impact for the planning area. These data were used to provide a preliminary and generalized overview of the potential impacts of one facet of climate change for the planning area. According to NOAA:

> *These data depict the potential inundation of coastal areas in Hawaii resulting from a projected 1 to 6 feet rise in sea level above current Mean Higher High Water (MHHW) conditions…The model used to produce these data does not account for erosion, subsidence, or any future changes in an area's hydrodynamics. It is simply a method to derive data in order to visualize the potential scale, not exact location, of inundation from sea level rise.*

The planning team overlaid this data with on the population, land use, general building stock and critical facility and asset data developed for the hazard of concern risk assessment portion of this plan. The results of this assessment are available in Table 6-1 through Table 6-3. This assessment assumes that these sea level rise impacts occur on present day Maui County rather than occurring gradually over years or decades.

TABLE 6-1.
ESTIMATED POPULATION EXPOSURE FOR 1 FOOT AND 6 FEET SEA LEVEL RISE

	1 Foot Sea Level Rise			6 Feet Sea Level Rise		
Community Planning Area	**Residents**	**Visitors**	**Total**	**Residents**	**Visitors**	**Total**
Hana	0	0	0	8	0	8
Kihei-Makena	7	0	7	1,268	531	1,799
Lanai	2	0	2	12	0	12
Makawao-Pukalani-Kula	0	0	0	0	0	-
Molokai	34	0	34	1,284	302	1,586
Paia-Haiku	0	0	0	0	0	-
Wailuku-Kahului	7	0	7	169	0	169
West Maui	4	0	4	49	0	49
Total	**55**	**0**	**55**	**2,790**	**833**	**3,623**

TABLE 6-2.
LAND USE IN 1 FOOT AND 6 FEET SEA LEVEL RISE

	1 foot Sea Level Rise		6 feet Sea Level Rise	
Land Use	**Area (acres)**	**% of total**	**Area (acres)**	**% of total**
Agricultural	762.67	28.9%	3,504.62	45.9%
Apartment	1.29	0.0%	31.65	0.4%
Commercial	50.74	1.9%	357.81	4.7%
Commercialized Residential	3.76	0.1%	5.59	0.1%
Conservation	1,336.83	50.6%	1,964.58	25.7%
Hotel/Resort	11.23	0.4%	48.82	0.6%
Industrial	117.64	4.5%	240.90	3.2%
Residential	278.16	10.5%	979.41	12.8%
Time Share	0.00	0.0%	0.02	0.0%
Not Classified	80.10	3.0%	501.50	6.6%
Total	**2,642.43**	100.0%	7,634.90	100.0%

TABLE 6-3.
CRITICAL FACILITIES AND ASSETS IN 1 FEET AND 6 FEET SEA LEVEL RISE

Facility Type	Number in 1 foot Sea Level Rise	Number in 6 feet Sea Level Rise
Emergency Services		
Emergency Operations	0	0
Police & Fire	0	2
Community Shelter[a]	0	0
Medical & Health	0	0

TABLE 6-3.
CRITICAL FACILITIES AND ASSETS IN 1 FEET AND 6 FEET SEA LEVEL RISE

Facility Type	Number in 1 foot Sea Level Rise	Number in 6 feet Sea Level Rise
Government and Services		
Government	-	-
Schools[a]	0	5
Critical Infrastructure and Lifelines		
Transportation	1	9
Water Supply	0	0
Wastewater	1	9
Dams	0	0
Energy	0	1
Telecommunications	0	3
Hazardous Materials	0	1
Other Assets		
Financial	0	14
Tourist Lodging	0	7
Early Assistance	0	0
Total	**2**	**51**

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.

Data sources: See Table 5-1

6.6 Potential Climate Change Impact on Hazards

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches, the more subject to changing dynamics it becomes.

Although quantitative estimates are rare and subject to concerns about changing conditions, qualitative assessments can be made of its potential impacts on those risks. Discussions of the potential impacts of climate change on each hazard are provided in Chapter 7 through Chapter 18. These qualitative assessments are available below to provide an overview on the potential impacts relevant to this plan:

6.6.1 Coastal Erosion

Coastal areas may be impacted by climate change in different ways. Coastal areas are sensitive to sea-level rise, changes in the frequency and intensity of storms, increase in precipitation, and warmer ocean temperatures. According to NASA, warmer temperatures may lead to an increase in frequency of storms, thus leading to more weather events that cause coastal erosion. A study on increased storm wave heights from climate change indicated that coastal erosion and flooding may occur twice as fast from sea level rise alone and up to four times as fast as a doubling of the frequency of major El Niño events occurring. Should all these potential subsequent events from climate change occur simultaneously, there could be up to an order of magnitude increase in both coastal erosion and flood frequency (compared against the current rate of those processes). While erosion rates would still be partially dependent on beach slopes and dune crest elevations, this possibility highlights the importance of incorporating climate change and climate control into mitigation practices (Ruggiero, 2008).

As a series of small islands, Maui County is particularly sensitive to the impacts of coastal erosion as caused by climate change. According to the Intergovernmental Panel on Climate Change, small islands can anticipate the following biogeophysical effects of climate change:

- Inundated and displaced wetlands and lowlands
- Eroded shorelines
- Exacerbated coastal storm flooding
- Increase in salinity of estuaries, threatening freshwater aquifers and otherwise impair water quality
- Alteration of tidal ranges in rivers and bays
- Alteration of sediment depositional patterns.

As islands, Maui, Lanai, and Molokai contain open coasts around the perimeter of the land mass. These coasts are primarily made up of unconsolidated sands and gravels exposed to winds and wave action. As sea levels rise, so does the increase in pressure and strength of wave action against Maui County's coastlines. Additionally, sewage and siltation are among the most significant causes of coral-reef and other natural coastal system human caused degradation in Hawaii. This degradation is exacerbated by higher sea levels caused by climate change that adds additional pressure to an already taxed ecosystem (Bijlsma et al., 1999).

6.6.2 Dam and Reservoir Failure

Dams are designed partly based on assumptions about a stream's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or its entire designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream.

Dams are constructed with safety features known as "spillways," which provide a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to as "design failures," result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures.

6.6.3 Drought

The long-term effects of climate change on island water resources are unknown, but global water resources are already experiencing the following stresses without climate change:

- Growing populations
- Increased competition for available water
- Poor water quality
- Environmental claims
- Uncertain reserved water rights
- Groundwater overdraft
- Aging urban water infrastructure.

Nearly every region in the country is facing some increased risk of seasonal drought. Climate change can significantly affect the sustainability of water supplies in the future. As parts of the United States get drier, the amount and quality of water available will likely decrease, impacting people's health and food supplies. Western United States have already been experiencing water shortages due to severe dry-spells. With climate change, the entire country will likely face some level of drought. A report by the National Resources Defense Council (NRDC) found that 1,100 counties (one-third of all counties in the contiguous 48 states) face higher risks of water shortages by mid-century as a result of climate change. More than 400 of these counties will face extremely high risks of water shortages.

The NRDC states that global warming is projected to alter precipitation patterns, increase the frequency and intensity of major storm events, and increase the flood risk throughout the United States, particularly the Midwest and the Northeast. Between 2000 and 2009, approximately 30 to 60 percent of the United States experienced drought conditions at any one time (NRDC, n.d.). Hawaii has definitively experienced longer droughts on all the populated islands, as demonstrated by a comparison of length of dry periods from 1980-2011 against 1950-1970 (University of Hawaii, 2014).

With a warmer climate, droughts could become more frequent, more severe, and longer-lasting. More frequent extreme droughts could result in decreased stream flows in local rivers, affecting water supplies for domestic and agricultural uses.

The best advice to water resource managers regarding climate change is to start addressing current stresses on water supplies and build flexibility and robustness into any system. Flexibility helps to ensure a quick response to changing conditions, and robustness helps people prepare for and survive the worst conditions. With this approach to planning, water system managers will be better able to adapt to the impacts of climate change.

6.6.4 Earthquake

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity, according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction or an increased propensity for slides during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

6.6.5 Flood

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must

happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already impacting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

As hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, bypass channels and levees, as well as the design of local sewers and storm drains. Additionally, rising sea levels, coupled with high water levels caused by tropical and extra-tropical storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism (Leong et al., 2014).

6.6.6 High Surf

Changes in global temperatures, hydrologic cycles, coverage of glaciers and ice sheets, and storm frequency and intensity are captured in long-term sea level records. Sea levels provide a key to understanding the impact of climate change (NOAA, 2013). Sea level rise increases the risks coastal communities face from coastal hazards (floods, storm surges, and chronic erosion).

Specifically, sea level rise, coupled with overall global warming and other climate change impacts can lead to more frequent high surf events. It may also lead to surf levels increasing to such an extent that high surf levels of 10 to 20 feet become normal surf levels. This change can create several secondary, negative impacts and vulnerabilities, including:

- Loss of important coastal habitats
- Increased beach and coastal erosion
- Increased life safety and property risks
- More frequent coastal flood events and greater damage from all coastal flood-related hazards.

According to briefing prepared by the University of Hawaii Sea Grant program, the historical rate of sea level rise on Maui is about 9 inches over the past century. Although the global average sea level rose 7 inches during the 20th century,

satellite observations data has shown the sea level rising at a rate of 12 inches per century since 1993. Coastal tide gage measurements confirm this record, and also show that sea levels do not rise uniformly around the world. Global sea level rise is projected to accelerate during the 21st century, however accelerated sea level rise has not yet been detected in the Hawaii tide gage records (Owens, 2013).

6.6.7 High Wind Storm

Historical data shows that the probability for severe weather events such as high wind storms increases in a warmer climate.

6.6.8 Landslide, Debris Flow, and Rock Fall

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

6.6.9 Tropical Cyclone

A tropical storm's strong winds and intense low pressure can generate storm surge along coastal communities. While not all tropical storms will have devastating impacts or create significant levels of storm surge, the surge index record shows a significant positive trend between warmer years and extreme events (i.e., Katrina-level events). In fact, one scientist noted that basin wide Category 4 and 5 hurricanes could increase up to 81 percent in frequency with a temperature increase of only 2.5ºC. While surge levels will vary because of situational factors, projected changes in hurricane surge levels above the mean sea level in Hawaii State are more likely to increase than decrease with global warming (i.e., results range from a 10 percent reduction to 50 percent increase with a 2.8ºC temperature increase).

Figure 6-2 provides a visual representation of the number of Katrina-magnitude surge events per decade in the past and projected changes. Each line shows the results based off different modeling techniques and data contributions. Although there is some variation depending on the model, the results show an overall positive correlation between temperature/climate increase and storm surge frequency (Grinsted et al., 2013). Although this study is focused on hurricanes and the Atlantic Ocean, which are not exactly comparable to the tropical cyclone events that impact the County of Maui, these results still highlight how a small temperature change can significantly increase damages and vulnerability. In addition, Hawaii is expected to see an additional increase in tropical cyclone events unrelated to the increase from warmer temperatures, as the storm track may shift north toward the Central North Pacific (University of Hawaii 2014).

Source: Grinsted et al., 2013

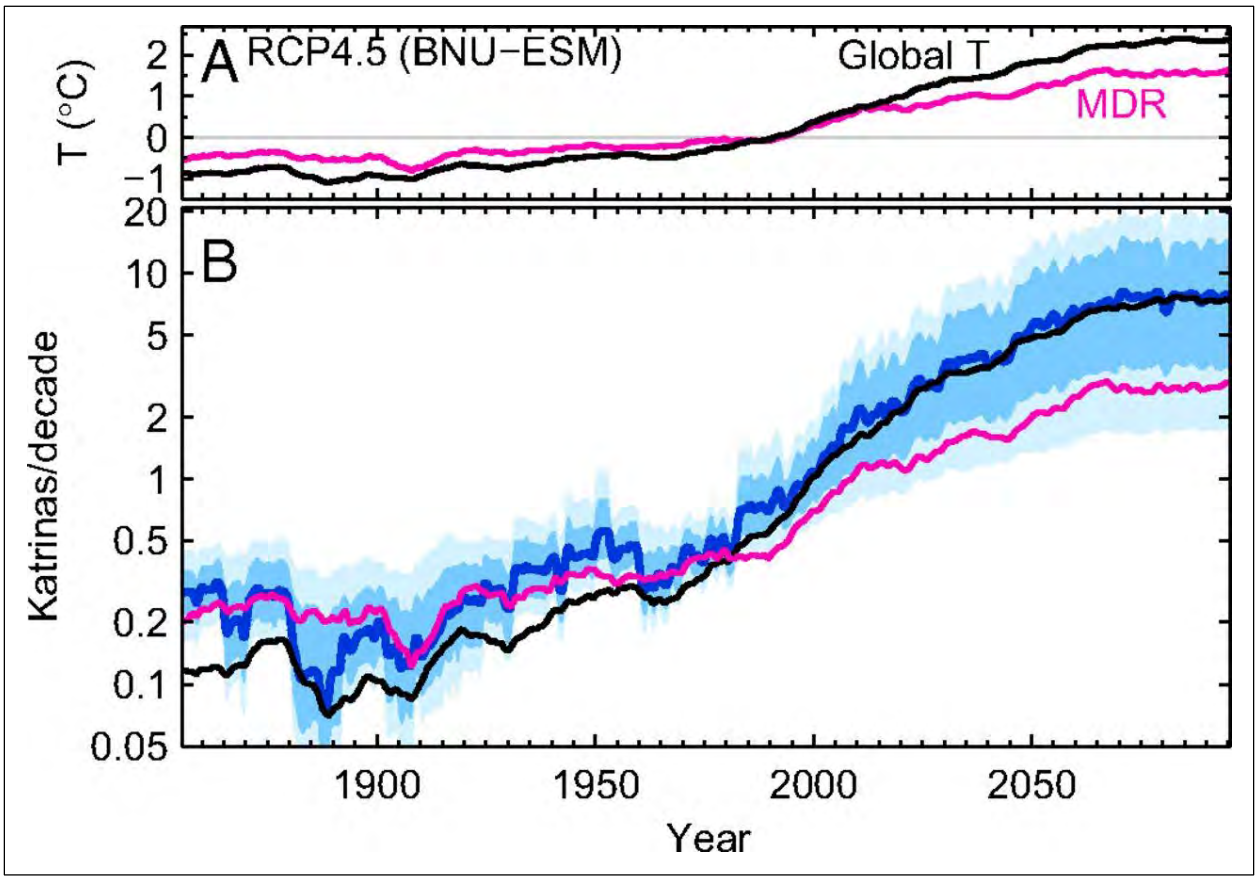


FIGURE 6-2. SURGE EVENT FREQUENCY OVER TIME AND CLIMATE CHANGES

The projected increase in sea level rise has the potential to increase risk of storm surge-related flooding along the coast; expand areas at-risk of coastal flooding; increase vulnerability of energy facilities located in coastal areas; flood transportation and telecommunication facilities; and cause saltwater intrusion into some freshwater supplies near the coasts. High water levels, strong winds, and heavy precipitation resulting from severe coastal storms already cause billions of dollars in damages and disrupt transportation and utility distribution systems. Sea level rise will lead to more frequent and extensive coastal flooding. Warming ocean waters raise sea level through thermal expansion and have the potential to strengthen the most powerful tropical cyclones.

6.6.10 Tsunami

Any rise is sea level resulting from climate change could increase the risk to coastal communities exposed to the tsunami hazard. Oceanic waves and surge could reach further inland, resulting in more damage to infrastructure and increased life safety concerns.

6.6.11 Volcanic Hazards

Climate change is not likely to affect the risk associated with volcanoes; however, volcanic activity can affect climate change. The massive outpouring of gases and ash can influence climate patterns for years following a volcanic eruption. The conversion of sulfur dioxide to sulfuric acid is the most significant climate impact from a volcano. The Pinatubo

eruption in 1991 was one of the largest volcanic events in the 20th century, injecting 20 million tons of sulfur dioxide into the stratosphere. It ultimately cooled the Earth's surface by as much as 1.3ºF for 3 years after its eruption. In contrast, the carbon dioxide released in recent eruptions has not been shown to lead to a detectable increase in global warming (USGS, 2015b).

6.6.12 Wildfire

Wildfire is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

According to a briefing sheet produced by the University of Hawaii Sea Grant College Program, Hawaii is getting warmer. Data shows a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with stronger warming at high elevations (above 2600 feet). The rate of temperature rise at low elevations (below 2600 feet), 0.16°F per decade, is less than the global rate (about 0.36°F per decade); however, the rate of warming at high elevations in Hawaii, 0.48°F per decade, is faster than the global rate. Most of the warming is related to a larger increase in minimum temperatures compared to the maximum—a net warming about 3 times as large— causing a reduction of the daily temperature range. This response to global warming is consistent with similar trends observed in North America. Despite recent years where the rate of global warming was low, surface temperatures in Hawaii have remained high. As temperatures rise, modeling results indicate to some extent that the State of Hawaii should expect to see decreased rainfall in response to climate change. Studies over the past 20 years have confirmed this phenomenon, as rainfall in throughout the state has steadily declined about 15 percent over the past 20 years (Fletcher, 2010). This increase in temperature coupled with a noticeable decrease in precipitation exacerbates droughts and has the potential to contribute to an increased frequency of wildfire.

Chapter 7. Coastal Erosion

7.1 Hazard Description

In Hawaii, beaches 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. 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 tourism industry (County of Maui, 2010a).

DEFINITIONS

Coastal Erosion—the process of wearing away material from a coastal profile due to imbalance in the supply and export of material from a certain section (ConScience, n.d.)

Beach Erosion—the gradual narrowing of a beach due to sediment deficiency, or a loss of sand (Fletcher et al., n.d.).

In the County of Maui, beaches serve as natural protective buffers between the ocean and the land. Waves reaching the islands of Molokai, Maui, and Lanai from storms across the Pacific Ocean carry tremendous amounts of energy, and beaches absorb much of this energy before it reaches the shoreline and coastal properties. During storm events, beaches are able to modify their slope and overall morphology to dissipate the waves. The narrowing of healthy beaches in response to a high wave event is often a temporary condition. In these scenarios, the beach profile is flattened, and the waves coming inshore shoal further offshore, minimizing further erosion. Beaches recover when sand is moved back onto the shore by smaller waves, and then is blown inland to reestablish frontal dunes. The final stage of recovery occurs when vegetation grows back over the new dunes (County of Maui, 2010a).

When beaches and coastlines are unable to recover in a natural time period due to extreme incidents or human caused events, the result is often coastal erosion. As shorelines retreat inland, waterfront homes and 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 ocean. Nationally, 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 United States shorelines. According to the report, most of the damage will occur in beaches and low-lying areas also subject to the highest risk of flooding. Some additional damage will also occur along eroding coastal bluffs (County of Maui, 2010a).

7.1.1 Types of Coastal Erosion

Overall, coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a period of time. It is generally caused naturally by storm surges, hurricanes, windstorms, and flooding. (FEMA, 1996). Natural recovery after erosion events can take months or years. If a dune or beach does not recover quickly enough via natural processes, coastal and upland property may be exposed to further damage in subsequent events. Long-term coastal erosion threatens developed areas with potential loss of life and millions of dollars in property damage. As shorelines retreat inland, waterfront homes and public infrastructure may become damaged beyond use (FEMA, 1996).

Three types of erosion occur in Maui County, as described in the following sections.

Beach Erosion

Beach erosion occurs when waves and currents remove sand from the beach system. The sand is carried away from the land and deposited in large sandbars. Over time, the sand is returned by typical tidal cycles. Multiple severe storm events that occur within a short span of time can significantly damage beaches and cause a significant retreat of the shoreline (USGS, 2014). Figure 7-1 illustrates beach erosion.

Source: Maui County, 2010a

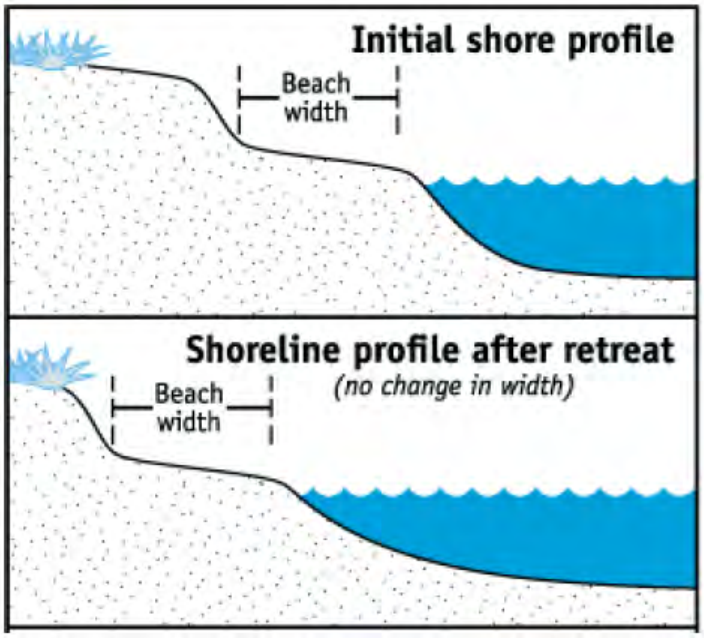


FIGURE 7-1. COASTAL EROSION ON A HEALTHY BEACH

Dune Erosion

Dune erosion is characterized by a sweeping away of sediment associated with coastlines and beaches, particularly, sandy areas not typically touched by regular tidal cycles. This sediment is pulled away from the mainland and deposited in deeper water. Under normal tidal circumstances, this sediment is replaced and removed in a cyclical manner. Dune erosion under storm surge conditions reshapes the coastline by pulling away more materials than can naturally be replenished with normal tidal cycles. As a result, sediment not often affected by tidal cycles (control volume) becomes washed away or weakened as support sediment is pulled away and subsequently collapses into the retreating surge (van de Graffe, 2008) (Figure 7-2). Extreme storms can erode and completely remove dunes, degrading land elevations and exposing them to inundation and further change if recovery does not occur before the next storm (Wong et al., 2014). Dune erosion increases the possibility of overwash and instability for properties located behind the affected area, making them more vulnerable to future storms (USGS, 2014). In Maui County, dune erosion often occurs with seasonal change and associated high waves.

Source: van de Graffe, 2008

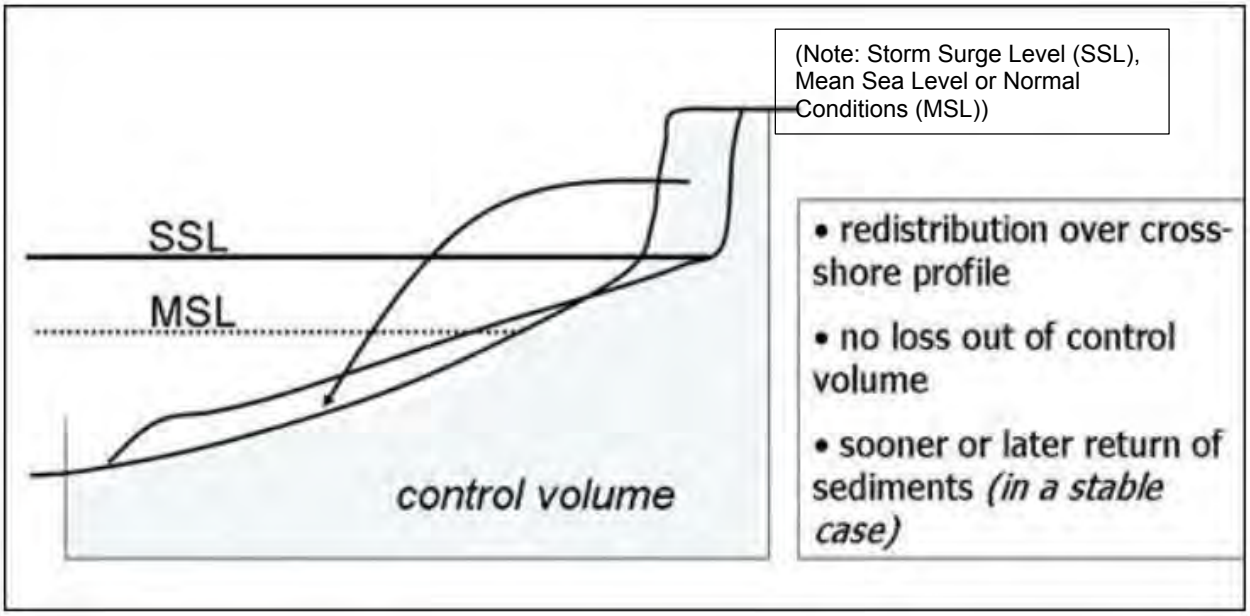


FIGURE 7-2. DUNE EROSION DUE TO STORM SURGE

Structural Erosion

Structural erosion is a slower process of erosion caused by the gradual loss of sediment, often occurring over a number of years. Unlike dune erosion, the sediment removed as a result of structural erosion is not replaced. Structural erosion is characterized by waterline shifting landward by a small, but measurable amount per year (van de Graffe, 2008).

Coral Reef Degradation

Coastal erosion plays a large part in the degradation of one of Maui County's most distinctive features: coral reef. According to the USGS, earthen sediment run-off and deposition on coral reefs can significantly impact coral health by blocking light and inhibiting photosynthesis, directly smothering and abrading coral, and triggering increases in macro algae. The delivery of sediment and pollutants to reefs has increased globally as a response to human-induced changes to watersheds. Sediment run-off is the major stressor to reefs in Hawaii (USGS, 2015a).

7.1.2 Human-Induced Sources of Coastal Erosion

Human interruption of natural sand movement and sand supply in the form of coastal armoring, dune leveling and grading, sand mining, and harbor and waterway dredging have are a significant source of coastal erosion. These human sources described in the following sections (County of Maui, 2010a):

Shoreline Hardening

Shoreline hardening, shown in **Figure 7-3**, is also known as coastal armoring, is characterized by the impoundment of sediments due to seawalls, revetments, and other similar structures. Sands that would normally be released into coastal waters during high wave events and with seasonal profile fluctuations are trapped behind these structures and prevented from adding to the beach sediment budget. Eventually, the beach narrows until it is ultimately lost. One seawall may have minimal impact, but along many Hawaiian coastlines, myriads of armoring structures 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.

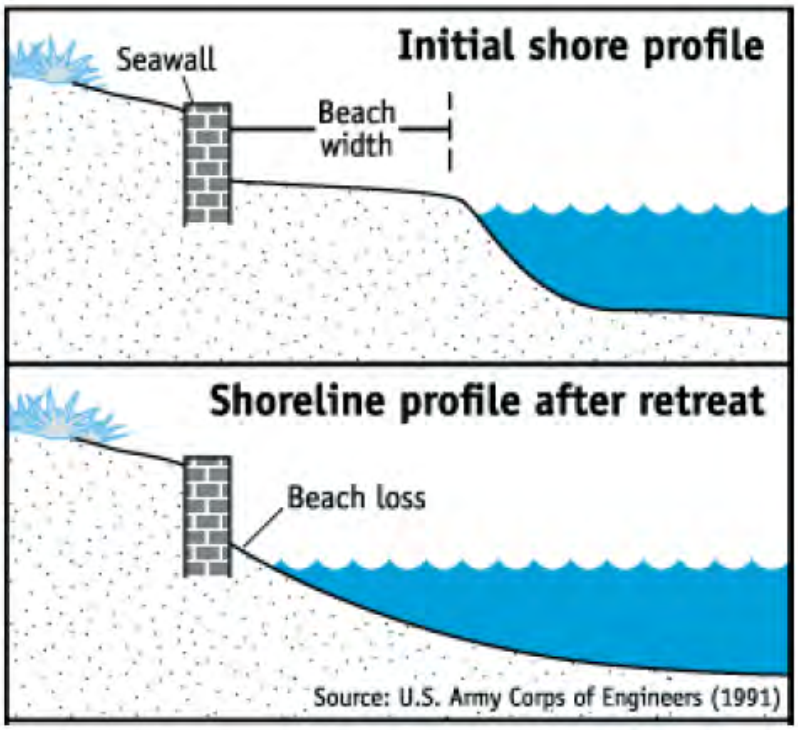


FIGURE 7-3. BEACH LOSS DUE TO SHORELINE HARDENING

Breakwaters

Breakwaters are common in Hawaiian shorelines to protection of harbor, marinas, and boat basins. Breakwaters have the potential to cause sediment deficiencies along adjacent beaches because they interfere with patterns of sand flow and accumulation. For this reason, it is important to conduct careful assessments of dynamics and patterns along shorelines in order to minimize the impacts of existing and future breakwaters 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.

Canalization

Canalization occurs throughout Maui County as a mitigation effort against the flash flooding of the most hazardous streams that flow intermittently from Maui's mountain ranges to the coast during heavy rainfall events. Any streams that flow intermittently from Hawaiian mountains ranges to the coast are subject to flash flooding during heavy rainfall events. These canals serve as concrete passages or gutters to contain floodwaters. Where canals and similar infrastructure 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). This process 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 proper adjacent beach replenishment, it is necessary to conduct reviews of the ambient littoral processes and develop schedules of transport direction around each channel mouth, with guidelines on the placement of returned sand.

Sand Mining

Sand mining is a presently outlawed past practice which refers to the process of collecting large amounts of coastal sands to produce building materials. In the Island of Maui, for example, Baldwin Beach, Sugar Cove, and other beaches were past sand mining sites. 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. Besides loss of vegetation and beach foreshore, sand mining impacts beaches negatively by decreasing sand volumes, steepening the morphology of the shoreline, and reducing the ability of profiles to respond to seasonal wave stresses. Although outlawed in Hawaii, there are occasional requests to mine remote beaches that are perceived as being of low socioeconomic value and high sand volume.

7.2 Hazard Profile

7.2.1 Past Events

South Maui – Kihei Area

Along the Kihei coastline, there is a general trend of erosion, with widely varying rates and patterns of shoreline movement. The shoreline at the south end of Kalama Park receded approximately 100 yards between 1912 and 1949 and accreted about 115 yards between 1900 and 1949. Along the Kalama Park/Halama Street area, the beach has mostly disappeared in front of coastal armoring. Other beaches in the Kihei area prone to episodic erosion include Keawakapu, Mokapu, 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 have often been sited too close to the ocean. Some resort hotels in the Sugar Beach area were constructed in the dynamic zone of the beach, seaward of the 1949 vegetation line (County of Maui, 2010a).

North Maui – Kanaha Area

Kanaha Beach, on the Island of Maui's north shore, is part of an approximately 5-mile stretch of coastline between Kahului Harbor and the town of Paia that experienced severe erosion since at least 1950. Past mining of beach sand for processing sugarcane contributed to the problem. Construction of Kahului Harbor in 1910 may be contributing to the problem as well. A wastewater facility serving the Wailuku-Kahului area was constructed in this area in the mid-1970s despite an obvious erosion hazard. A rock revetment that today protects the wastewater facility, along with another revetment built at Baldwin Beach, have resulted in loss of the beach in front of these structures. However, wide beaches front adjacent undeveloped shoreline segments despite severe coastal erosion. 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. The area is subject to high wind and wave energy despite the wide fringing reef offshore (County of Maui, 2010a).

West Maui – Lahaina Area

Honoapiilani Highway (State Highway 30) runs right along the ocean for much of the West Maui coastline from Papalaua to a couple of miles south of Lahaina. Several areas of the highway are close enough to the ocean to interfere with active beach processes. The beaches and offshore reefs along here are being damaged in some cases, and threatened in others, by the proximity of the highway. Revetments and seawalls armor several short segments of the highway, but many of these segments are still subject to coastal flooding, wave splash, and wave overtopping. Wave run-up during moderate and high wave episodes floods portions of this highway, leading to occasional temporary road closures (County of Maui, 2010a).

West Maui – Maalaea Coral Reef Degradation

The end result of reef degradation is evident at Maalaea Bay. In 1972, Maalaea coral reefs were described as being 'striking in their diversity and in the presence of rare corals species.' As late as 1993, estimated coral cover was 50- 75 percent close to the site where cover is now 8 percent. Therefore, in just a few decades, the Maalaea reef has transformed from a healthy and diverse ecosystem into a badly degraded habitat overgrown by algae and with little surviving coral (County of Maui, 2010a).

One consequence of severe loss of living coral is that degrading reefs change from being actively-growing and structurally-complex habitats, into eroding and relatively flat areas which do not support abundant marine life. That process is well advanced at Maalaea, where fish stocks are now in very poor condition, being dominated by small wrasse, triggerfish and puffers. Given that the Maalaea reef is now a poor habitat for most grazing fishes, and that existing blooms of algae will continue to inhibit new coral growth, even in the best of circumstances (without water quality or fishing impacts), recovery of Maalaea would likely take many years (DAR, 2007) (County of Maui, 2010a).

7.2.2 Location

All of Maui County's shoreline is susceptible to coastal erosion to some degree. On the Island of Maui, approximately 78 percent of beaches eroded over the past century with an overall (island-wide) average shoreline change rate of 13 cm of erosion per year (Romine et al., 2013). Though all of Maui and the State of Hawaii's beaches are at risk of experiencing some degree of coastal erosion, researchers found that the rate and amount of coastal erosion is highly variable. Pockets of erosion are typically separated by hundreds of feet on continuous beaches or by rocky headlands that divide the coast into many small embankments (USGS, 2012a)

Researchers at the University of Hawaii, under contract from Maui County, developed maps of coastal erosion hazards along the coasts of West Maui, North Shore, and Kihei. The erosion hazard maps depict the average annual erosion rate calculated by linear regression of historical shoreline positions. Examples are shown on Figure 7-4 and Figure 7-5.

Source: Hawaii Coastal Erosion Website, 2015

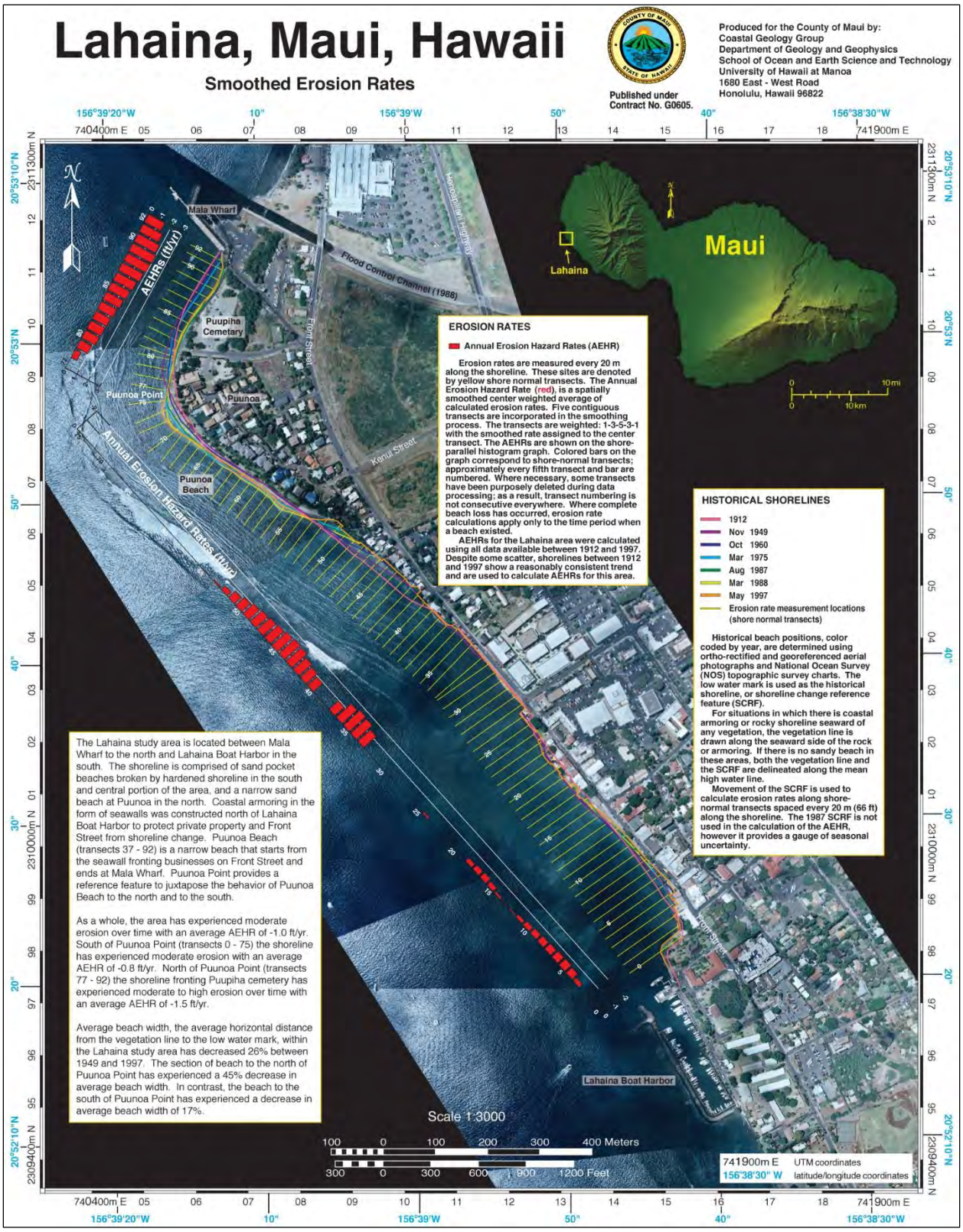


FIGURE 7-4. COASTAL EROSION MAP FOR LAHAINA

Source: Hawaii Coastal Erosion Website, 2015

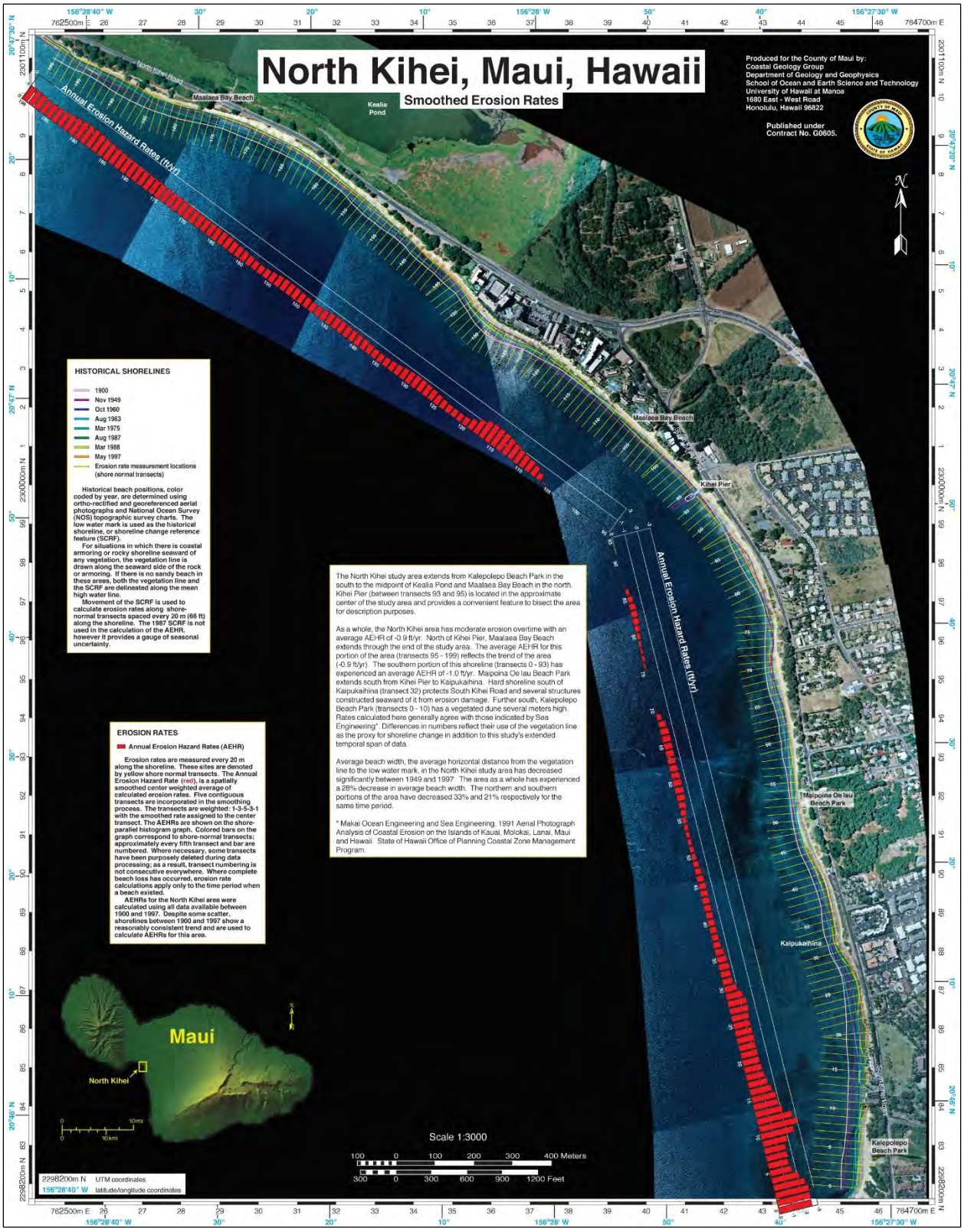


FIGURE 7-5. COASTAL EROSION MAP FOR NORTH KIHEI

The Islands of Maui and Molokai largely protect the Island of Lanai from major erosion to the north and northeast. As a result, the majority of erosion on Lanai occurs on the southwest side of the island, where waves and storms caused by Kona Winds have noticeably undercut the basalt rock (Moberly and Cox, 1963; USGS, n.d.).

Coastal erosion affects long sections of the Island of Molokai along the southern shoreline as indicated by scarped dunes, fallen trees, and extensive outcrops of beach rock, as seen at Kolo Wharf. Widespread upland erosion on west Molokai has developed as a result of poor land management practices (Coastal Geology Group, 2013).

Coral reef areas are found just offshore of all islands that encompass Maui County, however, Molokai contains the most extensive coral reef in the main Hawaiian Islands.

7.2.3 Frequency

Sandy beaches naturally experience phases of erosion and accretion, or sediment return that operate over a range of time intervals. Frequent short-term changes are seasonal; erosion mostly occurs when storms that generate erosional wave regimes are more frequent. Rapid erosional episodes may also be produced by high- magnitude storms, such as tropical cyclones or intense low pressure systems. The degree of erosion within a particular erosional phase can be highly variable, depending on the magnitude and frequency of storms. During a 100-year storm, waves may erode several meters into a dune that sits well behind the normally active zone of accretion and erosion. Lower-magnitude storms occurring in quick succession can produce a similar degree of erosion because the intervening periods are too short for constructive swell waves to push a significant amount of sediment back to the shoreline (County of Maui, 2010a).

Hawaii has two dominant wave “seasons.” In winter, large north Pacific swells affect north and west exposed shorelines while relatively calm conditions prevail along sheltered southern shores. In summer, southern hemisphere swells affect exposed southern and western shorelines and calm conditions are typical on north shores. At any time of year, extended periods of high trade wind waves from the east to northeast can cause short-term beach erosion and damage to coastal property on windward shores. Winter storm fronts and occasional hurricanes bring onshore “Kona” (westerly and southerly) winds and damaging waves to typically leeward shores (Romine et al., 2013).

Regardless of cyclical normalcies, the Maui County coastline may take several years for a beach to return to its pre-storm condition after one major storm or several smaller storms in quick succession (County of Maui, 2010a).

7.2.4 Severity

Scientists from the USGS and the University of Hawaii School of Ocean and Earth Science and Technology conducted an assessment of coastal changes of beaches on the islands of Kauai, Oahu, and Maui over the past century. According to this assessment, the Island of Maui is suffering from both long-term and short-term erosion with an alarmingly small accretion rate (Table 7-1). In the short term, the Island of Maui can expect 76 percent of its beaches to erode, with an 18 percent accretion rate. Over the long term, the island can expect 85 percent of its beaches to erode with only a 14 percent accretion rate (USGS, 2012).

TABLE 7-1.
SHORELINE CHANGE TRENDS FOR THE ISLAND OF MAUI

	Beach Loss		Percent Eroding		Percent Accreting	
Region	(km)	(%)	Long Term	Short Term	Long Term	Short Term
North	0.9	6	87	74	12	16
Kihei	2.1	11	83	77	16	20
West	3.8	14	85	77	14	18
Total	6.8	11	85	76	14	18

Source: USGS, 2011

7.2.5 Warning Time

Meteorologists can often predict the likelihood of weather events that can impact shoreline communities in the short term and ultimately the shoreline. NOAA's National Weather Service monitors potential events, and provides forecasts and information, sometimes several days in advance of a storm, to help prepare for an incident.

7.2.6 Potential Impacts of Climate Change

Coastal areas may be impacted by climate change in different ways. Coastal areas are sensitive to sea-level rise, changes in the frequency and intensity of storms, increase in precipitation, and warmer ocean temperatures. According to NASA, warmer temperatures may lead to an increase in frequency of storms, thus leading to more weather events that cause coastal erosion. A study on increased storm wave heights from climate change indicated that coastal erosion and flooding may occur twice as fast from sea level rise alone and up to four times as fast as a doubling of the frequency of major El Niño events occurring. Should all these potential subsequent events from climate change occur simultaneously, there could be up to an order of magnitude increase in both coastal erosion and flood frequency (compared against the current rate of those processes). While erosion rates would still be partially dependent on beach slopes and dune crest elevations, this possibility highlights the importance of incorporating climate change and climate control into mitigation practices (Ruggiero, 2008).

As a series of small islands, Maui County is particularly sensitive to the impacts of coastal erosion as caused by climate change. According to the Intergovernmental Panel on Climate Change, small islands can anticipate the following biogeophysical effects of climate change:

- Inundated and displaced wetlands and lowlands
- Eroded shorelines
- Exacerbated coastal storm flooding
- Increase in salinity of estuaries, threatening freshwater aquifers and otherwise impair water quality
- Alteration of tidal ranges in rivers and bays
- Alteration of sediment depositional patterns.

As islands, Maui, Lanai, and Molokai contain open coasts around the perimeter of the land mass. These coasts are primarily made up of unconsolidated sands and gravels exposed to winds and wave action. As sea levels rise, so does

the increase in pressure and strength of wave action against Maui County's coastlines. Additionally, sewage and siltation are among the most significant causes of coral-reef and other natural coastal system human caused degradation in Hawaii. This degradation is exacerbated by higher sea levels caused by climate change that adds additional pressure to an already taxed ecosystem (Bijlsma et al., 1999).

7.2.7 Secondary Hazards

Shore protection structures such as seawalls and revetments often are built to attempt to stabilize the upland property. However, typically they eliminate natural wave run-up and sand deposition processes and can increase reflected wave action and currents at the waterline. Increased wave action can cause localized scour in front of structures and prevent settlement of suspended sediment (FEMA, 1996).

According to NOAA, sea level rise can amplify factors that currently contribute to coastal flooding: high tides, storm surge, high waves, and high runoff from rivers and creeks. All of these factors change during extreme weather and climate events (NOAA, 2012). When paired with severely eroded coastline, coastal flooding becomes further exacerbated as previously unflooded areas become exposed.

7.3 Exposure

This section describes the populations, property, critical facilities/infrastructure, and environment that are currently exposed to the hazard. No spatial data sets were available to perform an in-depth spatial analysis of exposure, so a qualitative discussion follows.

7.3.1 Population

Coastal erosion has both short- and long-term effects for populations within Maui County. Exposure to populations, however, is different than other hazards profiled in this plan due to the usually slow nature of this hazard. Populations exposed to the hazard include beach visitors. As beaches shrink, populations who visit Maui County's beaches are subject to less recreational space. Immediately, populations feel the beach squeeze as people crowd onto the disappearing coastline. Over the long term, the economic effects may be felt as visitors forgo trips to Maui County and choose more spacious, less crowded vacation areas and beaches.

Populations that visit slowly eroding coastal cliff areas of the County are at risk of the slow destabilization of land due to the process of undercutting. Maui County officials must remain diligent in regular assessment and proper marking of hazardous areas as they become unstable over a number of years.

7.3.2 Property

Properties located on or near areas experiencing coastal erosion are exposed to the coastal erosion hazard. Because erosion reduces shoreline and decreases the distance from building footprints to erosion areas, more properties have the potential to be exposed overtime.

7.3.3 Critical Facilities and Assets

Facilities and infrastructure that are located on or near areas experiencing coastal erosion are exposed to the coastal erosion hazard.

7.3.4 Onshore and Offshore Natural Environment

The environment currently exposed to the coastal erosion hazard is all of the exposed coastlines around the Maui County islands. While all areas of the coast are affected by the threat of coastal erosion, some areas are more prone to erosion than others.

In 1999, The Hawaii Division of Aquatic Resources (DAR) in partnership with the Coral Reef Assessment and Monitoring Program began annual surveys of coral condition at 9 reef areas in Maui County. Coral status and trends throughout the monitored area paint a dire picture of the health of the County's coral reefs:

- Coral cover in 2006 ranged from 74 percent at Molokini to less than 10 percent at 4 sites: Honolua (9 percent), Puamana (8 percent), Maalaea (8 percent), and Kanahena Point (6 percent).
- Coral cover increased at only 1 reef (Kanahena Bay, 17 to 30 percent), remained stable (less than 5 percent change), at 3 reefs (Molokini, Papaula Point, and Puamana), and declined at 5 reefs, most dramatically at Honolua (42 to 9 percent) and at Kahekili (55 to 33 percent).
- Mean coral cover of the 9 reefs declined from 35 percent when sites were first surveyed (1994 for West Maui, 1999 elsewhere) to 27 percent in 2006. Thus, nearly a quarter of all living coral was lost over that period (DAR 2007).

7.4 Vulnerability

7.4.1 Population

As coastal erosion recedes beaches and destroys barrier dunes, the potential for population vulnerability increases. Individuals who live around the area are exposed to secondary hazards such as high tides, storm surges, and flooding.

7.4.2 Property

Like populations, structures located beyond the protective dunes of the coast are vulnerable to high tides, storm surges, and flooding.

7.4.3 Critical Facilities and Assets

All critical facilities and assets that are exposed to coastal erosion are also vulnerable.

7.4.4 Onshore and Offshore Natural Environment

As the coastline recedes, new areas become vulnerable to erosions effects. For example, previously separated bodies of water erode and allow ocean waters to rush into low lying freshwater wetland, including the Kealia Poing National Wildlife Refuge, destroying the associated freshwater ecosystem.

7.4.5 Economic Impact

As mentioned earlier, the economic impact may be felt in Maui County's tourism industry, as visitors avoid Maui's shrinking beaches for more space and less crowd. Additionally, as coastal zones become further eroded, thus exposing additional areas to potential hazards, the County will need to commit increasing amounts of funds to rebuild the buffer and harden current flooding capabilities.

7.5 Future Trends in Development

Because coastal erosion in a significant concern in Hawaii and because near-shore development has been known to exacerbate coastal erosion rates, the state requires that developments must be built 20 to 40 feet away from the shoreline. Maui has adopted even more stringent rules than the state requirements, wherein the required setbacks (distance between the ocean and development) are based on measured rates of erosion. These rates are calculated by multiplying the current rate of erosion by a number of years. Such requirements are some of the most restrictive in the region and will ideally help protect life, property, and coastal resources (EPA, 2013d). Future development in Maui will be guided by these regulations and by the general plan documents adopted by the County.

7.6 Scenario

A worst-case scenario for the coastal erosion hazard involves a series of severe storms that do not allow the natural accretion of sediment back to the coastal area. These storms cause the beaches on Maui to erode and eventually cause dune collapse in certain area. A hurricane then hits Maui County during high tide, which causes massive coastal flooding in neighborhoods and inundates coastal transportation infrastructure with water, making transportation impossible and causing a series of cascading events that affect life, property, and safety. After the flood waters recede, the coastal landscape becomes much smaller and the previous dune buffer between the ocean and populated coastal areas is nonexistent. Lengthy and costly beach reconstruction is needed to restore the coastal area.

7.7 Issues

The following issues and potential approaches may be considered for the coastal erosion hazard:

- **Artificial beach regeneration**—Artificial beach regeneration is a potential solution to beach erosion in Maui County. The benefits of this include restructured beaches to accommodate continued tourism and the strengthening of the beach buffer during high tide and storm surge events. Cons associated with this approach include a repetitive need to continually replenish materials, particularly after a severe storm, and the inability for the County of Maui to support artificial beach regeneration at all impacted locations in the planning area, and the costs associated with beach regeneration.
- **Monitoring and impact studies on future human-caused aggravators**—Many of the human caused issues associated with coastal erosion, such as breakwaters and seawalls, are necessary for Maui County. Impact studies for future development will allow the County to investigate how new development will impact coastal erosion. This will, however, increase budgetary expenditures for such studies and increase development and construction time for projects.
- **Coastline development monitoring**—Studies have shown that coastline development contributes to the degradation of natural coral reefs. This slow destruction is attributed to the hardening of the shoreline with an inability for sediment to return via natural processes and an increase in pollution that occurs with both development materials and occupant waste. In order to minimize the effects of human-caused coral reef degradation, Maui County may consider conducting impact analyses and other reports on new development along shorelines that are in proximity to sensitive coral reef areas.
- **New coastal setback requirements**—Although Maui County has adopted new shoreline setback requirements, structures built before these requirements were in place remain vulnerable.

Chapter 8. Dam and Reservoir Failure

8.1 Hazard Description

Hawaii Administrative Rules (Chapter 190.1) define a state regulated dam as any artificial barrier, including appurtenant works that impounds or diverts water and has one of the following characteristics (County of Maui, 2010a):

- It stores at least 15 acre-feet and the maximum water storage elevation is 25 feet or more above the natural bed of the watercourse at the downstream toe of the barrier, or from the lowest elevation of the outside limit of the barrier if it is not across a watercourse.
- It is at least 6 feet high and has an impounding capacity at maximum water storage elevation of 50 acre-feet or more.

There are three types of dams (County of Maui, 2010a):

- Detention dams are constructed to minimize the effects of flood runoff by storing all or part of an anticipated flood runoff. The stored floodwater 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 to be used during periods of drought for crop irrigation, livestock watering, municipal and industrial water supply, and electricity generation.
- Diversion dams are non-regulated and constructed to provide hydraulic head for diverting water from streams and rivers into ditches or canals.

Reservoirs control flooding by holding high flows behind dams or in storage basins. After a flood peaks, water is released slowly at a rate that the stream can handle downstream. The lake created may provide recreational benefits such as fishing and water sports. Wet or dry basins can serve multiple uses by doubling as parks or other open space uses. Reservoirs may be the only flood control measure that can protect development close to a watercourse. They are most efficient in deep valleys with room to store water. Designs for reservoirs built for water supply, recreation or other purposes should include flood protection measures. Flood pools and flood protection measures should be considered when existing reservoirs are rehabbed or retrofitted (County of Maui, 2010a).

DEFINITIONS

Dam—Any artificial barrier and/or any controlling works, together with appurtenant works, that can or does impound or divert water and is 25 feet or more high or impounds 50 acre-feet or more (Hawaii Administrative Rules, Chapter 190.1.)

Dam Failure—An uncontrolled release of impounded water.

Emergency Action Plan—A document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize property damage and loss of life. The plan specifies actions the dam owner should take to alleviate problems at a dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show emergency management authorities the critical areas for action in case of an emergency. (FEMA 64)

High Hazard Dam—Dams where failure or operational error will probably cause loss of human life. (FEMA 333)

Significant Hazard Dam—Dams where failure or operational error will result in no probable loss of human life but can cause economic loss, environmental damage or disruption of lifeline facilities, or can impact other concerns. Significant hazard dams are often located in rural or agricultural areas but could be located in areas with population and significant infrastructure. (FEMA 333)

Partial or full failure of dams and reservoirs has the potential to cause massive destruction to the ecosystems and communities located downstream. Partial or full failure can occur as a result of one or a combination of the following reasons:

- Overtopping caused by floods that exceed the dam capacity (inadequate spillway capacity)
- Prolonged periods of rainfall and flooding
- Deliberate acts of sabotage (terrorism)
- Structural failure of materials used in dam construction
- Movement and/or failure of the foundation supporting the dam
- Settlement and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate or negligent operation, maintenance, and upkeep
- Failure of upstream dams on the same waterway
- Earthquake (liquefaction/landslides) (FEMA, 2015).

Many dam failures in the United States have been secondary results of other disasters. The most common causes are earthquakes, landslides, extreme storms, equipment malfunction, structural damage, foundation failures, and sabotage. Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies. The potential for catastrophic flooding due to dam failures led to passage of the National Dam Safety Act (Public Law 92-367). The National Dam Safety Program requires a periodic engineering analysis of every major dam in the country. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public.

The U.S. Army Corps of Engineers (USACE) is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding design, construction, operation and maintenance of the dams; and developed guidelines for inspection and evaluation of dam safety USACE, 1997).

The Federal Energy Regulatory Commission (FERC) cooperates with a large number of federal and state agencies to ensure and promote dam safety. More than 3,000 dams are part of regulated hydroelectric projects in the FERC program. Two-thirds of these are more than 50 years old. As dams age, concern about their safety and integrity grows, so oversight and regular inspection are important. FERC inspects hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems
- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with the terms and conditions of a license.

State and federal initiatives have been established to reduce the potential of full or partial failures. The State of Hawaii's 2010 Dam Safety Act (HAR, Title 13, Subtitle 7, Chapter 190.1) is administered by the Department of Land and Natural Resources (DLNR), which reviews and approves plans and specifications for the construction of new or modified dams. Any individual or entity seeking to construct, alter, repair or remove an existing dam must fill out the DLNR's *Application for Approval of Plans and Specifications for Construction, Enlargement, Repair, Alteration, or Removal of Dam* (County of Maui, 2010a).

In 2009, the DLNR launched a study to generate dam failure inundation maps for all regulated dams in the state. The following assumptions were used to model dam failure scenarios for each reservoir using DHI's MIKE 11, MIKE 21 and MIKE-Flood models. (County of Maui, 2010a):

- Failure occurs during a sunny day with dry downstream conditions
- Failure occurs when dam is at its maximum capacity
- Failure results from a piping failure halfway up the face of the dam
- Spillways and dam outlets are inoperable at the time of the breach.

In addition to the dam failure inundation maps, the study provides individual dam assessment reports with the following information (County of Maui, 2010a):

- Total maximum water depth
- Time of maximum water depth
- Time to first inundation
- Water velocity
- Number of people potentially impacted downstream
- Water depth and velocity at bridges and road crossings
- Impacts on building infrastructure
- Impacts on critical facilities.

The State of Hawaii County Civil Defense Agencies generated evacuation maps using information from the inundation analyses (PDC, 2010). These evacuation maps form the basis for the exposure and vulnerability analysis described later in this chapter.

8.2 Hazard Profile

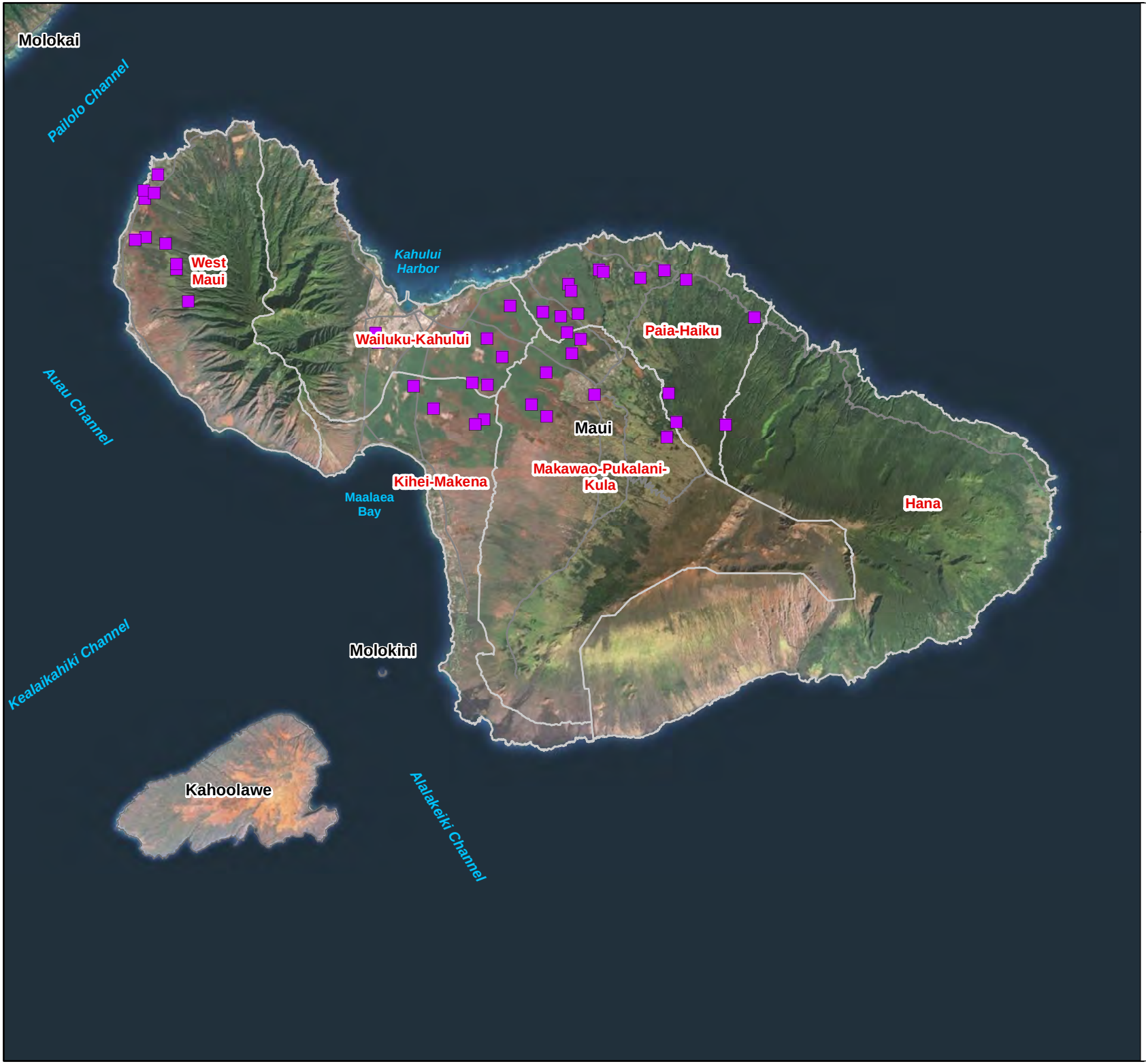
8.2.1 Past Events

There has been one recorded historical dam or reservoir failure in the County of Maui. Horner Reservoir failed on November 13, 1994; however, little information could be found on the failure's impacts. In addition, privately owned Ka Loko Dam, which failed on the Island of Kauai, had similarities in dam construction, ground topography, and rainfall intensity to dams in Maui County. On March 14, 2006, a 120-foot long portion of the dam breached after an unusually long period of torrential rain. Approximately 300 million gallons of water and debris destroyed several homes, devastated a 300-foot long portion of state highway, overturned several utility poles and lines, and killed seven people. An independent civil investigation identified conditions and practices that could have contributed to the failure:

inadequate inspections, non-permitted grading operations, inadequate maintenance, and non-enforcement of regulations (County of Maui, 2010a).

8.2.2 Location

Maui County has 56 dams and reservoirs—one on the Island of Molokai and the rest on the Island of Maui. Their locations are shown on Figure 8-1.



Maui County Islands of Maui and Kahoolawe

Dams

Legend

- **Community Plan Boundaries**
- Dams

Base Map Data Sources:
Maui County, Hazus, ESRI
HI Office of Planning

TETRA TECH

N

0 4.5 9 Miles

8.2.3 Frequency

Given increased monitoring procedures enacted following the breach of the La Loko Dam, the probability of a dam failure anywhere in Hawaii has been significantly reduced. A major dam failure is a rare event for which there is no defined recurrence interval. However, the potential does exist during an extreme rainfall event or during a major earthquake at any location (County of Maui, 2010a).

8.2.4 Severity

Dam failure can be catastrophic to all life and property downstream. The State of Hawaii classifies dams and reservoirs in a three-tier hazard rating system based on potential consequences to downstream life and property that could result from a failure of the dam (County of Maui, 2010a):

- **High Hazard**—Dams assigned the high hazard potential classification are those where failure or mis-operation would probably cause loss of human life.
- **Significant Hazard**—Dams assigned the significant hazard potential classification are those where failure or mis-operation would result in no probable loss of human life but could cause/economic loss, environmental damage, disruption of lifeline facilities, or other concerns.
- **Low Hazard**—Dams assigned the low hazard potential classification are those where failure or mis-operation would result in no probable loss of human life and in low economic and/or environmental losses.

Of the 56 dams in the County of Maui, 38 are rated high hazard with an additional 15 proposed to be rated high hazard, 2 are rated significant hazard, and 1 is rated low hazard (see Table 8-1).

8.2.5 Warning Time

Warning time for dam failure depends on the cause of the failure. In events of extreme precipitation, evacuations can be planned with sufficient time. In the event of a structural failure due to earthquake, there may be little warning time. A dam's structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach, as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

TABLE 8-1.
MAUI COUNTY DAMS AND HAZARD RATINGS

Dam/Reservoir Name	Hazard Rating[a]	ID[b]	Dam/Reservoir Name	Hazard Rating[a]	ID[b]
Haiku Reservoir	H	HI00095	Reservoir 20	H	HI00070
Hanakaoo Reservoir	H	HI00056	Reservoir 21	H	HI00071
Honokowai Dam	H	HI00130	Reservoir 22	H	HI00072
Honokowai Reservoir	H	HI00058	Reservoir 24	H	HI00073
Horner Reservoir	H	HI00054	Reservoir 25	H	HI00074

TABLE 8-1.
MAUI COUNTY DAMS AND HAZARD RATINGS

Kahakapao Reservoirs	H	HI00138	Reservoir 30	H	HI00075
Kahana Dam (Structure #5)	H	HI00126	Reservoir 33	H	HI00076
Kahoma Reservoir	H	HI00057	Reservoir 40	H	HI00077
Kailiilii Reservoir	Proposed H	HI00143	Reservoir 42	H	HI00078
Kapalaalaea Reservoir	Proposed H	HI00094	Reservoir 52	H	HI00079
Kaupakulua Reservoir	Proposed H	HI00093	Reservoir 60	H	HI00080
Kehalani Detention Basin	H	HI00141	Reservoir 61	H	HI00081
Koapala Basin (Structure #4)	H	HI00134	Reservoir 70	H	HI00082
Kualapuu (Molokai) Reservoir	H	HI00041	Reservoir 73 (Waiale Reservoir No. 1)	H	HI00083
Mahinahina Reservoir	Proposed H	HI00144	Reservoir 74 (Waiale Reservoir No.2)	H	HI00084
Maui Field 290 Reservoir	Proposed H	HI00139	Reservoir 80	H	HI00085
Middle Field 14 Reservoir	Proposed H	HI00142	Reservoir 81	Proposed H	HI00086
Napili 2-3 Desilting Basin	H	HI00128	Reservoir 82	S	HI00087
Napili 4-5 Desilting Basin	Proposed H	HI00127	Reservoir 84	H	HI00088
Olinda Reservoir	H	HI00048	Reservoir 90	Proposed H	HI00089
Papaaea Reservoir	Proposed H	HI00092	Reservoir 92	Proposed H	HI00090
Pauwela Reservoir	H	HI00096	Ukumehame Reservoir	H	HI00140
Peahi Reservoir	Proposed H	HI00091	Upper Field 14 Reservoir	Proposed H	HI00132
Piiholo 50-Mg Reservoir	Proposed H	HI00047	Reservoir 140	H	HI00059
Plantation Reservoir	H	HI00153	Waikamoi Reservoir	S	HI00152
Puu Koa Reservoir	Proposed H	HI00133	Waikamoi Dam No. 2	L	HI00046
Reservoir 14	H	HI00068	Wailuku Water 10 Reservoir	H	HI00151
Reservoir 15	H	HI00069	Wailuku Water 6 Reservoir	H	HI00150

a. H = high hazard; S = significant hazard; L = low hazard

b. Identification code used in National Inventory of Dams

8.2.6 Potential Impacts of Climate Change

Dams are designed partly based on assumptions about a stream's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or its entire designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream.

Dams are constructed with safety features known as "spillways," which provide a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of spillway flows.

8.2.7 Secondary Hazards

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on streams, and destruction of downstream habitat. Dam failure may worsen the severity of a drought by releasing water that might have been used as a potable water source.

8.3 Exposure

Dam failure evacuation area mapping for the planning area was collected for all state regulated dams. The building exposure (in dollars) for each evacuation area was analyzed by overlaying each evacuation area on the general building stock information developed from the County Assessor data. Exposure estimates for each evacuation area can be seen in Table 8-2.

TABLE 8-2.
EXPOSURE AND VALUE OF STRUCTURES IN DAM FAILURE INUNDATION AREAS

	Value Exposed			Community Planning
Dam Name	**Structure**	**Contents**	**Total**	**Areas Impacted**
Haiku Reservoir	$28,413,366	$14,206,683	$42,620,049	Paia-Haiku
Hanakaoo Reservoir	$1,450,875,864	$738,832,119	$2,189,707,983	West Maui
Honokowai Dam	$1,572,060,209	$799,454,656	$2,371,514,865	West Maui
Honokowai Reservoir	$0	$0	$0	West Maui
Horner Reservoir	$1,632,928,229	$830,876,641	$2,463,804,870	West Maui
Kahakapao Reservoirs	$23,058,788	$12,524,074	$35,582,862	Makawao-Pukalani-Kula, Paia-Haiku
Kahana Dam (Structure #5)	$88,643,564	$44,676,487	$133,320,051	West Maui
Kahoma Reservoir	$35,346,498	$17,673,249	$53,019,747	West Maui
Kailiilii Reservoir	$11,512,526	$5,756,263	$17,268,789	Paia-Haiku
Kapalaalaea Reservoir	$0	$0	$0	Paia-Haiku
Kaupakulua Reservoir	$14,247,588	$7,123,794	$21,371,382	Paia-Haiku
Kehalani Detention Basin	$1,075,992,938	$810,398,503	$1,886,391,441	Wailuku-Kahului
Koapala Basin (Structure #4)	$5,715,553	$2,857,777	$8,573,330	West Maui
Kualapuu (Molokai) Reservoir	$30,967,578	$24,850,099	$55,817,677	Molokai
Maui County Water West (Mahinahina Reservoir)	$44,290,926	$23,361,644	$67,652,570	West Maui
Maui Field 290 Reservoir	$10,578,697	$12,082,343	$22,661,040	Makawao-Pukalani-Kula, Wailuku-Kahului

TABLE 8-2.
EXPOSURE AND VALUE OF STRUCTURES IN DAM FAILURE INUNDATION AREAS

Dam Name	Value Exposed			Community Planning Areas Impacted
	Structure	Contents	Total	
Middle Field 14 Reservoir	$48,836,573	$24,418,286	$73,254,859	West Maui
Napili 2-3 Desilting Basin	$49,107,270	$25,585,477	$74,692,747	West Maui
Napili 4-5 Desilting Basin	$25,340,789	$13,260,874	$38,601,662	West Maui
Olinda Reservoir	$43,362,906	$22,084,287	$65,447,193	Makawao-Pukalani-Kula, Paia-Haiku
Papaaea Reservoir	$0	$0	$0	Paia-Haiku
Pauwela Reservoir	$6,795,481	$3,397,741	$10,193,222	Paia-Haiku
Peahi Reservoir	$3,782,383	$1,891,192	$5,673,575	Paia-Haiku
Piiholo 50-Mg Reservoir	$16,668,201	$8,819,444	$25,487,645	Makawao-Pukalani-Kula, Paia-Haiku
Plantation Reservoir	$103,483	$51,741	$155,224	West Maui
Puu Koa Reservoir	$70,085,797	$35,445,732	$105,531,529	Makawao-Pukalani-Kula, Paia-Haiku
Reservoir 14	$23,978,591	$12,639,872	$36,618,464	Paia-Haiku
Reservoir 15	$24,729,913	$13,015,533	$37,745,447	Paia-Haiku
Reservoir 20	$111,984,339	$75,224,689	$187,209,028	Makawao-Pukalani-Kula, Paia-Haiku
Reservoir 21	$99,205,495	$66,779,705	$165,985,200	Paia-Haiku
Reservoir 22	$97,981,730	$67,743,298	$165,725,028	Paia-Haiku
Reservoir 24	$105,836,354	$72,715,199	$178,551,552	Paia-Haiku
Reservoir 25	$103,079,955	$75,294,658	$178,374,613	Paia-Haiku, Wailuku-Kahului
Reservoir 30	$85,360,771	$45,165,383	$130,526,153	Makawao-Pukalani-Kula, Paia-Haiku, Wailuku-Kahului
Reservoir 33	$95,266,770	$104,444,749	$199,711,519	Makawao-Pukalani-Kula, Wailuku-Kahului
Reservoir 40	$735,770,411	$743,538,035	$1,479,308,446	Makawao-Pukalani-Kula, Wailuku-Kahului
Reservoir 42	$347,777,843	$351,372,162	$699,150,005	Makawao-Pukalani-Kula, Wailuku-Kahului
Reservoir 52	$162,475,411	$172,031,578	$334,506,989	Wailuku-Kahului
Reservoir 60	$31,197,348	$16,446,304	$47,643,652	Paia-Haiku, Wailuku-Kahului
Reservoir 61	$238,335,667	$247,891,835	$486,227,502	Wailuku-Kahului
Reservoir 70	$432,239,406	$511,613,135	$943,852,541	Wailuku-Kahului
Reservoir 73 (Waiale Reservoir 1)	$622,806,907	$568,366,801	$1,191,173,708	Wailuku-Kahului
Reservoir 74 (Waiale Reservoir 2)	$616,478,056	$558,722,538	$1,175,200,595	Wailuku-Kahului
Reservoir 80	$701,080,607	$794,652,358	$1,495,732,965	Kihei-Makena, Wailuku-Kahului
Reservoir 81	$22,332,194	$25,166,438	$47,498,632	Kihei-Makena
Reservoir 82	$0	$0	$0	Kihei-Makena
Reservoir 84	$555,600,319	$677,337,295	$1,232,937,614	Kihei-Makena, Wailuku-Kahului

TABLE 8-2.
EXPOSURE AND VALUE OF STRUCTURES IN DAM FAILURE INUNDATION AREAS

Dam Name	Value Exposed			Community Planning Areas Impacted
	Structure	Contents	Total	
Reservoir 90	$0	$0	$0	Kihei-Makena
Reservoir 92	$289,448	$289,448	$578,896	Kihei-Makena
Ukumehame Reservoir	$803,259	$401,629	$1,204,888	West Maui
Upper Field 14 Reservoir	$0	$0	$0	West Maui
Reservoir 140	$0	$0	$0	West Maui
Waikamoi Reservoir	$0	$0	$0	Hana, Paia-Haiku
Waikamoi Dam No. 2	$0	$0	$0	Hana
Wailuku Water 10	$1,010,631,858	$881,601,877	$1,892,233,735	Wailuku-Kahului
Wailuku Water 6	$2,007,004,106	$1,514,111,768	$3,521,115,874	Wailuku-Kahului

Three dams were chosen for a more in depth exposure and vulnerability analysis: Horner Reservoir and Wailuku Water 6 on Maui and Kualapuu on Molokai. These dams were selected because they represent the largest, non-overlapping exposure areas on each island.

8.3.1 Population

It is assumed that all populations in a dam failure evacuation zone would be exposed to the risk of a dam failure. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation. The estimated population living or staying in the mapped evacuation areas of the dams chosen for further analysis are as follows:

- **Horner Reservoir**—459 residents or less than 1 percent of the resident population, 7,983 visitors or 14.7 percent of the visitor population.
- **Wailuku Water 6**—16,387 residents or 11 percent of the resident population, 859 visitors or 1.6 percent of the visitor population.
- **Kualapuu**—263 residents or less than 1 percent of the resident population, 0 visitors or 0 percent of the visitor population.

8.3.2 Property

The estimated number of buildings, value of structure and contents exposed and percent of total structure and content value in the planning area for the mapped evacuation areas of the dams chosen for further analysis are as follows:

- **Horner Reservoir**—112 buildings, $2.46 billion in property exposure accounting for 5.4 percent of the total value of the planning area
- **Wailuku Water 6**—4,569 buildings, $3.52 billion in property exposure accounting for 7.7 percent of the total value of the planning area

- **Kualapuu**—108 buildings, $55 million in property exposure accounting for 0.12 percent of the total value of the planning area.

Table 8-3 shows the general land use of parcels exposed to the three dam failure evacuations areas chosen for further analysis.

- **Horner Reservoir**—The vast majority of the land area of parcels (69.9 percent) intersecting this evacuation area are agricultural. Residential parcels comprise 2.8 percent of the total acreage.
- **Wailuku Water 6**—Residential parcels account for 33.5 percent of evacuation areas followed by agricultural (13.9 percent), commercial (13.6 percent) and conservation (12.4 percent) areas.
- **Kualapuu**— The vast majority of the land area of parcels (90.4 percent) intersecting this evacuation area are agricultural. Residential parcels comprise 0.1 percent of the total acreage.

8.3.3 Critical Facilities and Assets

GIS analysis determined the number of the planning area's critical facilities and assets in each of the dam failure evacuation areas chosen for further analysis. The results are summarized in Table 8-4.

TABLE 8-3.
LAND USE WITHIN THE DAM EVACUATION AREAS

	Horner Reservoir		Wailuku Water 6		Kualapuu	
Land Use	**Area (acres)**	**% of total**	**Area (acres)**	**% of total**	**Area (acres)**	**% of total**
Agricultural	576.97	69.9%	399.84	13.9%	4,621.74	90.4%
Apartment	23.32	2.8%	12.71	0.4%	0.00	0.0%
Commercial	12.07	1.5%	444.37	15.4%	0.73	0.0%
Commercialized Residential	0.00	0.0%	0.00	0.0%	0.00	0.0%
Conservation	20.38	2.5%	358.58	12.4%	0.00	0.0%
Hotel/Resort	113.15	13.7%	18.93	0.7%	0.00	0.0%
Industrial	13.72	1.7%	392.64	13.6%	198.83	3.9%
Residential	23.38	2.8%	964.55	33.5%	4.17	0.1%
Time Share	7.43	0.9%	0.00	0.0%	0.00	0.0%
Not Classified	34.88	4.2%	289.30	10.0%	286.73	5.6%
Total	825.31	100.0%	2,880.92	100.0%	5,112.20	100.0%

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified."
Acreage includes only areas intersecting mapped hazard layers.

TABLE 8-4.
CRITICAL FACILITIES AND ASSETS IN DAM FAILURE EVACUATION AREAS

Facility Type	Number in Horner Evacuation Area[a]	Number in Wailuku Water 6 Evacuation Area[b]	Number in Kualapuu Evacuation Area[c]
Emergency Services			
Emergency Operations	0	0	0
Police & Fire	0	0	0

TABLE 8-4.
CRITICAL FACILITIES AND ASSETS IN DAM FAILURE EVACUATION AREAS

Facility Type	Number in Horner Evacuation Area[a]	Number in Wailuku Water 6 Evacuation Area[b]	Number in Kualapuu Evacuation Area[c]
Community Shelter[d]	0	1	0
Medical & Health	0	0	0
Government and Services			
Government[e]	—	—	—
Schools[d]	0	12	1
Critical Infrastructure and Lifelines			
Transportation	1	6	1
Water Supply	0	0	0
Wastewater	4	13	0
Dams	1	0	0
Energy	0	3	1
Telecommunications	0	0	0
Hazardous Materials	0	3	0
Other Important Assets			
Financial	0	13	0
Tourist Lodging	9	2	0
Early Assistance	0	1	0
Total	15	54	3

a. Horner dam failure would affect only the West Maui Community Planning Area.
b. Wailuku dam failure would affect only the Wailuku-Kahului Community Planning Area.
c. Kualapuu dam failure would affect only the Molokai Community Planning Area.
d. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.
e. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Note: Sources of data used in Hazus-MH modeling are described in Table 5-2.

8.3.4 Onshore and Offshore Natural Environment

Reservoirs held behind dams affect many ecological aspects of a stream. Stream topography and dynamics depend on a wide range of flows, but streams below dams often experience long periods of very stable flow conditions or saw-tooth flow patterns caused by releases followed by no releases. Water releases from dams usually contain very little suspended sediment; this can lead to scouring of stream beds and banks.

The environment would be exposed to a number of risks in the event of dam failure. The inundation could introduce many foreign elements into local waterways. This could result in destruction of downstream habitat and could have detrimental effects on many species of animals and plants, especially endangered species or delicate coral ecosystems.

8.4 Vulnerability

Vulnerability is the effect of dam failure on the surrounding community and planning area as a whole. These effects can be felt beyond the immediately affected area.

8.4.1 Population

Vulnerable populations are all populations downstream from dam failures that are incapable of escaping the area within the allowable time frame. This population includes the elderly, young, and individuals with disabilities, access, or functional needs who may be unable to get themselves out of the inundation area. The vulnerable population also includes those who would not have adequate warning from a television or radio emergency warning system. Population adversely affected by a dam failure may also include those beyond the disaster area that rely on the dam for providing potable water.

Impacts on persons and households for the three dams chosen for further analysis were estimated for each event through the Level 2 Hazus-MH analysis. The methodology and/or scenarios utilized to develop the evacuation maps were utilized for the analysis. Table 8-5 summarizes the results.

TABLE 8-5.
ESTIMATED DAM FAILURE IMPACTS ON PERSONS AND HOUSEHOLDS

Dam Name	Number of Displaced Households	Number of Residents Requiring Short-Term Shelter
Horner Reservoir[a]	342	290
Wailuku Water 6[b]	14,555	14,496
Kualapuu[c]	285	103

a. Horner dam failure would affect only the West Maui Community Planning Area.
b. Wailuku dam failure would affect only the Wailuku-Kahului Community Planning Area.
c. Kualapuu dam failure would affect only the Molokai Community Planning Area.
Note: Vulnerability for the visitor population was unable to be determined. Modeled results for the resident population are based on a variety of factors that are unavailable for the visitor population.

8.4.2 Property

Vulnerable properties are those closest to the dam inundation area. These properties would experience the largest, most destructive surge of water. Low-lying areas are also vulnerable since they are where the dam waters would collect. Table 8-6 shows the loss estimates that could result from a failure of each of the three dams chosen for additional analysis. The methodology and/or scenarios utilized to develop the evacuation maps were utilized for the analysis.

TABLE 8-6.
LOSS ESTIMATES FOR DAM FAILURE

Dam Name	Structure	Contents	Total	Estimated Loss As % Of Total Replacement Value
Horner Reservoir[a]	$144,321,000	$143,062,000	$287,383,000	2.88%
Wailuku Water 6[b]	$443,637,000	$535,757,000	$979,394,000	2.14%
Kualapuu[c]	$11,500,000	$14,519,000	$26,019,000	0.06%

a. Horner dam failure would affect only the West Maui Community Planning Area.
b. Wailuku dam failure would affect only the Wailuku-Kahului Community Planning Area.
c. Kualapuu dam failure would affect only the Molokai Community Planning Area.

8.4.3 Critical Facilities and Assets

Hazus-MH estimated damage to critical facilities and assets in the dam failure inundation zone as summarized in Table 8-7. Transportation routes are vulnerable to dam inundation and have the potential to be wiped out, creating isolation issues. This includes all roads, railroad related facilities and bridges in the path of the dam inundation. Those that are most vulnerable are those that are already in poor condition and would not be able to withstand a large water surge. Utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas. The methodology and/or scenarios utilized to develop the evacuation maps were utilized for the analysis.

TABLE 8-7.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM DAM FAILURE

	Number of Facilities Affected	Average % of Total Value Damaged		Days to 100% Functionality
		Building	Contents	
Emergency Services				
Horner Reservoir[a]	0	-	-	-
Wailuku Water 6[b]	1	7%	8%	480
Kualapuu[c]	0	-	-	-
Government[d] and Services				
Horner Reservoir[a]	0	-	-	-
Wailuku Water 6[b]	12	44%	89%	773
Kualapuu[c]	1	13%	72%	630
Critical Infrastructure and Lifelines				
Horner Reservoir[a]	6	20%	N/A	N/A
Wailuku Water 6[b]	25	34%	35%	N/A
Kualapuu[c]	2	79%	72%	N/A
Other Important Assets				
Horner Reservoir[a]	9	6%	19%	N/A
Wailuku Water 6[b]	16	69%	55%	N/A
Kualapuu[c]	0	-	-	-

a. Horner dam failure would affect only the West Maui Community Planning Area.
b. Wailuku dam failure would affect only the Wailuku-Kahului Community Planning Area.
c. Kualapuu dam failure would affect only the Molokai Community Planning Area.
d. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Note: Sources of data used in Hazus-MH modeling are described in Table 5-2.

8.4.4 Onshore and Offshore Natural Environment

The environment would be vulnerable to a number of risks in the event of dam failure. The inundation could introduce foreign elements into local waterways, resulting in destruction of downstream habitat and detrimental effects on many

species of animals, especially endangered species and delicate coral ecosystems. The extent of the vulnerability of the environment is the same as the exposure of the environment.

8.4.5 Economic Impact

The economic impact of dam failures varies depending on the location of the dam and the severity of the failure or partial failure. Potential economic losses in agriculture, business, and tourism may result from such an incident.

8.5 Future Trends in Development

Land use in the planning area will be directed by the general plan and community plans adopted under state law. The natural hazard elements of the general plans establish standards and policies for the protection of the community from hazards. Dam failure is currently not explicitly addressed in the countywide policy plan or many of the older community plans. Many of these plans are currently in the update process and the results and recommendations on this hazard mitigation plan will be incorporated into updated policies and planning actions. For example, the recently updated Maui Island Plan currently identifies a policy to "Consider the location of dams, reservoirs, holding ponds, and other water-containing entities that are upstream of inhabited areas to anticipate, avoid, and mitigate inundation risks, and discourage new development in areas where possible inundation hazards may exist." As these plans continue to be updated, Maui County's commitment to protecting life and property in dam failure inundation areas will be strengthened.

8.6 Scenario

An earthquake in the region could lead to liquefaction of soils around a high hazard dam. This could occur without warning during any time of the day. While the probability of dam failure is very low, the probability of flooding associated with changes to dam operational parameters in response to climate change is higher. Dam designs and operations are developed based on hydrographs with historical record. If these hydrographs experience significant changes over time due to the impacts of climate change, the design and operations may no longer be valid for the changed condition. This could have significant impacts on dams that provide flood control. Specified release rates and impound thresholds may need to be changed. This could result in increased discharges downstream of these facilities, thus increasing the probability and severity of flooding.

8.7 Issues

The most significant issue associated with dam failure involves the properties and populations in the inundation and evacuation zones. Flooding as a result of a dam failure could significantly impact these areas. There is often limited warning time for dam failure. These events are frequently associated with other natural hazard events such as earthquakes, landslides or tropical cyclones, which limits their predictability and compounds the hazard. Important issues associated with dam failure hazards include the following:

- **Residual Risk**—The concept of residual risk associated with structural flood control projects should be considered in the design of capital projects and the application of land-use regulations.
- **Security**—Addressing security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.

- U**nregulated Dams** - There are 81 (73 on Maui, 6 on Molokai, and 2 on Lanai) unregulated dams located in Maui County. Inundation and evacuation zones are not identified for unregulated dams. Further outreach to gather data on unregulated dams should be considered in the future.

Chapter 9. Drought

9.1 Hazard Description

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.

Drought is characterized by long durations of below normal precipitation. Drought occurs in virtually all climatic zones, yet its characteristics vary significantly from one region to another, because it is relative to the normal precipitation in that region. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life. Drought is a temporary irregularity in typical weather patterns that may last up to a number of years. Drought differs from aridity, which reflects low rainfall in a specific region and is a permanent feature of the climate of that area.

There are four generally accepted operational definitions of drought (National Drought Mitigation Center, 2006):

DEFINITIONS

Drought—The cumulative impacts of several dry years on water users. It can include deficiencies in surface and subsurface water supplies and generally impacts health, well-being, and quality of life.

Hydrological Drought—Deficiencies in surface and subsurface water supplies.

Socioeconomic Drought—Drought impacts on health, well-being and quality of life.

- **Meteorological drought** is an expression of precipitation's departure from normal over some period of time. Meteorological measurements are the first indicators of drought. Definitions are usually region-specific, and based on an understanding of regional climatology. A definition of drought developed in one part of the world may not apply to another, given the wide range of meteorological definitions.
- **Agricultural drought** is when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.
- **Hydrological drought** refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir, and groundwater levels. There is a time lag between lack of rain and less water in streams, rivers, lakes and reservoirs, so hydrological measurements are not the earliest indicators of drought. After precipitation has been reduced or deficient over an extended period of time, this shortage is reflected in declining surface and subsurface water levels. Water supply is controlled not only by precipitation, but also by other factors, including evaporation (which is increased by higher than normal heat and winds), transpiration (the use of water by plants), and human use.
- **Socioeconomic drought** occurs when a physical water shortage starts to affect people, individually and collectively. Most socioeconomic definitions of drought associate it with the supply and demand of an economic good.

Defining when drought begins is a function of the impacts of drought on water users, and includes consideration of the supplies available to local water users as well as the stored water they may have available in surface reservoirs or groundwater basins. Different local water agencies have different criteria for defining drought conditions in their

jurisdictions. Some agencies issue drought watch or drought warning announcements to their customers. Determinations of regional or statewide drought conditions are usually based on a combination of hydrologic and water supply factors.

Scientists and academics commonly use drought indices to monitor and forecast droughts. The most common indices vary in their suitability for assessing drought in Hawaii (County of Maui, 2010a):

- **Standardized Precipitation Index (SPI)**—The SPI considers only precipitation. An index value of zero represents the median precipitation amount; the index is negative for drought and positive for wet conditions. The SPI is computed for time scales ranging from one to 24 months. Because the SPI values are normalized, the wide range of rainfall conditions across Hawaii can be replacement on an equal basis. SPI values can be generated for multiple time scales, which is useful for monitoring because the effects of droughts occur over wide ranges of time scales. Because the SPI uses standard statistical principles, it can be used to monitor other data such as stream flow, reservoir levels, and groundwater levels. SPI Categories are as follows:

2.00 AND GREATER	EXTREMELY WET
1.50 TO 1.99	VERY WET
1.00 TO 1.49	MODERATELY WET
0.99 TO -0.99	NEAR NORMAL
-1.00 TO -1.49	MODERATELY DRY
-1.50 TO -1.99	VERY DRY
-2.00 AND LESS	EXTREMELY DRY

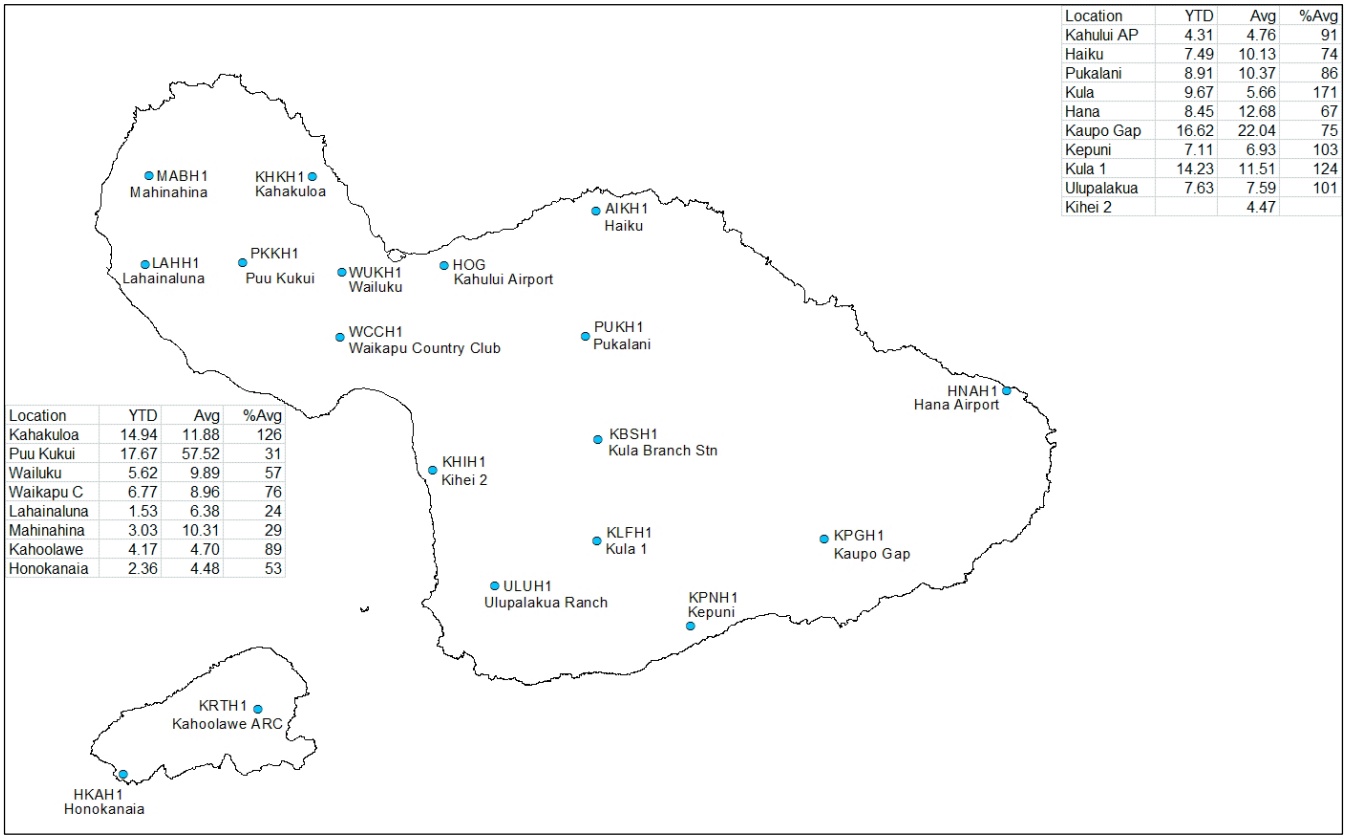
- The **Percent of Normal Rainfall Index (PNRI)**—The PNRI is based on current rainfall compared to the long-term mean. The PNRI is one of the simplest methods of comparing current precipitation to historical averages. The index is calculated by dividing the actual precipitation amount by a 30-year (typically) precipitation mean. Time scales are generally stated in months or a year. The PNRI is effective for comparing a single region or season in easily understood terms. A disadvantage of using the PNRI is that the mean precipitation is often not the same as the median precipitation. Precipitation does not have a normal distribution on monthly or seasonal scales, but the PNRI implies a normal distribution by considering the mean and median to be the same. Another disadvantage is that the variety in precipitation records over time and location makes it impossible to determine the frequency of departures from normal or compare different locations. Table 9-1 and Table 9-2 are examples of the year-to-date percent of normal rainfall and departure from the mean for Maui County.
- **Palmer Drought Severity Index (PDSI)**—The Palmer Drought Severity Index is based not only on precipitation, but also on temperature and soil moisture. This additional data is sparse or non-existent for Hawaii. Furthermore, the PDSI is more applicable to broad climatic areas and is not suited for representing conditions in the small-scale climatic zones of the Hawaiian Islands. This index is widely used in the mainland United States, but it is not appropriate for Hawaii; general consensus is that it should be used as an initial drought index only.
- **Temperature and Precipitation** - The NOAA Climate Prediction Center produces a suite of short and long-range precipitation forecasts for Hawaii and the tropical Pacific islands, which are represented on maps showing estimates of rainfall anomalies (Hawaii Drought Monitor, 2015).

Droughts originate from a deficiency of precipitation resulting from an unusual weather pattern. If the weather pattern lasts a short time (a few weeks or a couple months), the drought is considered short-term. If the weather pattern

becomes entrenched and the precipitation deficits last for several months or years, the drought is considered to be long-term. It is possible for a region to experience a long-term circulation pattern that produces drought, and to have short-term changes in this long-term pattern that result in short-term wet spells. Likewise, it is possible for a long-term wet circulation pattern to be interrupted by short-term weather spells that result in short-term drought.

The Honolulu Forecast Office (HFO) of the National Weather Service (NWS) has tailored SPI software for use in Hawaii. At present, 59 sites have been selected as part of the SPI monitoring network. These sites are separated into "quick-look sites" and "standard sites." The quick-look sites use data from 16 out of 69 real-time reporting stations in the HFO flash flood monitoring network. They provide data immediately after the end of a month so that SPI values can be quickly determined. The standard sites are locations from the NWS Cooperative Observer Network. Rainfall readings at these sites are taken manually and submitted via mail after the end of the month. The SPI method is designed to be flexible in terms of drought duration specified by users. In Hawaii, 3-month and 12-month durations are considered (County of Maui, 2010a). Figure 9-3 is an example SPI map for the Island of Maui.

Source: NOAA/NWS, 2015a

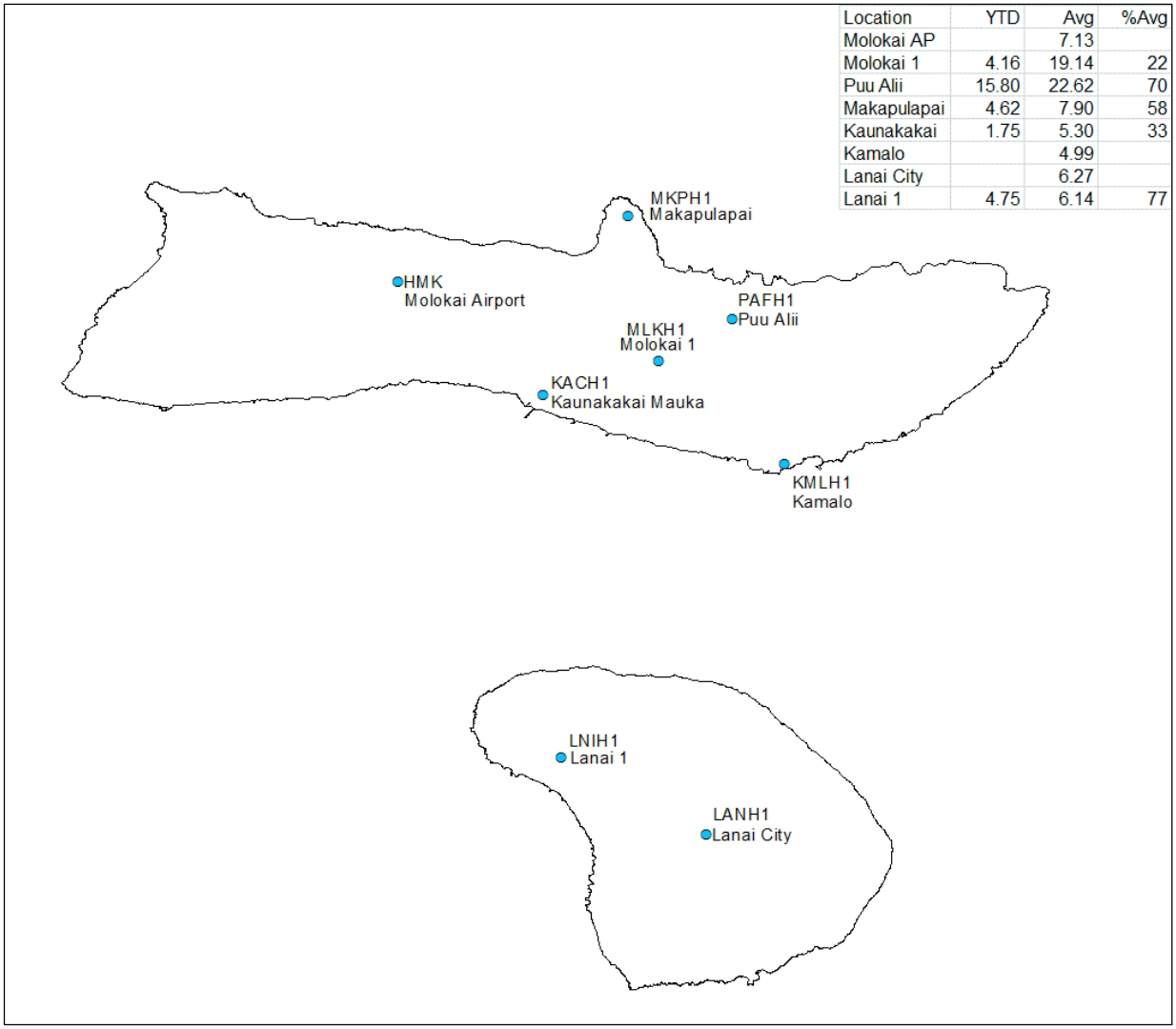


Location	YTD	Avg	%Avg
Kahului AP	4.31	4.76	91
Haiku	7.49	10.13	74
Pukalani	8.91	10.37	86
Kula	9.67	5.66	171
Hana	8.45	12.68	67
Kaupo Gap	16.62	22.04	75
Kepuni	7.11	6.93	103
Kula 1	14.23	11.51	124
Ulupalakua	7.63	7.59	101
Kihei 2		4.47	

Location	YTD	Avg	%Avg
Kahakuloa	14.94	11.88	126
Puu Kukui	17.67	57.52	31
Wailuku	5.62	9.89	57
Waikapu C	6.77	8.96	76
Lahainaluna	1.53	6.38	24
Mahinahina	3.03	10.31	29
Kahoolawe	4.17	4.70	89
Honokanaia	2.36	4.48	53

FIGURE 9-1. ISLAND OF MAUI YEAR TO DATE PRECIPITATION SUMMARY, AS OF FEBRUARY 2015

Source: NOAA/NWS, 2015a



Location	YTD	Avg	%Avg
Molokai AP		7.13	
Molokai 1	4.16	19.14	22
Puu Alii	15.80	22.62	70
Makapulapai	4.62	7.90	58
Kaunakakai	1.75	5.30	33
Kamalo		4.99	
Lanai City		6.27	
Lanai 1	4.75	6.14	77

FIGURE 9-2. ISLAND OF MOLOKAI AND LANAI YEAR TO DATE PRECIPITATION SUMMARY, AS OF FEBRUARY 2015

Source: NOAA/NWS, 2015b

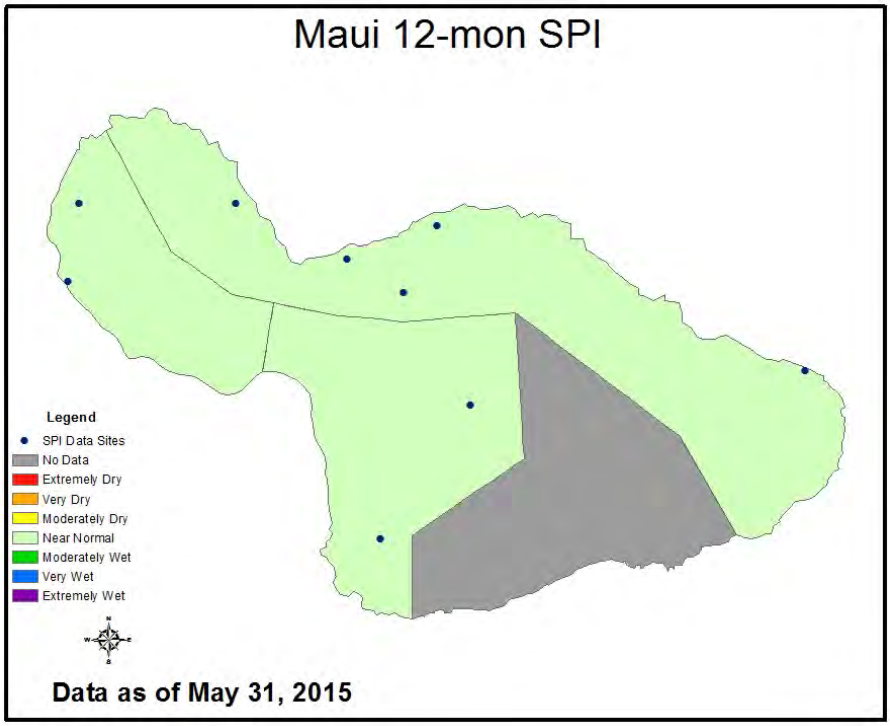


FIGURE 9-3. ISLAND OF MAUI 12-MONTH STANDARD PRECIPITATION INDEX (SPI), AS OF MAY 2015

"Quick Look" SPI Datasets available through NOAA provide the most recent SPI summary available as of the writing of this plan. This dataset provides information through the end of June 2015. Maui County falls within the Near Normal to Moderately Wet Categories from the 1- to 24- month periods ending in June 2015. Table 9-1 provides the specific SPI values for Maui County through the end of June 2015.

TABLE 9-1.
SPI CATEGORIES THROUGH JUNE 2015 – MAUI COUNTY

Station	1-Month	2-Month	3-Month	6-Month	12-Month	18 Month	24-Month
HANA AP	-0.04	0.20	-0.14	-0.13	-0.21	0.07	-0.21
KAHULUI AP	-0.26	1.45	1.39	-99.00	-99.00	-99.00	-99.00
KULA BRANCH	0.59	0.10	-0.02	0.32	0.60	1.07	0.87
MOLOKAI AP	0.11	-0.03	-0.22	-99.00	-99.00	-99.00	-99.00
ULUPALAKUA	2.21	1.80	1.20	0.70	0.78	0.78	0.81

Source:NOAA/NWS, 2015c

Note: Areal Averages are not available in this most recent version of the summary

El Niño and Drought

Every 2 to 7 years off the western coast of South America, ocean currents and winds shift, causing water temperatures to warm and displacing the nutrient-rich cold water that normally wells up from deep in the ocean. The invasion of

warm water disrupts both the marine food chain and the economies of coastal communities that are based on fishing and related industries. Because the phenomenon peaks around the Christmas season, the fishermen who first observed it named it El Niño. Typically, it lasts anywhere from 14 to 22 months, but it can be much longer or shorter. El Niño often begins early in the year and peaks between the following November and January, but no two El Niño events behave in the same way. El Niño is by no means a new phenomenon, and researchers are still working to determine whether climate change would intensify or otherwise affect El Niño. Evidence of the events goes back hundreds of years (NDMC, 2015b).

El Niño events are closely linked to drought conditions in Hawaii. The most severe drought events of the past 15 years within the state are associated with the El Niño phenomenon (Hawaii Drought Monitor, 2015).

9.2 Hazard profile

9.2.1 Past Events

Dry conditions in Hawaii have generally been associated with persistent zones of high-pressure systems ridging over the islands and preventing winter storms from brushing by the state, particularly for the southern islands. This feature is typical of larger-scale effects on atmospheric circulation in the tropical Pacific related to El Niño. Droughts occurred in winter and spring during the El Niño years of 1982-1983, 1997-1998, and 2004-2005. The following were the most severe droughts affecting the County of Maui from 1953 to the present (County of Maui, 2010a; State of Hawaii, 2010; FSA, 2013; FSA, 2014; FSA, 2015):

- 1953—Water rationing; Pineapple production on Molokai reduced by 30 percent. Rainfall totals were 40 percent less than normal.
- 1962—State declared disaster. Crop damage, cattle deaths, and severe fire hazards.
- 1971—Irrigation and domestic water use sharply curtailed.
- 1977-78—State declared disaster for the Island of Maui. Residents asked to reduce water consumption by 30 percent
- 1980-81—State declared disaster. Heavy agricultural and cattle losses; damages totaling at least $1.4 million.
- 1996—Drought emergency declared. Heavy damage to agriculture and cattle industries.
- 1998—State declared drought emergency for the Island of Maui
- 2000-02—Counties declare drought emergencies. Governor proclaims statewide emergency. Secretary of the Agriculture designates all Counties as primary disaster areas due to drought (2000), east Maui streams at record low levels.
- 2003—Secretary of the Agriculture designates all Counties as primary disaster areas due to drought, Governor proclaims statewide drought emergency
- 2006—Primary Disaster Area declared because of drought from the months of April through September
- 2010—U.S. Department of Agriculture (USDA) designates all Counties as primary disaster areas due to drought.
- 2012— USDA designates all Counties as primary disaster areas due to drought.
- 2013-14—USDA designates Hawaii and Maui Counties as primary disaster areas due to drought.

Due to the variation in sources researched while identifying previous occurences, SPI values could not be determined for these historical events.

9.2.2 Location

The climate, and hence the amount of rainfall, of the Hawaiian Islands is directly influenced by the northeasterly trade winds. Typically, leeward locations (south and west shores) are much drier and sunnier than windward locations (north and east shores). Within leeward and windward locations, rainfall varies considerably according to elevation. All areas of Maui County are susceptible to drought, although the extent and severity of the drought will depend on the variance of rainfall throughout the planning area based on location as described above (County of Maui, 2010a).

According to the most recent draft of the State Water Protection Plan, drought can lead to difficult decisions regarding the allocation of water, as well as stringent water use restrictions, water quality problems, and inadequate water supplies for fire suppression. In Hawaii, droughts and wildland fires can threaten all the islands in any given year. There are also additional issues such as growing conflicts between agricultural uses of surface water and in-stream uses, "surface and ground water" interrelationships, and the effects of growing water demands on traditional and cultural uses of water. The eastern portion of the Hawaiian Islands seem to have been most severely impacted by drought events since the year 1999. This includes the County of Maui – comprised of Molokai, Lanai, Kahoolawe, and Maui Islands and the Big Island of Hawaii. While drought has continued to affect Kauai and Oahu, the severity and duration of drought there has not been as bad as in Maui and Hawaii Counties (CWRM, 2014).

9.2.3 Frequency

Rainfall variability is far greater during the winter, when occasional storms contribute to rainfall totals, than during summer, when trade-wind showers provide most of the rain. With such variability, it is inevitable that there are occasional droughts. The severe drought years are the ones where the winter rains fail, in which there are only one or two or even no substantial rainstorms. Although such a deficit of winter storms can affect any portion of the state, it hits hardest in the normally dry areas that depend chiefly on winter rains and receive little rain from the trade wind showers. In these locations, the small amount of rainfall that occurs during the usual dry summer season is insufficient to prevent severe drought (WRCC, 2015).

Hawaii's 2003 *Drought Risk and Vulnerability Assessment and GIS Mapping Project* used GIS mapping to identify areas at risk of drought and assess the environmental and socioeconomic impacts of drought. The assessment included the creation of drought frequency maps for all the main Hawaiian Islands. The maps are a graphical representation of the spatial distribution of historical drought occurrences in the islands. They are available for both a 3-month and 12-month SPI interval for moderate, severe, and extreme drought stages (six maps total) (County of Maui, 2010a).

Figure 9-4 and Figure 9-5 show the 3-month and 12-month moderate drought frequency maps for the Counties of Maui and Hawaii. Contours on the maps indicate the percent of time from 1972 through 2001 that moderate drought occurred (County of Maui, 2010a).

Source: State of Hawaii, 2003

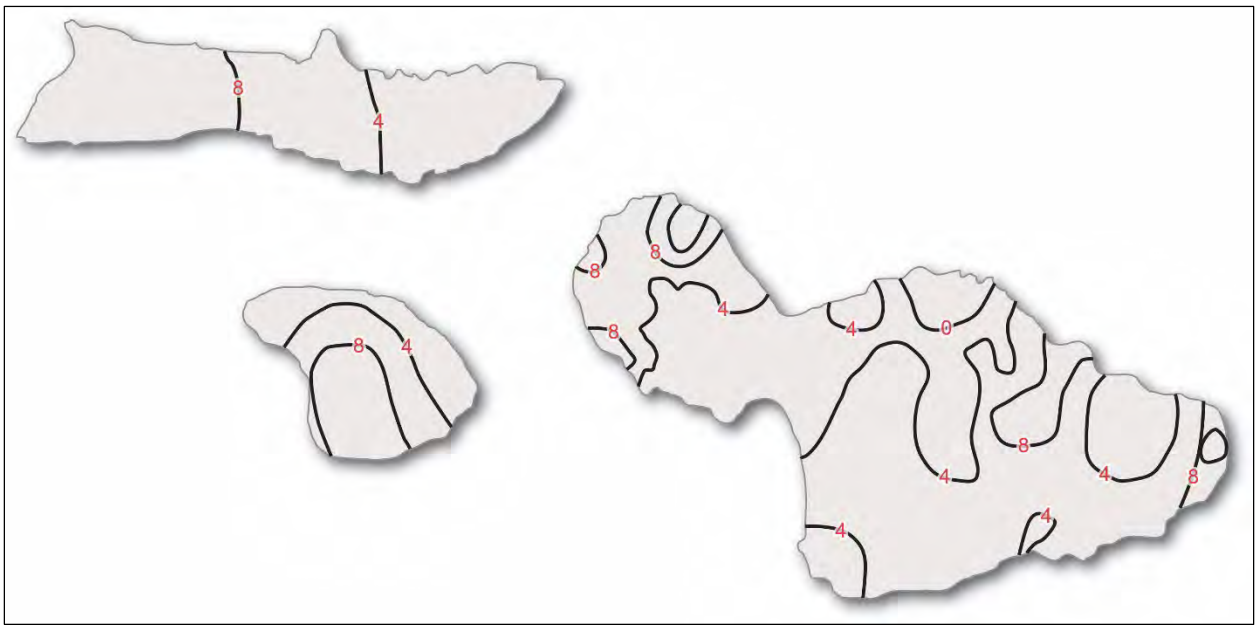


FIGURE 9-4. PERCENT OF TIME THAT MODERATE THREE-MONTH DROUGHT WAS EXPERIENCED, 1972 – 2001

Source: State of Hawaii, 2003

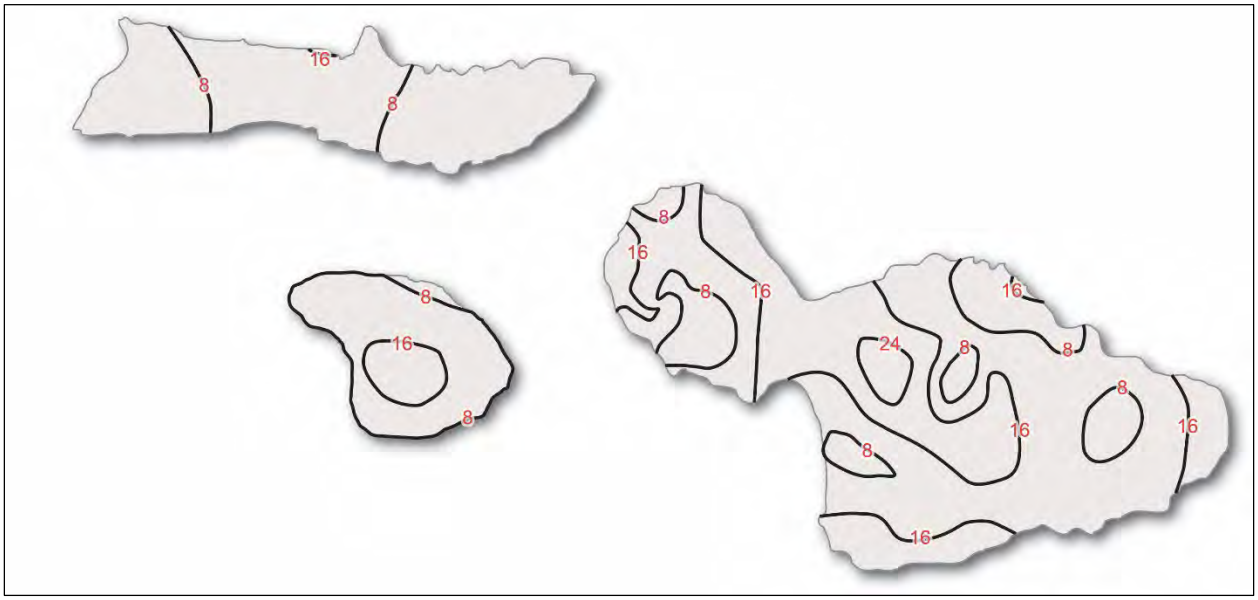


FIGURE 9-5. PERCENT OF TIME THAT MODERATE 12-MONTH DROUGHT WAS EXPERIENCED, 1972 – 2001

El Nino events are closely linked to drought conditions throughout Hawaii. The most severe drought events of the past 15 years are associated with the El Nino phenomenon (Hawaii Drought Monitor, 2015).

9.2.4 Severity

The following descriptions explain the severity of drought and applicable SPI intervals and values for key sectors in Hawaii (State of Hawaii, 2005) (County of Maui, 2010a):

- **Water Supply Sector**—The water supply sector is typically affected by long sustained periods of drought that affect ground and surface water resources. For this reason, a 12-month SPI is typically the best interval to evaluate drought severity for this sector.
- **Agriculture and Commerce Sector**—The agriculture sector is usually the first sector to feel the effects of drought. Farmers and ranchers who depend on rainfall for irrigation may be severely affected by even short-term moderate drought events. Because the agriculture and commerce sector is affected by short-term drought events, a 3-month SPI drought interval is best suited to evaluate drought severity for this sector.
- **Environment, Public Health, and Safety Sector**—Drought can have a number of effects on the environment, public health and safety sector. However, focus is often given exclusively to the area of wildfire impacts. Prolonged periods of drought can create dry landscapes that are vulnerable to wildfire hazard. Since even short drought periods can increase the risk of wildfire hazards, the 3-month SPI is best suited to evaluate drought severity for this sector.

Table 9-2 describes SPI intervals values that can be used to evaluate drought severity for the three key sectors.

TABLE 9-2.
DROUGHT STAGE AND SPI INTERVAL AND VALUE PER SECTOR

Drought Stage	SPI Time Interval and Value Water Supply Sector	Agriculture & Commerce Sector	Environmental, Public Health, & Safety Sector
Normal	12-month SPI 0.99 to -0.99	3-month SPI 0.99 to -0.99	3- and 12-month SPI 0.99 to -0.99
Moderate	12-month SPI -1.00 to -1.49 for 2 consecutive months	3-month SPI -1.00 to -1.49 for 2 consecutive months	3- and 12-month SPI -1.00 to -1.49 for 2 consecutive months
Severe	12-month SPI -1.50 to -1.99 for 2 consecutive months	3-month SPI -1.50 to -1.99 for 2 consecutive months	3- and 12-month SPI -1.50 to -1.99 for 2 consecutive months
Extreme	12-month SPI less than -2.00 for 2 consecutive months	3-month SPI less than -2.00 for 2 consecutive months	3- and 12-month SPI less than -2.00 for 2 consecutive months

Source: State of Hawaii, 2005.

Based on the most recent available data through the end of June 2015 as identified in Table 9-1 and cross referenced with the State SPI Interval and Value per Sector, the County of Maui is currently in a "Normal" Stage for all three key sectors.

9.2.5 Warning Time

Droughts are climatic patterns that occur over long periods of time. Only generalized warning can take place due to the numerous variables that scientists have not pieced together well enough to make accurate and precise predictions. Though only generalized warnings can take place, the U.S. Drought Monitor provides current and recent history of areas and populations affected by drought (NDMC, 2015a).

Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause. It is the result of many causes, often synergistic in nature; these include global weather patterns that

produce persistent, upper-level high-pressure systems along the West Coast with warm, dry air resulting in less precipitation.

Scientists at this time do not know how to predict drought more than a month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. The length of these anomalies depends on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale.

However, meteorologists have made significant advances in understanding the climate system in the tropics. It is now known that a major portion of the atmospheric variability that occurs on time scales of months to several years is associated with variations in tropical sea surface temperatures. The Tropical Ocean Global Atmosphere (TOGA) project has produced results that points to the possibility of predicting certain climatic conditions associated with El Nino Southern Oscillation events more than a year in advance. Since El Nino events are closely linked to drought conditions in Hawaii, the TOGA project results may help produce more reliable meteorological forecasts that can reduce risks in those economic sectors most sensitive to climate variability and, particularly, extreme events such as drought.

9.2.6 Potential Impacts of Climate Change

The long-term effects of climate change on island water resources are unknown, but global water resources are already experiencing the following stresses without climate change:

- Growing populations
- Increased competition for available water
- Poor water quality
- Environmental claims
- Uncertain reserved water rights
- Groundwater overdraft
- Aging urban water infrastructure.

Nearly every region in the country is facing some increased risk of seasonal drought. Climate change can significantly affect the sustainability of water supplies in the future. As parts of the United States get drier, the amount and quality of water available will likely decrease, impacting people's health and food supplies. Western United States have already been experiencing water shortages due to severe dry-spells. With climate change, the entire country will likely face some level of drought. A report by the National Resources Defense Council (NRDC) found that 1,100 counties (one-third of all counties in the contiguous 48 states) face higher risks of water shortages by mid-century as a result of climate change. More than 400 of these counties will face extremely high risks of water shortages.

The NRDC states that global warming is projected to alter precipitation patterns, increase the frequency and intensity of major storm events, and increase the flood risk throughout the United States, particularly the Midwest and the Northeast. Between 2000 and 2009, approximately 30 to 60 percent of the United States experienced drought conditions at any one time (NRDC, n.d.). Hawaii has definitively experienced longer droughts on all the populated

islands, as demonstrated by a comparison of length of dry periods from 1980-2011 against 1950-1970 (University of Hawaii, 2014).

With a warmer climate, droughts could become more frequent, more severe, and longer-lasting. More frequent extreme droughts could result in decreased stream flows in local rivers, affecting water supplies for domestic and agricultural uses.

The best advice to water resource managers regarding climate change is to start addressing current stresses on water supplies and build flexibility and robustness into any system. Flexibility helps to ensure a quick response to changing conditions, and robustness helps people prepare for and survive the worst conditions. With this approach to planning, water system managers will be better able to adapt to the impacts of climate change.

9.2.7 Secondary Hazards

The secondary hazard most commonly associated with drought is wildfire. A prolonged lack of precipitation dries out vegetation, which becomes increasingly susceptible to ignition as the duration of the drought extends.

9.3 Exposure

This section describes the populations, property, critical facilities/infrastructure, and environment that are currently exposed to the hazard.

9.3.1 Population

All people in the planning area would be exposed to some degree to the impacts of moderate to extreme drought conditions.

9.3.2 Property

All property in the planning area would be exposed to some degree to the impacts of moderate to extreme drought conditions.

9.3.3 Critical Facilities

All critical facilities in the planning area would be exposed to some degree to the impacts of moderate to extreme drought conditions.

9.3.4 Onshore and Offshore Natural Environment

All environments in the planning area would be exposed to some degree to the impacts of moderate to extreme drought conditions.

9.4 Vulnerability

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to the ability to produce goods and provide services. Drought can affect a wide range of economic, environmental, and social activities. The vulnerability

of an activity to the effects of drought usually depends on its water demand, how the demand is met, and what water supplies are available to meet the demand.

According to the Hawaii Drought Monitor, the impacts of drought vary between sectors of the community in both timing and severity. Impacts are complex and can be categorized into sectors: water supply; agriculture and commerce; and environment, public health, and safety sectors. The water supply sector encompasses urban and rural drinking water systems that are affected when a drought depletes ground water supplies due to reduced recharge from rainfall. The agriculture and commerce sector includes the reduction of crop yield and livestock sizes due to insufficient water supply for crop irrigation and maintenance of ground cover for grazing. The environmental, public health, and safety sector focuses on wildfires that are both detrimental to the forest ecosystem and hazardous to the public. It also includes the impact of desiccating streams, such as the reduction of in-stream habitats for native species (Hawaii Drought Monitor, 2015).

9.4.1 Population

Maui County has the ability to minimize the impacts on residents and water consumers should several consecutive dry years occur. No significant life or health impacts are anticipated as a result of drought within the planning area.

9.4.2 Property

No structures will be directly affected by drought conditions, though some structures may become vulnerable to wildfires, which are more likely following years of drought. Droughts can also have significant impacts on landscapes, which could cause a financial burden to property owners. However, these impacts are not considered critical in planning for impacts from the drought hazard.

9.4.3 Critical Facilities

Critical facilities as defined for this plan will continue to be operational during a drought. Critical facility elements such as landscaping may not be maintained due to limited resources, but the risk to the planning area's critical facilities inventory will be largely aesthetic. For example, when water conservation measures are in place, landscaped areas will not be watered and may die. These aesthetic impacts are not considered significant.

9.4.4 Onshore and Offshore Natural Environment

Environmental losses from drought are associated with damage to plants, animals, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Some of the effects are short-term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for some time or may even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes and vegetation. However, many species will eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these effects.

9.4.5 Economic Impact

Economic impact will be largely associated with industries that use water or depend on water for their business. For example, landscaping businesses were affected in the droughts of the past, as the demand for service significantly declined because landscaping was not watered. Agricultural industries will be impacted if water usage is restricted for irrigation.

9.5 Future Trends in Development

The Hawaii Drought Plan and the Maui County Water Use and Development Plan offer guidelines to future land use planning, water resource development, resource protection, water quality goals, and prioritizing water use (County of Maui Department of Water Supply, 2010). These plans provide the capability at the state and local level to respond to and develop long- and short-term mitigation strategies from the impacts of drought.

Because of the nature of drought and its ability to affect the County as a whole, all future development will be vulnerable to the drought hazard.

9.6 Scenario

An extreme drought with a combination of low precipitation and unusually high temperatures could occur over several consecutive years. Intensified by such conditions, extreme wildfires could break out throughout the planning area, increasing the need for water. If such conditions persisted for several years, the economy of Maui County could experience setbacks, especially in water dependent industries such as agriculture.

9.7 Issues

The planning team has identified the following drought-related issues:

- **Drought-tolerant landscape designs are not adequately encouraged** – Incorporating drought tolerant or xeriscaping practices into landscape ordinances, providing incentives for xeriscaping, and encouraging permeable driveways and surfaces will reduce dependence on irrigation.
- **Groundwater recharge techniques are not utilized**—During non-drought period, recharging groundwater to stabilize the groundwater supply should be a regular practice. By ensuring groundwater remain stable, impacts of future drought occurrences will be minimized.
- **Active water conservation even during non-drought periods needs to be promoted**—Active conservation during non-drought periods serves as a tool to anticipate how entities will use water during drought periods. If conservation is practiced during non-drought periods, needed conservation during drought periods will minimize the impact on the County and mitigate against overuse of minimal water supply. The con associated with this particular initiative is encouraging residents to adhere to water conservation. Public outreach initiatives regarding this issue must emphasize the need for water conservation during non-drought periods.

Chapter 10. Earthquake

10.1 Hazard Description

An earthquake is the vibration of the earth's surface following a release of energy in the Earth's crust. This energy can be generated by a sudden dislocation of the crust or by a volcanic eruption. Dislocations of the crust cause most destructive quakes. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called "seismic waves" are generated. These waves travel outward from the source of the earthquake at varying speeds.

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. The focal depth of an earthquake is the depth from the Earth's surface to the region where an earthquake's energy originates (the focus or hypocenter). The epicenter of an earthquake is the point on the Earth's surface directly above the hypocenter.

According to the U.S. Geological Society (USGS) Earthquake Hazards Program, an earthquake hazard is anything associated with an earthquake that may affect resident's normal activities. Within the County of Maui, this includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, and tsunamis. A description of each of these is provided below:

DEFINITIONS

Earthquake—The shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates.

Epicenter—The point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Fault—A fracture in the earth's crust along which two blocks of the crust have slipped with respect to each other.

Focal Depth—The depth from the earth's surface to the hypocenter.

Hypocenter—The region underground where an earthquake's energy originates

Liquefaction—Loosely packed, water-logged sediments losing their strength in response to strong shaking, causing major damage during earthquakes.

- **Surface Faulting**—Displacement that reaches the earth's surface during slip along a fault. Commonly occurs with shallow earthquakes, those with an epicenter less than 20 kilometers.
- **Ground Motion (shaking)**—The movement of the earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface.
- **Landslid**e—A movement of surface material down a slope.
- **Liquefaction**—A process by which water-saturated sediment temporarily loses strength and acts as a fluid. Earthquake shaking can cause this effect.
- **Tectonic Deformation**—A change in the original shape of a material due to stress and strain.
- **Tsunami**—A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or violent underwater volcanic eruptions.

Earthquakes in Hawaii can be tectonic or volcanic (County of Maui, 2010a):

- Tectonic earthquakes occur at or near the shield volcanoes that form the islands. The weight of the volcanoes bends the layer of the Earth beneath them, causing it to flex downward below the islands and upward away from them. After millions of years, the flexing of the lithosphere stops, and the accumulated strain is released in the form of earthquakes. Such earthquakes are most frequent beneath actively growing volcanoes.
- There are two categories of volcanic earthquakes:
  - Volcano-tectonic earthquakes are produced by stress changes in solid rock due to the injection or withdrawal of magma. These earthquakes can cause land to subside and produce large ground cracks.
  - Long-period earthquakes are a result of pressure changes during the unsteady transport of magma. Long-period earthquakes are typically indicative that a volcano eruption is eminent.

The majority of Hawaii's earthquakes is directly related to volcanic activity and is caused by magma moving beneath the earth's surface. Earthquakes may occur before or during an eruption, or they may result from the underground movement of magma that comes close to the surface but does not erupt. A few of the island's earthquakes are less directly related to volcanism; these earthquakes originate in zones of structural weakness at the base of the volcanoes or deep within the earth beneath the island (USGS, 1997).

10.1.1 Earthquake Classifications

The severity of an earthquake at a given location depends on the amount of energy released at the epicenter, and the location's distance from the epicenter. The terms "magnitude" and "intensity" are two terms used to describe the severity of an earthquake. An earthquake's "magnitude" is a measurement of the total amount of energy released while its "intensity" is a measure of the effects of an earthquake at a particular place.

Magnitude

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a measured value of the earthquake size, or amplitude of the seismic waves, using a seismograph. The Richter magnitude scale (Richter Scale) was developed in 1932 as a mathematical device to compare the sizes of earthquakes (USGS, 2012a). The Richter scale is the most widely-known scale that measures the magnitude of earthquakes (Shedlock and Pakiser, 1995). It has no upper limit and is not used to express damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, may have the same magnitude and shock in a remote area that did not cause any damage (USGS, 2013). Table 10.1 presents the Richter scale magnitudes and corresponding earthquake effects.

Intensity

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. Intensity is expressed by the Modified Mercalli Scale; a subjective measure that describes how strong a shock was felt at a particular location (Shedlock and Pakiser, 1995).

TABLE 10-1.
RICHTER SCALE

Richter Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but only causes minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake; can totally destroy communities near the epicenter

Source: MTU, n.d.

The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII (USGS, 1989):

I. Not felt except by a very few under especially favorable conditions
II. Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
VIII. Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Ground Motion

Another way to express an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity. Peak Ground Acceleration (PGA) measures the rate of change in motion of the earth's surface and expresses it as a percent of the established rate of acceleration due to gravity (9.8 m/sec^2). PGA is expressed as a percent acceleration force of gravity (%g). For example, 1.0 %g PGA in an earthquake (an extremely strong ground motion)

means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10 %g PGA means that the ground acceleration is 10 percent that of gravity. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures as noted in Table 10.2.

TABLE 10-2.
DAMAGE LEVELS EXPERIENCED IN EARTHQUAKES

Ground Motion Percentage	Explanation of Damages
1-2 %g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
Below 10 %g	Usually cause only slight damage, except in unusually vulnerable facilities.
10-20 %g	May cause minor to moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20-50 %g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
50% + g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

Source: NJOEM, 2014

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures as noted in Table 10.3, which shows an approximated relationship between PGA, magnitude, and intensity of an earthquake. Using this table, one can approximate that, for an earthquake of expected severity for Maui County (PGA values of 2 to 4 %g), perceived shaking would be light to moderate (depending upon the distance from the epicenter) and potential damage could range from none to very light (also depending upon the distance from the epicenter).

An earthquake with a 10 percent chance of exceedance over 50 years in Maui County would have a PGA of 2 to 4 %g and an intensity ranging from only IV to V, which would result in light to moderate perceived shaking, and damages ranging from none to very light. For comparison purposes, an earthquake of intensity IV on the Modified Mercalli Scale would most likely cause vibrations similar to heavy trucks driving over roads, or the sensation of a jolt. Hanging objects would swing; standing cars would rock; windows, dishes and doors would rattle; and, in the upper ranges of intensity IV, wooden walls and frames would creak. An earthquake of intensity V on the Modified Mercalli Scale would be felt outdoors, awaken sleepers, disturb or spill liquids, displace small unstable objects, swing doors, and cause shutters and pictures to move.

TABLE 10-3.
EARTHQUAKE MAGNITUDE/INTENSITY COMPARISON

PGA	Magnitude	Intensity	Perceived Shaking	Potential Damage
< 0.17	1.0 - 3.0	I	Not Felt	None
0.17 – 1.4	3.0 – 3.9	II - III	Weak	None

TABLE 10-3.
EARTHQUAKE MAGNITUDE/INTENSITY COMPARISON

PGA	Magnitude	Intensity	Perceived Shaking	Potential Damage
1.4 – 9.2	4.0 – 4.9	IV – V	IV. Light V. Moderate	IV. None V. Very Light
9.2 - 34	5.0 – 5.9	VI – VII	VI. Strong VII. Very Strong	VI. Light VII. Moderate
34 - 124	6.0 – 6.9	VIII - IX	VIII. Severe IX. Violent	VIII. Moderate/Heavy IX. Heavy
> 124	7.0 and higher	X and higher	Extreme	Very Heavy

Sources: FEMA, 2001; Wald, D. et al., 1999

10.1.2 Effect of Soil Types

The impact of an earthquake on structures and infrastructure is largely a function of ground shaking, distance from the source of the quake, and liquefaction. Liquefaction generally occurs in soft, unconsolidated sedimentary soils. A program called the National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics to help identify locations subject to liquefaction. Table 10.4 summarizes NEHRP soil classifications. NEHRP Soils B and C typically can sustain ground shaking without much effect, dependent on the earthquake magnitude. The areas that are commonly most affected by ground shaking have NEHRP Soils D, E, and F. In general, these areas are also most susceptible to liquefaction.

TABLE 10-4.
NEHRP SOIL CLASSIFICATION SYSTEM

NEHRP Soil Type	Description	Mean Shear Velocity to 30 m (m/s)
A	Hard Rock	1,500
B	Firm to Hard Rock	760-1,500
C	Dense Soil/Soft Rock	360-760
D	Stiff Soil	180-360
E	Soft Clays	< 180
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)	

10.2 Hazard Profile

10.2.1 Past Events

Each year, thousands of earthquakes occur in or near the Hawaiian Islands, but most are too small to be perceived except by scientific instruments. The list below represents major historical earthquakes in Hawaii (County of Maui, 2010a).

- **1871 Lanai Earthquake**—The Lanai earthquake of 1871 was one of the most significant earthquakes to have affected the County of Maui. From the geographic distribution of its effects, its magnitude is estimated to have been 7.0 and its epicenter to be near the south coast of the Island of Lanai.
- **1938 Maui Earthquake**—The January 22, 1938 Magnitude-6.9 earthquake had an epicenter about 12 miles northeast of Keanae Point in East Maui. The Island of Maui suffered more damage than any other Hawaiian Island, though there were few injuries and no mortalities. Damage on Molokai and Lanai was small and resulted from a few ground cracks. No tsunami accompanied the shock.
- **2006 Kiholo Bay and Mahukona Earthquakes**—The most recent earthquakes to strike Hawaii were the Kiholo Bay and Mahukona earthquakes of October 15, 2006, centered in the Pacific Ocean west of the Island of Hawaii. The Magnitude-6.7 Kiholo Bay earthquake occurred at 7:07 a.m., followed by the Magnitude-6.0 Mahukona earthquake at 7:14 a.m. Although the Mahukona earthquake was the smaller of the two in magnitude, its intensity of was reportedly equal to or greater than that of the Kiholo Bay earthquake in some areas due to its shallower depth. On the Island of Maui, the earthquakes induced several landslides and rockfalls along Piilani Highway (Highway 31) on the southeastern coast. About 500 residents were cut off in the Manawainui area due to an incipient rockfall hazard and due to closure of a bridge damaged by erosion at Pahihi.

Table 10 5 lists additional earthquakes that have affected Maui County since the late 1860s.

10.2.2 Location

Identifying the extent and location of an earthquake is not as simple as it is for other hazards such as flood, landslide or wild fire. The impact of an earthquake is largely a function of the following components:

- Ground shaking (ground motion accelerations)
- Liquefaction (soil instability)
- Distance from the source (both horizontally and vertically).

Mapping that shows the impacts of these components was used to assess the risk of earthquakes within the planning area. While the impacts from each of these components can build upon each other during an earthquake event, the mapping looks at each component individually. The mapping techniques used in this assessment are described below.

Shake Maps

A shake map is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because shake maps focus on the ground shaking resulting from the earthquake, rather than the parameters describing the earthquake source.

TABLE 10-5.
SIGNIFICANT HISTORICAL EARTHQUAKES THAT AFFECTED MAUI COUNTY (1868 TO PRESENT)

Year	Date	Richter Magnitude	Source / Epicenter
1868	March 28	6.5 – 7.0	Mauna Loa south flank
1868	April 2	7.5 – 8.1	Mauna Loa south flank
1871	February 19	7.0	South of Lanai Island
1908	September 20	6.7	Kilauea South Flank

TABLE 10-5.
SIGNIFICANT HISTORICAL EARTHQUAKES THAT AFFECTED MAUI COUNTY (1868 TO PRESENT)

1918	November 2	6.2	Kaoiki, between Mauna Loa & Kilauea
1919	September 14	6.1	Kau District, Mauna Loa south flank
1926	March 19	>6.0	NW of Hawaii Island
1927	March 20	6.0	NE of Hawaii Island
1929	September 25	6.1	Hualalai
1938	January 22	6.9	North of Maui Island
1940	June 16	6.0	North of Hawaii Island
1941	September 25	6.0	Kaoiki
1948	June 28	4.6	South of Oahu Island
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	Kaoiki
1973	April 26	6.3	Lithospheric
1975	November 29	7.2	Kilauea south flank
1983	November 16	6.6	Kaoiki
1989	June 25	6.1	Kilauea south flank
2006	October 15	6.7	Kiholo Bay, Hawaii Island
2006	October 15	6.0	Mahukona, Hawaii Island

Source: Maui County, 2010a

An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A shake map shows the extent and variation of ground shaking in a region immediately following significant earthquakes.

Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. Two types of shake maps are typically generated from the data:

- A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10-percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas. Figure 10 1 and Figure 10 2 show the estimated ground motion for the 100-year and 500-year probabilistic earthquakes in the planning area.
- Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. The following scenarios were chosen for this plan:

- **Scenario Earthquake 1**—Magnitude-7.0 event approximately 5 miles north of the Island of Lanai in the Kalohi Channel (see Figure 10-3 through Figure 10-5)
- **Scenario Earthquake 2**—Magnitude-7.0 event approximately 32 miles northeast east of Kahului (see Figure 10-6 through Figure 10-8).

NEHRP Soil Maps

NEHRP soil type maps define the locations that will be significantly impacted by an earthquake. NEHRP Soils B and C typically can sustain low-magnitude ground shaking without much effect. The areas that are most commonly affected by ground shaking have NEHRP Soils D, E and F. Approximate NEHRP soil classifications in Maui County are shown on Figure 10-9 through Figure 10-11.

Liquefaction Maps

Soil liquefaction maps are useful tools to assess potential damage from earthquakes. When the ground liquefies, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. In general, areas with NEHRP Soils D, E, and F are also susceptible to liquefaction. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it, creating sand boils. No liquefaction mapping is currently available for the planning area.

10.2.3 Frequency

Due to the volcanic activity associated with the State of Hawaii, and the consistent and frequent historical occurrence of earthquakes, Maui County can expect to experience thousands of earthquakes per year, though only feel a few.

The USGS estimates a 50-percent probability of a 6.5 magnitude or greater earthquake occurring in the Hawaii Islands in the next 10 years. Since 1868, more than 30 magnitude-6.0 or greater earthquakes have impacted residents across the State resulting in a return interval of every 5 years on average (USGS, 2014).

Maui County Islands of Maui and Kahoolawe

500-Year Probabilistic Earthquake Peak Ground Acceleration

Legend

Community Plan Boundaries

Mercalli Scale

(Potential Damage, Perceived Shaking)

VII (Moderate, Very Strong)

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

N

0 4.5 9 Miles

Maui County Islands of Maui and Kahoolawe

100-Year Probabilistic Earthquake Peak Ground Acceleration

Legend

Community Plan Boundaries

Mercalli Scale

(Potential Damage, Perceived Shaking)

V (Very Light, Moderate)

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County Islands of Maui and Kahoolawe

Lanai M7.0 Scenario Peak Ground Acceleration

Legend

Community Plan Boundaries

Mercalli Scale (Potential Damage Perceived Shaking)

V (Very Light, Moderate)

VI (Light, Strong)

VII (Moderate, Very Strong)

Magnitude: 7.0
Epicenter: N21.0 W157.0

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Lanai M7.0 Scenario
Peak Ground
Acceleration

Legend

Mercalli Scale (Potential Damage Perceived Shaking)

- V (Very Light, Moderate)
- VI (Light, Strong)
- VII (Moderate, Very Strong)

Magnitude: 7.0
Epicenter: N21.0 W157.0

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Lanai M7.0 Scenario Peak Ground Acceleration

Legend

Kalawao County

Mercalli Scale (Potential Damage Perceived Shaking)

V (Very Light, Moderate)

VI (Light, Strong)

VII (Moderate, Very Strong)

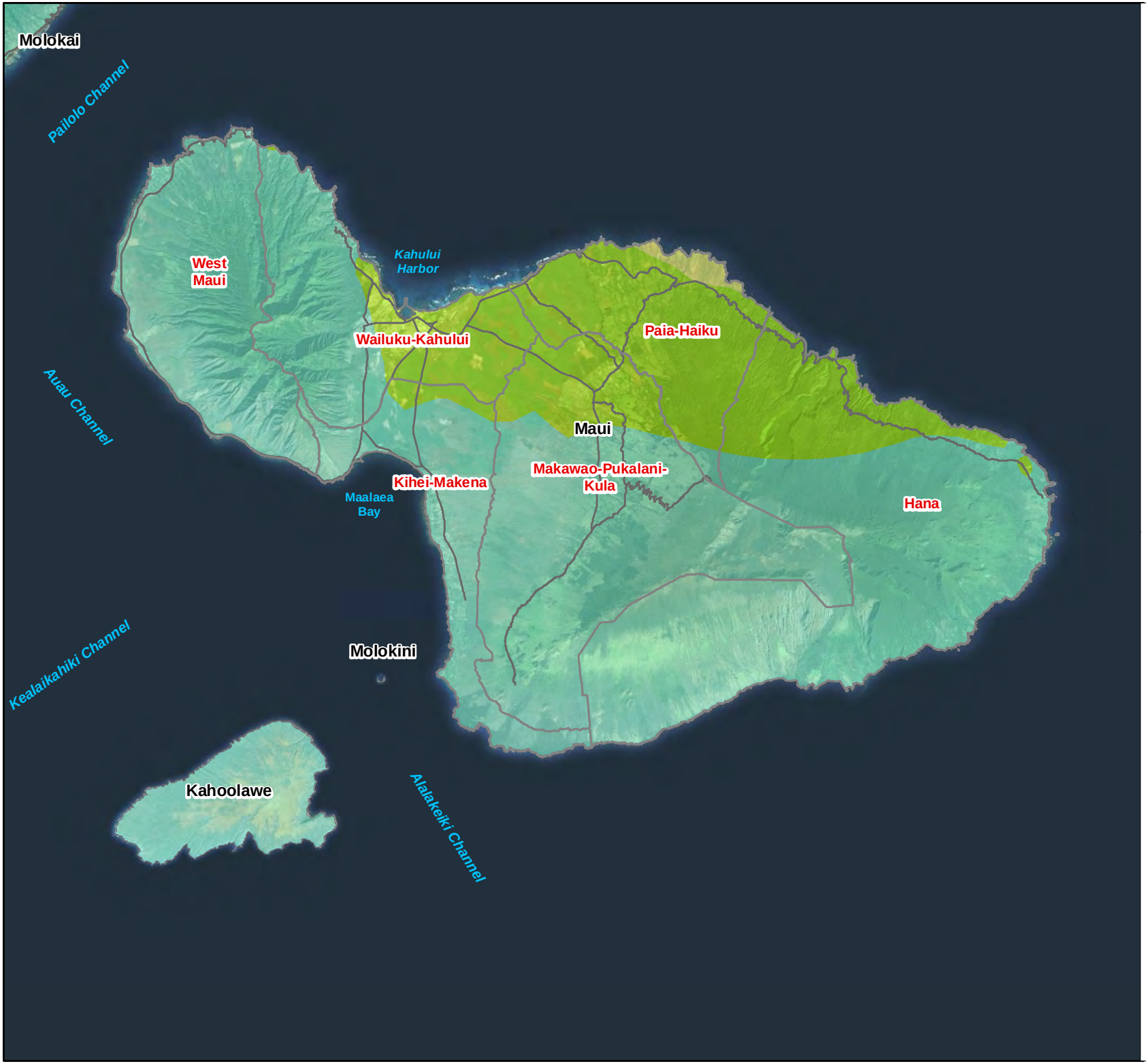
Magnitude: 7.0
Epicenter: N21.0 W157.0

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 3.5 7 Miles



Maui County Islands of Maui and Kahoolawe

NE Maui M7.0 Scenario Peak Ground Acceleration

Legend

Community Plan Boundaries

Mercalli Scale (Potential Damage Perceived Shaking)

V (Very Light, Moderate)

VI (Light, Strong)

VII (Moderate, Very Strong)

Magnitude: 7.0
Epicenter: N21.2 W156.1

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

NE Maui M7.0
Scenario Peak Ground
Acceleration

Legend

Mercalli Scale (Potential Damage Perceived Shaking)

- V (Very Light, Moderate)
- VI (Light, Strong)
- VII (Moderate, Very Strong)

Magnitude: 7.0
Epicenter: N21.2 W156.1

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

NE Maui M7.0 Scenario Peak Ground Acceleration

Legend

Kalawao County

Mercalli Scale (Potential Damage Perceived Shaking)

V (Very Light, Moderate)

VI (Light, Strong)

VII (Moderate, Very Strong)

Magnitude: 7.0
Epicenter: N21.2 W156.1

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 3.5 7 Miles

Maui County Islands of Maui and Kahoolawe

Soil Classification: National Hazards Earthquake Reduction Program (NEHRP)

Legend

Community Plan Boundaries

Soil Types by Site Class

Class B - Rock

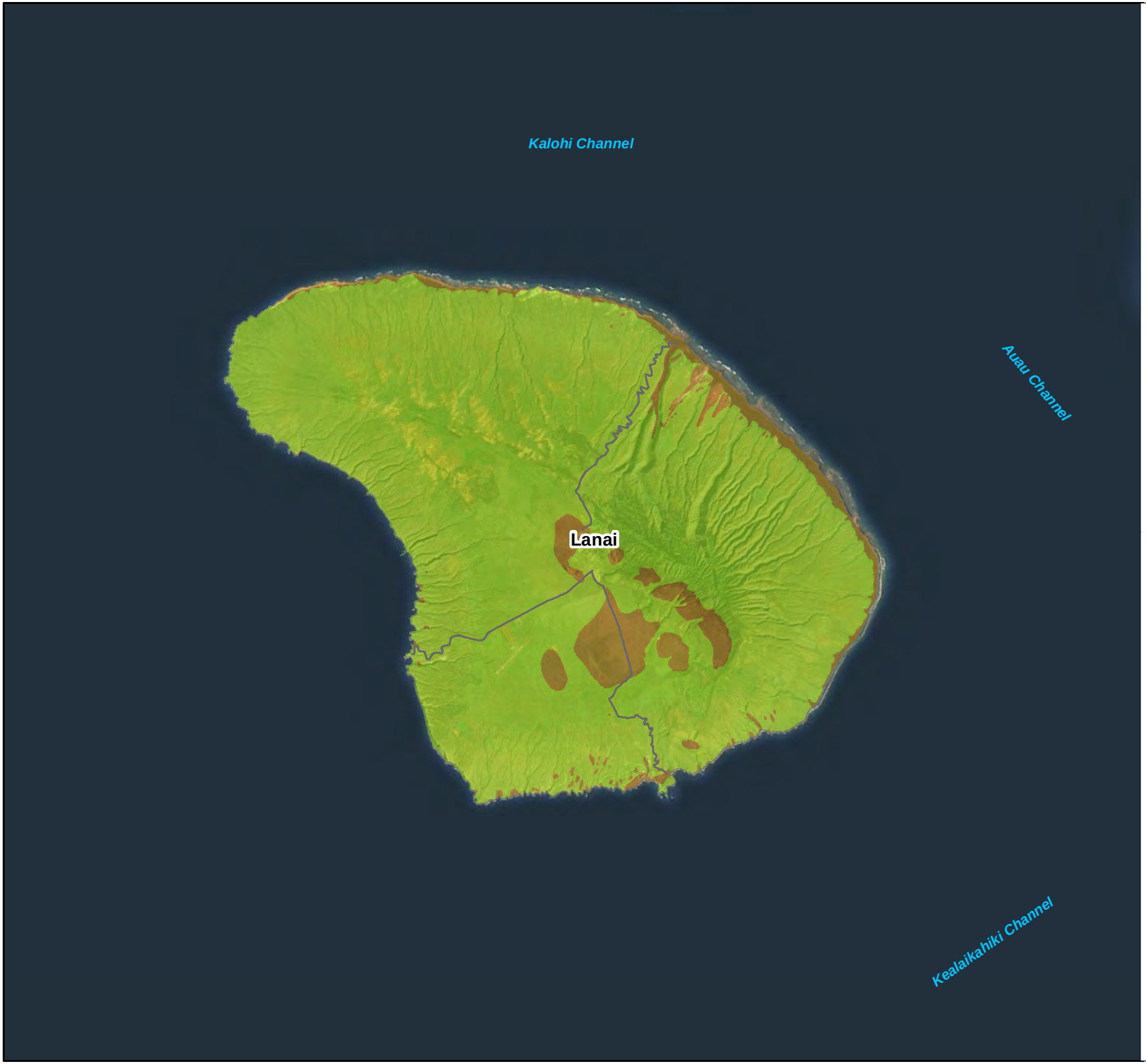
Class D - Stiff Soil

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 4.5 9 Miles



Maui County
Island of Lanai

Soil Classification:
National Hazards
Earthquake Reduction
Program (NEHRP)

Legend

Soil Types by Site Class

- Class B - Rock
- Class D - Stiff Soil

Base Map Data Sources:
Maui County, U.S. Geologic
Survey, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Soil Classification: National Hazards Earthquake Reduction Program (NEHRP)

Legend

Kalawao County

Soil Types by Site Class

Class B - Rock

Class D - Stiff Soil

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 3.5 7 Miles

10.2.4 Severity

In simplistic terms, the severity of the event can be measured in the following terms:

- How hard did the ground shake?
- How did the ground move? (horizontally or vertically)
- How stable was the soil?
- What is the fragility of the built environment in the area of impact?

The USGS has created ground motion maps based on current information about several fault zones. These maps show the PGA that has a certain probability (2 or 10 percent) of being exceeded in a 50-year period. The PGA is measured in numbers of g's (the acceleration associated with gravity). Figure 10-12 shows the PGAs with a 2-percent exceedance chance in 50 years in Hawaii. Maui County is a low-risk area.

Source: USGS, 1998

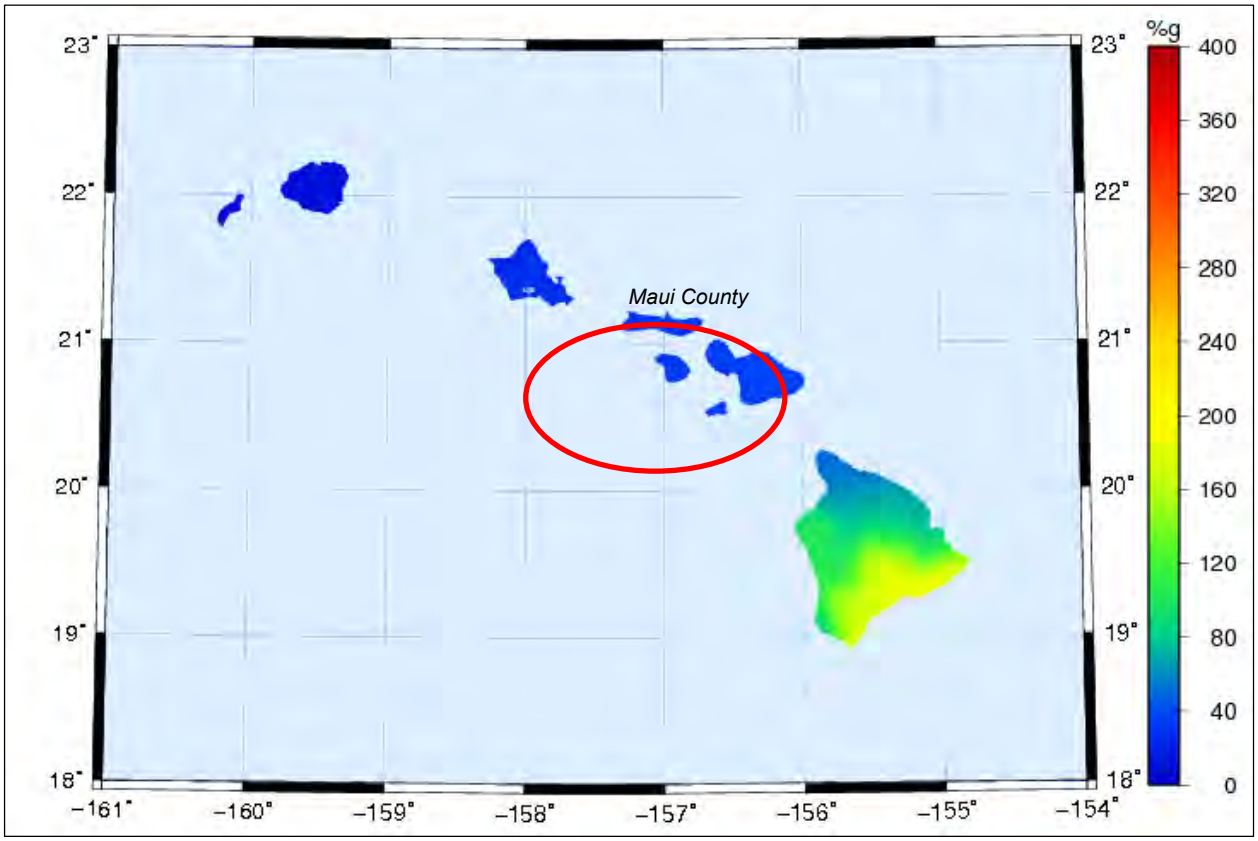


FIGURE 10-12. PGA WITH 2-PERCENT PROBABILITY OF EXCEEDANCE IN 50 YEARS, HAWAIIAN ISLANDS

10.2.5 Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. The warning

time is very short but it could allow for someone to get under a desk, step away from a hazardous material they are working with, or shut down a computer system.

10.2.6 Potential Impacts of Climate Change

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity, according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction or an increased propensity for slides during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

10.2.7 Secondary Hazards

Earthquakes can cause large and sometimes disastrous landslides and mudslides. River and stream valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction occurs when water-saturated sands, silts or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink into what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes. Fire may also occur from broken gas lines or downed electric wires. Additionally, tsunamis and run-ups may result from earthquakes, leading to potential coastal flooding and coastal erosion.

10.3 Exposure

10.3.1 Population

The entire population of the planning area is potentially exposed to direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and construction type of the structures people live in, the soil type their homes are constructed on, the intensity of the earthquake, etc. Whether directly impacted or indirectly impact, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

10.3.2 Property

According to an estimate based on Maui County assessor records, there are 48,277 buildings in the planning area. These structures are estimated to have a total replacement value of $45.7 billion. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees, this total represents the countywide property exposure to seismic events. Most of the buildings (93 percent) are residential.

10.3.3 Critical Facilities and Assets

All critical facilities in the planning area are exposed to the earthquake hazard. Table 4 4 lists the number of each type of facility. Hazardous materials releases can occur during an earthquake from fixed facilities or transportation-related incidents. Transportation corridors can be disrupted during an earthquake, leading to the release of materials to the surrounding environment. Facilities holding hazardous materials are of particular concern because of possible isolation of neighborhoods surrounding them. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment.

10.3.4 Onshore and Offshore Natural Environment

Secondary hazards associated with earthquakes will likely have some of the most damaging effects on the environment. Earthquake-induced landslides can significantly impact surrounding habitat including coral reefs. Earthquakes can result in underwater avalanches, which can potentially damage the reefs surrounding the Islands of Maui, Molokai, and Lanai. It is also possible for streams to be rerouted after an earthquake. This can change the water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater drying up because of changes in underlying geology.

10.4 Vulnerability

Earthquake vulnerability data were generated using a Level 2 Hazus-MH analysis. Once the location and size of a hypothetical earthquake are identified, Hazus-MH estimates the intensity of the ground shaking, the number of buildings damaged, the number of casualties, the damage to transportation systems and utilities, the number of people displaced from their homes, and the estimated cost of repair and clean up.

10.4.1 Population

There are estimated to be 63,919 people in over 21,742 households living on NEHRP Class D or E soils within the planning area. This represents about 50 percent of the total population. Of this population, the following three groups are particularly vulnerable to earthquake hazards:

- **Population Below Poverty Level**—Approximately 4,089 households in the planning area census blocks on NEHRP D and E soils are listed as earning less than $20,000 in annual income. This is about 18.8 percent of all households in these census blocks. These households may lack the financial resources to improve their homes to prevent or mitigate earthquake damage. Poorer residents are also less likely to have insurance to compensate for losses in earthquakes.
- **Population Over 65 Years Old**—Approximately 8,551 residents in the planning area census blocks on NEHRP D and E soils are over 65 years old. This is about 13.4 percent of all residents in these census blocks. This population group is vulnerable because they are more likely to need special medical attention, which may not be available due to isolation caused by earthquakes. Elderly residents also have more difficulty leaving their homes during earthquake events and could be stranded in dangerous situations.

Additionally, there are estimated to be 54,233 visitors in Maui on any given day. This segment of the population would also be considered to be vulnerable to earthquake hazards. Those visitors whose lodgings are located on NEHRP Class D and E soils may be especially vulnerable.

Impacts on persons and households in the planning area were estimated for the 100-year and 500-year earthquakes and the two scenario events through the Level 2 Hazus-MH analysis. Table 10-6 summarizes the results.

TABLE 10-6.
ESTIMATED EARTHQUAKE IMPACT ON PERSONS AND HOUSEHOLDS

Earthquake Event	Number of Displaced Households	Number of Residents Requiring Short-Term Shelter
100-Year Earthquake	11	8
500-Year Earthquake	149	105
Lanai M7.0	0	0
Kahului M7.0	0	0

Note: Vulnerability for the visitor population was unable to be determined. Modeled results for the resident population are based on a variety of factors that are unavailable for the visitor population.

10.4.2 Property

Property losses were estimated through the Level 2 Hazus-MH analysis for the 100-year and 500-year earthquakes and the two scenario events. Table 10-7 and Table 10-8 show the results for two types of property loss:

- Structural loss, representing damage to building structures
- Non-structural loss, representing the value of lost contents.

TABLE 10-7.
LOSS ESTIMATES FOR PROBABILISTIC EARTHQUAKES

Community Planning Area	Estimated Loss Associated with Earthquake					
	100- Year Earthquake			500- Year Earthquake		
	Structure	Contents	Total	Structure	Contents	Total
Hana	$785,987	$175,053	$961,039	$5,192,217	$1,673,759	$6,865,977
Kihei-Makena	$53,552,880	$12,577,615	$66,130,495	$225,198,305	$63,684,234	$288,882,538
Lanai	$708,041	$220,338	$928,379	$7,849,346	$2,686,360	$10,535,706
Makawao-Pukalani-Kula	$8,508,883	$1,786,940	$10,295,823	$53,984,467	$16,398,904	$70,383,371
Molokai	$893,245	$225,081	$1,118,326	$11,374,940	$3,480,442	$14,855,381
Paia-Haiku	$3,365,780	$696,836	$4,062,616	$25,125,597	$7,540,298	$32,665,895
Wailuku-Kahului	$38,648,579	$15,185,272	$53,833,851	$349,938,901	$130,422,745	$480,361,645
West Maui	$9,648,487	$2,518,254	$12,166,740	$116,703,124	$32,726,920	$149,430,044
Total	**$116,111,881**	**$33,385,389**	**$149,497,270**	**$795,366,895**	**$258,613,661**	**$1,053,980,556**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 10-8.
LOSS ESTIMATES FOR SCENARIO EVENT EARTHQUAKES

Community Planning Area	Estimated Loss Associated with Earthquake: Lanai M7.0 Structure	Lanai M7.0 Contents	Lanai M7.0 Total	Kahului M7.0 Structure	Kahului M7.0 Contents	Kahului M7.0 Total
Hana	$6,241	$3,804	$10,045	$140,872	$78,218	$219,089
Kihei-Makena	$2,626,244	$1,258,692	$3,884,936	$2,477,579	$1,158,728	$3,636,307
Lanai	$25,732,296	$9,687,524	$35,419,820	$17,992	$11,693	$29,684
Makawao-Pukalani-Kula	$192,189	$91,557	$283,746	$3,367,498	$1,808,856	$5,176,354
Molokai	$21,113,596	$9,058,163	$30,171,759	$19,769	$12,200	$31,968
Paia-Haiku	$164,819	$88,138	$252,956	$4,477,658	$2,226,256	$6,703,913
Wailuku-Kahului	$6,314,112	$4,240,625	$10,554,738	$16,199,471	$10,786,752	$26,986,223
West Maui	$8,285,392	$3,260,802	$11,546,194	$2,345,266	$1,085,933	$3,431,198
Total	**$64,434,889**	**$27,689,305**	**$92,124,194**	**$29,046,102**	**$17,168,635**	**$46,214,737**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

The total of the two types of losses is also shown in the tables. A summary of the property-related loss results is as follows:

- For a 100-year probabilistic earthquake, the estimated damage potential is $149.5 million, or less than 1 percent of the total replacement value for the planning area.
- For a 500-year probabilistic earthquake, the estimated damage potential is $1 billion, or 2.3 percent of the total replacement value for the planning area.
- For the Lanai 7.0-magnitude scenario event, the estimated damage potential is $92.1 million, or less than 1 percent of the total replacement value for the planning area.
- For the Kahului 7.0-magnitude scenario event, the estimated damage potential is $46.2 million, or less than 1 percent of the total replacement value for the planning area.

The Hazus-MH analysis also estimated the amount of earthquake-caused debris in the planning area for the 100-year and 500-year earthquakes and the two scenario events, as summarized in Table 10-9.

TABLE 10-9.
ESTIMATED EARTHQUAKE-CAUSED DEBRIS

	Debris to Be Removed (tons)
100-Year Earthquake	22,520
500-Year Earthquake	198,390
Lanai M7.0	7,890
Kahului M7.0	2,110

10.4.3 Critical Facilities and Assets

Level of Damage

Hazus-MH classifies the vulnerability of critical facilities to earthquake damage in five categories: no damage, slight damage, moderate damage, extensive damage, or complete damage. The model was used to assign a vulnerability category to each critical facility in the planning area except hazardous material (hazmat) facilities and "other infrastructure" facilities, for which there are no established damage functions. The analysis was performed for the 100-year event and 500-year events. Table 10-10 and Table 10-11 summarize the results.

TABLE 10-10.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM 100-YEAR EARTHQUAKE

Category[a]	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Emergency Services	0	44	0	0	0
Government[b] and Services	0	92	0	0	0
Critical Infrastructure and Lifelines	471	4	0	0	2
Other Important Assets	0	3	0	0	0
Total	**0**	**0**	**0**	**0**	**0**

a. Vulnerability not estimated for hazardous material facilities or for all "other important assets" due to lack of established damage functions for these type facilities.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

TABLE 10-11.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM 500-YEAR EARTHQUAKE

Category[a]	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Emergency Services	0	43	1	0	0
Government[b] and Services	0	90	2	0	0
Critical Infrastructure and Lifelines	5	320	15	0	2
Other Important Assets	0	3	0	0	0
Total	**0**	**0**	**0**	**0**	**0**

a. Vulnerability not estimated for hazardous material facilities or for all "other important assets" due to lack of established damage functions for these type facilities.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Hazus-MH estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments: 1, 3, 7, 14, 30 and 90 days after the event. For example, Hazus-MH may

estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. The analysis of critical facilities in the planning area was performed for the 100-year and 500-year events. Table 10-12 and Table 10-13 summarize the results.

TABLE 10-12.
FUNCTIONALITY OF CRITICAL FACILITIES FOR 100-YEAR EARTHQUAKE

Planning Unit	# of Critical Facilities	Probability of Being Fully Functional (%) at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Emergency Services	44	24%	25%	86%	88%	97%	98%
Government[a] and Services	92	21%	22%	85%	86%	97%	98%
Critical Infrastructure and Lifelines	477	91%	98%	99%	99%	99%	99%
Other Important Assets	3	17%	18%	83%	85%	97%	98%
Total/Average	**616**	**38%**	**41%**	**88%**	**90%**	**98%**	**98%**

a. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

TABLE 10-13.
FUNCTIONALITY OF CRITICAL FACILITIES FOR 500-YEAR EARTHQUAKE

Planning Unit	# of Critical Facilities	Probability of Being Fully Functional (%) at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Emergency Services	44	3%	4%	48%	49%	77%	85%
Government[a] and Services	92	2%	3%	42%	43%	73%	82%
Critical Infrastructure and Lifelines	477	68%	88%	95%	97%	97%	99%
Other Important Assets	3	1%	1%	31%	32%	63%	75%
Total/Average	**616**	**19%**	**24%**	**54%**	**55%**	**78%**	**85%**

a. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

10.4.4 Onshore and Offshore Natural Environment

The environment vulnerable to earthquake hazard is the same as the environment exposed to the hazard.

10.4.5 Economic Impact

Economic impact will be largely associated with the disruption of services caused by an earthquake event. In general, significant events may cause damage to land, buildings, transportation infrastructure, and businesses. With an event of such significance, economic recovery could take years depending on available recovery funds.

10.5 Future Trends in Development

Land use in the planning area will be directed by general plans adopted by the Maui County Council. These plans include the Countywide Policy Plan; the Maui Island Plan; and nine community plans that encompass Molokai, Lanai, Kahoolawe, and specific communities on the Island of Maui. The protective and preventative elements of these plans, from building height to transportation and environmental aspects, establish standards and plans for the protection of the community from hazards. The information in this plan provides a tool to ensure that there is no increase in exposure in areas of high seismic risk. Development in the planning area will be regulated through building standards and performance measures so that the degree of risk will be reduced. The International Building Code establishes provisions to address seismic risk. Due to regular occurrence of seismic activity in the area of Maui County, all future development will become vulnerable to the earthquake hazard.

10.6 Scenario

Any seismic activity of 6.0 or greater felt within the planning area would have significant impacts throughout the planning area. Potential warning systems could give approximately 40 seconds notice that a major earthquake is about to occur. This would not provide adequate time for preparation. Earthquakes of this magnitude or higher would lead to massive structural failure of property on NEHRP C, D, E, and F soils. Levees and revetments built on these poor soils would likely fail, representing a loss of critical infrastructure. These events could cause secondary hazards, including landslides and mudslides that would further damage structures.

10.7 Issues

Important issues associated with an earthquake include but are not limited to the following:

- **Facility Retrofit**—Based on the modeling of critical facility performance performed for this plan, a high number of facilities in the planning area are expected to have complete or extensive damage from scenario events. These facilities are prime targets for structural retrofits.
- **Continuity of Operations**—Critical facility owners should be encouraged to create or enhance continuity of operations plans using the information on risk and vulnerability contained in this plan.
- **Standardization of Future Development**—Geotechnical standards should be established that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- **Continued Public Education**—Citizens are expected to be self-sufficient up to 7 days following a major earthquake without government response agencies, utilities, private sector services and infrastructure components. Education programs are currently in place to facilitate the development of individual, family, neighborhood, and business earthquake preparedness. Government alone can never make this region fully prepared. It takes individuals, families, and communities working in concert with one another to truly be prepared for disaster.

Chapter 11. Flood

11.1 Hazard Description

Floods are one of the most common natural hazards in the U.S. They can develop slowly over a period of days or develop quickly, with disastrous effects that can be local (impacting a neighborhood or community) or regional (affecting entire river basins, coastlines and multiple counties or states).

11.1.1 General Background

A floodplain is defined as the land adjoining the channel of a river, stream, ocean, lake, or other watercourse or water body that becomes inundated with water during a flood. Most often floodplains are referred to as 100-year floodplains. A 100-year floodplain is not the flood that will occur once every 100 years, rather it is the flood that has a 1-percent chance of being equaled or exceeded each year. Thus, the 100-year flood could occur more than once in a relatively short period of time. With this term being misleading, the Federal Emergency Management Agency (FEMA) has properly defined it as the 1-percent annual chance flood. This 1-percent annual chance flood is now the standard used by most federal and state agencies and by the National Flood Insurance Program (NFIP) (Dinicola, 2014; FEMA, 2014a).

When floodwaters recede after a flood event, they leave behind layers of rock and mud. These gradually build up to create a new floor of the floodplain. Floodplains generally contain unconsolidated sediments (accumulations of sand, gravel, loam, silt, and/or clay), often extending below the bed of the stream. These sediments provide a natural filtering system, with water percolating back into the ground and replenishing groundwater. These are often important aquifers, the water drawn from them being filtered compared to the water in the stream. Fertile, flat reclaimed floodplain lands are commonly used for agriculture, commerce and residential development.

DEFINITIONS

Flood —The inundation of normally dry land resulting from the rising and overflowing of a body of water.

Floodplain —The land area along the sides of a river that becomes inundated with water during a flood.

Regulatory Floodway —The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. Communities must regulate development in these floodways to ensure that there are no increases in upstream flood elevations.

1-Percent Annual Chance Flood — Also known as the Special Flood Hazard Area (SFHA) or a 100-year floodplain. The area inundated by a flood that has a 1-percent chance of being equaled or exceeded each year.

0.2-Percent Annual Chance Flood —Also known as the 500-year floodplain. The area inundated by floodwaters that has a 0.2-percent chance of being equaled or exceeded each year.

Return Period —The average number of years between occurrences of a hazard (equal to the inverse of the annual likelihood of occurrence).

Connections between a water source and its floodplain are most apparent during and after major flood events. These areas form a complex physical and biological system that not only supports a variety of natural resources but also provides natural flood and erosion control. When a river is separated from its floodplain with levees and other flood control facilities, natural, built-in benefits can be lost, altered, or significantly reduced.

11.1.2 Floodplain Ecosystems

Floodplains can support ecosystems that are rich in plant and animal species. A floodplain can contain 100 or even 1,000 times as many species as a river. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly birds) move in to take advantage. The production of nutrients peaks and falls away quickly, but the surge of new growth endures for some time. This makes floodplains valuable for agriculture. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees (trees that grow in floodplains) tend to be very tolerant of root disturbance and very quick-growing compared to non-riparian trees.

11.1.3 Effects of Human Activities

Because they border water bodies, floodplains have historically been popular sites to establish settlements. Human activities tend to concentrate in floodplains for a number of reasons: water is readily available; land is fertile and suitable for farming; transportation by water is easily accessible; and land is flatter and easier to develop. But human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream's capacity to contain flows, and it increases flow rates or velocities downstream during all stages of a flood event. As a result, Flood Insurance Rate Maps (FIRM) delineate regulatory floodways where development is minimized or prohibited. Development projects within floodways are highly regulated and proceed on a case by case basis.

11.1.4 Federal Flood Programs

National Flood Insurance Program (NFIP)

The NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in participating communities. For most participating communities, FEMA has prepared a detailed Flood Insurance Study (FIS). The study presents water surface elevations for floods of various magnitudes, including the 1-percent annual chance flood and the 0.2-percent annual chance flood. Base flood elevations and the boundaries of the 1-percent and 0.2-percent annual chance floodplains are shown on FIRMs, which are the principle tool for identifying the extent and location of the flood hazard. FIRMs are the most detailed and consistent data source available, and for many communities they represent the minimum area of oversight under their floodplain management program.

Participants in the NFIP must, at a minimum, regulate development in floodplain areas in accordance with NFIP criteria. Before issuing a permit to build in a floodplain, participating jurisdictions must ensure that three criteria are met:

- New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the base flood.
- New floodplain development must not aggravate existing flood problems or increase damage to other properties.
- New floodplain development must exercise a reasonable and prudent effort to reduce its adverse impacts on listed threatened/endangered aquatic species.

In participating communities, structures permitted or built in the planning area before NFIP and related building code regulations went into effect are called "pre-FIRM" structures, and structures built afterwards are called "post-FIRM." The insurance rate is different for the two types of structures. Communities participating in the NFIP may adopt regulations that are more stringent than those contained in 44 CFR 60.3, but not less stringent. The Maui County Municipal Code requires new construction to be elevated to 1 foot above the base flood elevation.

The most recent preliminary FIRMs in the County are dated August 8, 2014. These maps include revisions that were made to incorporate information from the 2008 hurricane study for the Island of Molokai and the de-accredited levees along Kaunakakai Stream. These preliminary FIRMs encompass changes that were made to the September 19, 2012 Flood Insurance Study that covers all floodplains in Maui County (FEMA, 2014b). These preliminary FIRMs form the basis of the risk assessment outlined later in this chapter.

In the State of Hawaii, the Department of Land and Natural Resources (DLNR) is the coordinating agency for floodplain management. DLNR works with FEMA and local governments by providing grants and technical assistance, evaluating community floodplain management programs, reviewing local floodplain ordinances, and participating in statewide flood hazard mitigation planning. Compliance is monitored by FEMA regional staff and by DLNR. Maintaining compliance under the NFIP is an important component of flood risk reduction.

The FIRM for the islands of Maui, Molokai, and Lanai was created in 1981. Structures permitted or built in the planning area before then are called "pre-FIRM" structures, and structures built afterwards are called "post-FIRM." The insurance rate is different for the two types of structures (County of Maui, 2010a).

Maui County is currently in good standing with the provisions of the NFIP. Maintaining compliance under the NFIP is an important component of flood risk reduction. Maui County has identified initiatives to maintain its compliance and good standing.

FEMA Regulatory Flood Zones

According to FEMA, flood hazard areas are defined as areas that are shown on a map to be inundated by a flood of a given magnitude. These areas are determined using statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with the community; floodplain topographic surveys; and hydrologic and hydraulic analyses. Flood hazard areas are delineated on FEMA's FIRM, which are official maps of a community on which the Federal Insurance and Mitigation Administration has delineated both the Special Flood Hazard Areas (SFHA) and the risk premium zones applicable to the community. These maps identify the SFHAs; the location of a specific property in relation to the SFHA; the base flood elevation (1-percent annual chance) at a specific site; the magnitude of flood a flood hazard in a specific area; the undeveloped coastal barriers where flood insurance is not available and locates regulatory floodways and floodplain boundaries (1-percent and 0.2-percent annual chance floodplain boundaries).

The land area covered by the floodwaters of the base flood is the SFHA on a FIRM. It is the area where the NFIP floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. This regulatory boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities since many communities have maps showing the extent of the base flood and likely depths that will be experienced.

The 1-percent annual chance flood is referred to as the base flood. As defined by NFIP, the base flood elevation on a FIRM is the elevation of a base flood event, or a flood which has a 1-percent chance of occurring in any given year. The base flood elevation describes the exact elevation of the water that will result from a given discharge level, which is one of the most important factors used in estimating the potential damage to occur in a given area. A structure located within a 1-percent annual chance floodplain has a 26-percent chance of suffering flood damage during the term of a 30-year mortgage. The 1-percent annual chance flood is a regulatory standard used by federal agencies and most states, to administer floodplain management programs. The 1-percent annual chance flood is used by the NFIP as the basis for insurance requirements nationwide. FIRMs also depict 0.2-percent annual chance flood designations.

Digitized Flood Insurance Rate Maps (DFIRM), FIRMs, and other flood hazard information can be used to identify the expected spatial extent of flooding from a 1-percent and 0.2-percent annual chance event. DFIRMS and FIRMS depict SFHAs - those areas subject to inundation from the 1-percent annual chance. Those areas are defined as follows:

- **Zones A1-30 and AE:** SFHAs that are subject to inundation by the base flood, determined using detailed hydraulic analysis. Base Flood Elevations are shown within these zones.
- **Zone A (Also known as Unnumbered A-zones**): SFHAs where no Base Flood Elevations or depths are shown because detailed hydraulic analyses have not been performed.
- **Zone AO:** SFHAs subject to inundation by types of shallow flooding where average depths are between 1 and 3 feet. These are normally areas prone to shallow sheet flow flooding on sloping terrain.
- **Zone VE, V1-30:** SFHAs along coasts that are subject to inundation by the base flood with additional hazards due to waves with heights of 3 feet or greater. Base Flood Elevations derived from detailed hydraulic analysis are shown within these zones. For Maui County, these zones also include the 1-percent annual chance tsunami risk.
- **Zone B and X (shaded):** Zones where the land elevation as been determined to be above the Base Flood Elevation, but below the 500-year flood elevation. These zones are not SFHAs.
- **Zones C and X (unshaded):** Zones where the land elevation has been determined to be above both the Base Flood Elevation and the 500-year flood elevation. These zones are not SFHAs.

Coastal SFHA are of particular concern to the islands within the planning area, particularly along the areas of the coastline that are at or slightly above sea level. In 2013, FEMA announced additional information regarding the flood hazard area associated with coastal zones

The NFIP depicts two coastal flood hazard zones on its DFIRMS:

- Zone VE, as described above
- Zone AE, where flood elevation includes wave heights less than 3 feet.

Post-storm field visits and laboratory tests throughout coastal areas of the United States have consistently confirmed that wave heights as low as 1.5 feet can cause significant damage to structures that are constructed without considering coastal hazards. FIRMs recently published also include a line showing the Limit of Moderate Wave Action (LiMWA), which is the inland limit of the area expected to receive 1.5-foot or greater breaking waves during the 1-percent annual-chance flood event beyond the coastal VE zones and into the AE zone (Figure 11-1).

Source: FEMA, 2014c

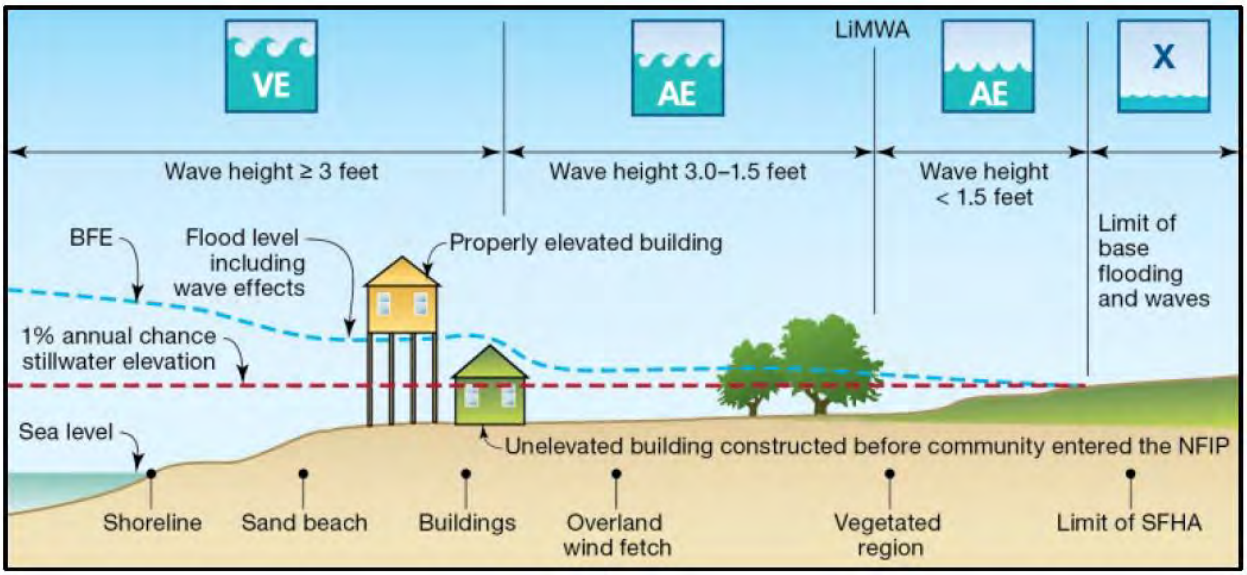


FIGURE 11-1. LIMIT OF MODERATE WAVE ACTION

The addition of the LiMWA area to FIRMs allows communities and individuals to better understand the flood risks to their property. The LiMWA area alerts property owners on the coastal side of the line that although their property is in Zone AE, their property may be affected by 1.5-foot or higher breaking waves and may therefore be at significant risk during a 1-percent-annual-chance flood event. While not formally defined in the NFIP regulations or mapped as a flood zone, the area between Zone VE and the LiMWA is called the Coastal A Zone. This area is subject to flood hazards associated with floating debris and high-velocity flow that can erode and scour building foundations and, in extreme cases, cause foundation failure (FEMA, 2014a).

The current effective FIRM for the County of Maui does not delineate LiMWA areas. Future map updates will include such information and should be used to develop additional coastal flooding mitigation items.

The Community Rating System

The CRS is a voluntary program within the NFIP that encourages floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions meeting the following three goals of the CRS:

- Reduce flood losses.
- Facilitate accurate insurance rating.
- Promote awareness of flood insurance.

For participating communities, flood insurance premium rates are discounted in increments of 5 percent. For example, a Class 1 community would receive a 45 percent premium discount, and a Class 9 community would receive a 5 percent discount. (Class 10 communities are those that do not participate in the CRS; they receive no discount.) The CRS classes for local communities are based on 18 creditable activities in the following categories:

- Public information

- Mapping and regulations
- Flood damage reduction
- Flood preparedness.

Figure 11-2 shows the nationwide number of CRS communities by class as of May 2014, when there were 1,211 communities receiving flood insurance premium discounts under the CRS program.

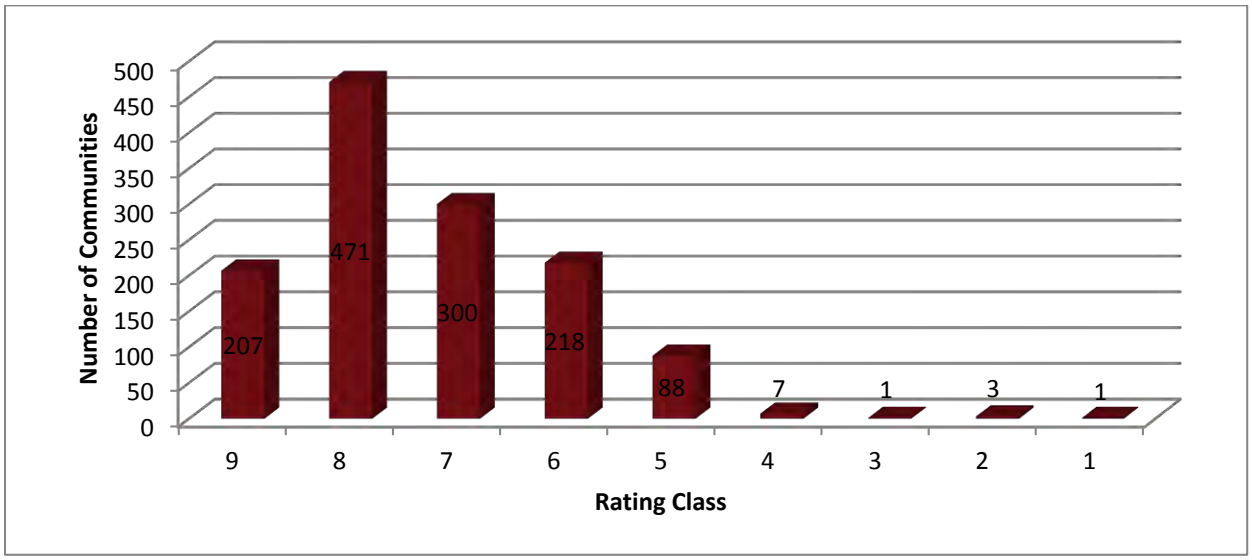


FIGURE 11-2. CRS COMMUNITIES BY CLASS NATIONWIDE AS OF MAY 2014

CRS activities can help to save lives and reduce property damage. Communities participating in the CRS represent a significant portion of the nation's flood risk; over 66 percent of the NFIP's policy base is located in these communities. Communities receiving premium discounts through the CRS range from small to large and represent a broad mixture of flood risks, including both coastal and riverine flood risks.

Maui County is currently participating in the CRS program. Its CRS status is as follows:

- NFIP Community #—150003
- CRS Entry Date—10/1/1995
- Current CRS Classification—8
- % Premium Discount, SFHA/non-SFHA—10/5

With a current CRS Classification of 8, Maui County received a 10-percent reduction in flood insurance premiums within the SFHA and a 5-percent reduction in flood insurance premiums outside of the SFHA. Many of the mitigation actions identified in this plan are creditable activities under the CRS program. Therefore, successful implementation of this plan offers the potential to enhance the CRS classification.

11.2 Hazard Profile

The following information is largely extracted from the Maui County Flood Insurance Study (FEMA, 2014b):

- Flood problems in the County are related primarily to channel overflow, overland flow, and standing water in poorly drained areas. Stream channel overflow is mainly due to the high frequency of intense rainfall typical of the Hawaiian Islands. Sandbars, which often form at the mouths of rivers and streams, may cause some backwater problems until washed out by large discharges. In addition to riverine flooding, unusual surf conditions, tsunamis, and hurricanes cause considerable damage in beach and low-lying coastal areas. In some areas along the coast, all three types of flooding may occur. (Note: High surf, tsunamis, and hurricanes are treated as separate hazards in this plan. However, the FEMA floodplain mapping of costal zones incorporates risks from all of these hazards. This has resulted in overlap among the exposure and vulnerability assessments of these hazards. Flooding as a result of dam failure is also addressed in a separate chapter.)
- While the specific cause of tsunami and hurricane-related flooding could be attributed to a single factor, the cause of flooding as a result of stream overflow may be due to various reasons. Possible flood causes include: debris-clogged streams, flash floods, and undefined streamflow patterns, isolated depressions in topography, inadequate drainage facilities, and changed drainage conditions because of development.
- Flooding in Maui County is attributable to fast-moving surface runoff from steep mountain slopes discharging onto low, flat, coastal plains. This condition causes stormwater from the highlands to overtop lowland streams and flood areas adjacent to the streams. Most flood problems on the island occur in the low-lying areas, which have largely been developed with inadequate or nonexistent flood control measures and storm drainage systems.
- Excessive surface water from overland flow frequently causes flooding in poorly drained areas. Many of these problems are found in developed areas where the natural drainage patterns have been altered during development. Other factors that contribute to this type of flooding are insufficient or excessive land slopes and poor soil conditions.

11.2.1 Types of Flood-related Hazards

In Hawaii, major floods typically occur during the rainy winter (October through April on Maui, December through March on Molokai), accounting for approximately 84 percent of the floods in the islands. Four types of storms produce heavy precipitation, and therefore floods (County of Maui, 2010a):

- **Kona Storms**—These storms occur during the wettest period of the year, from November to April. Trade winds from the northeast slack during this time, allowing storms from the south to more easily approach the islands. Kona winds are generally warmer and carry moisture that is dropped evenly as rain over the entire islands. The low-elevation and southern, drier sides of the islands get most of their rainfall (approximately 25 to 30 inches each season) during Kona storms. Because of the potential combination of high winds and heavy rains, these events can cause coastal and inland flooding over larger geographic areas.
- **Frontal Storms**—Frontal storms usually occur from December through March. They originate over the Pacific Ocean as a result of the intersection of polar and tropical air masses and move eastward over the islands. Heavy continuous rainfall over a period of several hours can create disaster conditions in high sloping areas of the islands. Low-lying areas with poor drainage are prone to landslides and flash floods during these storms.

- **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**—Tropical depressions, tropical storms, and hurricanes hitting or passing near the Hawaiian Islands cause heavy rains, storm surge, high winds and surf. Impacts from these events include severe coastal and inland flooding. Tropical cyclones also cause severe damage due to high surf.

The types of flooding commonly found in Maui County are described below.

Stormwater Runoff Floods

Stormwater runoff floods occur when natural or manmade drainage systems are overwhelmed by intense or prolonged precipitation. Runoff is a function of infiltration capacity (soil type), ground slope, vegetation cover, and type and extent of development (amount of impermeable surface). In addition to high water, stormwater runoff carries trash, motor oils, landscape chemicals, pet and livestock feces and other pollutants to streams and into the ocean (County of Maui, 2010a).

Stormwater runoff and debris flows negatively impact public infrastructure such as roads and bridges as water collects, creating ponding conditions that can make roads impassable. Ponding may interrupt road transportation and damage low-elevation buildings. Road closures due to ponding can be a critical issue in Hawaii because events of this nature have the potential to isolate communities temporarily or indefinitely (County of Maui, 2010a).

Riverine Floods

Riverine floods occur along a channel and include overbank and flash flooding. Channels are defined, ground features that carry water through and out of a watershed. They may be called rivers, creeks, streams, or ditches. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas. Small rivers and streams, such as those found in Maui County, are susceptible to flooding from large-scale and more localized weather systems that cause intense rainfall over small areas (County of Maui, 2010a).

Flash Floods

Flash floods are "a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters" (NWS, 2009).

Flash floods are capable of tearing out trees, undermining buildings and bridges, and scouring new channels. 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. The greatest risk from flash floods is that they occur with little to no warning. The major factors in predicting potential damage are the intensity and duration of rainfall and watershed and stream steepness (County of Maui, 2010a).

Coastal Floods

Coastal floods are characterized by inundation of normally dry lands by ocean waters. This flooding is often caused by storm surge caused by severe storms, tsunamis, or extreme high tide events that result in shallow flooding of low lying

coastal areas. Storm surge floods typically result in coastal erosion, salinization of freshwater sources, and contamination of water supplies. These floods are also responsible for significant agricultural losses, loss of life and damage to public and private structures and infrastructure (County of Maui, 2010a).

Coastal flooding is becoming increasingly exacerbated by sea level rise as a result of climate change or relative sea level rise caused by a local increase in the level of the ocean relative to land as a result of tectonic activity (NOAA, n.d.).

11.2.2 Principal Flooding Sources

Principal flooding sources on the Island of Maui as identified on FEMA flood maps include the following streams; for descriptions of each of these areas, please refer to Volume I of the Maui County FIS (FEMA, 2014b):

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

Principal flooding sources on the Island of Molokai as identified on FEMA flood maps include the following streams. For descriptions of each of these areas, please refer to Volume I of the Maui County FIS (2014b):

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

In addition to the streams above, detailed studies were also conducted on the entire coastlines of Maui and Molokai to determine tsunami inundation limits. Approximately 80 percent of the coastline of Lanai has undergone such assessment. Additionally, the following sections of coast were studied in whole for the hurricane storm surge and wave height hazard using detailed methods (FEMA, 2014b):

- On the Island of Lanai, the southwestern and southern coastline from Kaumalapau to Manele
- On the Island of Maui the western, southern, and eastern-facing coasts from Honokahua to Kulepeamoa Point
- On the Island of Molokai, the coastline south and east of Ilio Point to Cape Halawa.

More than 65 additional streams were also assessed on the Islands of Maui and Molokai. These streams were studied with approximate methods because the areas surrounding the streams were identified as having low development potential or impact from flooding.

11.2.3 Past Events

Table 11-1 summarizes flood events in the County of Maui since 1971, as recorded in the National Climatic Data Center's Storm Events Database and the Spatial Hazard Events and Losses Database for the United States (SHELDUS). There have been seven Presidential Disaster Declarations that named non-tsunami flooding as the type of event since 1963. This equates to a major, non-tsunami or hurricane-related flood event occurring every seven years on average.

Maui County as a whole is susceptible to a variety of flooding, whether coastal, riverine, or flash. The list below demonstrates some of the more severe occurrences of flooding within the County.

TABLE 11-1.
HISTORY OF FLOOD EVENTS

Date	Event	Date	Event	Date	Event
1/28/1971	Flood	11/12/1996	Flood	3/25/2001	Flood
2/7/1976	Flood	11/13/1996	Flood	6/5/2001	Flood
10/28/1981	Flood	11/14/1996	Flood	10/24/2001	Flood
3/17/1982	Flood	11/15/1996	Flood	11/27/2001	Flash Flood
3/30/1982	Flood	12/13/1996	Flood	11/27/2001	Flood
4/3/1982	Flood	12/14/1996	Flood	12/12/2001	Flood
12/25/1984	Flood	12/21/1996	Flood	1/29/2002[a]	Flash Flood
10/18/1985	Flash Flood	12/23/1996	Flash Flood	1/29/2002	Flood
11/18/1985	Flash Flood	12/24/1996	Flood	7/26/2002	Flash Flood
2/15/1986	Flash Flood	12/27/1996	Flood	10/15/2002	Flash Flood [a]
11/11/1986	Flash Flood	1/2/1997	Flood	10/17/2002	Flash Flood [a]
4/26/1987	Flash Flood	1/4/1997	Flash Flood	4/10/2003	Flash Flood [b]
5/6/1987	Flash Flood	1/19/1997	Flash Flood [a]	11/28/2003	Flash Flood
7/23/1987	Flash Flood	1/19/1997	Flood [a]	1/1/2004	Flash Flood
12/19/1987	Flash Flood	3/16/1997	Flood	1/23/2004	Flash Flood
2/15/1987	Flash Flood	3/17/1997	Flood	2/27/2004	Flash Flood
4/22/1987	Flash Flood	7/30/1997	Flash Flood [a]	8/3/2004	Flash Flood
9/27/1988	Flash Flood	7/30/1997	Flood	3/23/2006	Flash Flood
3/24/1988	Flash Flood	8/15/1997	Flood	3/31/2006	Flash Flood
1/29/1988	Flood	8/17/1997	Flood	10/16/2006	Flash Flood
11/5/1988	Flood	9/21/1997	Flood	11/2/2006	Flash Flood
12/6/1988	Flash Flood	10/10/1997	Flood	12/2/2006	Flash Flood
1/12/1989	Flash Flood	11/17/1998	Flood	11/5/2007	Flash Flood
2/5/1989	Flash Flood	12/31/1998	Flood	12/5/2007	Flash Flood [c]
2/10/1989	Flash Flood	1/22/1999	Flood	12/31/2007	Flash Flood
3/4/1989	Flash Flood	1/31/1999	Flash Flood	2/7/2008	Flash Flood
4/4/1989	Flash Flood	1/31/1999	Flood	11/18/2008	Flash Flood
8/20/1989	Flash Flood	3/20/1999	Flood	12/26/2008	Flash Flood
12/11/1989	Flash Flood	10/20/1999	Flash Flood	12/27/2008	Flash Flood

TABLE 11-1.
HISTORY OF FLOOD EVENTS

Date	Event	Date	Event	Date	Event
10/8/1989	Flash Flood	10/20/1999	Flood	12/26/2010	Flash Flood
1/27/1991	Flood	12/1/1999	Flood	1/10/2011	Flash Flood
3/8/1993	Flash Flood	12/3/1999	Flood	1/13/2011	Flash Flood
10/17/1993	Flash Flood	8/20/2000	Flood	2/11/2011	Flash Flood
9/18/1994	Flash Flood	9/6/2000	Flood	3/9/2012	Flash Flood
2/12/1994	Flash Flood	10/26/2000	Flood	1/28/2013	Flash Flood
2/24/1996	Flood	10/28/2000	Flash Flood	2/21/2013	Flash Flood
3/3/1996	Flood	10/29/2000	Flash Flood	7/29/2013	Flash Flood
3/30/1996	Flood	10/29/2000	Flood	11/10/2013	Flash Flood
6/9/1996	Flood	11/3/2000	Flood	1/22/2014	Flash Flood
		2/8/2001	Flood	7/20/2014	Flash Flood

a. Property damage recorded for this event.
b. Two fatalities resulted from this event.
c. This event resulted in one injury.
Source: National Climatic Data Center Storm Events Database; SHELDUS

Specific descriptions of flooding is provided below:

April 1968 Floods

During the storm of April 15-16, 1968, drainage ditches in Hana town, including their bedding and sections of the earth banks, were washed downstream into the ocean by sheet flow flooding. Additionally, road shoulders, retaining walls and pavement were also severely damaged (County of Maui, 2010a).

April 2003 Floods

Flash flooding occurred in April 2003 in Haleakala National Park (Kipahulu area) on the Island of Maui. The flash flood, which occurred at the bottom of the 184-foot Makahiku Falls, resulted in the death a man and a girl who were swept away by a 6-foot wall of water while crossing the stream at the bottom of the waterfall. The deaths led to a federal lawsuit by the family of the victims. Ultimately the United States government paid $5 million in 2009. According to Haleakala National Park officials, there have been nine deaths at the falls since 1983 (County of Maui, 2010a).

December 2007 Floods

On December 5, 2007, a low pressure system that formed north of the Hawaiian Islands caused very strong winds, with gusts up to 70 miles per hour, along with heavy rainfall. Before reaching the sea, much of the storm's runoff on the Island of Maui caused flooding, flash flooding, mudslides and collapses of solid ground around gulches and usually dry streambeds. At least five homes in the Kula area were severely damaged by wind and rain. One home in Keokea washed into a gulch and a fire department helicopter crew had to rescue residents from its rooftop. The floods affected utility service and transportation. Mud and debris carried by the floodwaters crossed Kula Highway (State Route 37) and forced closure of all traffic lanes. Ponding floods occurred along South Kihei Road near Hoonani Street. High surf and flooding runoff affected coastal park areas (County of Maui, 2010a).

The storm flooded urban and rural areas of the Island of Molokai. Mauna Loa Highway (State Highway 460) experienced runoff and ponding floods at several locations, though not enough to force the closure of the road. Ponding floods were also experienced in the Kaunakakai area. Here, the floods were of smaller scale than those witnessed in urban Maui (County of Maui, 2010a).

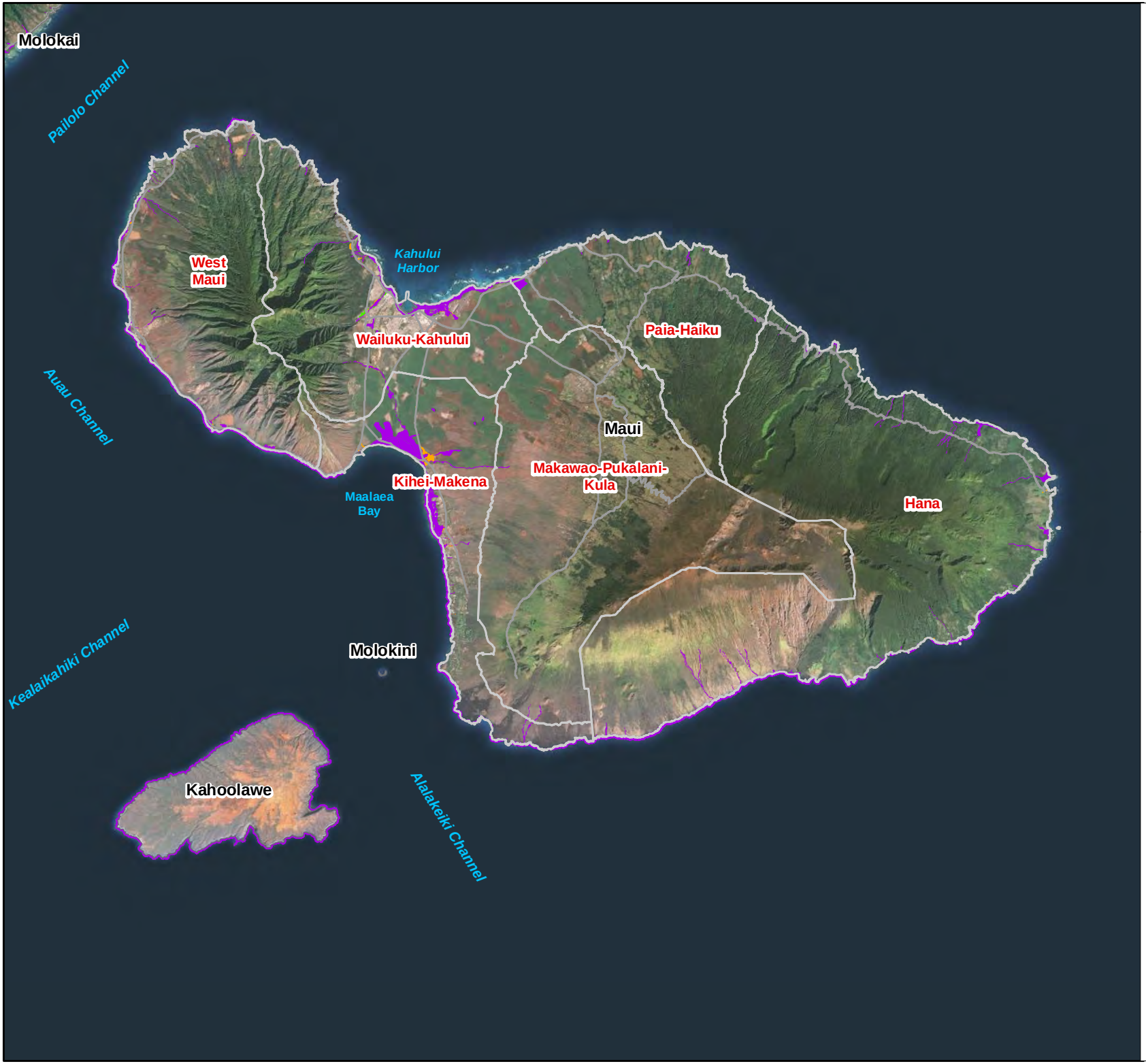
11.2.4 Location

Approximately 3.3 percent of the entire County (744,797.1 acres) is located within the mapped 1 percent annual chance (100-year) floodplain (Table 11 2). The flooding that has occurred in portions of the County has been extensively documented by gage records, high water marks, damage surveys, and personal accounts. This documentation was the basis for the FIRMs generated by FEMA for Maui County, which are shown in Figure 11 3 through Figure 11 5. All of the aforementioned principal flooding sources are incorporated in the currently effective FIRMs. The FIRMs are the most detailed and consistent data source available for determining flood extent. The 2014 Flood Insurance Study is the sole source of data used in this risk assessment to map the extent and location of the flood hazard.

TABLE 11-2.
AREA IN THE 1-PERCENT-ANNUAL-CHANCE FLOOD ZONE (100-YEAR FLOODPLAIN)

	1 percent annual chance (100-Year) floodplain	
Community Planning Area	**Area (acres)**	**% of total acreage**
Hana	3,848.35	15.52%
Kihei-Makena	4,561.43	18.39%
Lanai	6,207.60	25.03%
Makawao-Pukalani-Kula	55.30	0.22%
Molokai	5,564.04	22.43%
Paia-Haiku	419.12	1.69%
Wailuku-Kahului	1,715.54	6.92%
West Maui	2,429.46	9.80%
Total	**24,800.84**	**100.00%**

Source: Maui County community planning areas and FEMA DFIRM



Maui County Islands of Maui and Kahoolawe

FEMA DFIRM Flood Hazard Areas

Legend

Community Plan Boundaries

Flood Hazard

1% Annual Flood Hazard

0.2% Annual Flood Hazard

Areas with Reduced Flood Due to Leevee

Base Map Data Sources:
Maui County, FEMA, ESRI

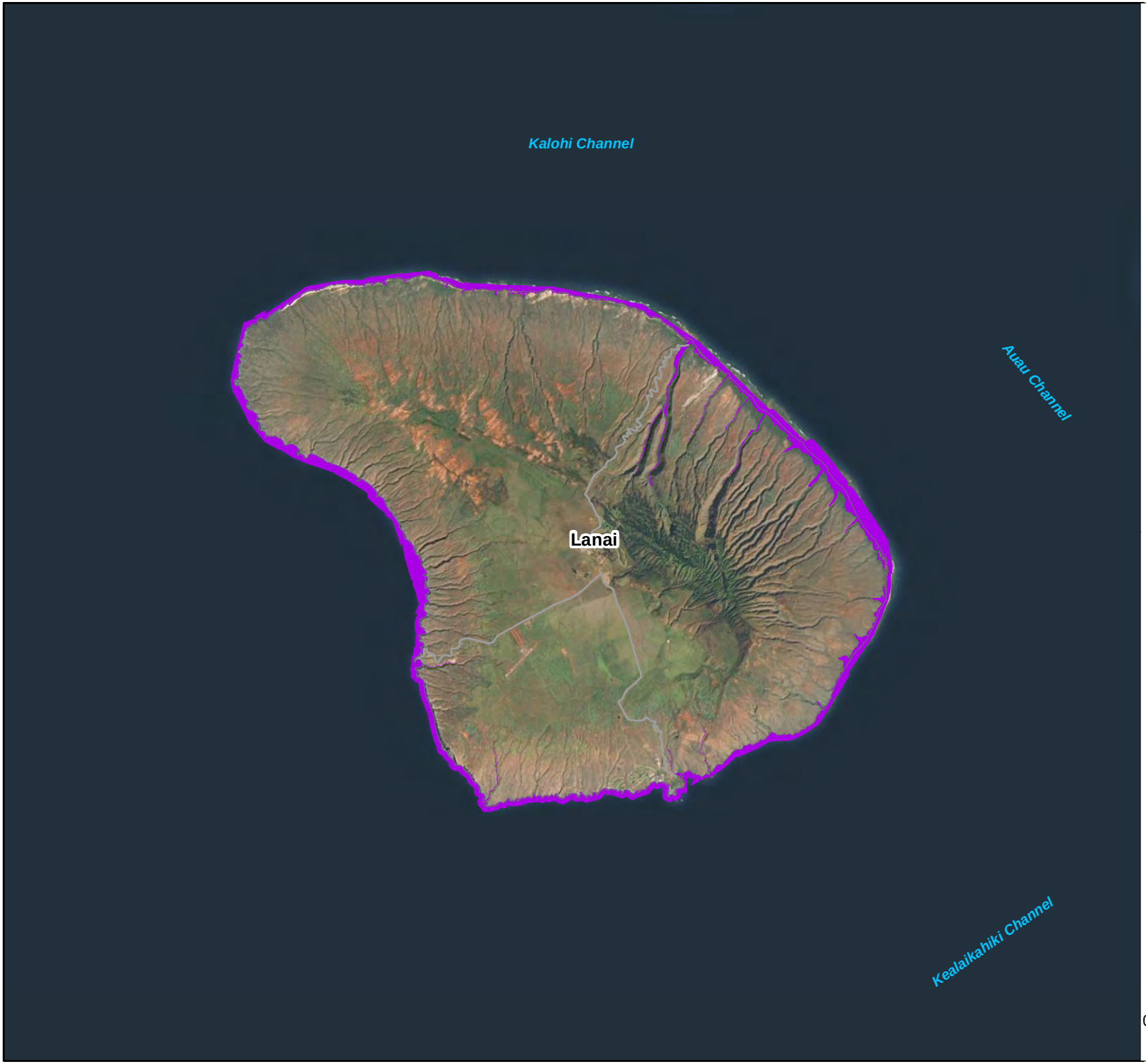
TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

FEMA DFIRM Flood Hazard Areas



Legend

Flood Hazard

- 1% Annual Flood Hazard
- 0.2% Annual Flood Hazard
- Areas with Reduced Flood Due to Leevee

Base Map Data Sources:
Maui County, FEMA, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

FEMA DFIRM Flood Hazard Areas

Legend

Kalawao County

Flood Hazard

1% Annual Flood Hazard

0.2% Annual Flood Hazard

Areas with Reduced Flood Due to Leevee

Base Map Data Sources:
Maui County, FEMA, ESRI

TETRA TECH

N

0 3.5 7 Miles

Coastal Flooding

Flooding from storm surge is a potential threat in heavily developed coastal areas near Maalaea, Kihei, and Makena on the Island of Maui. Kealia Pond and surrounding coastal lowlands can also be inundated by storm surges. The areas of Waiehu and Waihee, located in coastal embayments, are at a higher risk of high surf flooding due to the exposure to waves measuring as high as 20 feet during winter (County of Maui, 2010a).

Inland Flooding

Stream Floods

Stream flooding is common on the Island of Maui. The north and central areas of Maui and the Hana Coast have the most extensive histories of stream flooding. Kahului, the County of Maui's most urbanized area and location of the Island of Maui's major airport, commercial port, and retail and wholesale facilities, is a frequent location of severe stream flooding. The Iao Stream has caused the major flood problem in the Wailuku-Kahului area (County of Maui, 2010a).

Stream flooding is also significant in the south area of the Island of Maui, especially from streams draining the Kihei watershed on the western slope of the Haleakala volcano. Gulches, ravines, and gullies drain the mountain slopes above the Kihei coastal lowland, which is relatively flat and characterized by sandy beaches. The threat from stream flooding is high where there are small beaches that coincide with stream mouths near Wailea, and in the south at Poolenalena. Stream flooding risk is also high where streams are near residential development such Kalama Park, Kamaole Beach, and Lipoa Avenue. The principal streams within the watershed that flow westward and seaward only during periods of excessive rainfall are Kulanihakoi, Waipuilani, and Keokea streams. These streams are narrow and poorly defined. Localized depressions, ponds, swales, and ditches are typical of areas near the intersections of these streams with Kihei Road (County of Maui, 2010a).

Because of the lack of rainfall over most areas the Island of Molokai, the only perennial streams that reach the sea are those of the large valleys on the windward side of East Molokai. The permanence of the streams on the northern slope is the result of numerous high levels springs that issue from the dike complex where exposed by erosion. Other streams are fed from swamps. Due to geological conditions such as the steepness of the terrain and the intermittent character of 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 Molokai and most areas of West Molokai are perennial in the upper courses but normally lose their water to seepage and evaporation before reaching the coast. Flooding of these streams can occur after heavy rainfalls or Kona storms (County of Maui, 2010a).

The major flood problems in the Island of Molokai are associated with the heavy flow of four water courses in East Molokai: the Wailaua stream; and the Wawaia, Kamalo, and Kawela gulches. The primary causes of flood damage are overflow of the water courses, inadequate highway bridge openings, and periodical accumulation of deposits on the stream beds that reduce flow capacity (County of Maui, 2010a).

On the Island of Lanai, records indicate historical stream floods on the island's arid west coast. Nonetheless, because of the island's limited coastal development, stream floods are considered more of a hazard to the environment than to population centers (County of Maui, 2010a).

Flash Floods

On the Island of Maui, flash floods in the densely populated areas of Kihei and Lahaina are partially due to an abrupt transition in slope at the coastline. Many floods in these areas occurred after heavy precipitation at higher elevations, which fed to narrow stream channels and drainage channels near the arid coast to the point of overflow. In the Lahaina area, flash floods are caused by the steep slope of the foothills on the west side of the West Mountains and a lack of vegetation. Since 1879, 19 damaging floods have occurred in Lahaina. The city of Wailuku also experiences flash flooding. Flash flooding has been a serious problem in the Kahului and Wailuku areas, due to large amounts of water from the steep hillsides of the Iao valley collecting when encountering a coastal lowland area. Flash flooding also poses serious threats in the low-lying coastal terraced area near Waihee Point and Waihee Beach Park. High velocity flows from the streams within the Iao valley area bring rocks and boulders to the beaches near Waihee (County of Maui, 2010a).

Sheet Flow Floods

Sheet flow flooding is a problem in the western area of the Island of Maui, which encompasses the Lahaina and Honolua watersheds. The Honolua watershed covers 24,800 acres from the area north of the Kaanapali resort to Honolua Bay. The highest point of the watershed is the Puu Kukui peak in the mountains in western Maui. Deep valleys and narrow winding channels draining to the ocean incise the watershed. Grades begin at about 16 percent and flatten to 6 percent near the ocean. Defined channels in major valleys vary from 5 to 10 feet in depth and 10 to 20 feet in width. The Lahaina watershed is covers 4,920 acres around Lahaina Town and the Pomona subdivision. The upper area of the watershed is part of the West Maui Forest Reserve and features mountainous terrain with deeply incised canyons. Heavy precipitation from past storm events on the Island of Maui has created severe sheet flow floods due to the high velocities of water flowing down the pasturelands. In downtown Hana, high velocity sheet flow floods have caused road damage.

On the Island of Molokai, sheet flow flooding occurs along the eastern limits of the Wailaua Valley. Sheet flow flooding in this area is caused by water flowing rapidly down the steep hillside onto flat 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 (County of Maui, 2010a).

Stormwater Runoff Floods

On the Island of Maui, the Wailuku area has experienced stormwater runoff floods in the form of overtopping of agricultural irrigation ditches. During periods of heavy rainfall, the irrigation ditches are incapable of carrying the irrigation water and stormwater runoff that they intercept. Floods in and along Wailuku's Wells Park and Main Street have occurred during periods of heavy rainfall. Secondary areas of flooding occur in the low-lying sections of Kahului. There, the floods primarily consist of the inundation of 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 are the cause of such floods (County of Maui, 2010a).

Stormwater-related floods occur in both the arid and wetter regions of the Island of Molokai, but there are only a few places where stormwater runoff flooding has much impact on developed areas. The primary causes of these types of flows on the Island of Molokai are overflow of watercourses, inadequate highway openings, and periodic accumulation of deposits on the streambeds (County of Maui, 2010a).

The inadequate capacity of existing channels in the Kihei area on the Island of Maui causes flooding. Between Kihei Road and Piilani Highway (State Highway 31), there are four gulches (Waiakoa, Kulanihakoi, Waipuilani, and Keokea) that flow east-west and drain approximately 65 percent of the watershed. Storm runoff flows at high velocities above the coastal plain because of the steep ground gradient at upper elevations. 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. As floodwaters approach the coastline, ponding occurs because of inadequate outlets to the sea (outlets are frequently plugged with ocean-deposited sand). On their approach to the Kihei floodplain, the floodwaters of these streams cause overtopping of existing drainage structures crossing Kihei Road. This flat low-lying coastal area receives all of this surface runoff, contributing to flood problems in the Kihei area. In Kihei, transportation, and in some cases evacuation, problems are severe due to the North/South Kihei Road that runs parallel and very close to the coastline. This road has been flooded on many occasions by low-magnitude coastal flood events such as those caused by south swells, Kona storms, and heavy rains (County of Maui, 2010a).

11.2.5 Frequency

The most current precipitation frequency estimates for the Hawaiian Islands are included in Volume 4 of *Atlas 14 – Precipitation Frequency Atlas of the United States*, which provides precipitation frequency estimates for 5-minute through 60-day durations at recurrence intervals of 1 year through 1,000 years. Figure 11-7 shows a map of the County of Maui indicating the estimated precipitation for 60-minute duration and for 100-year average recurrence interval (County of Maui, 2010a).

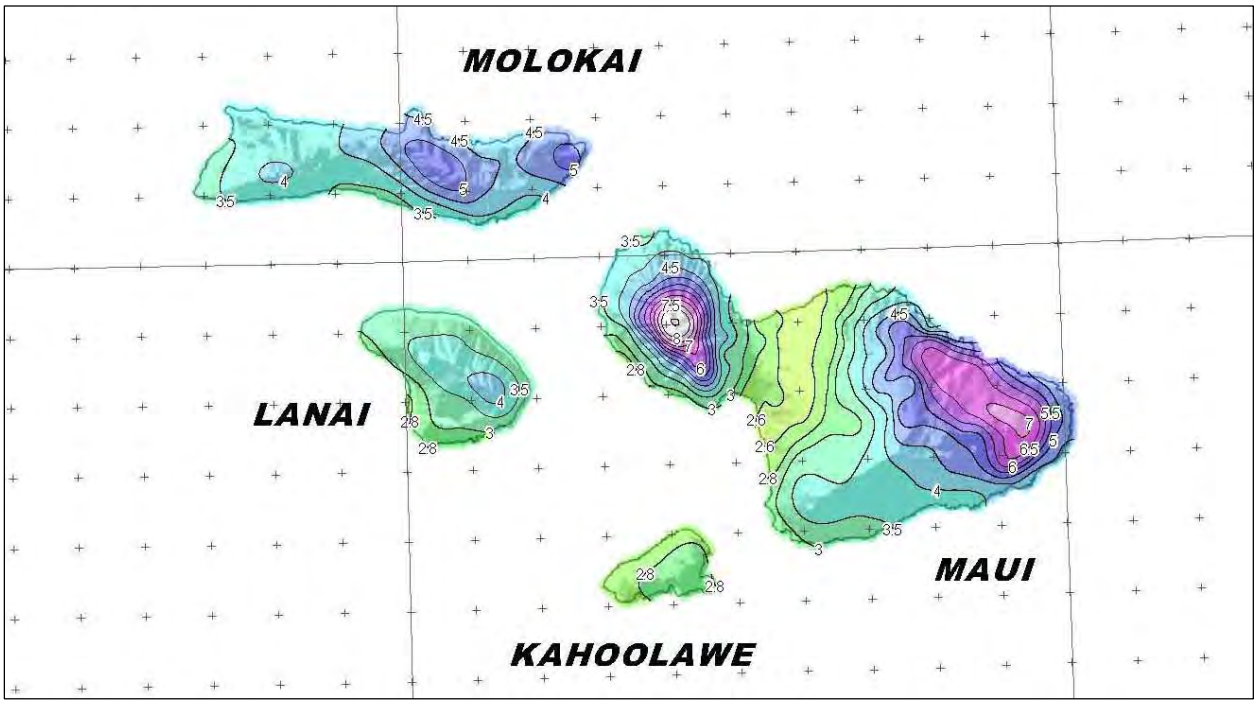


FIGURE 11-6. 60-MINUTE PRECIPITATION (INCHES) WITH AVERAGE RECURRENCE INTERVAL OF 100 YEARS IN MAUI COUNTY

There have been seven Presidential Disaster Declarations that named non-tsunami flooding as the type of event since 1963. This equates to a major, non-tsunami or hurricane-related flood event occurring every 7 years on average. More localized flood events can be expected to happen annually.

11.2.6 Severity

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity is often evaluated by examining peak discharges. Peak flows used by FEMA to map the floodplains of the planning area are listed in Table 11-3 and Table 11-4.

TABLE 11-3.
SUMMARY OF PEAK DISCHARGES ISLAND OF MAUI

Source/Location	Discharge (cubic feet/second)			
	10-Year	50-Year	100-Year	500-Year
Hahakea Gulch	1,800	3,600	4,600	7,500
Honokahua Stream	1,670	3,360	4,300	7,020
Honokeana Bay Gulch	350	670	830	1,300
Honokowai Stream	2,000	4,000	5,200	8,200
Iao Stream	6,100	11,000	13,800	20,600
Kahana Stream	2,000	4,000	5,100	8,400
Kahoma Stream	2,600	5,100	6,400	10,200
Kailua Gulch	2,700	6,000	8,000	13,800
Kalepa Gulch	522	887	1,114	1,402
Kalialinui Gulch (At Mouth)	2,700	7,300	10,300	20,800
Kalialinui Gulch (At Sunnyside and Airport Roads)	2,605	7,045	9,975	20,090
Kaluaihakoko Stream	129	332	461	897
Kamaole Gulch	1,132	2,756	3,765	7,044
Kaopala Gulch	550	1,100	1,300	2,100
Kauaula Stream	1,400	3,000	4,000	6,700
Keahaiwai Gulch (At Mouth)	N/A	N/A	8,950	N/A
Keahaiwai Gulch (Approximately 400 Feet Upstream Of Mokulele Highway)	N/A	N/A	7,600	N/A
Keokea Gulch	N/A	N/A	8,066	N/A
Kihei Gulch 1 (At Mouth)	421	813	1,007	1,515
Kihei Gulch 1 (At Ataloa Road)	309	580	712	1,056
Kihei Gulch 1 (At Piilani Highway)	223	421	518	765
Kihei Gulch 2	930	2,200	3,000	5,500
Kihei Gulch 3	870	2,060	2,790	5,130

TABLE 11-3.
SUMMARY OF PEAK DISCHARGES ISLAND OF MAUI

Source/Location	Discharge (cubic feet/second)			
	10-Year	50-Year	100-Year	500-Year
Kihei Gulch 4	590	1,400	1,900	3,400
Kope Gulch	1,047	1,737	2,216	2,787
Kulanihakoi Gulch (Subarea 7)	3,017	7,362	10,061	18,830
Kulanihakoi Gulch (Subarea 8)	79	197	271	516
Kulanihakoi Gulch (Subarea 9)	N/A	259	303	N/A
Liilioholo Gulch	920	2,200	3,000	5,700
Mahinahina Gulch	930	1,800	2,300	3,700
Napali Gulch 2-3	420	810	1,020	1,600
Napali Gulch 4-5	540	1,000	1,300	2,000
Olowalu Stream	1,600	3,600	4,700	8,100
Spreckels Ditch (Wailuku Town Area)	870	1,785	2,295	3,805
Unnamed Stream at Kuau Point	690	1,830	2,540	5,000
Waiakoa Gulch (At Piilani Highway)	N/A	N/A	6,800	N/A
Waiakoa Gulch (Subarea 5)	N/A	N/A	5,450	N/A
Waiehu Stream	3,700	6,300	7,770	11,200
Waiehu Stream (At Kehekili Highway)	2,697	4,383	5,550	6,960
Waihee River	7,450	10,837	12,844	15,784
Waikapu Stream (Just Upstream of Confluence with Kolaloa Gulch)	1,244	1,966	2,242	3,470
Waikapu Stream (Approximately 4,200 Feet Downstream of Kuihelani Highway)	1,180	1,900	2,173	2,981
Waikapu Stream (At Kuihelani Highway)	1,135	1,799	2,011	2,563
Waikapu Stream (At Honoapiilani Highway)	1,111	1,765	1,955	2,403
Waipuilani Gulch (Subarea 9)	2,913	6,868	9,275	16,941
Waipuilani Gulch (Subarea 10)	116	293	406	779
Waipuilani Gulch (Subarea 11)	66	162	222	422
Waipuilani Gulch (Subarea 12)	205	494	672	1,251
Waipuilani Gulch (Subarea 13)	28	58	78	141
Waipuilani Gulch (Subarea 14)	26	71	102	209
Waipuilani Gulch (Subarea 15)	38	106	152	313

Source: FEMA, 2014b
Note: All locations are at mouth unless otherwise noted

TABLE 11-4.
SUMMARY OF PEAK DISCHARGES ISLAND OF MOLOKAI

Source/Location	Discharge (cubic feet/second)			
	10-Year	50-Year	100-Year	500-Year
Kahananui Gulch	1,700	3,700	5,000	8,600
Kamalo Gulch	4,300	9,600	12,600	22,100
Kamiloloa Stream	2,525	6,000	8,200	15,655
Kaunakakai Stream	5,636	11,400	15,000	28,390
Kawela Gulch	5,800	13,000	17,000	30,000
Keawanui Gulch	1,400	3,100	4,100	7,400
Manawai Gulch	1,300	3,000	3,900	7,000
Mile 84 Stream	2,525	6,000	8,200	15,655
Ohia Gulch	2,100	4,500	6,000	10,600
Pukoo Gulch	960	2,320	2,900	5,200
Waialua Stream	3,500	7,700	10,200	18,000

Source: FEMA, 2014b
Note: All locations are at mouth unless otherwise noted

11.2.7 Warning Time

Due to the sequential pattern of weather conditions needed to cause serious flooding, it is unusual for a flood to occur without warning. Warning times for floods can be between 24 and 48 hours. Flash flooding can be less predictable, but potential hazard areas can be warned in advanced of potential flash flooding danger. The State of Hawaii has two systems for advance warning of flash floods (County of Maui, 2010a):

- **Hydronet System—**The Hydronet system is a statewide network of rain gages to support the flash flood forecast and warning operations of the National Weather Service's Honolulu Forecast Office. Data loggers record rainfall to a resolution of 0.01 inches every 15 minutes. Each gage is programmed to call the Hydronet computers when rainfall intensities reach a pre-selected threshold (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). The Hydronet workstation notifies forecasters of heavy rain events. Alarm messages are sent to County warning points for intensities of 2.00 inches per hour or greater. The alarm system at the County of Maui warning point is tested quarterly to ensure receipt of messages. All Hydronet gages are visited routinely for maintenance and calibration.
- **Areal Mean Basin Estimated Rainfall (AMBER)—**The AMBER system uses radar data to produce specific basin-averaged rainfall estimates. Output includes hourly basin accumulation rates as well as basin accumulation totals over user-specified periods. AMBER output is currently available from the WSR-88D radar on Molokai with basins delineated over other islands in the County of Maui. Flash flood guidance values are also tied to AMBER data to assist forecasters in the warning and advisory decision-making process. These values indicate the amount of basin-averaged rainfall needed to produce small stream flooding over different time periods.

The USGS also provides real time information on stream flows in Maui County through its Water Watcher program. This program provides information on real time stream flow information as well as flood and high flow information for eleven gages located throughout Maui County. An example image from this online tool is shown in Figure 11-7.

Source: USGS, 2015c

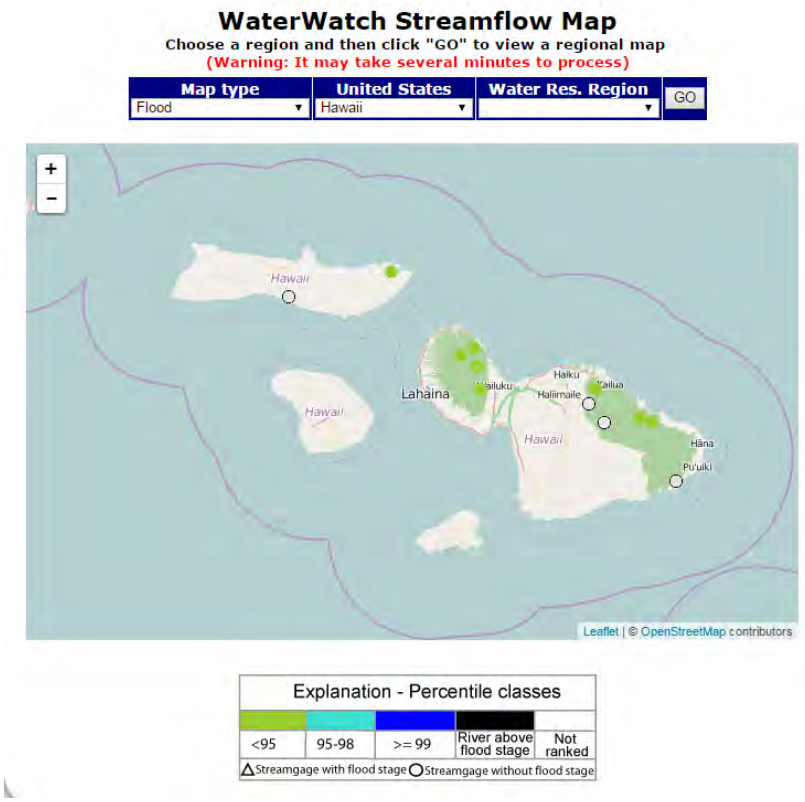


FIGURE 11-7. USGS WATERWATCH STREAMFLOW MAP

11.2.8 Potential Impacts of Climate Change

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already impacting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

As hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, bypass channels and levees, as well as the design of local sewers and storm drains. Additionally, rising sea levels, coupled with high water levels caused by tropical and extra-tropical storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism (Leong et al., 2014).

11.2.9 Secondary Hazards

The most problematic secondary hazard for riverine flooding is bank erosion, which in some cases can be more harmful than actual flooding. This is especially true in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage, but scour the banks, edging properties closer to the floodplain or causing them to fall in. Flooding is also responsible for hazards such as landslides when high flows over-saturate soils on steep slopes, causing them to fail. Hazardous materials spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers, or storm sewers. A secondary hazard along the coastal flood area includes coastal erosion, which, in turn has the potential to augment high surf or tsunami/run-up incidents along VE zones.

11.3 Exposure

The Level 2 Hazus-MH protocol was used to assess the risk and vulnerability to flooding in the planning area. The model used census data at the block level and FEMA floodplain data, which have a level of accuracy acceptable for planning purposes. Where possible, the Hazus-MH default data were enhanced using local GIS data from local, state and federal sources. It is important to note that the 1-percent annual flood hazard (100-year floodplain) and the 0.2 percent annual flood hazard (500-year floodplain) are very similar for the planning area. For the purposes of this risk assessment, only the exposure and associated impacts for the 1-percent-annual-chance flood event were modeled. The 0.2 percent event is assumed to affect approximately the same number of people and property, although flood depths may be increased resulting in greater losses per property impacted.

11.3.1 Population

A population exposure estimate was made by counting the number of buildings in the FEMA mapped 100-year floodplain and determining the percent of buildings in each community planning area exposed. This percentage was then applied to the estimated 2010 population to estimate exposure. Using this approach, the estimated resident population living in the 1-percent-annual-chance flood zone (100-year floodplain) is estimated to be 9,441 or 6.1 percent of the resident population. 12,003 visitors or 22.1 percent of the visitor population are estimated to have lodging in the 1-percent-annual-chance flood zone (100-year floodplain) (see Table 11-5).

TABLE 11-5.
POPULATION EXPOSED TO THE 1-PERCENT-ANNUAL-CHANCE (100-YEAR) FLOOD

Community Planning Area	Residents	Visitors	Total
Hana	160	0	160
Kihei-Makena	4,025	4,588	8,613
Lanai	14	0	14
Makawao-Pukalani-Kula	0	0	0
Molokai	902	212	1,114
Paia-Haiku	165	0	165
Wailuku-Kahului	2,346	859	2,405
West Maui	1,829	6,344	8,173
Total	**9,441**	**12,003**	**21,444**

11.3.2 Property

Structures in the Floodplain

The total area of Maui County that is in the 1-percent-annual-chance flood zone (100-year floodplain) is 24,800 acres. The number of exposed structures is as follows:

- Residential—2,405
- Commercial—234
- Industrial—47
- Agricultural—0
- Religion—16
- Government—1
- Education—6
- **Total—2,709**

The Hazus-MH model determined that there are 2,709 structures within the 1-percent-annual-chance flood zone (100-year floodplain), about 88.8 percent are residential, and 10.4 percent are commercial or industrial.

Exposed Value

Table 11-6 summarizes the estimated value of exposed buildings in the planning area. This methodology estimated $4.3 billion worth of building-and-contents exposure to the 1-percent-annual-chance flood zone (100-year floodplain), representing 9.5 percent of the total replacement value of the planning area.

TABLE 11-6.
STRUCTURES IN THE 1-PERCENT-ANNUAL-CHANCE FLOOD ZONE (100-YEAR FLOODPLAIN)

	Buildings Exposed	Value Exposed			% of Total Replacement Value
		Structure	Contents	Total	
Hana	77	$15,873,331	$8,663,603	$24,536,934	5.57%
Kihei-Makena	1,092	$859,200,045	$507,225,035	$1,366,425,080	14.52%
Lanai	6	$1,505,522	$1,056,154	$2,561,676	0.25%
Makawao-Pukalani-Kula	0	$0	$0	$0	0.00%
Molokai	371	$110,657,090	$59,387,383	$170,044,473	11.88%
Paia-Haiku	63	$21,102,743	$12,306,731	$33,409,474	1.50%
Wailuku-Kahului	654	$438,280,089	$350,721,950	$789,002,039	4.79%
West Maui	446	$1,283,020,121	$660,402,008	$1,943,422,130	19.46%
Total	**2,709**	**$2,729,638,940**	**$1,599,762,866**	**$4,329,401,805**	**9.47%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

Land Use in the Floodplain

Some land uses are more vulnerable to flooding, such as single-family homes, while others are less vulnerable, such as agricultural land or parks. The amount of the floodplain that contains vacant, developable land is not known. This would be valuable information for gauging the future development potential of the floodplain.

Table 11-7 shows the existing land use of all parcels in the 1 percent annual chance floodplain (100-year floodplain), including vacant parcels and those in public/open space uses, broken down for the community planning area. About 71.6 percent of the parcels are currently being used for agricultural uses or open space. These are favorable, lower-risk uses for the floodplain.

TABLE 11-7.
LAND USE IN THE 1-PERCENT-ANNUAL-CHANCE FLOOD ZONE (100-YEAR FLOODPLAIN)

	100-Year Floodplain	
Land Use	Area (acres)	% of total
Agricultural	7,128.11	53.0%
Apartment	124.21	0.9%
Commercial	601.04	4.5%
Commercialized Residential	3.87	0.0%
Conservation	2,501.86	18.6%
Hotel/Resort	209.29	1.6%
Industrial	165.80	1.2%
Residential	2,022.88	15.0%

TABLE 11-7.
LAND USE IN THE 1-PERCENT-ANNUAL-CHANCE FLOOD ZONE (100-YEAR FLOODPLAIN)

Land Use	100-Year Floodplain Area (acres)	100-Year Floodplain % of total
Time Share	12.46	0.1%
Not Classified	687.16	5.1%
Total	13,456.70	100%

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified." Acreage includes only areas intersecting mapped hazard layers.

11.3.3 Critical Facilities and Assets

Table 11-8 summarizes the critical facilities and assets in the 1-percent-annual-chance flood zone (100-year floodplain) of the planning area. Details are provided in the following sections.

Toxic Release Inventory Reporting Facilities

Toxic Release Inventory (TRI) facilities are known facilities that manufacture, process, store or other wise use certain chemicals above minimum thresholds. If damaged by a flood, these facilities may potentially release chemicals that cause cancer or other human health effects, significant adverse acute human health effects, significant adverse environmental effects (EPA, 2015). During a flood event, containers holding these materials can rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents. One facility in the 1 percent annual chance flood zone is a TRI reporting facility.

TABLE 11-8.
CRITICAL FACILITIES AND ASSETS IN THE 1-PERCENT-ANNUAL-CHANCE (100-YEAR) FLOOD ZONE

Facility Type	Number of Exposed Facilities
Emergency Services	
Emergency Operations	0
Police & Fire	3
Community Shelter[a]	0
Medical & Health	0
Government and Services	
Government[b]	—
Schools[a]	6
Critical Infrastructure and Lifelines	
Transportation	20
Water Supply	1
Wastewater	28
Dams	6
Energy	2
Telecommunications	3
Hazardous Materials	1
Other Important Assets	
Financial	9
Tourist Lodging	51
Early Assistance	0

TABLE 11-8.
CRITICAL FACILITIES AND ASSETS IN THE 1-PERCENT-ANNUAL-CHANCE (100-YEAR) FLOOD ZONE

Facility Type	Number of Exposed Facilities
Total	**130**

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Utilities and Infrastructure

It is important to determine who may be at risk if flooding damages infrastructure. Roads that are blocked or damaged can isolate residents and can prevent access throughout the planning area, including for emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by floods or debris also can cause isolation. Water and sewer systems can be flooded or backed up, causing health problems. Underground utilities can be damaged. Dikes can fail or be overtopped, inundating the land that they protect. The following sections describe specific types of critical infrastructure.

Roads

The following major roads in the planning area pass through the 1-percent-annual-chance flood zone (100-year floodplain) and thus are exposed to flooding:

- Island of Maui
  - State Highway 31
  - State Highway 311
  - State Highway 330
  - State Highway 3400
  - State Highway 36
  - State Highway 380
- Island of Molokai
  - State Highway 460
  - Keomuku Highway
  - State Highway 30
  - State Highway 310
  - State Highway 32
  - State Highway 340
  - State Highway 3500
  - State Highway 360
  - County Highway 340
  - State Highway 450
- Island of Lanai

Some of these roads are built above the flood level, and others function as levees to prevent flooding. Still, in severe flood events these roads can be blocked or damaged, preventing access to some areas.

Bridges

Flooding events can significantly impact road bridges. These are important because often they provide the only ingress and egress to some neighborhoods. An analysis showed that there are 14 bridges that are in or cross over the 1-percent-annual-chance flood zone (100-year floodplain).

Levees

Levees in Maui have been assessed and accredited as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year. As mentioned previously during the most recent revision to the Maui County FIRM the Kaunakakai Stream levees on Molkai were de-accredited. The following levees maintained their accreditation for the 1-percent annual flood risk:

- Embankment structure on the Waialua Stream
- Embankment structure on the Kamilana Gulch
- Embankment structures on the Kahana Stream
- Levee structures on the Iao Stream
- Embankment structure on the Kalialinui Stream
- Embankment structure on the Kihei Gulch 4.

Although these levees remain accredited, residual risk still remains for behind levee properties from events that exceed the 1-percent annual flood hazard.

Water and Sewer Infrastructure

Water and sewer systems can be affected by flooding. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing wastewater to spill into homes, neighborhoods, rivers and streams.

11.3.4 Onshore and Offshore Natural Environment

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Fish can wash into roads or over dikes into flooded fields, with no possibility of escape. Pollution from roads, such as oil, and hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development such as bridge abutments and levees, and logjams from downed trees can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses.

11.4 Vulnerability

Many of the areas exposed to flooding may not experience serious flooding or flood damage. This section describes vulnerabilities in terms of population, property, infrastructure and environment.

11.4.1 Population

A geographic analysis of demographics using the Hazus-MH-MH model identified populations vulnerable to the flood hazard as follows:

- **Economically Disadvantaged Populations**—It is estimated that 19 percent of the people within the 1-percent-annual-chance flood zone (100-year floodplain) are economically disadvantaged, defined as having household incomes of $20,000 or less.

- **Population over 65 Years Old**—It is estimated that 11.1 percent of the population in the census blocks that intersect the 1-percent-annual-chance flood zone (100-year floodplain) are over 65 years old.
- **Population under 16 Years Old**—It is estimated that 21.3 percent of the population within census blocks located in or near the 1-percent-annual-chance flood zone (100-year floodplain) are under 16 years of age.

Additionally, there are estimated to be 54,233 visitors in Maui on any given day. This segment of the population would also be considered to be vulnerable to the flood hazard. Those visitors whose lodgings are located in or near the 1-percent-annual-chance flood zone (100-year floodplain) may be especially vulnerable.

Impacts on Persons and Households

Impacts on persons and households in the planning area were estimated for the 100-year event through the Level 2 Hazus-MH analysis. Table 11-9 summarizes the results.

TABLE 11-9.
ESTIMATED FLOOD IMPACT ON PERSONS AND HOUSEHOLDS

Community Planning Area	Number of Displaced Households	Number of Persons Requiring Short-Term Shelter
Hana	97	22
Kihei-Makena	4,327	4,040
Lanai	1	0
Makawao-Pukalani-Kula	0	0
Molokai	813	564
Paia-Haiku	142	77
Wailuku-Kahului	2,513	2,132
West Maui	1,486	1,202
Total	**9,379**	**8,037**

Note: Vulnerability for the visitor population was unable to be determined. Modeled results for the resident population are based on a variety of factors that are unavailable for the visitor population.

Public Health and Safety

Floods and their aftermath present the following threats to public health and safety:

- **Unsafe food—**Floodwaters contain disease-causing bacteria, dirt, oil, human and animal waste, and farm and industrial chemicals. They carry away whatever lies on the ground and upstream. Their contact with food items, including food crops in agricultural lands, can make that food unsafe to eat and hazardous to human health. Power failures caused by floods damage stored food. Refrigerated and frozen foods are affected during the outage periods, and must be carefully monitored and examined prior to consumption. Foods kept inside cardboard, plastic bags, jars, bottles, and paper packaging are subject to disposal if contaminated by floodwaters. Even though the packages do not appear to be wet, they may be unhygienic with mold contamination and deteriorate rapidly.
- **Contaminated drinking and washing water and poor sanitation—**Flooding impairs clean water sources with pollutants. Contact with the contaminants—whether through direct food intake, vector insects such as flies,

unclean hands, or dirty plates and utensils—can result in waterborne illnesses and life-threatening infectious disease. The pollutants also saturate into the groundwater or can infiltrate into sanitary sewer lines through the ground. Wastewater treatment plants, if flooded and caused to malfunction, can be overloaded with polluted runoff waters and sewage beyond their disposal capacity, resulting in backflows of raw sewage to homes and low-lying grounds. Private wells can be contaminated or damaged severely by floodwaters, while private sewage disposal systems can become a cause of infection if they are broken or overflow. Unclean drinking and washing water and sanitation, coupled with lack of adequate sewage treatment, can lead to disease outbreaks.

- **Mosquitoes and animals—**Prolonged rainfall and floods provide new breeding grounds for mosquitoes—wet areas and stagnant pools—and can lead to an increase in the number of mosquito-borne diseases such as malaria and dengue and West Nile fevers. Rats and other rodents and wild animals also can carry viruses and diseases. The public should avoid such animals and should dispose of dead animals in accordance with guidelines issued by local animal control authorities. Leptospirosis—a bacterial disease associated predominantly with rats—often accompanies floods in developing countries, although the risk is low in industrialized regions unless cuts or wounds have direct contact with disease-contaminated floodwaters or animals.
- **Mold and mildew—**Excessive exposure to mold and mildew can cause flood victims—especially those with allergies and asthma—to contract upper respiratory diseases, triggering cold-like symptoms. Molds grow in as short a period as 24 to 48 hours in wet and damp areas of buildings and homes that have not been cleaned after flooding, such as water-infiltrated walls, floors, carpets, toilets and bathrooms. Very small mold spores can be easily inhaled by human bodies and, in large enough quantities, cause allergic reactions, asthma episodes, and other respiratory problems. Infants, children, elderly people and pregnant women are considered most vulnerable to mold-induced health problems.
- **Carbon monoxide poisoning—**Carbon monoxide poisoning is as a potential hazard after major floods. In the event of power outages following floods, flood victims tend to use alternative sources of fuels for heating or cooking inside enclosed or partly enclosed houses, garages or buildings without an adequate level of air ventilation. Carbon monoxide can be found in combustion fumes such as those generated by small gasoline engines, stoves, generators, lanterns, gas ranges, or the burning of charcoal or wood. Built-up carbon monoxide from these sources can poison people and animals.
- **Hazards when reentering and cleaning flooded homes and buildings—**Flooded buildings can pose significant health hazards to people entering and cleaning damaged buildings or working to restore utility service after floodwaters recede. Electrical power systems, including fallen power lines, can become hazardous. Gas leaks from pipelines or propane tanks can trigger fire and explosion. Flood debris—such as broken bottles, wood, stones and walls—may cause wounds and injuries to those removing contaminated mud and cleaning damaged buildings. Containers of hazardous chemicals, including pesticides, insecticides, fertilizers, car batteries, propane tanks and other industrial chemicals, may be hidden or buried under flood debris. A health hazard can also occur when hazardous dust and mold in ducts, fans and ventilators of air-conditioning and heating equipment are circulated through a building and inhaled by those engaged in cleanup and restoration.

- **Mental stress and fatigue**—Having experienced a devastating flood and seen loved ones lost or injured and homes damaged or destroyed, flood victims can experience long-term psychological impact. The expense and effort required to repair flood-damaged homes places severe financial and psychological burdens on the people affected, in particular the unprepared and uninsured. Post-flood recovery—especially when it becomes prolonged—can cause mental disorders, anxiety, anger, depression, lethargy, hyperactivity, sleeplessness, and, in an extreme case, suicide. Behavior changes may also occur in children such as an increase in bed-wetting and aggression. There is also a long-term concern among the affected that their homes can be flooded again in the future.

Current loss estimation models such as Hazus-MH are not equipped to measure public health impacts such as these. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with them in responding to flood events.

11.4.2 Property

Hazus-MH calculates losses to structures from flooding by looking at depth of flooding and type of structure. Using historical flood insurance claim data, Hazus-MH estimates the percentage of damage to structures and their contents by applying established damage functions to an inventory. For this analysis, local data on facilities was used instead of the default inventory data provided with Hazus-MH.

The analysis is summarized in Table 11-10 for the 1-percent-annual-chance flood zone (100-year floodplain). It is estimated that there would be more than $903 million of flood loss from a 1 percent annual (100-year) flood event in the planning area. This represents 20.9 percent of the total exposure to the 1-percent-annual-chance flood (100-year floodplain) and almost 2 percent of the total replacement value for the planning area.

National Flood Insurance Program

Table 11-11 lists flood insurance statistics that help identify vulnerability in the planning area. There are more than 12,500 policies in force providing more than $2.6 billion in insurance. According to FEMA statistics, 292 flood insurance claims were paid between January 1, 1978 and January 31, 2015, for a total of $6.1 million, an average of $20,854 per claim.

Properties constructed after a FIRM has been adopted are eligible for reduced flood insurance rates. Such structures are less vulnerable to flooding since they were constructed after regulations and codes were adopted to decrease vulnerability. Properties built before a FIRM is adopted are more vulnerable to flooding because they do not meet code or are located in hazardous areas. The first FIRMs in the planning area were available in June 1981.

TABLE 11-10.
LOSS ESTIMATES FOR 1-PERCENT-ANNUAL-CHANCE FLOOD (100-YEAR FLOOD)

	Estimated Loss Associated with Flood			% of Total
	Structure	Contents	Total	Replacement Value
Hana	$3,656,000	$2,907,000	$6,563,000	1.49%
Kihei-Makena	$87,185,000	$72,951,000	$160,136,000	1.70%
Lanai	$273,000	$217,000	$490,000	0.05%

TABLE 11-10.
LOSS ESTIMATES FOR 1-PERCENT-ANNUAL-CHANCE FLOOD (100-YEAR FLOOD)

	Estimated Loss Associated with Flood			% of Total
	Structure	Contents	Total	Replacement Value
Makawao-Pukalani-Kula	$0	$0	$0	0.00%
Molokai	$11,982,000	$8,714,000	$20,696,000	1.45%
Paia-Haiku	$5,703,000	$6,615,000	$12,318,000	0.55%
Wailuku-Kahului	$175,571,000	$342,135,000	$517,706,000	3.14%
West Maui	$101,230,000	$84,817,000	$186,047,000	1.86%
Total	**$385,600,000**	**$518,356,000**	**$903,956,000**	**1.98%**

a. Impacted structures are those structures with finished floor elevations below the flood event water surface elevation. These structures are the most likely to receive significant damage in a flood event.

TABLE 11-11.
FLOOD INSURANCE STATISTICS

Date of Entry Initial FIRM Effective Date	06/01/1981
# of Flood Insurance Policies as of 03/31/2015	12,567
Insurance In Force	$2,639,539,800
Total Annual Premium	$6,896,847
Claims, 11/1978 to 03/31/2015	505
Value of Claims paid, 11/1978 to 03/31/2015	$6,089,495.32

Repetitive Loss

A repetitive loss property is defined by FEMA as an NFIP-insured property that has experienced any of the following since 1978, regardless of any changes in ownership:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period
- Three or more paid losses that equal or exceed the current value of the insured property.

Repetitive loss properties make up only 1 to 2 percent of flood insurance policies in force nationally, yet they account for 40 percent of the nation's flood insurance claim payments. In 1998, FEMA reported that the NFIP's 75,000 repetitive loss structures have already cost $2.8 billion in flood insurance payments and that numerous other flood-prone structures remain in the floodplain at high risk. The government has instituted programs encouraging communities to identify and mitigate the causes of repetitive losses. A recent report on repetitive losses by the National Wildlife Federation found that 20 percent of these properties are outside any mapped 1 percent annual chance (100-year) floodplain. The key identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by the policies.

FEMA-sponsored programs, such as the Community Rating System (CRS), require participating communities to identify repetitive loss areas. A repetitive loss area is the portion of a floodplain holding structures that FEMA has identified as meeting the definition of repetitive loss. Identifying repetitive loss areas helps to identify structures that are at risk but

are not on FEMA's list of repetitive loss structures because no flood insurance policy was in force at the time of loss. FEMA has identified 36 repetitive loss properties in the planning area as of April 30, 2015. Two of these properties have been mitigated. Of the remaining 34 properties all have been identified as residential structures (single- or multi-family, condos or other residential) and all are located within three of Maui Count's community planning areas:

- Kihei-Makena – 22 properties
- Wailuku-Kahului – 1 property
- West Maui– 11 properties.

Of the identified properties, all were able to be geocoded for spatial analysis. A review of these properties provided the following insights regarding the likely causes of flooding for the recorded loss events:

- The following 22 properties are located within the 1 percent annual chance flood hazard areas:
    - Eight of these properties have average loss claims of less than $10,000 dollars. Such losses are generally associated with localized flood events resulting from urban drainage issues or other smaller scale occurrences such as a water main break.
    - Twelve of the remaining properties experienced flood damage that can be attributed to heavy rain and flash flooding events occurring in early December 2007, late December 2010 and mid-January 2011.
    - One property incurred flood damages on two occasions in the 1990s, but has not filed a claim in almost twenty years. One of the claims was consistent with a recorded flood event.
    - One property incurred damage after two recorded flash flood events in the early 2000s.
- One property is located on the edge of the 1 percent annual chance flood hazard in the 0.2 percent annual flood hazard (500-year floodplain). This property experienced damages corresponding with recorded flood events in December 2010 and January 2011 when many other properties were damaged.
- The following nine properties are located outside of both the 1 and 0.2 percent annual flood chance hazard areas:
    - Three of these properties have average loss claims of less than $10,000 dollars. Such losses are generally associated with localized flood events resulting from urban drainage issues or other smaller scale occurrences such as a water main break.
    - One property is located less than 200 feet and approximately the same elevation from the 1 percent annual chance flood hazard area and experienced losses during two recorded flash flood events.
    - Three properties are located outside of mapped flood hazard areas or streams and have either none or one loss date corresponding with known storm or flood events. Additional outreach should be conducted with the property owners to determine likely causes and to identify mitigation opportunities.
    - One property is located far from any mapped flood hazard areas or streams. Flood loss dates for the property correspond with recorded flash flood event dates that likely resulted in urban drainage issues and/or localized flooding.
    - One property is located adjacent to dry, shrub-covered slopes and has loss dates corresponding with flash flood events.

- Two properties were included on the repetitive loss list, but associated loss dates were not provided. These properties are not located in mapped flood hazard areas. Additional outreach should be conducted with the property owners to determine likely causes and to identify mitigation opportunities.

Repetitive loss properties in Maui County are shown in Figure 11 7 through Figure 11 9

11.4.3 Critical Facilities and Assets

Hazus-MH was used to estimate the flood loss potential to critical facilities exposed to the flood risk. Using depth/damage function curves to estimate the percent of damage to the building and contents of critical facilities, Hazus-MH correlates these estimates into an estimate of functional down-time (the estimated time it will take to restore a facility to 100 percent of its functionality). This helps to gauge how long the planning area could have limited usage of facilities deemed critical to flood response and recovery. The Hazus-MH critical facility results are summarized in Table 11 12.

On average, critical facilities would receive 12 percent damage to the structure and 39 percent damage to the contents during a 1 percent annual chance (100-year) flood event. The estimated time to restore these facilities to 100 percent of their functionality is 488 days

11.4.4 Onshore and Offshore Natural Environment

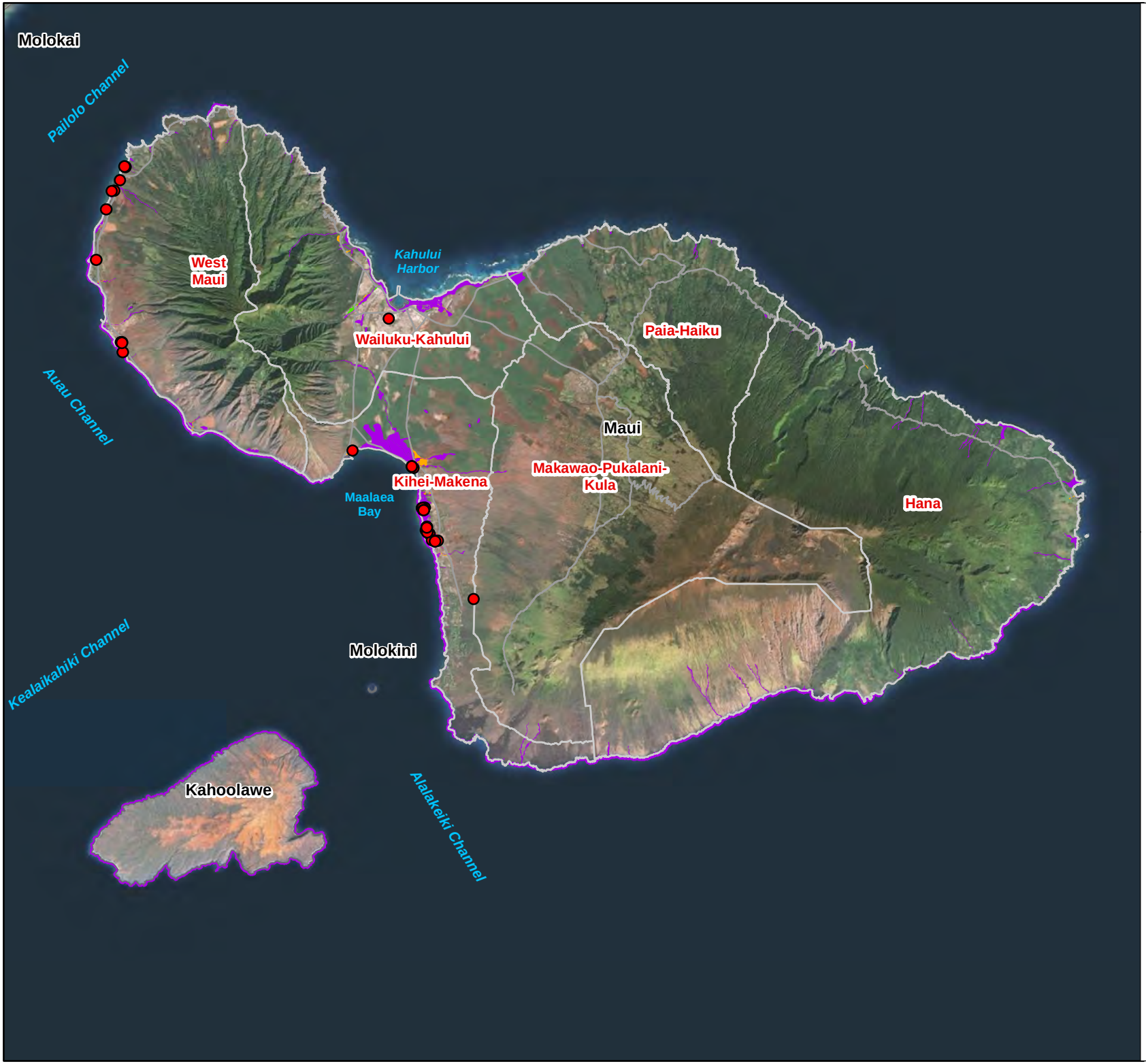
The environment vulnerable to flood hazard is the same as the environment exposed to the hazard. Loss estimation platforms such as Hazus-MH are not currently equipped to measure environmental impacts of flood hazards. The best gauge of vulnerability of the environment would be a review of damage from past flood events. Loss data that segregates damage to the environment was not available at the time of this plan. Capturing this data from future events could be beneficial in measuring the vulnerability of the environment for future updates.

11.4.5 Economic Impact

Economic impact will be largely associated with the location in which flooding occurred. In such areas, commercial buildings may need to be renovated, causing a disruption in associated services. Additionally, agricultural areas may suffer significantly, as crops and other agricultural products are destroyed. The tourism industry may also be impacted by major floods events, as popular vacation areas tend to overlap with flood hazard zones.

Maui County Islands of Maui and Kahoolawe

Repetitive Loss Areas



Legend

- Community Plan Boundaries

Flood Hazard

- 1% Annual Flood Hazard
- 0.2% Annual Flood Hazard
- Areas with Reduced Flood Due to Leevee
- Repetitive Loss Property

Base Map Data Sources:
Maui County, FEMA, ESRI

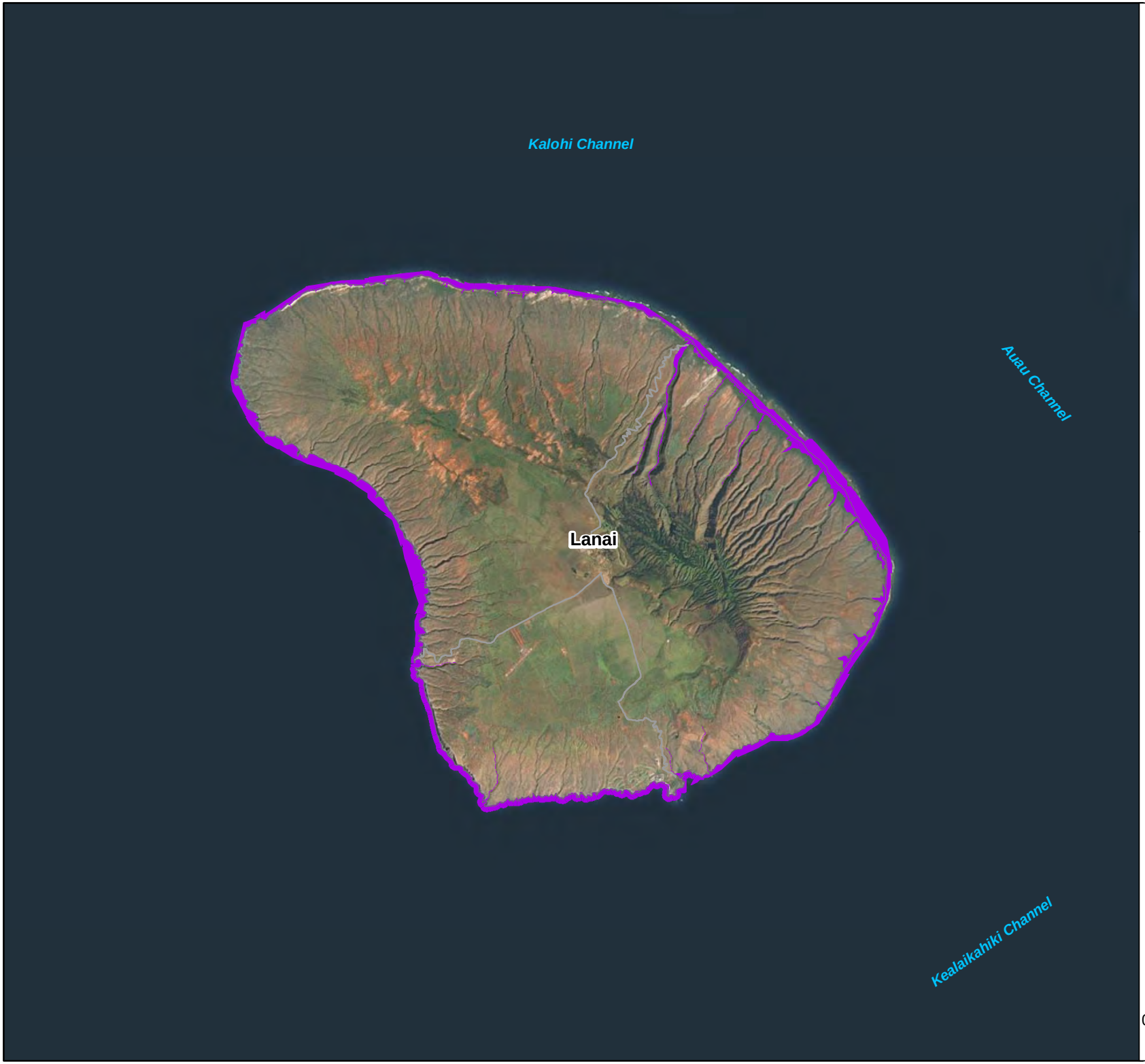
TETRA TECH

N

0 4.25 8.5 Miles

Maui County
Island of Lanai

Repetitive Loss Areas



Legend

Flood Hazard

- 1% Annual Flood Hazard
- 0.2% Annual Flood Hazard
- Areas with Reduced Flood Due to Leevee
- Repetitive Loss Property

Base Map Data Sources:
Maui County, FEMA, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Repetitive Loss Areas

Legend

- Kalawao County

Flood Hazard

- 1% Annual Flood Hazard
- 0.2% Annual Flood Hazard
- Areas with Reduced Flood Due to Leevee
- Repetitive Loss Property

Base Map Data Sources:
Maui County, FEMA, ESRI

TETRA TECH

N

0 3.5 7 Miles

TABLE 11-12.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM 1 PERCENT ANNUAL (100-YEAR) FLOOD

Category[a]	Number of Facilities Impacted	% Damage to Building	% Damage to Content	Days to 100% Functionality
Emergency Services	6	8%	35%	445
Government[b] and Services	3	11%	41%	530
Critical Infrastructure and Lifelines	34	23%	58%	N/A
Other Important Assets	43	5%	22%	N/A
Total/Average	**86**	**12%**	**39%**	**488**

a. Vulnerability not estimated for all facilities due to lack of established damage functions.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

11.5 Future Trends in Development

The planning area has experienced steady upward growth over the past 10 years. Between 2010 and 2030, the resident population is expected to grow by 35 percent to an estimated 194,630 residents on the Island of Maui alone (County of Maui, 2006). Maui County is equipped to handle future growth within flood hazard areas and participates in the NFIP and has adopted a flood damage prevention ordinance in response to its requirements. Maui County has committed to maintaining its good standing under the NFIP through initiatives identified in this plan. Maui County has committed to linking its general policy and community plans to this hazard mitigation plan update. This will create an opportunity for wise land use decisions as future growth impacts flood hazard areas.

11.6 Scenario

The worst-case scenario is a major, rain producing storm during the rainy season that occurs during high tide. This storm has the potential to flood numerous areas in a short time. This could overwhelm the response and floodplain management capability within the planning area, as the planning area would be subject immediately to flash flooding and coastal flooding with later influences on the County's streams. Major roads could be blocked, preventing critical access for many residents and critical functions. High in-channel flows could cause water courses to scour, possibly washing out roads and creating more isolation problems. In the case of multi-basin flooding, Maui County would not be able to make repairs quickly enough to restore critical facilities and assets.

11.7 Issues

The planning team has identified the following flood-related issues relevant to the planning area:

- **Hiker Outreach for Flash Flooding**—Tourists hiking Maui County's numerous trails are not always cognizant of issues associated with flash flooding. As such, the County could develop a tourism outreach program specifically designed to inform hikers about the danger and potential for flash flooding.
- **Climate Change Future Impacts**—Climate change has the potential to drastically alter the severity, location, and extent of flooding within Maui County. The County must remain vigilant and be prepared to address anticipated and new issues as they occur as a direct result of climate change.

- **Levee Renovation**—Older levees are subject to failure or do not meet current building practices for flood protection. The County should discuss and investigate the resources needed to bring these levees up to date and reaccredited.
- **Multi-hazard Mitigation Techniques**—The risk associated with the flood hazard overlaps the risk associated with other hazards such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.
- **Risk Based Analysis**—Collect more information on flood risk to support the concept of risk-based analysis of capital projects.
- **Historical Data Collection**—There needs to be a sustained effort to gather historical damage data, such as high water marks on structures and damage reports, to measure the cost-effectiveness of future mitigation projects.
- **Funding Identification**—Ongoing flood hazard mitigation will require funding from multiple sources.
- **Resident Education**—Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.
- **Residual Risk**—Residual risk associated with the flooding hazard is high due to the topography and nature of flooding in Maui County. The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.
- **Continue Emphasizing the Value of Flood Insurance**—As a flood-prone County, Maui understands the importance and power of educated residents. As a result, Maui should continue the promotion of flood insurance as a means of protecting private property owners from the economic impacts of frequent flood events.
- **Upholding Land-Use Regulations**—Existing floodplain-compatible uses such as agricultural and open space need to be maintained. There is constant pressure to convert these existing uses to more intense uses within the planning area during times of moderate to high growth.
- **Proactive Floodplain Management**—The economy affects a jurisdiction's ability to manage its floodplains. Budget cuts and personnel losses can strain resources needed to support floodplain management. The County should proactively manage current and future floodplains during affluent times to ensure self-sustainment of floodplains during budget cuts and personal losses.
- **Coastal AE Zone Building Standards**—Coastal AE zones have the potential to become affected by wave movement spilling over from the VE zones. Such flooding results in greater stressors for current and future development. Additional building standards should be investigated regarding the effect of LiMWA on Coastal AE properties.
- **Repetitive Loss Properties**—Several repetitive loss properties are located outside of FEMA mapped flood zones. Additional investigation and outreach should be conducted to determine likely sources of flood damage for these properties.

Chapter 12. High Surf

12.1 Hazard Description

The most predictable and frequent coastal hazard in the Hawaiian Islands is sudden high waves combined with strong near shore currents. The greatest number of deaths, injuries and rescues in the archipelago are from high waves breaking at the shoreline. High surf, resulting from dangerous and damaging waves, is typically described as waves ranging in height from 10 feet to 20 feet or more. These waves result from storms passing across the higher latitudes of the Northern and Southern Hemispheres in addition to storms passing across the Central Pacific in proximity to the Islands. These high wave events threaten lives and coastal property and infrastructure (County of Maui, 2010a).

DEFINITIONS

Overwash—the washing of sediment landward from the sea.

Rip Current—a powerful, narrow channel of fast-moving water.

The hazards associated with high surf include debris overwash, flooding, erosion, high wave energy and turbulence in the near shore zone, and strong currents. Waves that reach the shoreline are determined by the energy inherent in the approaching swell (a function of wave height and wave length – the distance between successive wave crests), shoreline aspect, slope, morphology, and geology, and offshore characteristics including seafloor depth, morphology, and barriers (islands, rocks, reefs, sandbars) (County of Maui, 2010a).

When deep-water ocean swells encounter the shallow island margins, they rise to great heights because their tops stack up on their slower moving bottoms due to friction along the shallower seafloor. Because the contact between deep water and the shallow margins around the Hawaiian Islands is abrupt, surface waves can grow very tall, very rapidly. Large waves tend to travel in sets, and after breaking they rush up onto the beach temporarily elevating the sea surface near the shoreline. Rip currents form as the water that is pushed up on the shore by successive large waves tries to flow back to the sea (County of Maui, 2010a).

High waves from hurricanes present a more complex hazard, as they may coincide with high tide, storm surge, and wind and wave setup, to produce a combined threat. High waves from hurricanes generally occur during hurricane season between the months of June and December. High waves from hurricanes most often hit the eastern shores of the Hawaiian Islands as hurricanes approach the islands from the east, south, and west-facing shorelines as the storm passes to the south and west (County of Maui, 2010a). For more information on hurricanes and tropical storms, please refer to Chapter 15.

12.2 Hazard Profile

12.2.1 Past Events

Table 12 1 summarizes high surf events in the planning area since 1968.

TABLE 12-1.
PAST HIGH SURF EVENTS IMPACTING PLANNING AREA

Start Date	End Date	Location	Description	Injuries[a]	Fatalities[a]
12/5/1968	12/6/1968	All Islands	Surf/ High Seas	0	0
12/1/1969	12/4/1969	Maui	Surf	4	1
4/19/1972	4/19/1972	Honolua Bay	Large swell/ gusty winds	0	2
4/30/1972	4/30/1972	Kaiwi Channel	Large wave	0	1
11/26/1972	11/26/1972	Molokai	High Waves	0	1
11/11/1976	11/13/1976	North and Western shores of Islands	High Surf	0	0
2/5/1976	2/7/1976	Kihei/ Maui and Puako	High wind/ high surf/ flood	0	0
1/7/1978	1/7/1978	Maui	High swell and surf	1	1
3/16/1978	3/16/1978	Penguin Banks	High winds and sea	0	1
12/10/1978	12/10/1978	Hawaiian waters	Rough seas	0	3
2/11/1979	2/11/1979	Off East Maui	Rough seas	0	5
3/11/1979	3/11/1979	Molokai/ Maui County	Rough surf	0	2
8/1/1982	8/1/1982	Hawaii and Maui	Rain/Surf/Wind	0	0
8/14/1982	8/16/1982	Statewide	Rain/Surf/Wind	0	0
10/15/1983	10/20/1983	Hawaii All Islands	Wind/ Surf	0	0
1/13/1985	1/15/1985	Maui	Wind/Surf	0	0
3/1/1985	3/11/1985	All Islands	Wind/Surf	0	0
12/21/1985	12/21/1985	All Islands	Surf	0	0
7/1/1985	7/1/1985	All Islands	High Surf	1	0
12/9/1985	12/11/1985	All Islands	Surf	0	0
12/8/1986	12/9/1986	North and west shores of all islands	High surf	0	0
1/9/1987	1/10/1987	All Islands	High Surf	0	0
12/30/1988	12/31/1988	Statewide	Wind and Surf	0	0
3/1/1989	3/4/1989	All Islands	Wind/ Flash Flooding/ Surf	0	0
12/16/2004	12/18/2004	Maui	Heavy Surf/High Surf	0	1
12/20/2004	12/23/2004	Maui	Heavy Surf/High Surf	0	1
12/15/2006	12/21/2006	Maui	High Surf	1	0
10/12/2008	10/14/2008	Maui	High Surf	0	1
12/6/2009	12/10/2009	Maui	High Surf	1	0
3/13/2009	3/15/2009	Maui	High Surf	0	1
3/13/2009	3/15/2009	Maui	High Surf	0	1
1/4/2010	1/14/2010	Maui, Lanai, Molokai	High Surf	1	0
1/16/2010	1/19/2010	Maui, Lanai, Molokai	High Surf	0	0
1/27/2010	1/29/2010	Maui, Molokai	High Surf	0	0
3/1/2010	3/3/2010	Maui, Molokai	High Surf	0	0
11/2/2010	11/5/2010	Maui, Molokai	High Surf	0	0
1/15/2011	1/17/2011	Maui, Molokai	High Surf	0	0
1/19/2011	1/26/2011	Statewide	High Surf	0	0
2/1/2011	2/2/2011	Maui, Molokai	High Surf	0	0
3/14/2011	3/16/2011	Maui, Molokai	High Surf	0	0
1/1/2012	1/6/2011	Maui, Molokai	High Surf	0	0

TABLE 12-1.
PAST HIGH SURF EVENTS IMPACTING PLANNING AREA

Start Date	End Date	Location	Description	Injuries[a]	Fatalities[a]
11/4/2012	11/7/2012	Maui, Molokai	High Surf	0	0
12/24/2012	12/26/2012	Maui, Molokai	High Surf	0	0
12/27/2012	12/31/2012	Maui, Molokai	High Surf	0	0
1/1/2013	1/3/2013	Maui, Molokai	High Surf	0	0
1/17/2013	1/22/2013	Maui, Molokai, Lanai	High Surf	0	0
2/1/2013	2/2/2013	Maui, Molokai	High Surf	0	0
11/13/2013	11/15/2013	Maui, Molokai	High Surf	0	0
12/19/2013	12/22/2013	Statewide	High Surf	0	0
12/24/2013	12/31/2013	Maui, Molokai	High Surf	0	0
1/16/2014	1/28/2014	Maui, Molokai	High Surf	0	0
3/1/2014	3/6/2014	Maui, Molokai	High Surf	0	0
3/7/2014	3/9/2014	Maui, Molokai	High Surf	0	0
Total				**9**	**22**

a. Counts of injuries and fatalities are for the entire event and are not specified by county; some of the counts shown may include injuries and fatalities in other counties.

Source: SHELDUS; NCDC

12.2.2 Location

Island of Maui

Waves from the north Pacific swells 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 et al., 2002). According to Fletcher in "Atlas of Natural Hazards in the Hawaiian Coastal Zone," north Pacific swells generate wave heights reaching 15 to 20 feet in the island's north and northwestern shores and, in rare occasions, up to 30 to 40 feet. North Pacific swell-induced wave heights typically range between 5 and 10 feet in the vicinity of Kaanapali in the northwest coast of the island and between 10 to 20 feet near Honolua Bay also in northwest Maui (Fletcher et al., 2002). North Pacific swell-induced waves can also reach heights of 10 to 20 feet along Maui's north shore between Waihee and Paia (County of Maui, 2010a).

Fortunately for the Island of Maui, much of its northern and western coastlines (where deep ocean swell waves tend to be the highest) have wide-fringing reefs that dissipate wave energy offshore. However, areas of touristic and commercial importance such as Lahaina, Kaanapali, Honokowai, Olowalu, Kihei, and Kahului are located on low coastal plains. As Fletcher indicates, these locations therefore experience wave overwash, which causes rapid erosion and temporarily disrupts transportation along the coastal Honoapiilani Highway (State Route 30) (Fletcher et al., 2002; County of Maui, 2010a).

According to Fletcher et al. (2002), trade wind swell-induced high waves, typically between 3 and 4 feet high, affect the eastern facing shores of the island. Conversely, Kona storms generated high waves that affect the south-facing coast of the island. However, the island's south-facing shores are somewhat protected by the Islands of Kahoolawe and Lanai located immediately to the south and southwest, respectively. Even with this protection, waves induced by Kona storms

can reach heights of up to 5 feet in the southern coast of the Island of Maui (Fletcher et al., 2002; County of Maui, 2010a).

Even though deep ocean swells typically produce the highest waves affecting the Island of Maui, much of the high waves and surf on the island is attributable to passing tropical cyclones. For example, wave heights ranging between 10 and 15 feet reached the north and east shores of the Island of Maui as Hurricanes Susan, Ignacio, and Estelle traveled through Hawaiian waters (Fletcher et al., 2002; County of Maui, 2010a).

Islands of Molokai and Lanai

In *Atlas of Natural Hazards in the Hawaiian Coastal Zone*, Fletcher describes that high waves ranging from 15 to 20 feet produced by north Pacific swells affect the entire northern coast of the Island of Molokai. Fletcher mentions that east of the Kalaupapa peninsula, steep sea cliffs dominate the island's north shore. Therefore, high waves from north swells do not have much of an impact to property and human life in this portion of the north shore. On the contrary, as Fletcher points out, high waves from north Pacific swells are a greater threat to the more accessible and frequented areas along the north facing shores west of the Kalaupapa Peninsula (between Ilio Point and the town of Moomomi). According to Fletcher, high waves from trade wind typically range from 3 to 5 feet along the Island of Molokai's eastern shores. North Pacific and trade wind swells do not typically pose a significant threat to the north shores of the Island of Lanai because it is sheltered to the north by the Island of Molokai (County of Maui, 2010a).

Similarly to trade wind swell generated high waves, Fletcher mentions that Kona storm generated high waves can reach heights of 3 to 6 feet along the Island of Lanai south facing shores. In particular, the low laying areas between Kiei and Kaunolu Bays and between Hulopoe and Manele Bays are at a higher risk from high waves generated by Kona storms. In the case of the Island of Molokai, Kona storm generated high waves do not have a significant impact along the island's south shores because the waves are dampened by the presence of the Island of Lanai to the south (Fletcher et al., 2002; County of Maui, 2010a).

FEMA Coastal Mapping

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) zones give probabilities of coastal flooding in zones that may be impacted by episodes of high surf as shown in Table 12 2. Although the coastal flood zones were not developed exclusively to address the impacts of high surf, they do provide an approximate delineation of areas that may be at risk. The coastal zones in Maui also include tsunami inundation risk in some areas, so these zones are likely to greatly overestimate the risk from high surf impacts alone.

TABLE 12-2.
FEMA FIRM COASTAL FLOOD ZONE CLASSIFICATIONS

Zone	Description
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE, V1-30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

12.2.3 Frequency

High surf events occur quite frequently on all coasts of all islands in the County of Maui. Nonetheless, events that actually cause damage to property or loss of human life are far less common. According to the record of past events, injuries from high surf occur approximately every 5 years, while fatalities occur once every 2 years on average.

12.2.4 Severity

The highest hazard occurs in most cases for north-facing shorelines where north Pacific swells arrive in the winter with regularity in heights exceeding 12 feet (often exceeding 20 feet). Sets of these large waves are characterized by rapid onset so that within a few seconds they can double in size, often catching unaware swimmers, fishermen, and hikers walking along the shoreline. The water level on the coast increases with these large waves and rip currents are generated as this excess water surges seaward (County of Maui, 2010a).

The wave zone of impact coincides to some extent with FEMA's V and VE FIRM zones. These zones, which are established by the National Flood Insurance Program (NFIP), are subject to flooding and high velocity wave action (although some action identified is from tsunami events). The inland extent of the wave impact zone is expected to be much greater than the erosion zone. For residences displaced by the threat of high surf, shelters may be opened in or nearby the affected areas (County of Maui, 2010a).

12.2.5 Warning Time

The timing of individual waves cannot be predicted, however general forecasting can be made about surf conditions. Wave forecasting involves the prediction and evolution of wind-generated waves using numerical models. These mathematical simulations, often known as ocean surface wave models, consider atmospheric and oceanic conditions, wave interaction, and frictional dissipation. The models output typically consists of statistics regarding wave heights and periods that can be used by officials and managers in the shipping industry, emergency response personnel, news media, and the public (County of Maui, 2010a).

The National Weather Service issues high surf warnings and advisories when general forecasting indicates high surf conditions. The definitions of the warning and advisory is found below (NWS, 2014):

- **High Surf Warning**—A High Surf Warning is issued when waves reach threshold criteria for a particular island and shoreline. High Surf Warnings may be issued up to 24 hours ahead of the arrival of the swell and may remain in effect for several days.
- **High Surf Advisory**—A High Surf Advisory is issued when waves reach threshold criteria for a particular island and shoreline. High Surf Advisories may be issued up to 24 hours ahead of the arrival of the swell and may remain in effect for several days.

12.2.6 Potential Impacts of Climate Change

Changes in global temperatures, hydrologic cycles, coverage of glaciers and ice sheets, and storm frequency and intensity are captured in long-term sea level records. Sea levels provide a key to understanding the impact of climate change (NOAA, 2013). Sea level rise increases the risks coastal communities face from coastal hazards (floods, storm surges, and chronic erosion).

Specifically, sea level rise, coupled with overall global warming and other climate change impacts can lead to more frequent high surf events. It may also lead to surf levels increasing to such an extent that high surf levels of 10 to 20 feet become normal surf levels. This change can create several secondary, negative impacts and vulnerabilities, including:

- Loss of important coastal habitats
- Increased beach and coastal erosion
- Increased life safety and property risks
- More frequent coastal flood events and greater damage from all coastal flood-related hazards.

According to briefing prepared by the University of Hawaii Sea Grant program, the historical rate of sea level rise on Maui is about 9 inches over the past century. Although the global average sea level rose 7 inches during the 20th century, satellite observations data has shown the sea level rising at a rate of 12 inches per century since 1993. Coastal tide gage measurements confirm this record, and also show that sea levels do not rise uniformly around the world. Global sea level rise is projected to accelerate during the 21st century, however accelerated sea level rise has not yet been detected in the Hawaii tide gage records (Owens, 2013).

12.2.7 Secondary Hazards

Hazards associated with high waves include debris overwash, flooding, erosion, high wave energy and turbulence in the nearshore zone, and strong currents.

12.3 Exposure

Although the coastal flood zones were not developed exclusively to address the impacts of high surf, they do provide an approximate delineation of areas that may be at risk. The coastal zones in Maui also include tsunami inundation risk in some areas, so these zones are likely to greatly overestimate the risk from high surf impacts alone. FEMA mapped V and VE zones thus form the basis of the high surf hazard risk and vulnerability assessment. It is important to note that these coastal zones are also included in the exposure and vulnerability assessment for the flood hazard in Chapter 11

12.3.1 Population

The population at greatest risk for exposure to the high surf hazard is individuals along the affected beachfront areas. Surfers are potentially most at risk, as they will pursue their sporting activity during times when surf conditions are high. Results of the Hazus evaluation of population exposure are summarized in Table 12 3

12.3.2 Property

Structures in FEMA Coastal Zones

Property immediately exposed to high surf events include structures located near shorelines. Table 12 4 summarizes the estimated value of exposed buildings in the planning area. This methodology estimated $1.7 billion worth of building-and-contents exposure in FEMA coastal zones, representing 3.8 percent of the total replacement value of the planning area.

TABLE 12-3.
ESTIMATED POPULATION EXPOSURE FOR FEMA COASTAL ZONES

Community Planning Area	Residents	Visitors	Total
Hana	73	0	73
Kihei-Makena	96	1,275	1,371
Lanai	12	0	12
Makawao-Pukalani-Kula	0	0	0
Molokai	36	0	36
Paia-Haiku	60	0	60
Wailuku-Kahului	757	481	1,238
West Maui	512	1,563	2,075
Total	**1,547**	**3,319**	**4,866**

TABLE 12-4.
EXPOSURE AND VALUE OF STRUCTURES IN THE FEMA COASTAL ZONES

	Buildings Exposed	Value Exposed			% of Total Replacement Value
		Structure	Contents	Total	
Hana	35	$7,965,748	$4,282,626	$12,248,375	2.78%
Kihei-Makena	26	$82,679,416	$43,304,167	$125,983,584	1.34%
Lanai	5	$898,736	$449,368	$1,348,104	0.13%
Makawao-Pukalani-Kula	0	$0	$0	$0	0.00%
Molokai	15	$2,748,432	$1,571,270	$4,319,701	0.30%
Paia-Haiku	23	$6,193,875	$3,496,155	$9,690,031	0.43%
Wailuku-Kahului	211	$206,636,076	$152,551,289	$359,187,365	2.18%
West Maui	125	$806,207,668	$407,837,697	$1,214,045,365	12.16%
Total	**440**	**$1,113,329,951**	**$613,492,573**	**$1,726,822,524**	**3.78%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

Land Use in the Floodplain

Some land uses are more vulnerable to high surf, such as single-family homes, while others are less vulnerable, such as agricultural land or recreation areas. Table 12 5 shows the existing land use of all parcels in the FEMA coastal zones broken down by community planning area.

12.3.3 Critical Facilities and Assets

Critical facilities and assets located just beyond the coastal dune area may be exposed if previous high surf or storm evens destroyed the beach buffer. Table 12 6 summarizes the critical facilities and assets in the coastal flood zones of the planning area.

TABLE 12-5.
LAND USE WITHIN FEMA COSTAL ZONES

Land Use	V and VE Zones Area (acres)	% of total
Agricultural	1,513.19	34.2%
Apartment	15.70	0.4%
Commercial	185.54	4.2%
Commercialized Residential	1.54	0.0%
Conservation	1,403.54	31.8%
Hotel/Resort	99.54	2.3%
Industrial	108.31	2.5%
Residential	904.33	20.5%
Time Share	3.19	0.1%
Not Classified	183.47	4.2%
Total	**4,418.35**	**100.0%**

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified." Acreage includes only areas intersecting mapped hazard layers.

In addition to facilities that may be exposed to high surf, coastal transportation routes may be exposed. These routes are often located in areas in which coastal erosion has gradually worn away the beach buffer, causing the potential for roadway inundation during high surf events.

12.3.4 Onshore and Offshore Natural Environment

All beaches are vulnerable to the effects of high surf events. In 2014, a study published in the Nature Communications journal indicated that coral reef plays an extremely large role in the dissipation of wave energy that affects high surf on beach areas. This study indicated that wave energy is reduced by an average of 97 percent, with reef crests alone dissipating most of the energy. This study further explores and asserts that natural reef formations can provide comparable wave attenuation benefits to those provided by artificial means, such as breakwaters (Ferrario et al., 2014).

12.4 Vulnerability

12.4.1 Population

The population most vulnerable to high surf events and strong currents are beach goers, swimmers, fisherman, and hikers along the shoreline. A particular population vulnerable to the high surf hazard is surfers. High surf indicates larger waves, which many amateur and professional surfers actively seek. As a result, warnings and advisories may cause an opposite, anticipated effect for these populations. This effect requires beach patrol and first responders to remain on alert during days when surfers may ignore warnings and advisories in an effort to catch large waves.

12.4.2 Property

Loss estimations for the high surf hazard are not based on modeling utilizing damage functions, because the available modeling includes impacts from other hazards such as hurricanes and tsunami, not exclusively high surf. Instead, loss estimates were developed representing 1 percent, 10 percent, 30 percent and 50 percent of the replacement value of

exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 12-6 shows the general building stock loss estimates in FEMA mapped coastal zones.

12.4.3 Critical Facilities and Assets

The areas important for tourism and commerce between Lahaina and Napili, and along the Kihei and Kahului coasts are situated on low coastal plains, and so experience periodic wave overwash, which causes rapid erosion and temporarily disrupts transportation (USGS, n.d.).

TABLE 12-6.
CRITICAL FACILITIES AND ASSETS IN COASTAL ZONES

Facility Type	Number in Coastal Flood Zones
Emergency Services	
Emergency Operations	0
Police & Fire	1
Community Shelter[a]	0
Medical & Health	0
Government and Services	
Government[b]	-
Schools[a]	1
Critical Infrastructure and Lifelines	
Transportation	8
Water Supply	0
Wastewater	13
Dams	0
Energy	1
Telecommunications	0
Hazardous Materials	1
Other Important Assets	
Financial	3
Tourist Lodging	17
Early Assistance	0
Total	45

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.
Data sources: See Table 5-1

12.4.4 Onshore and Offshore Natural Environment

Secondary hazards associated with high surf events will likely have some of the most damaging effects on the environment. A combination of wave height and a long duration of swells impacting the shoreline can increase shore

erosion, damage homes and infrastructure, as well as blocking coastal highways with sand, debris, and water (Meiers, 2014).

12.4.5 Economic Impact

The County of Maui may experience temporary economic impacts associated with disrupted transportation infrastructure along coastal areas. Long-term economic impacts are not expected as a result of this hazard.

TABLE 12-7.
LOSS POTENTIAL FOR COASTAL FLOOD ZONES

Community Planning Area	Exposed Value	Estimated Loss Potential from High Surf			
		1% Damage	10% Damage	30% Damage	50% Damage
Hana	$12,248,375	$122,484	$1,224,838	$3,674,513	$6,124,188
Kihei-Makena	$125,983,584	$1,259,836	$12,598,358	$37,795,075	$62,991,792
Lanai	$1,348,104	$13,481	$134,810	$404,431	$674,052
Makawao-Pukalani-Kula	$0	$0	$0	$0	$0
Molokai	$4,319,701	$43,197	$431,970	$1,295,910	$2,159,851
Paia-Haiku	$9,690,031	$96,900	$969,003	$2,907,009	$4,845,016
Wailuku-Kahului	$359,187,365	$3,591,874	$35,918,737	$107,756,210	$179,593,683
West Maui	$1,214,045,365	$12,140,454	$121,404,537	$364,213,610	$607,022,683
Total	**$1,726,822,524**	**$17,268,225**	**$172,682,252**	**$518,046,757**	**$863,411,262**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

12.5 Future Trends in Development

Development in Maui County is guided by Maui County code and the documents that make up the General Plan. This guidance includes requirements pertaining to development in coastal hazard areas, which would include areas that are susceptible to high surf.

12.6 Scenario

The worst case scenario would be high wave events from hurricanes coinciding with high tide, storm surge, wind and wave setup, producing a combined threat. During a scenario of this magnitude, individuals and properties alike are potentially impacted by high surf.

12.7 Issues

- **High Surf Public Information**—Those most prone to high surf are individuals that choose to be in areas that are impacted by high surf, whether for recreation or because they are unfamiliar with their surroundings. Develop pamphlets and other messaging about the dangers of high surf. Distribute in hotels, tourists venues, and high schools.

- **Future Development Impact Studies**—High surf events are particularly destructive when natural processes are unable to replenish beaches due to development, causing high surf to impact infrastructure. Ensure that future development does not contribute to coastal erosion, and subsequently, harmful high surf events.
- **SLOSH Data—**An updated sea, lake, and overland surges from hurricane (SLOSH) dataset is currently being developed by NOAA. This data should be incorporated into future plan updates.

Chapter 13. High Wind Storm

13.1 Hazard Description

Wind is one of the most costly hazards to insured property, causing more damage than earthquakes or other natural hazards. Wind is defined as the horizontal component of natural air moving close to the surface of the earth. Wind speeds vary with height above ground – the higher the elevation, the stronger the wind. Internal and external pressures on structures generated by wind, as well as windborne debris, can cause damage to property (County of Maui, 2010a).

DEFINITIONS

Wind—The horizontal component of natural air moving close to the surface of the earth

Windstorm—A storm featuring violent winds.

There are many ways to measure the speed at which air is moving, or wind speed. Descriptions of the most commonly used methodologies for measuring wind speed are as follows (County of Maui, 2010a):

- **The Fastest Mile Wind speed** is the highest recorded speed during a time interval in which one mile of wind passes a fixed measuring point. The measurement is taken at an elevation of 33 feet in open terrain. The Fastest Mile Wind speed measurement has been historically used in many building codes and design standards such as the Uniform Building Code (all editions) and the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (until the 1993 edition).
- **Sustained Wind** is the wind speed averaged over 1 minute.
- **Peak Gusts** are the maximum wind gust speeds averaged over a period of 2 to 5 seconds.

The average wind speed at 50 meters (164 feet) above mean sea level for the County of Maui is shown on Figure 13-1.

It is important to understand that it is wind pressure, and not wind speed, that causes wind damage. There are three types of wind pressure: positive, negative, and internal (County of Maui, 2010a).

- **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 sheltered from wind) side of a building.
- **Interior pressure** increases dramatically when a building loses a door or window on its windward side. The roof is placed under tremendous internal pressures pushing up from inside of the building together with the negative wind pressure lifting the roof from the outside.

Besides the high wind pressures exerted on structures during wind storms, and especially during hurricanes, windborne debris can be a major factor in causing damage. Such debris includes flying objects, such as tree limbs, outdoor furniture, signs, roofs, gravel, and loose building components.

Source: Hawaiian Electric Company, 2014

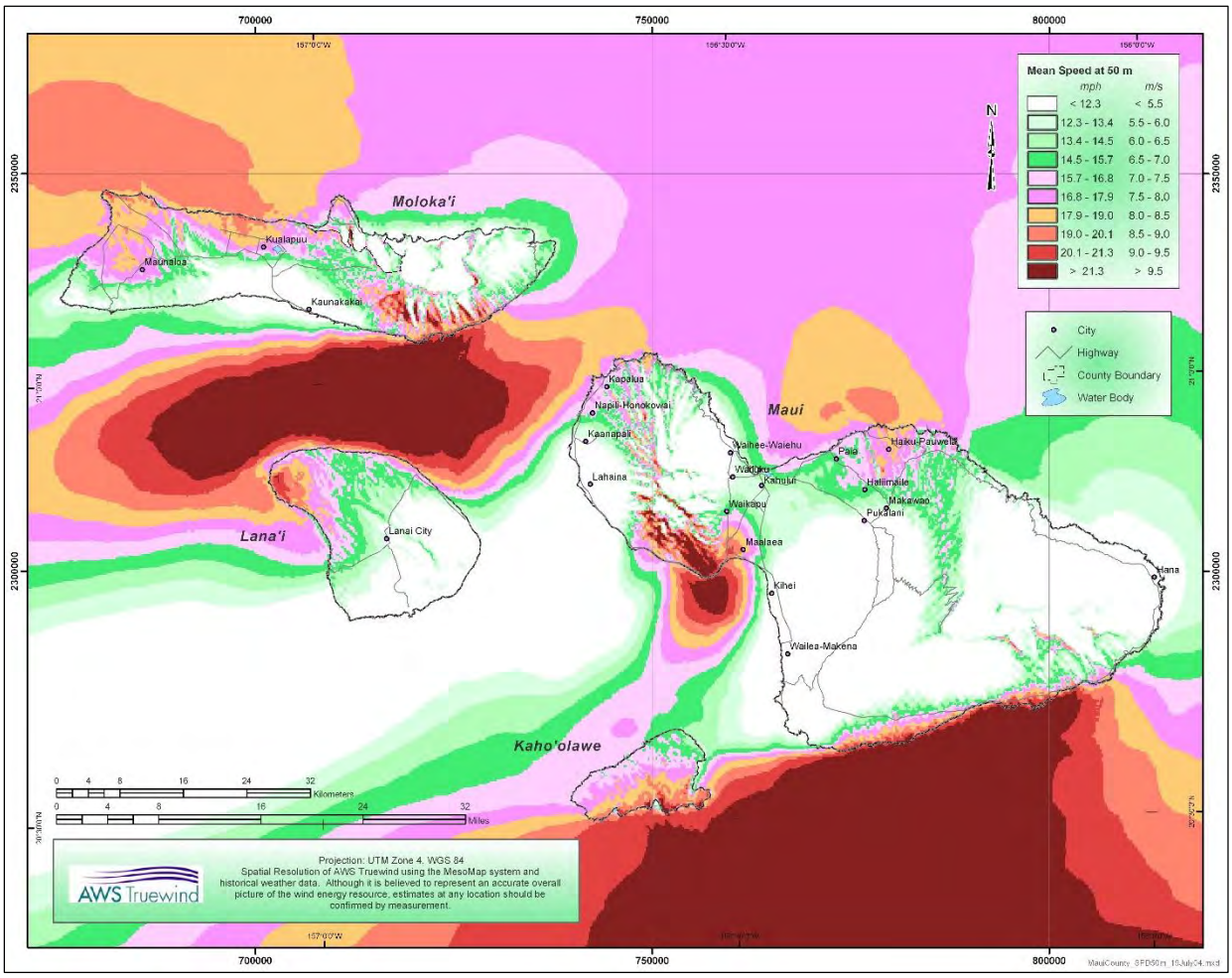


FIGURE 13-1. AVERAGE WIND SPEED AT 50 METERS ELEVATION

13.1.1 Types of Winds

High trade winds, Kona winds, hurricane winds, and tropical storm winds all affect the County of Maui (County of Maui, 2010a). Trade and Kona winds are discussed in more detail below. For more information on high winds, please see Chapter 15 Tropical Cyclones.

Trade Winds

Trade winds are the most common winds over Hawaiian waters. These persistent winds blow 70 percent of the time from a northeast to east-northeast direction and generally range from 10 to 25 miles per hour. Occasional extreme events reach 40 to 50 miles per hour when the sub-tropical high-pressure cell north of the islands intensifies. Trade winds occur up to 90 percent of the time in summer (June through August) and 50 percent of the time in winter (December through January) (County of Maui, 2010a).

On the Island of Maui, trade winds appear to be stronger when passing through the isthmus between the West Maui Mountains and Haleakala. Wind speeds may be higher at locations such as Maalaea and north Kihei than along the

island's north shore. This increase in wind speed is the result of wind funneling, which occurs when wind passes between two mountains or into a valley (County of Maui, 2010a).

Strong, gusty trade winds can cause problems for mariners when they funnel through the major channels between the islands at speeds 5 to 20 knots faster than over the open ocean. North Pacific high-pressure systems can cause gusty trade wind episodes over Hawaiian waters, which commonly persist for several days (County of Maui, 2010a).

Kona Winds

Kona is a Hawaiian term for the rain-bearing winds that blow over the islands from the southwest or south-southwest. The western sides of the islands become windward during Kona winds, as the trade wind pattern is reversed. Kona winds occur as light and variable winds during winter when trade wind circulation diminishes, and as strong generally southerly winds when storm systems move across Hawaiian waters. Strong Kona winds are most likely when a system with an unusually low central pressure is located within 500 miles northwest of the islands. Kona storms move erratically with a slow tendency toward the west (County of Maui, 2010a).

Damaging Kona winds have reached velocities of 50 miles per hour for several days. Though most strong Kona wind episodes last no more than 1 day, occasionally these storms last up to 2 weeks. During this time, considerable damage can be inflicted to boats caught in the open ocean or anchored in southwest-exposed anchorages (County of Maui, 2010a).

The effects of Kona winds on land can also be severe. Winds can accelerate down the slopes of Maui's mountains, hills, and escarpments to over 100 miles per hour. Winds with these speeds can be very destructive when they reach heavily populated low-lying areas. It is common for trees to be uprooted, for signs and utility poles to be overturned, and for residential roofs to be blown off (County of Maui, 2010a).

13.2 Hazard Profile

13.2.1 Past Events

Table 13-1 summarizes high wind storm events in the planning area since 1970, as recorded by the National Oceanic and Atmospheric Administration (NOAA). According to this data, there have been 3 recorded fatalities, 5 injuries and more than $2.5 million in property damage attributable to high wind events in Maui County since 1970.

13.2.2 Location

High wind storms have the potential to happen anywhere in the planning area. However, 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 (County of Maui, 2010a).

13.2.3 Frequency

The high wind storm events for the planning area shown in Table 13-1 are often related to high winds associated with severe storms and thunderstorms. The planning area can expect to experience exposure to a high wind storm at least annually, with the most violent of storms taking place during the winter months.

TABLE 13-1.
PAST HIGH WIND STORM EVENTS IMPACTING PLANNING AREA

Start Date	End Date	Description	Property Damage	Injuries	Fatalities
12/25/1970	12/29/1970	High winds	$0	0	0
1/5/1971	1/5/1971	Wind	$5,752.02	0	0
4/19/1972	4/19/1972	Large swell and gusty winds	$0	0	2
2/8/1973	2/8/1973	Dust devil	$262.34	4	0
12/30/1973	12/30/1973	High winds and rough seas	$26,233.90	0	0
11/23/1975	11/27/1975	High seas/ high winds/ heavy rain	$5,412.57	0	0
2/5/1976	2/7/1976	High wind/ high surf/ flood	$51,176.85	0	0
3/16/1978	3/16/1978	High winds and sea	$17,864.80	0	1
7/2/1979	7/2/1979	High winds	$160.44	0	0
1/8/1980	1/10/1980	High winds	$0	0	0
2/11/1981	2/11/1981	Wind	$25,627.83	0	0
12/25/1981	12/26/1981	Heavy rain and wind	$256,278	0	0
8/3/1981	8/4/1981	Heavy rain and wind	$2,563	0	0
2/11/1982	2/11/1982	Rain/hail/wind	$402,345	0	0
7/21/1982	7/22/1982	Rain and wind	$603,516	0	0
8/1/1982	8/1/1982	Rain/Surf/Wind	$60,352	0	0
8/14/1982	8/16/1982	Rain/Surf/Wind	$24,141	0	0
12/18/1982	12/19/1982	Wind	$24,141	0	0
12/23/1982	12/24/1982	Wind	$24,141	0	0
12/24/1983	12/26/1983	Wind and heavy rain	$23,389	0	0
3/10/1983	3/10/1983	Dust devil	$1,169	0	0
10/15/1983	10/20/1983	Wind and surf	$2,339	0	0
12/24/1983	12/26/1983	Strong winds with 50 mph gusts	$0	0	0
12/24/1984	12/25/1984	Wind and flood	$22,421	0	0
1/13/1985	1/15/1985	Wind and surf	$216,503	0	0
3/1/1985	3/11/1985	Wind and surf	$21,650	0	0
11/30/1985	11/30/1985	Wind	$21,650	0	0
12/30/1988	12/31/1988	Wind and surf	$1,969	0	0
11/4/1988	11/5/1988	Wind/ flood/ lightning	$196,921	0	0
12/5/1988	12/6/1988	Flash flooding/ wind/ lightning	$32,820	0	0
3/1/1989	3/4/1989	Wind/ flash flooding/ surf	$187,869	0	0
12/9/1989	12/11/1989	Flash flooding and wind	$18,787	0	0
1/27/1991	1/27/1991	Wind and flooding	$171,040	0	0

TABLE 13-1.
PAST HIGH WIND STORM EVENTS IMPACTING PLANNING AREA

Start Date	End Date	Description	Property Damage	Injuries	Fatalities
12/4/1993	12/6/1993	Strong trade winds	$0	0	0
3/14/1994	3/17/1994	Winds	$15,719	0	0
12/23/1996	12/25/1996	Southwest winds 40 mph	$0	0	0
1/25/1997	1/28/1997	Southwest winds	$0	0	0
2/25/1997	2/27/1997	High winds	$0	0	0
1/5/1998	1/8/1998	Westerly winds of 40 to 60 mph	$0	0	0
1/29/1998	1/29/1998	High winds of 50 to 60 mph	$0	0	0
4/3/1998	4/4/1998	High winds of 40 to 60 mph	$0	0	0
4/9/1998	4/11/1998	High winds up to 50 mph	$0	0	0
4/13/1998	4/13/1998	High winds up to 40 to 60 mph	$0	0	0
11/30/1998	11/30/1998	High winds of 50 to 60 mph	$0	0	0
1/15/1999	1/15/1999	High winds	$0	0	0
2/3/1999	2/4/1999	High winds	$0	0	0
3/20/1999	3/21/1999	Wind gusts up to 55 mph	$0	0	0
7/26/1999	7/26/1999	Winds with gusts over 70 mph	$0	0	0
8/31/1999	8/31/1999	Winds with gusts between 35 and 55 mph	$0	0	0
11/28/1999	11/29/1999	Trade winds of 30 to 45 mph	$0	0	0
3/22/2000	3/23/2000	Winds with gusts up to 45 mph	$0	0	0
4/1/2000	4/5/2000	Winds gusts up to 60 mph	$0	0	0
11/17/2000	11/17/2000	Wind of 30 to 40 mph with gusts up to 50 mph	$0	0	0
1/14/2001	1/14/2001	Wind of 35 to 40 mph with gusts up to 50 mph	$0	0	0
4/12/2001	4/12/2001	Wind up to 30 mph with gusts up to 43 mph	$0	0	0
8/31/2001	8/31/2001	Wind up to 35 mph with gusts up to 51 mph	$0	0	0
12/2/2001	12/3/2001	Wind up to 40 mph with gusts up to 50 mph	$0	0	0
12/11/2001	12/14/2001	Wind up to 40 mph with gusts up to 55 mph	$0	0	0
1/17/2002	1/20/2002	Wind up to 40 mph with gusts up to 50 mph	$0	0	0
1/29/2002	1/30/2002	Wind up to 40 mph with gusts up to 45 mph	$0	0	0
2/26/2002	2/27/2002	Wind up to 40 mph with gusts up to 44 mph	$0	0	0
3/17/2002	3/18/2002	Wind up to 40 mph with gusts up to 50 mph	$0	0	0
4/1/2002	4/2/2002	Wind	$0	1	0
1/4/2003	1/4/2003	High winds	$0	0	0
1/14/2003	1/13/2003	High winds with gusts up to 70 mph	$0	0	0
1/19/2003	1/19/2003	Wind up to 60 mph with gusts up to 70 mph	$0	0	0

TABLE 13-1.
PAST HIGH WIND STORM EVENTS IMPACTING PLANNING AREA

Start Date	End Date	Description	Property Damage	Injuries	Fatalities
12/21/2003	12/21/2003	Wind up to 45 mph with gusts up to 50 mph	$0	0	0
12/29/2004	12/29/2004	Wind up to 60 mph with gusts up to 90 mph	$0	0	0
1/12/2004	1/12/2004	High winds with gusts up to 70 mph	$0	0	0
1/14/2004	1/14/2004	High winds	$0	0	0
2/27/2004	2/27/2004	Thunderstorm winds with gusts up to 58 mph	$0	0	0
3/11/2004	3/11/2004	Strong winds with gusts up to 53 mph	$0	0	0
12/2/2004	12/2/2004	High winds with gusts up to 70 mph	$0	0	0
12/6/2004	12/6/2004	High winds with gusts up to 60 mph	$0	0	0
1/10/2005	1/10/2005	High winds in excess of 45 mph	$0	0	0
3/10/2005	3/10/2005	Gusty winds	$0	0	0
3/12/2005	3/15/2005	Wind up to 50 mph with gusts up to 70 mph	$0	0	0
12/18/2005	12/18/2005	High winds with gusts up to 57 mph	$0	0	0
2/18/2007	2/18/2007	Trade winds with gusts up to 57 mph	$0	0	0
12/4/2007	12/4/2007	High winds with gusts up to 57 mph	$0	0	0
3/9/2012	3/9/2012	Thunderstorm wind	$25,366	0	0
5/31/2012	5/31/2012	Dust Devil	$20,293	0	0
7/31/2013	7/31/2013	Strong wind	$5,000	0	0
2/18/2013	2/18/2013	Strong wind	$5,000	0	0
		Total	**$2,519,871**	**5**	**3**

Source: Maui County, 2010a; SHELDUS; NCDC, 2015b

Notes: $0 in property damage represents, zero or unknown damage. There may be gaps in available data as no events were reported between 2008 and 2011. Injuries or fatalities may have been occurred that were not recorded in available datasets.

13.2.4 Severity

Windstorms can be a frequent problem in the planning area and have been known to cause damage to utilities. According to 100 years of hurricane history data collected by FEMA, Maui County is located in Wind Zone II with speeds up to 160 miles per hour. The County is also located within the hurricane-susceptible region (FEMA, 2010). For more information on hurricane force winds, please see Chapter 13.

13.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher

The National Weather Service Forecast Office in Honolulu issues specific watches, warnings, and advisories when weather threatens the state. For high wind hazards, the following may be issued:

- **High Wind Watch**—A High Wind Watch is issued when sustained winds exceeding 40 mph and/or frequent gusts over 60 mph are likely to develop in the next 24 to 48 hours. For summit areas, high wind watches are issued when sustained winds are expected to exceed 56 mph and/or frequently gust over 66 mph. If you are in an area for which a High Wind Watch has been issued you should prepare secure loose objects outdoors that may blow about and avoid outdoor activity that exposes you to high winds.
- **High Wind Warning**—A High Wind Warning is issued when sustained winds exceeding 40 mph and/or frequent gusts over 60 mph are occurring or imminent. For summit areas, warnings are issued for winds exceeding 56 mph and/or frequently gusting over 66 mph. Wind warnings may be issued up to 24 hours ahead of the onset of high winds. If you are in an area where a high wind warning is in effect you should avoid activities that expose you to high winds. Loose objects may be blown around. Tree limbs may break and fall. Power lines may be blown down.
- **Wind Advisory**—A Wind Advisory is issued when sustained winds of 30 to 39 mph and/or frequent gusts to 50 mph or greater are occurring or imminent. For summit areas the sustained wind range is 45 to 55 mph and/or frequent gusts of 55 to 65 mph. Wind advisories may be in effect for 6 to 12 hours. If you are in an area where a wind advisory is in effect you should secure loose objects that may be blown about outdoors and limit activity that may expose you to high winds.
- **Small Craft Advisory**—A Small Craft Advisory is issued for the coastal waters when winds of 25-33 knots and seas 10 feet or higher are occurring or forecast.
- **Gale Warning**—A Gale Warning is issued for coastal, offshore, and high seas areas when winds of 34- to 47 knots not associated with a tropical cyclone are occurring or forecast.

13.2.6 Potential Impacts of Climate Change

Historical data shows that the probability for severe weather events such as high wind storms increases in a warmer climate.

13.2.7 Secondary Hazards

The most significant secondary hazards associated with severe local storms are falling and downed trees and downed power lines. Coastal erosion can also result from extended periods of heavy rain, strong surf and high winds.

13.3 Exposure

13.3.1 Population

It can be assumed that the entire planning area is exposed to some extent to high wind storms. Certain areas are more exposed due to geographic location and local weather patterns. Populations living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and black out.

13.3.2 Property

All of the structures in the planning area are exposed to high winds. Most of these buildings are residential. Structures that were built before the building code incorporated provisions for windload are particularly vulnerable

13.3.3 Critical Facilities and Assets

All critical facilities are exposed to high wind storms. The most common problems associated with high wind storms are loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. Phone, water and sewer systems may not function.

13.3.4 Onshore and Offshore Natural Environment

The environment is highly exposed to high wind storms. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction including downed debris, uprooted trees, and debris-blocked rivers and streams.

13.4 Vulnerability

13.4.1 Population

Vulnerable populations are the elderly, low income or linguistically isolated populations, and people with life-threatening illnesses. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during high wind storms and could suffer more secondary effects of the hazard.

13.4.2 Property

All property is vulnerable during high wind storms, but properties in poor condition or in particularly vulnerable locations may risk the most damage. Those in higher elevations and on ridges may be more prone to wind damage. Those that are located under or near overhead lines or near large trees may be vulnerable to falling lines or trees.

Loss estimations for high winds were modeled as part of the tropical cyclone risk assessment. For the 50-year probabilistic tropical cyclone with estimated wind speeds between 74 and 95 miles per hour, the estimated damage potential is $357.3 million, or less than 1 percent of the total replacement cost value for the planning area.

13.4.3 Critical Facilities and Assets

High winds can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating population, and disrupting ingress and egress. Of particular concern are roads providing access to isolated areas and to the elderly. Severe windstorms and downed trees can create serious impacts on power and above-ground communication lines. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance.

High wind events pose a problem for facilities that house hazardous materials. Facilities that house such materials are often dependent on electricity and other utilities in order to maintain safe operations. During a severe high wind event,

downed trees may cut off power sources to such facilities. While most of these facilities have a back-up power source that will ensure continued operations, this time is finite and prolonged utility disruption could have dire consequences.

13.4.4 Onshore and Offshore Natural Environment

The vulnerability of the environment to high wind storms is the same as the exposure.

13.4.5 Economic Impact

Economic impact will be largely associated with disrupted services as a result of downed debris blocking transportation infrastructure and potential disruption of energy resources. Outside of a catastrophic high wind event, the economic disruption caused by this hazard is expected to remain short-term.

13.5 Future Trends in Development

All future development throughout the County will be affected by high wind storms. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. Maui County has adopted the International Building Code and has developed Maui-specific wind load requirements. These codes are equipped to deal with the impacts of high wind storms. Land use policies identified in general plans within the planning area also address many of the secondary impacts of high wind storms. With these tools, Maui County is well equipped to deal with future growth and the associated impacts of high wind storms.

13.6 Scenario

A worst-case event would involve prolonged high winds. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to power outages caused by high winds and downed debris. Some isolated communities throughout the planning area could experience limited or no ingress and egress. Additionally, temporary structures and structures unable to resist sustained wind speeds may collapse, posing an immediate threat to those within or around the structure. Long-term effects may include the removal of collapsed buildings and removal of debris from waterways.

13.7 Issues

Important issues associated with high wind storms in the planning area include the following:

- **Review of Building Stock**—Older building stock in the planning area is built to low code standards or none at all. These structures could be highly vulnerable to windstorms. The County could conduct a study within the planning area to identify at-risk buildings and investigate options for bringing these building up to code standards.
- **Alternate Power Supply**—Redundancy of power supply must be evaluated to ensure continuity of power at critical facilities throughout the planning area.
- **Public Outreach for Isolated Population Centers**—Depending on the severity of the storm, isolated population centers could potentially become stranded from the rest of the island. As such, the County should take steps to inform such isolated population centers about what to do if they become stranded. This could include public

information on sheltering in place, tips on developing a personal go-kit, and instructions on developing a personal emergency plan.

Chapter 14. Landslide, Debris Flow, and Rock Fall

14.1 Hazard Description

According to the U.S. Geological Survey (USGS), "ground failure" is the term used to describe zones of ground cracking, fissuring, and localized horizontal and vertical permanent ground displacement. This displacement may be caused by surface rupture along faults; secondary movement on shallow faults; shaking-induced compaction of natural deposits in sedimentary basins and river valleys; liquefaction of loose, sandy sediment (USGS, 2013); landslides; and land subsidence and sinkholes. Maui County is vulnerable to the ground failure hazard that includes, but is not limited to, landslides, which are further defined below.

DEFINITIONS

Landslide—The sliding movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them.

Mass Movement—A collective term for landslides, debris flows, falls and sinkholes.

Mudslide (or Mudflow or Debris Flow)—A river of rock, earth, organic matter and other materials saturated with water.

Rock Fall— The falling of newly detached mass of rock from a cliff or down a very steep slope.

A landslide is a mass of rock, earth or debris moving down a slope. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, volcanic eruptions or human modification of the land.

Mudslides (or mudflows or debris flows) are rivers of rock, earth, organic matter and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil's reduced resistance can then easily be overcome by gravity, changing the earth into a flowing river of mud or "slurry." A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them. Locally, they can be some of the most destructive events in nature.

All mass movements are caused by a combination of geological and climate conditions, as well as the encroaching influence of urbanization. Vulnerable natural conditions are affected by human residential, agricultural, commercial and industrial development and the infrastructure that supports it.

Landslides are caused by one or a combination of the following factors: change in slope of the terrain, increased load on the land, shocks and vibrations, change in water content, groundwater movement, frost action, weathering of rocks, and removing or changing the type of vegetation covering slopes. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following:

- A slope greater than 33 percent
- A history of landslide activity or movement during the last 10,000 years

- Stream or wave activity, which has caused erosion, undercut a bank or cut into a bank to cause the surrounding land to be unstable
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

Flows and slides are commonly categorized by the form of initial ground failure. Figure 14-1 through 14-4 show common types of slides. The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types.

Source: Washington State Department of Ecology, n.d.

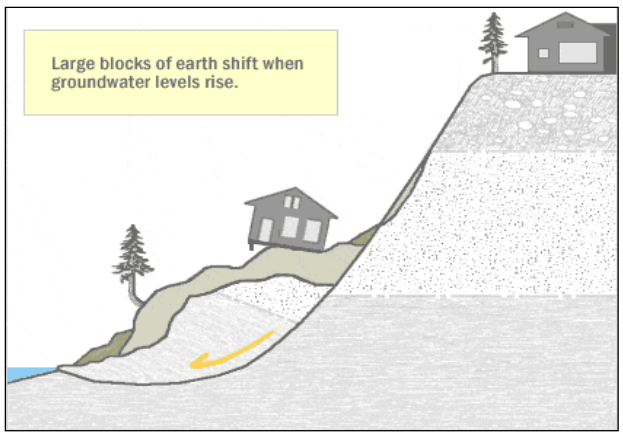


FIGURE 14-1. DEEP SEATED SLIDE

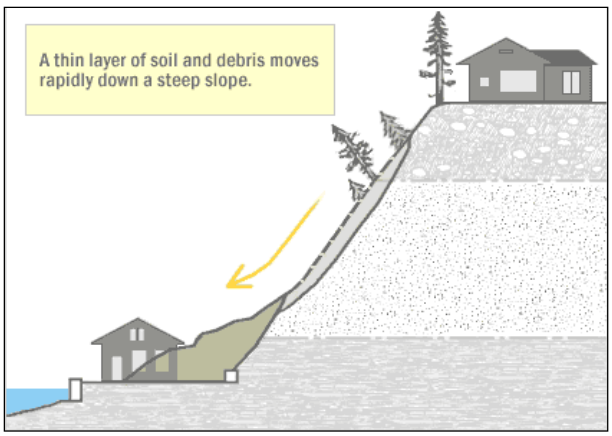


FIGURE 14-2. SHALLOW COLLUVIAL SLIDE

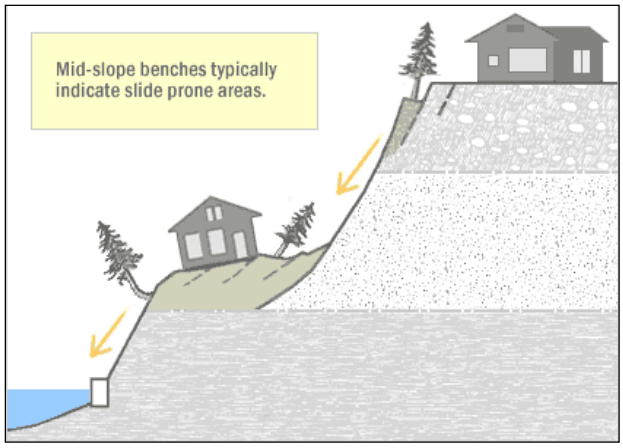


FIGURE 14-3. BENCH SLIDE

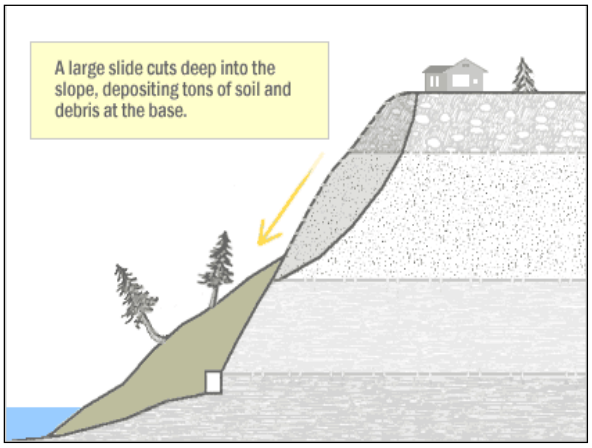


FIGURE 14-4. LARGE SLIDE

Slides and earth flows can pose serious hazard to property in hillside terrain. When they move—in response to such changes as increased water content, earthquake shaking, addition of load, or removal of downslope support—they deform and tilt the ground surface. The result can be destruction of foundations, offset of roads, breaking of underground pipes, or overriding of downslope property and structures.

14.2 Hazard Profile

14.2.1 Past Events

The Island of Maui

The Island of Maui has a recurrent history of landslides, debris flows, and rockfalls. Most of these types of events have occurred along coastal highways where the road is right up against mountain slopes. The following is a brief discussion of recent noteworthy events (also illustrated on Figure 14-5):

- On September 14, 2004, a female ranger at Haleakala National Park was fatally injured while trying to clear a rockslide on Piilani Highway (State Highway 31) near Kipahulu. The ranger was on duty when she was hit by a falling rock from the nearby hillside while removing rocks on the narrow road (County of Maui, 2010a).
- On the first week of December 2007, a strong Kona storm hit the Island of Maui causing runoff induced debris flows across several roads and highways. In the Kihei area, runoff from gathering from the slopes of Haleakala volcano pushed boulders and debris onto Highway (State Highway 31) forcing temporary closure of the road. Similarly, the storm's runoff carried debris across portions of Honoapiilani Highway (State Highway 30) near Napili in East Maui. The storm also generated debris flows in the Kula region of upcountry Maui. For instance, mud, rocks, and loosen vegetation were carried across Lower Kula Road. More noteworthy is the case of a debris flow across Polipoli Road also in the Kula region. In this case, debris including remains of a private residence, forced the closure of the road for several days until county crews removed all the leftovers from the debris flow (County of Maui, 2010a).
- On March 21, 2009, a mudslide on northeast Maui forced the closure of the Hana Highway (State Highway 360). The incident occurred at 9:30 a.m. near mile-post 21, approximately 2 miles on the Keanae side of Puaa Kaa State Wayside Park. State and County public works crew cleared the mud and debris using heavy equipment. The highway reopened 5 hours after the mudslide. The County said the area had not been identified as a potential slide problem area, but that wet weather in the few weeks before the incident may have saturated the soil resulting in the slide (County of Maui, 2010a).
- On April 23, 2009, another landslide occurred at the same location of the Hana Highway following an episode of intense rainfall. The landslide occurred at 10:00 p.m. and forced the closure of the highway in both directions between mile-post 19 near the Wailua lookout and mile-post 21. The cleanup work on both lanes had to be postponed until the morning of the April 24 due to unsafe conditions resulting from nighttime wet weather. After the partial removal of rocks and debris on the morning of April 24, the highway reopened intermittently for a few days until cleanup work was completed. Also on April 23, 2009, a rockfall occurred on Kahekili Highway (State Highway 340) at around 5:00 p.m. The rockfall resulted in large boulders blocking the highway near Waihale Gulch resulting in the closure of the road near mile-post 15. Debris removal began the morning of April 24, 2009, and extended well into the afternoon (County of Maui, 2010a).
- In early May 2014, Hana Highway, near mile-post 14.8 on the Kahului side of Keanae, succumbed to a large landslide that spanned 100 feet and was an estimated 20 feet in height. Maui County District crews, working with Maui County Public Works cleared approximately 2,000 cubic yards of mud and debris from the landslide (Osher, 2014).

- Winter weather in March 2015 caused landslides on roads heading to eastern Maui. In this instance, heavy rains saturated soils and caused instability, resulting in landslides (Tanji, 2015).

Source: Maui County, 2010a

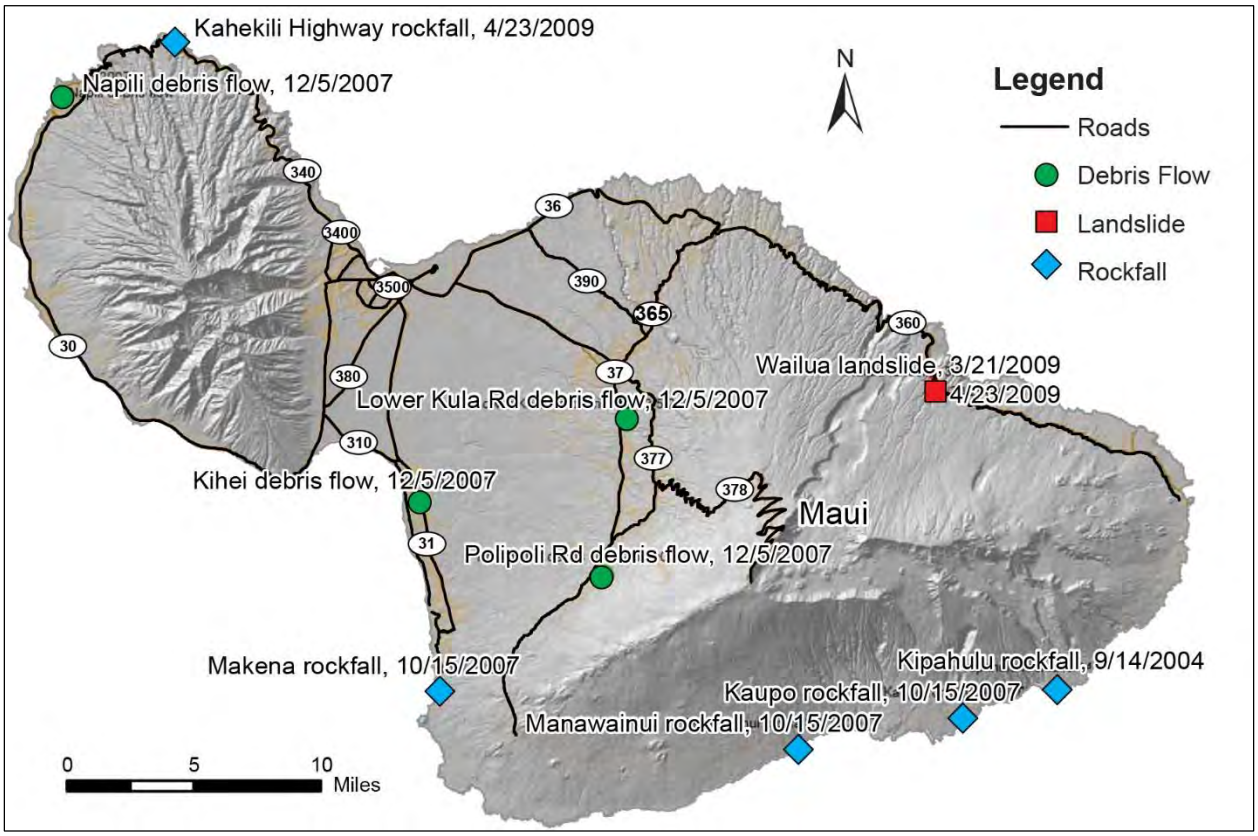


FIGURE 14-5. LOCATIONS OF LANDSLIDES, DEBRIS FLOWS AND ROCK FALLS, ISLAND OF MAUI, 2004-2009

Landslides, Debris Flows, and Rockfalls Induced by Kiholo Bay and Mahukona Earthquakes

The Kiholo Bay and Mahukona Earthquakes of October 15, 2006 resulted in several landslides and rockfalls at various locations on the Island of Maui (peak ground accelerations of approximately 10 to 17 percent g were experienced on this island) (County of Maui, 2010a).

During the Kiholo Bay and Mahukona earthquakes of October 15, 2006, several major landslides and rockfalls occurred on the east side of the Island of Maui. A report of observations of the earthquakes described rockfall incidents on the Island of Maui as follows (Earthquake Engineering Research Institute et al., 2006):

> Rockfall debris at the Kalepa cliffs impacted the highway. About 500 Maui residents were cut-off between an incipient rockfall hazard of that road in the Manawainui area and a bridge closure due to abutment erosion at Paihi. After and engineering evaluation and fast-track design, the installation of a temporary steel truss bridge was completed at the end of November. Sections of that highway along the coastline are inherently vulnerable to rockfalls and landslides. A few days after the opening of the temporary bridge, new rockfalls at Kalepa closed the highway again. The County of Maui is scaling

loosened rock and boulders from several vulnerable slopes. The discontinuous and often contorted inclusions of massive basalt are irregularly fractured.

Other roads were closed on Piilani Highway due to earthquake-induced rockfalls besides those near Manawainui. In the vicinity of Kaupo and Kipahulu, for instance, a 10-mile stretch of road was undermined and blocked to traffic due to another rockfall. The road was finally cleared and reopened in October 5, 200890 – nearly 2 years after the earthquakes (County of Maui, 2010a).

Rockslides caused by the Kiholo Bay and Mahukona Earthquakes were not limited to the southeast coast of the east side of the Island of Maui. At Makena State Park, in the southwest coast of the east side of the Island of Maui, at least 10 rockfalls occurred along the rocky coastal cliffs. The rockfalls occurred at three of the major beaches in the park: Black Sand Beach, Big Beach, and Small Beach (County of Maui, 2010a).

Islands of Molokai and Lanai

On November 5, 2007, heavy rains resulted in rockfalls and debris flows along different portions of Kamehameha V Highway (State Highway 450) on the east side of the Island of Molokai.

There are no records of landslides, debris flows, or rockfalls on the Island of Lanai (County of Maui, 2010a).

14.2.2 Location

The best available predictor of where movement of slides and earth flows might occur is the location of past movements. Past landslides can be recognized by their distinctive topographic shapes, which can remain in place for thousands of years. Most landslides recognizable in this fashion range from a few acres to several square miles. Most show no evidence of recent movement and are not currently active. A small proportion of them may become active in any given year, with movements concentrated within all or part of the landslide masses or around their edges.

The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding. While both saturation of soil and seismicity play a part is landslide risk, Maui County has a greater risk of landslides from earthquakes caused by the volcanic activity in neighboring Hawaii County (State of Hawaii, 2010).

The landslide risk assessment for this plan identified areas with landslide potential based on steepness and soil type. Landslide hazard areas were categorized as follows:

- High—NEHRP soil class D and slope greater than 30 percent
- Moderate—NEHRP soil class D and slope greater than 15 percent and less than 30 percent
- Low—NEHRP soil class D and slope less than 15 percent.

Figure 14-6 shows the hazard areas based on these criteria are shown in Figure 14-6 through Figure 14-8.

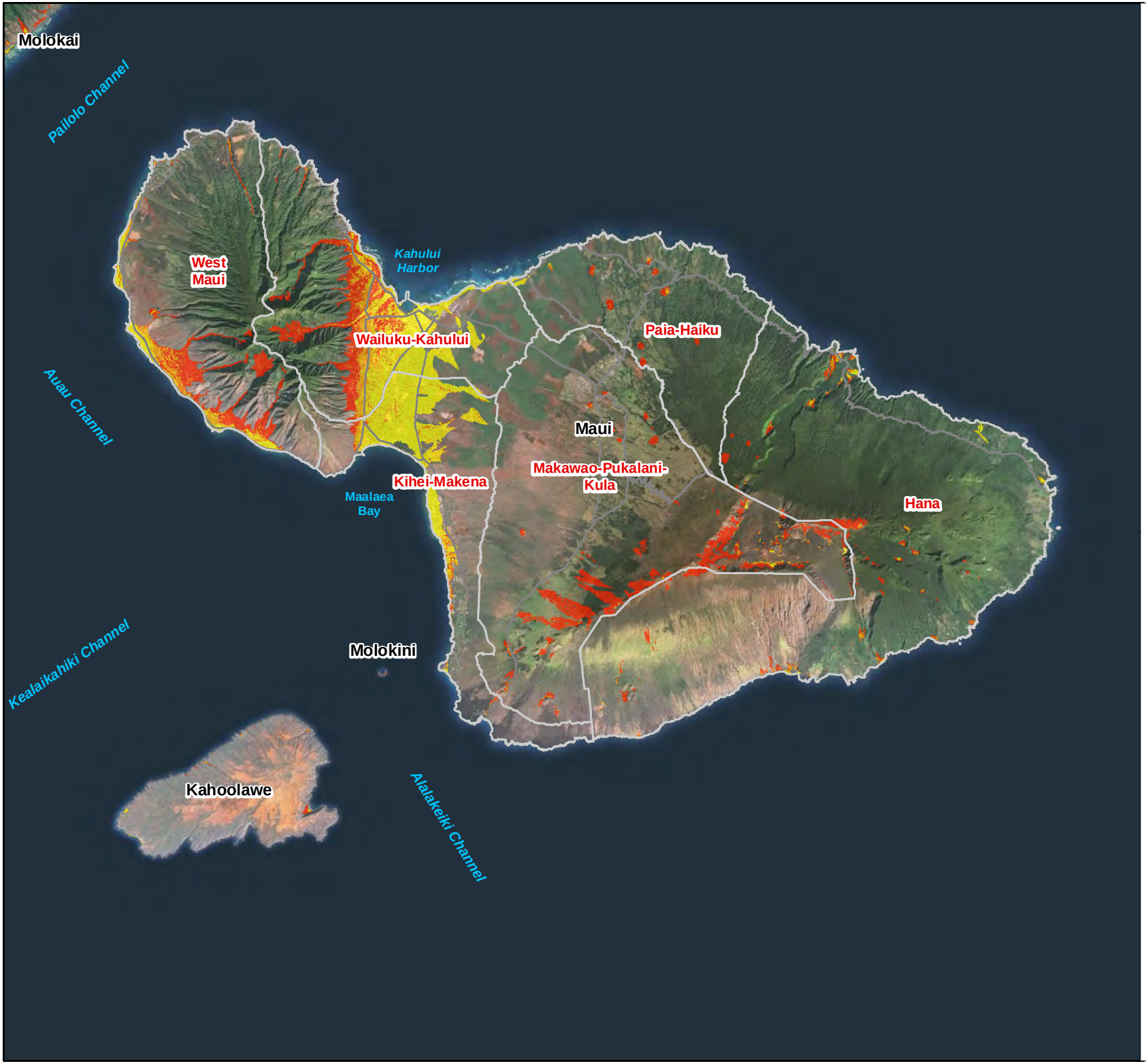
14.2.3 Frequency

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildfires, so landslide frequency is often related to the frequency of these other hazards. In the planning area, landslides typically occur as a direct result of seismic activity within the area and during and after major storms. Until better data is generated specifically for landslide hazards, this seismic activity and severe storm frequency is appropriate for the purpose of ranking risk associated with the landslide hazard. During storm-related landslide events, the ground must be saturated prior to the onset of a major storm for significant landsliding to occur.

Landslides are commonly related to tropical cyclone events, heavy rain on saturated ground, or earthquakes. During storm-related landslide events, the ground must be saturated prior to the onset of a major storm for significant landsliding to occur. Because the County of Maui is susceptible to all three factors that trigger landslides, landslides may occur at any time one of the factors is experienced. Tropical cyclone events are more likely during the Pacific Cyclone season. Heavy rain may result from cyclonic storms or seasonally rainy weather. Earthquakes may occur at any time of the year (County of Maui, 2014).

14.2.4 Severity

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion.



Maui County Islands of Maui and Kahoolawe

Slope/Soils Analysis Landslide Probability Areas

Legend

Community Plan Boundaries

Probability

Low

Moderate

High

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

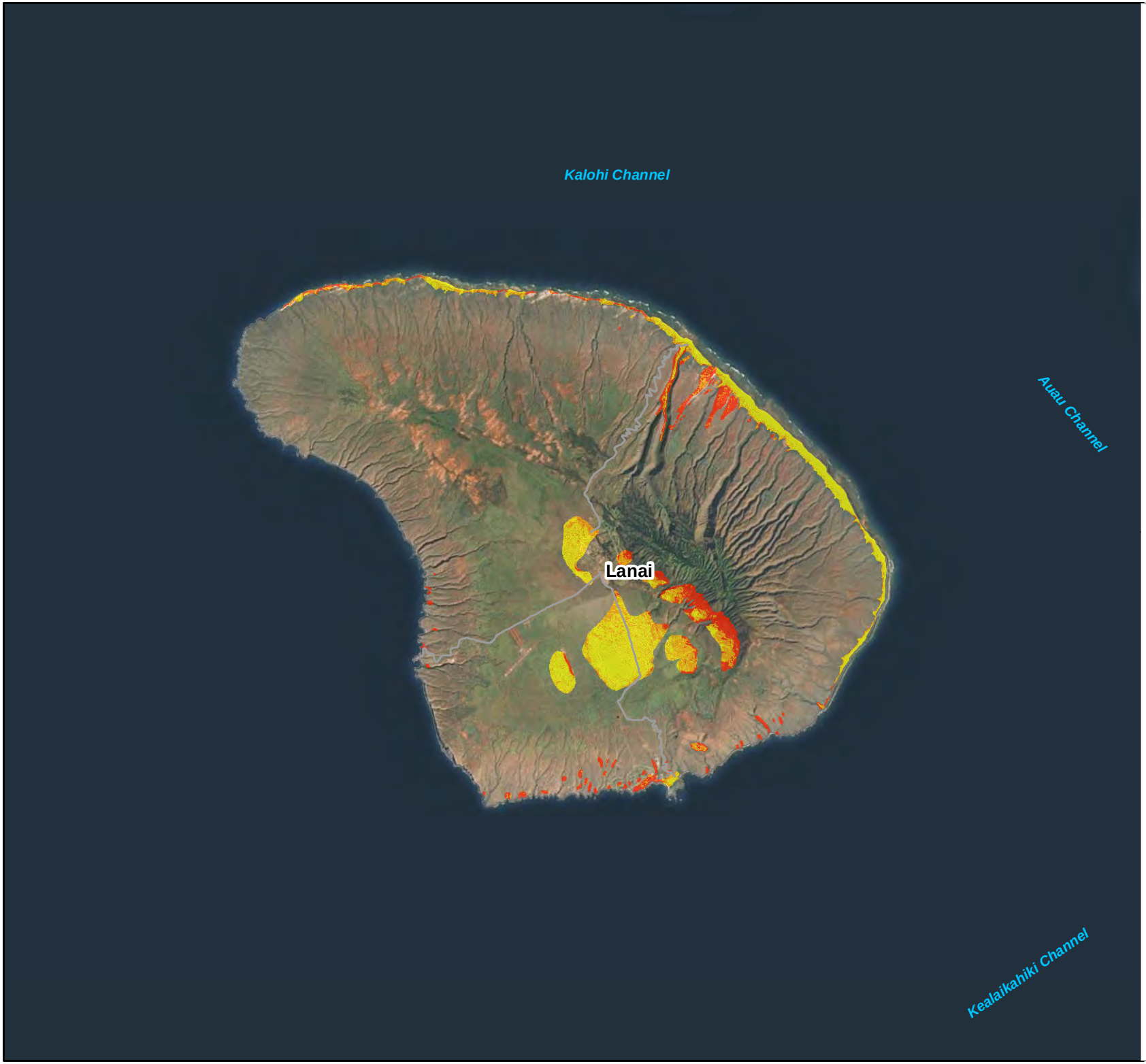
TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Slope/Soils Analysis
Landslide Probability
Areas



Legend

Probability

- Low
- Moderate
- High

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

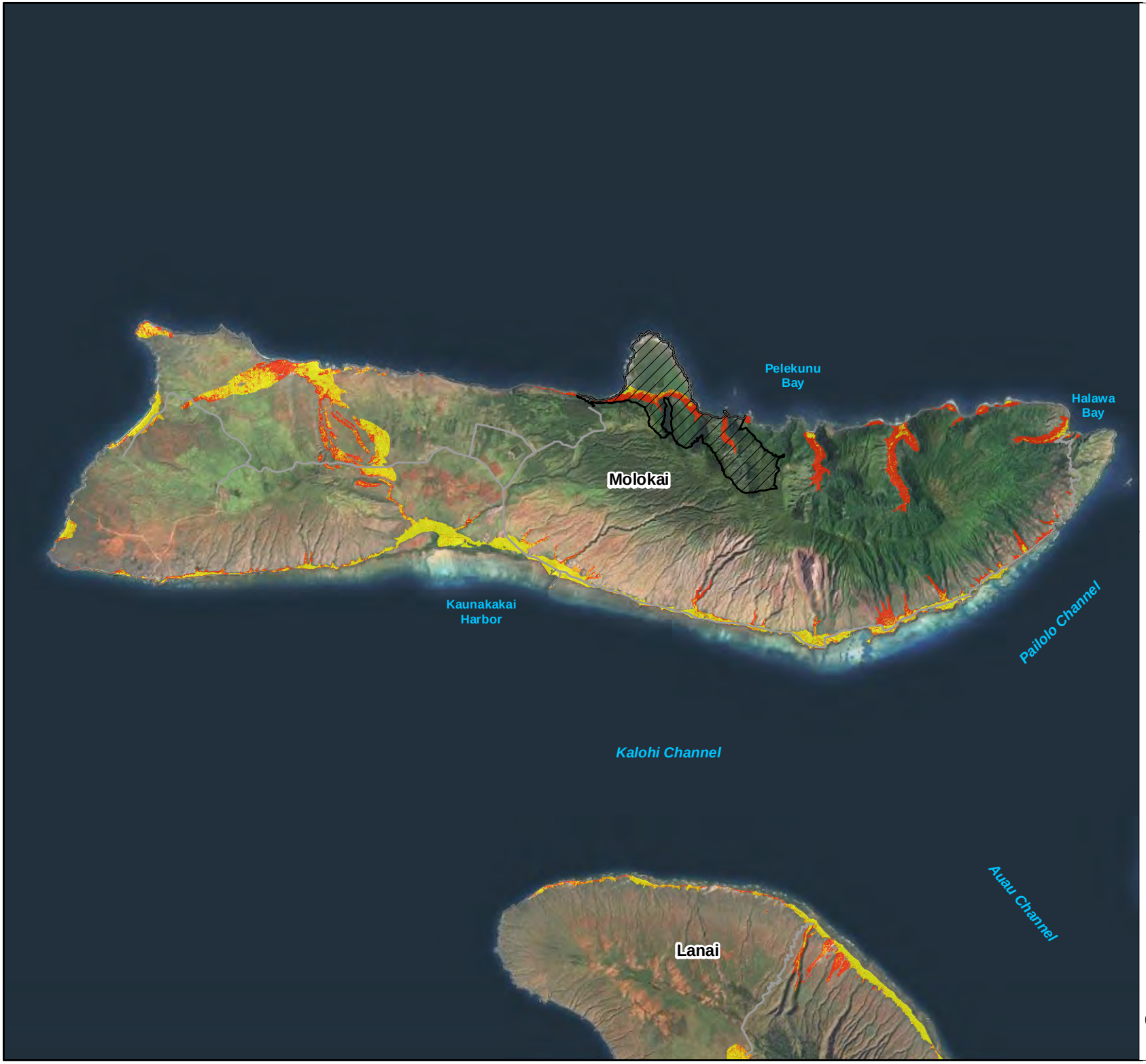
TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Slope/Soils Analysis Landslide Probability Areas



Legend

Kalawao County

Probability

Low

Moderate

High

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 3.5 7 Miles

14.2.5 Warning Time

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material and water content. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together.

14.2.6 Potential Impacts of Climate Change

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

14.2.7 Secondary Hazards

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents.

14.3 Exposure

14.3.1 Population

Population exposure was estimated by determining the percent of buildings in each community planning area exposed to the landslide hazard and applying the percentage to the estimated 2010 population. As shown in Table 14-1, the estimated population living in high landslide risk areas is 15,936 residents (10.3 percent of the resident population) and 2,431 visitors. The estimated resident populations in moderate and low landslide risk areas are 25,583 (16.5 percent of the total) and 37,851 (24.4 percent of the total), respectively.

TABLE 14-1.
ESTIMATED POPULATION EXPOSURE FOR HIGH LANDSLIDE RISK AREAS

Community Planning Area	Residents	Visitors	Total
Hana	15	0	15
Kihei-Makena	605	1,676	2,281
Lanai	96	0	96
Makawao-Pukalani-Kula	117	0	117
Molokai	338	117	455
Paia-Haiku	168	0	168
Wailuku-Kahului	13,331	26	13,357
West Maui	1,267	612	1,879
Total	**15,936**	**2,431**	**18,367**

14.3.2 Property

Table 14-2 shows the number and replacement value of structures exposed to the landslide risk. There are 4,486 structures on parcels in the landslide risk areas, with an estimated value of $3.5 billion.

TABLE 14-2.
EXPOSURE AND VALUE OF STRUCTURES IN HIGH LANDSLIDE RISK AREAS

	Buildings Exposed	Value Exposed			% of Replacement Value
		Structure	Contents	Total	
Hana	7	$1,559,196	$851,806	$2,411,002	0.6%
Kihei-Makena	164	$327,265,863	$167,972,090	$495,237,953	5.3%
Lanai	40	$40,095,554	$22,090,335	$62,185,889	6.1%
Makawao-Pukalani-Kula	46	$14,725,755	$7,362,878	$22,088,633	0.5%
Molokai	139	$50,628,812	$25,554,590	$76,183,402	5.3%
Paia-Haiku	64	$25,185,719	$12,779,160	$37,964,879	1.7%
Wailuku-Kahului	3,717	$1,584,956,329	$943,959,127	$2,528,915,457	15.4%
West Maui	309	$157,406,932	$86,926,893	$244,333,824	2.5%
Total	**4,486**	**$2,201,824,160**	**$1,267,496,878**	**$3,469,321,038**	**7.59%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

Table 14-3 shows the general land use of parcels exposed to high landslide risk areas in the planning area. Agricultural and conservation land make up the greatest extent of exposed areas. However, over 95 percent of the exposed structures are dwellings.

TABLE 14-3.
LAND USE IN HIGH LANDSLIDE RISK AREAS

Land Use	Area in Landslide Risk Area (acres)	% of total
Agricultural	12,915.73	47.2%
Apartment	105.56	0.4%
Commercial	112.67	0.4%
Commercialized Residential	11.96	0.0%
Conservation	10,786.96	39.5%
Hotel/Resort	95.77	0.4%
Industrial	38.46	0.1%
Residential	2,856.46	10.4%
Time Share	0.93	0.0%
Not Classified	410.62	1.5%
Total	**27,335.12**	**100.0%**

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified." Acreage includes only areas intersecting mapped hazard layers.

14.3.3 Critical Facilities and Assets

Table 14-4 summarizes the critical facilities exposed to the landslide hazard. No loss estimation of these facilities was performed due to the lack of established damage functions for the landslide hazard. A significant amount of infrastructure can be exposed to mass movements:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems and delays for public and private transportation. This can result in economic losses for businesses.
- **Bridges**—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- **Power Lines**—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

TABLE 14-4.
CRITICAL FACILITIES AND ASSETS IN LANDSLIDE RISK AREAS

Facility Type	High	Moderate	Low
Emergency Services			
Emergency Operations	0	0	1
Police & Fire	0	3	7
Community Shelter[a]	1	0	1

TABLE 14-4.
CRITICAL FACILITIES AND ASSETS IN LANDSLIDE RISK AREAS

Facility Type	High	Moderate	Low
Medical & Health	0	1	0
Government and Services			
Government[b]	—	—	—
Schools[a]	4	19	27
Critical Infrastructure and Lifelines			
Transportation	9	13	30
Water Supply	33	5	1
Wastewater	5	23	33
Dams	2	2	2
Energy	0	0	5
Telecommunications	0	3	3
Hazardous Materials	0	1	4
Other Important Assets			
Financial	0	6	33
Tourist Lodging	13	33	77
Early Assistance	2	1	0
Total	**69**	**110**	**225**

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.
Data sources: See Table 5-1

14.3.4 Onshore and Offshore Natural Environment

Environmental problems as a result of mass movements can be numerous. Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolong periods of time due to landslides.

Landslides that occur along coastal areas pose a particular threat to Maui County's coastal coral reefs. As massive amounts of land falls into surrounding ocean waters, tides and waves may draw the earthen sediment to the reef area, choking the natural habitat. Natural cyclical processes normally remove earthen sediment and clean the coral reef area, however a large landslide may produce too much sediment to be removed by the natural processes (Piniak, 2004).

14.4 Vulnerability

14.4.1 Population

Due to the preliminary nature of the analysis used to determine exposure, it is difficult to determine demographics of populations vulnerable to mass movements. In general, all of the estimated 18,367 persons exposed to higher risk landslide areas are considered to be vulnerable.

14.4.2 Property

Loss estimations for the landslide hazard are not based on modeling utilizing damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14-5 shows the general building stock loss estimates in landslide risk areas.

TABLE 14-5.
LOSS POTENTIAL FOR LANDSLIDE

Community Planning Area	Exposed Value	Estimated Loss Potential from Landslide		
		10% Damage	30% Damage	50% Damage
Hana	$2,411,002	$241,100	$723,301	$1,205,501
Kihei-Makena	$495,237,953	$49,523,795	$148,571,386	$247,618,977
Lanai	$62,185,889	$6,218,589	$18,655,767	$31,092,945
Makawao-Pukalani-Kula	$22,088,633	$2,208,863	$6,626,590	$11,044,317
Molokai	$76,183,402	$7,618,340	$22,855,021	$38,091,701
Paia-Haiku	$37,964,879	$3,796,488	$11,389,464	$18,982,440
Wailuku-Kahului	$2,528,915,457	$252,891,546	$758,674,637	$1,264,457,729
West Maui	$244,333,824	$24,433,382	$73,300,147	$122,166,912
Total	**$3,469,321,038**	**$346,932,104**	**$1,040,796,311**	**$520,398,156**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

14.4.3 Critical Facilities and Assets

There are 404 critical facilities or assets exposed to the landslide hazard to some degree. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand impacts of a mass movement.

Several types of infrastructure are exposed to mass movements, including transportation, water and sewer and power infrastructure. Highly susceptible areas of the planning area include mountain and coastal roads and transportation infrastructure. Many roads in Maui are single lane highways that if blocked would cause a significant impact to the areas they serve. If impacted from a landslide, blocked highways could possibly isolate communities for a significant amount of time. At this time all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available.

14.4.4 Onshore and Offshore Natural Environment

The environment vulnerable to landslide hazard is the same as the environment exposed to the hazard.

14.4.5 Economic Impact

Economic impact will be largely associated with the disruption of transportation infrastructure. Communities that are isolated as a result of the landslide hazard may suffer from economic issues resulting from a lack of resource movement in and out of the area. This issue could last for a significant amount of time based on the extent of the event.

14.5 Future Trends in Development

Land use in the planning area will be directed by general plans adopted by the Maui County Council. These plans include the Countywide Policy Plan; the Maui Island Plan; and nine community plans that encompass Molokai, Lanai, Kahoolawe, and specific communities on the Island of Maui. The protective and preventative elements of these plans, from building height to transportation and environmental aspects, establish standards and plans for the protection of the community from hazards.

14.6 Scenario

Major landslides in the planning area occur as a result of soil conditions that have been affected by severe storms, groundwater, or human development. The worst-case scenario for landslide hazards in the planning area would generally correspond to a severe storm that had heavy rain and caused flooding and an unrelated seismic event associated with volcanic activity in Hawaii County. After heavy rains, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. A short intense storm could cause saturated soil to move, resulting in landslides. As rains continue, the groundwater table rises, adding to the weakening of the slope. Gravity, poor drainage, a rising groundwater table, poor soil, and ground shaking exacerbate hazardous conditions.

Most mass movements would be isolated events affecting specific areas. It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide prone ravines and knock out rail service through the planning area. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas. Property owners exposed to steep slopes may suffer damage to property or structures. Landslides carrying vegetation such as shrubs and trees may cause a break in utility lines, cutting off power and communication access to residents.

Continued heavy rains and flooding will complicate the problem further. As emergency response resources are applied to problems with flooding, it is possible they will be unavailable to assist with landslides occurring all over the planning area.

14.7 Issues

Important issues associated with landslides in the planning area include the following:

- **Collection of Detailed Information**—Existing homes and transportation corridors are situated in landslide risk areas throughout the planning area. The degree of vulnerability of these structures depends on the codes and standards the structures were constructed to. Information to this level of detail is not currently available.

- **Monitoring of Future Development**—Future development could lead to more homes in landslide risk or potentially isolated areas. By continuing to monitor land use and development, Maui County could play an integral part in minimizing development in known landslide risk areas or areas prone to isolation due to blocked transportation corridors by landslides.
- **Reevaluation of Current Data**—Mapping and assessment of landslide hazards are constantly evolving. As new data and science become available, assessments of landslide risk should be reevaluated.
- **Water Quality Degradation**—Landslides may cause negative environmental consequences, including water quality degradation. The County must continue to monitor water quality during potentially impactful landslide events.
- **Multi-hazard Mitigation Planning**—The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood and wildfire. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.

Chapter 15. Tropical Cyclone

15.1 Hazard Description

One of the most dramatic, damaging, and potentially deadly events that occur in the Hawaiian Islands are tropical cyclones. Tropical cyclones typically form in three regions in the Northern Hemisphere: the tropical Atlantic, the eastern tropical Pacific, and the western tropical Pacific. In the Southern Hemisphere there are two primary areas where tropical cyclones form: the western tropical Pacific and Indian Ocean. Hawaii lies in the Central Pacific, which, on average, experiences four to five tropical cyclones every year.

In the United States, forecast centers classify tropical cyclones in the following categories according to their maximum sustained winds:

- **Tropical Depression**—A weak tropical cyclone with a surface circulation including one or more closed isobars (lines or curves of constant pressure) and highest sustained winds (measured over one minute or more) of less than 38 miles per hour. Tropical depressions are assigned a number denoting their chronological order of formation in a given year.
- **Tropical Storm**—A tropical cyclone with highest sustained winds between 39 and 73 miles per hour.
- **Hurricane (or Typhoon only west of 180º longitude)** —A tropical cyclone with highest sustained winds greater than 74 miles per hour. Intensity is quantified by category.

DEFINITIONS

Tropical Cyclone —Low pressure systems that form over the warm tropical oceans. They are smaller than mid-latitude cyclonic storms and are characterized by a core in which air temperatures are warmer than those of the surrounding environment. In contrast mid-latitude cyclones are colder than their surrounding environments.

Tropical Depression— an organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds of less than 38 mph. It has no "eye" (the calm area in the center of the storm) and does not typically have the organization or the spiral shape of more powerful storms

Almost all tropical storms and hurricanes in the Pacific basin form between June 1 and November 30. This time frame is known as hurricane season. August and September are peak months for hurricane development (CPHC, 2012). The threats caused by an approaching hurricane can be divided into three main categories: storm surge, wind damage, and rainfall/flooding:

- **Storm Surge**—water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the mean water level 15 feet or more. Storm surge is responsible for nearly 90 percent of all hurricane-related deaths and injuries.
- **Wind Damage**—the force of wind that can quickly decimate the tree population, down power lines and utility poles, knock over signs, and damage/destroy homes and buildings. Flying debris can also cause damage to both structures and the general population. When hurricanes first make landfall, it is common for tornadoes to form, which can cause severe localized wind damage.
- **Rainfall/Flooding**—the torrential rains that normally accompany a hurricane can cause serious flooding. Whereas the storm surge and high winds are concentrated around the "eye," the rain may extend for hundreds of miles and may last for several days, affecting areas well after the hurricane has diminished (Mandia, n.d.).

15.2 Hazard Profile

15.2.1 Past Events

Historically, the islands that constitute the County of Maui have only been brushed by a tropical depression. Molokai, Lanai, and Maui have, however, sustained some damage from the impact of winds from nearby passing tropical depressions and hurricanes. Hurricane Nina, for example, brought gusts greater than 90 miles per hour to parts of the Island of Maui in November 1957. Tropical Storm Sarah in 1971 and storm Die Deutsche Seewarte III in 1874 destroyed a number of houses in Lanai and Molokai. No damage resulting in economic losses has ever been recorded in Kahoolawe since the island has historically been uninhabited. In 2014, Maui County was again brushed by two specific storm systems, Iselle and Ana:

- Tropical Storm Iselle, which made landfall on the Big Island in August 2014, was the strongest recorded tropical cyclone that made landfall on Hawaii County since the beginning of reliable recordkeeping in 1950. Though never passing over Maui County, Iselle caused power outages, washed out roads, and caused widespread flooding throughout the planning area (Lada, 2014). Maui County spent $2,273,786.00 responding to, and recovering from the damages caused by Tropical Storm Iselle.
- Tropical Storm Ana followed Iselle roughly 2 months later. Initial models indicated another severe event; however, the system swung to the southwest of Hawaii. Though Ana did not cause any major damage, Maui County experienced gusty winds, heavy rain, and high surf (Pydynowski, 2014).

Figure 15-1 depicts historical storm tracks in the vicinity of Hawaii from 1950 to 2014.

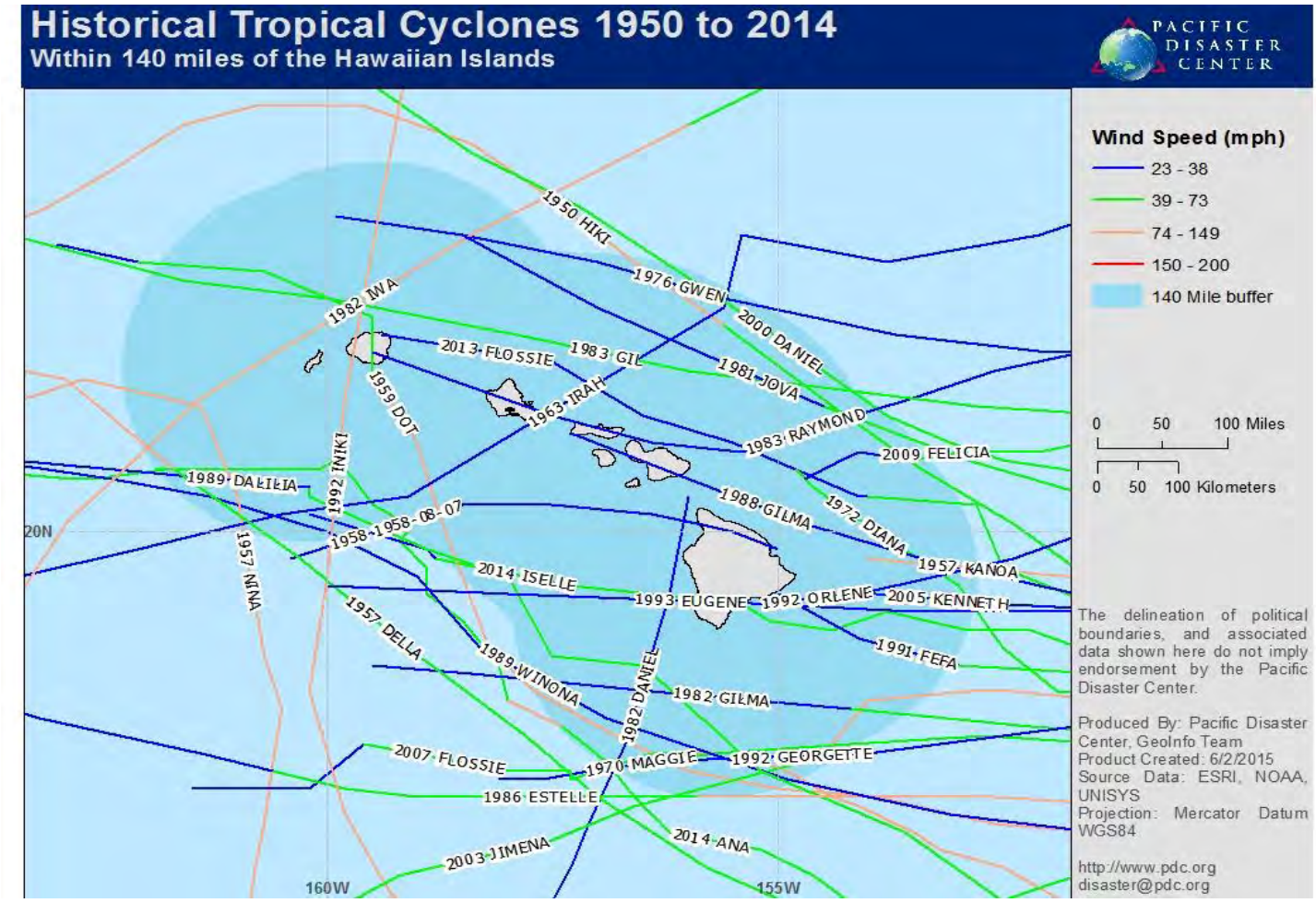


FIGURE 15-1. HISTORICAL TROPICAL CYCLONES 1950 TO 2014

15.2.2 Location

A myth in Hawaii is that the islands that constitute the County of Maui and the Island of Oahu are less vulnerable to a direct hit by a hurricane than the islands of Kauai and Hawaii. This myth has developed as a result of the fact that, until 1950, tropical storms hitting the Hawaiian Islands were not classified as hurricanes. It was not until the advent of weather satellites that the nature of storms in this part of the world was understood to be hurricanes (County of Maui, 2010a).

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

Since 1950, six hurricanes or tropical storms have caused serious damage in Hawaii. Hurricane Nina in 1957 produced record winds in Honolulu on the Island of Oahu. Hurricane Dot was responsible for extensive damage on the Island of

Kauai in 1959. Hurricane Iwa resulted in widespread damage on the islands of Kauai and Oahu in 1982. Hurricane Estelle produced very high surf on the islands of Hawaii and Maui and floods on the Island of Oahu in 1986. Hurricane Iniki produced widespread severe damage on the Island of Kauai and on the leeward coast of the Island of Oahu in 1992. Tropical Storm Iselle made landfall in Hawaii County in August 2014 with maximum sustained winds of 60 mph (TWC, 2014). In addition to all these destructive hurricanes, seven other tropical storms or hurricanes could have caused serious damage to the islands since 1950. Among these hurricanes that missed the islands are Hurricane Fernanda in 1993, Hurricane Emilia in 1994, and Hurricane Ana in 2014. Therefore, contrary to popular belief, all of the Main Hawaiian Islands are at approximately the same risk of a direct hit by a hurricane (County of Maui, 2010a).

Table 15-1 indicates how the frequency and strength of windstorms impacts the U.S. and the general location of the most wind activity. This is based on 40 years of tornado history and 100 years of hurricane history, collected by FEMA. Maui County is located in Wind Zone II with speeds up to 160 miles per hour. The County is also located within the hurricane-susceptible region (FEMA, n.d.).

15.2.3 Frequency

In evaluating the potential for hazard events of a given magnitude, a mean return period (MRP) is often used. The MRP provides an estimate of the magnitude of an event that may occur within any given year based on past recorded events. MRP is the average period of time, in years, between occurrences of a particular hazard event (equal to the inverse of the annual frequency of exceedance).

Maximum 3-second gust wind speeds associated with the 50-, 100-, and 500-year MRP Hazus-MH model runs are shown on Figure 15 2 through Figure 15 10. For the 50-year event, the maximum ranges from 39 to 95 miles per hour (mph), characteristic of a Category 1 hurricane. For the 100-year event, the maximum ranges from 74 to 110 mph, characteristic of a Category 2 hurricane. For the 500-year event, the maximum ranges from 111 to more than 157 mph, characteristic of a Category 5 hurricane. The associated impacts and losses from these 50-, 100-year, and 500-year MRP hurricane event model runs are reported in the vulnerability section of this profile.

15.2.4 Severity

The Saffir-Simpson Hurricane Scale categorizes the severity of a hurricane. The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous and require preventative measures (NOAA, 2013). Table 15-2 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

TABLE 15-1.
THE SAFFIR-SIMPSON HURRICANE SCALE

Category	Wind Speed (mph)	Expected Damage
1	74-95 mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	>157 mph	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: NWS, 2013

Note: mph=Miles per hour; > =Greater than

Maui County Islands of Maui and Kahoolawe

Tropical Cyclone 50-Year Probabilistic Peak Gusts

Legend

Community Plan Boundaries

Wind Speed

Tropical Storm: 39-73 mph

Category 1: 74-95 mph

Base Map Data Sources:
Maui County, Hazus, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Tropical Cyclone
50-Year Probabilistic
Peak Gusts

Legend

Wind Speed

- Tropical Storm: 39-73 mph
- Category 1: 74-95 mph

Base Map Data Sources:
Maui County, Hazus, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Tropical Cyclone 50-Year Probabilistic Peak Gusts

Legend

Kalawao County

Wind Speed

Tropical Storm: 39-73 mph

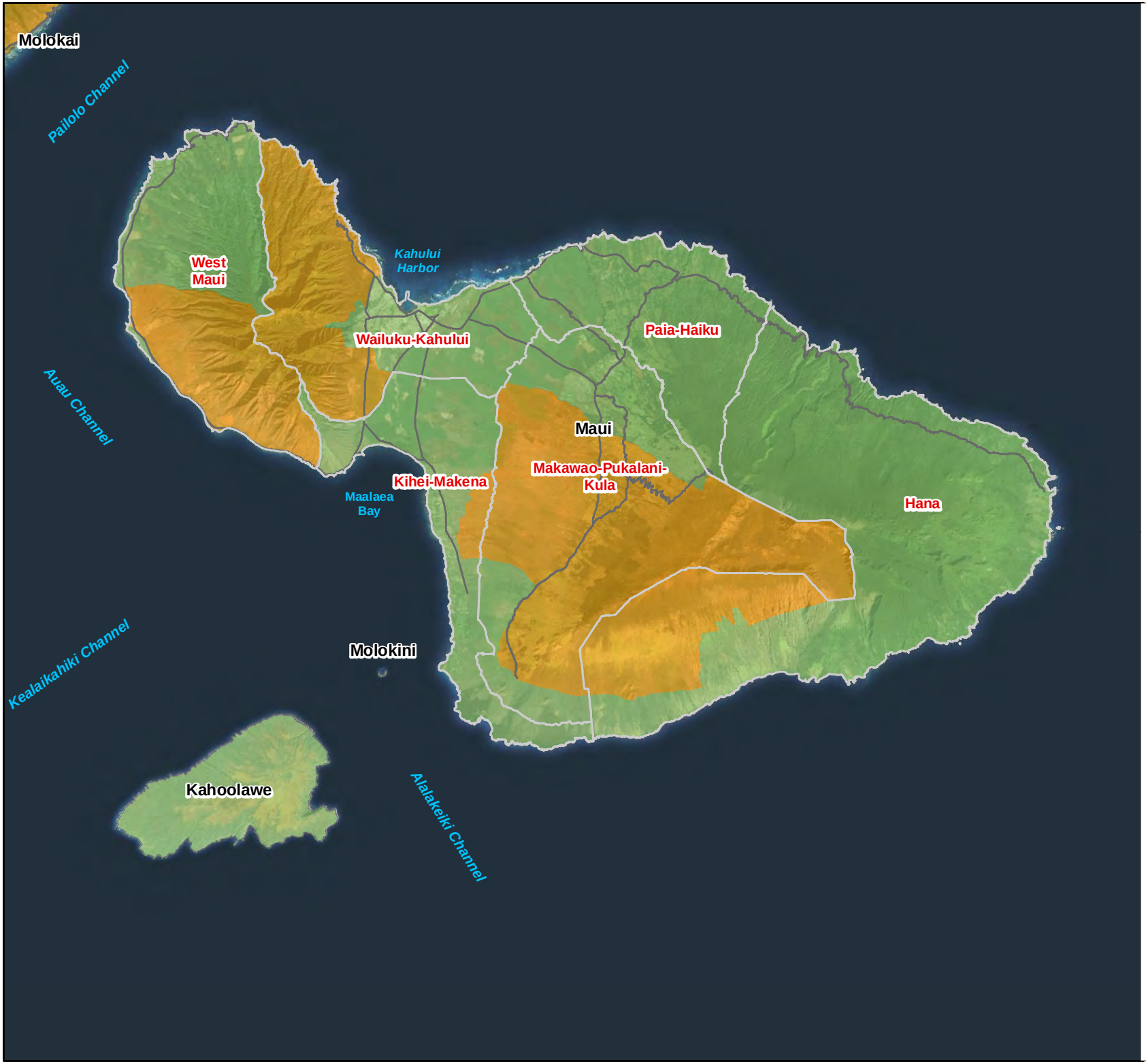
Category 1: 74-95 mph

Base Map Data Sources:
Maui County, Hazus, ESRI

TETRA TECH

N

0 3.5 7 Miles



Maui County Islands of Maui and Kahoolawe

Tropical Cyclone 100-Year Probabilistic Peak Gusts

Legend

Community Plan Boundaries

f100yr

Category 1: 74-95 mph

Category 2: 96-110 mph

Base Map Data Sources: Maui County, U.S. Geologic Survey, Hazus, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Tropical Cyclone
100-Year Probabilistic
Peak Gusts

Legend

Wind Speed

- Category 1: 74-95 mph
- Category 2: 96-110 mph

Base Map Data Sources:
Maui County, U.S. Geologic Survey, Hazus, ESRI

TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Tropical Cyclone 100-Year Probabilistic Peak Gusts

Legend

Kalawao County

Wind Speed

Category 1: 74-95 mph

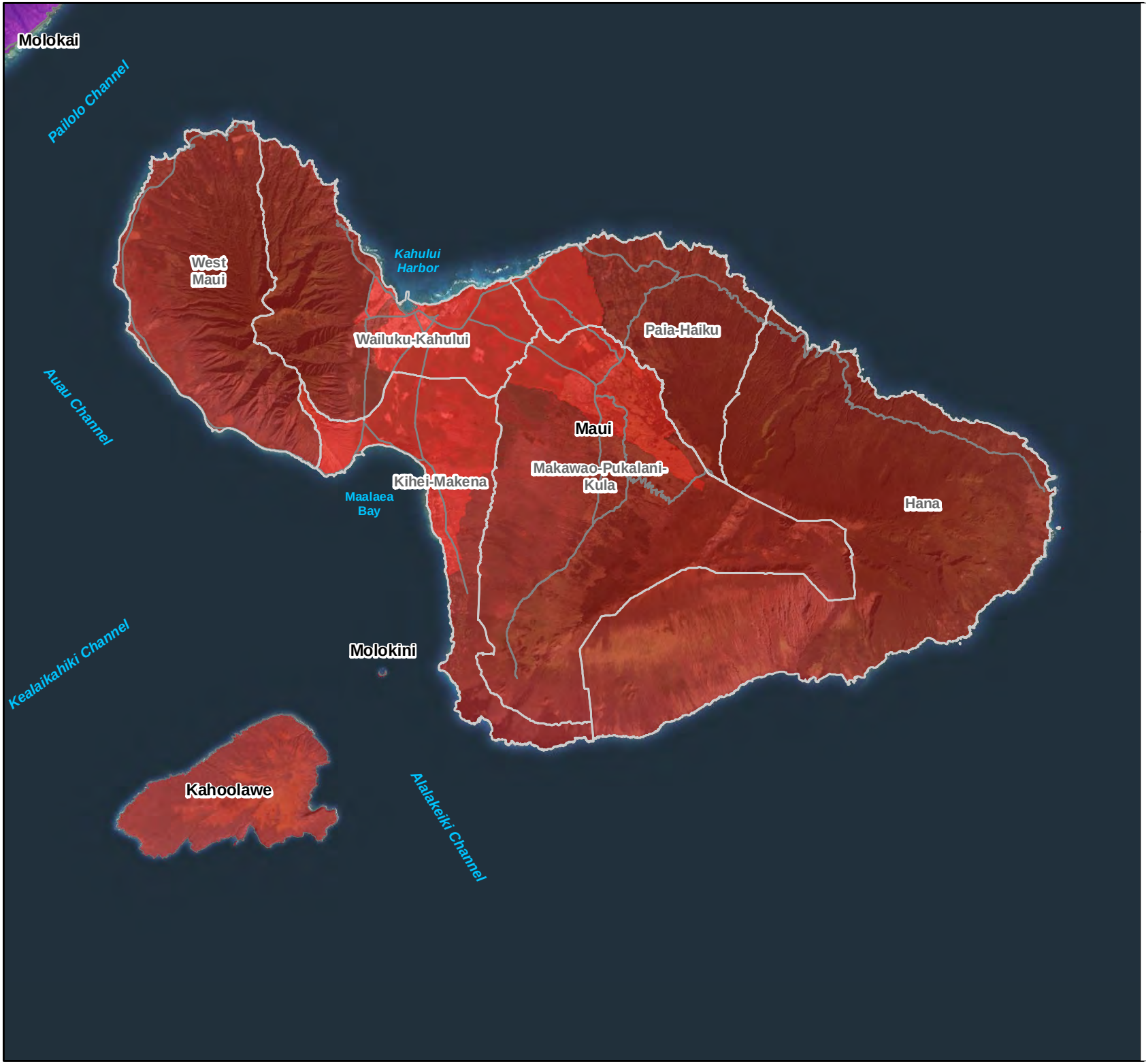
Category 2: 96-110 mph

Base Map Data Sources: Maui County, U.S. Geologic Survey, Hazus, ESRI

TETRA TECH

N

0 3.5 7 Miles



Maui County Islands of Maui and Kahoolawe

Tropical Cyclone 500-Year Probabilistic Peak Gusts

Legend

Community Plan Boundaries

Wind Speed

Category 3: 111-129 mph

Category 4: 130-156 mph

Category 5: 157+ mph

Base Map Data Sources: Maui County, U.S. Geologic Survey Hazus, ESRI

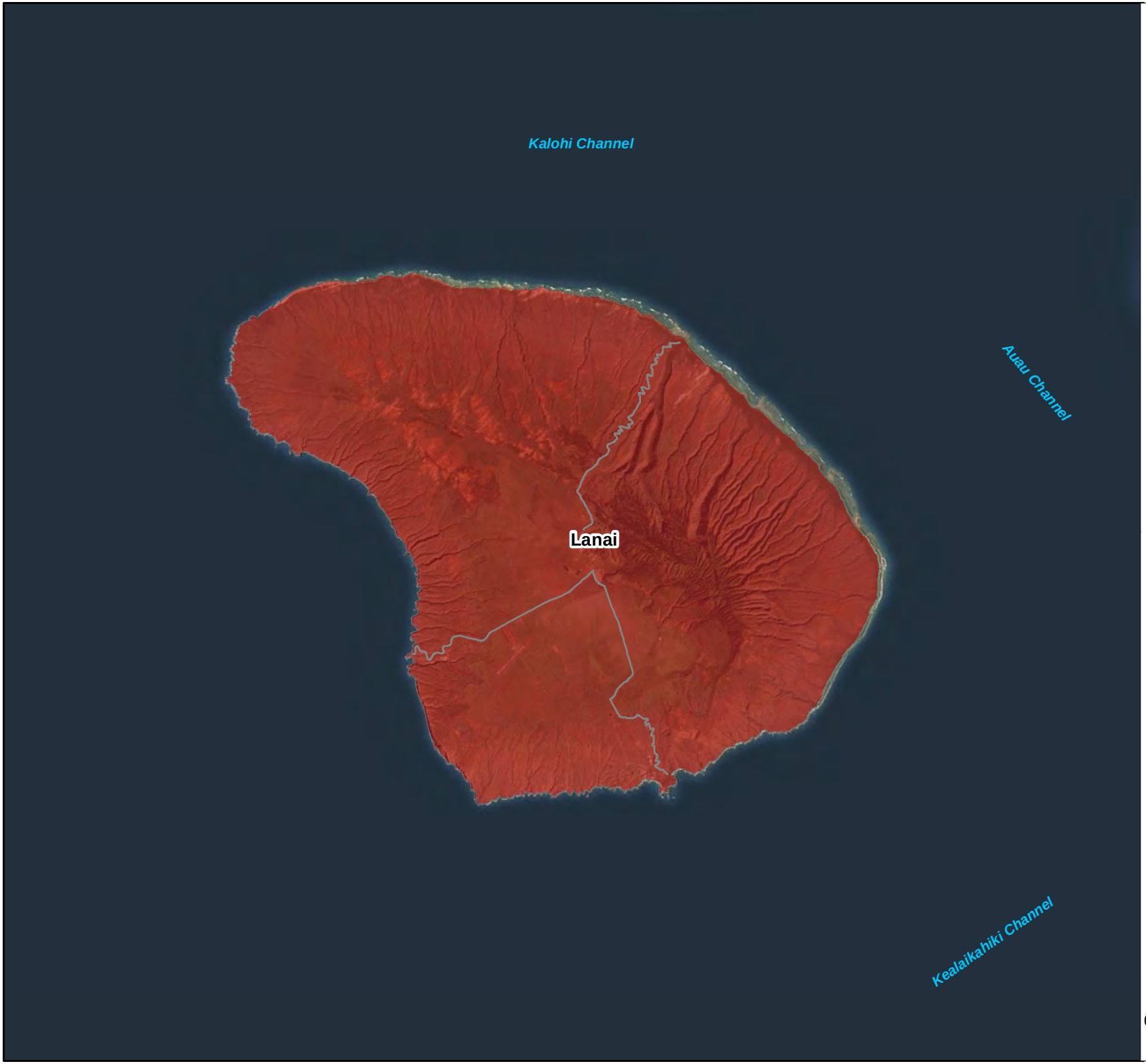
TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Tropical Cyclone
500-Year Probabilistic
Peak Gusts



Legend

Wind Speed

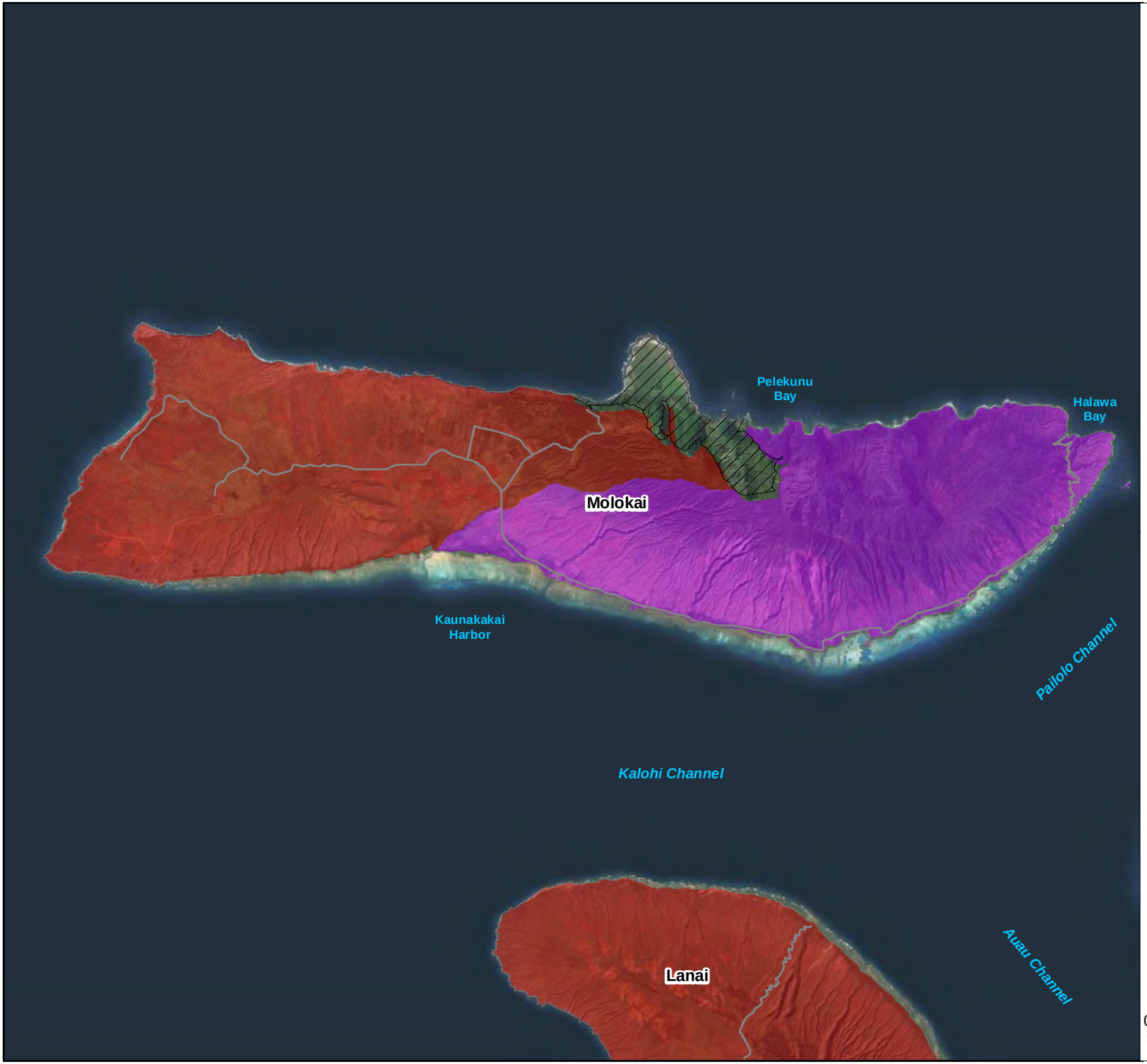
- Category 3: 111-129 mph
- Category 4: 130-156 mph
- Category 5: 157+ mph

Base Map Data Sources:
Maui County, U.S. Geologic
Survey Hazus, ESRI

TETRA TECH

N

0 2.5 5 Miles



Maui County Island of Molokai

Tropical Cyclone 500-Year Probabilistic Peak Gusts

Legend

Kalawao County

Wind Speed

Category 3: 111-129 mph

Category 4: 130-156 mph

Category 5: 157+ mph

Base Map Data Sources: Maui County, U.S. Geologic Survey Hazus, ESRI

TETRA TECH

N

0 3.5 7 Miles

15.2.5 Warning Time

Tropical cyclones are a unique weather phenomenon because they can be closely monitored and tracked. As a result, accurate warnings up to days in advance of the event are possible with the track modeling offering possible storm movement up to a week prior. Track forecasts have improved due in part to the increased numbers of satellites, outfitted with more sophisticated weather-monitoring devices. At the same time, supercomputing power has increased exponentially, and computer models used to forecast a cyclone's direction keep improving (Main, 2014). The National Oceanic and Atmospheric Administration (NOAA) offers multiple watch, warning, and resource tools through their National Hurricane Center including, but not limited to the following (NWS, 2015):

Tropical Cyclone Public Advisory

The Tropical Cyclone Public Advisory contains a list of all current watches and warnings on a tropical or subtropical cyclone. It also gives the cyclone position in terms of latitude and longitude coordinates and distance from a selected land point or island, as well as the current motion. The advisory includes the maximum sustained winds in miles per hour and the estimated or measured minimum central pressure in millibars and inches. The advisory may also include information on potential storm tides, rainfall or tornadoes associated with the cyclone, as well as any pertinent weather observations.

Public advisories are issued for all Atlantic, eastern Pacific and central Pacific tropical or subtropical cyclones. Prior to 2008, public advisories for eastern Pacific and central Pacific tropical or subtropical cyclones were issued only when the cyclones threatened land. Public advisories for eastern Pacific and central Pacific tropical cyclones are normally issued every 6 hours.

Intermediate public advisories may be issued every 3 hours when coastal watches or warnings are in effect, and every 2 hours when coastal watches or warnings are in effect and land-based radars have identified a reliable storm center. Additionally, special public advisories may be issued at any time due to significant changes in warnings or in the cyclone.

Tropical Cyclone Forecast/Advisory

The Tropical Cyclone Forecast/Advisory contains a list of all current watches and warnings on a tropical or subtropical cyclone, as well as the current latitude and longitude coordinates, intensity, and system motion. The advisory contains forecasts of the cyclone positions, intensities, and wind fields for 12, 24, 36, 48, and 72 hours from the current synoptic time. The advisory may also include information on any pertinent storm tides associated with the cyclone. All wind speeds in the forecast advisory in given in knots (nautical miles per hour). Forecast/advisories are issued on all eastern Pacific tropical and subtropical cyclones every 6 hours.

Tropical Cyclone Discussion

The Tropical Cyclone Discussion explains the reasoning for the analysis and forecast of a tropical or subtropical cyclone. It includes a table of the forecast track and intensity. Tropical Cyclone Discussions are issued on all Atlantic and eastern Pacific tropical and subtropical cyclones every 6 hours. Special tropical cyclone discussions may be issued at any time due to significant changes in warnings or in the cyclone. Tropical Cyclone Discussions for eastern and central Pacific tropical cyclones are normally issued every 6 hours.

15.2.6 Potential Impacts of Climate Change

A tropical storm's strong winds and intense low pressure can generate storm surge along coastal communities. While not all tropical storms will have devastating impacts or create significant levels of storm surge, the surge index record shows a significant positive trend between warmer years and extreme events (i.e., Katrina-level events). In fact, one scientist noted that basinwide Category 4 and 5 hurricanes could increase up to 81 percent in frequency with a temperature increase of only 2.5ºC. While surge levels will vary because of situational factors, projected changes in hurricane surge levels above the mean sea level in Hawaii are more likely to increase than decrease with global warming (i.e., results range from a 10 percent reduction to 50 percent increase with a 2.8ºC temperature increase).

Figure 15-11 provides a visual representation of the number of Katrina-magnitude surge events per decade in the past and projected changes. Each line shows the results based off different modeling techniques and data contributions. Although there is some variation depending on the model, the results show an overall positive correlation between temperature/climate increase and storm surge frequency (Grinsted et al., 2013). Although this study is focused on hurricanes and the Atlantic Ocean, which are not exactly comparable to the tropical cyclone events that impact the County of Maui, these results still highlight how a small temperature change can significantly increase damages and vulnerability. In addition, Hawaii is expected to see an additional increase in tropical cyclone events unrelated to the increase from warmer temperatures, as the storm track may shift north toward the Central North Pacific (University of Hawaii, 2014).

Source: Grinsted et al., 2013

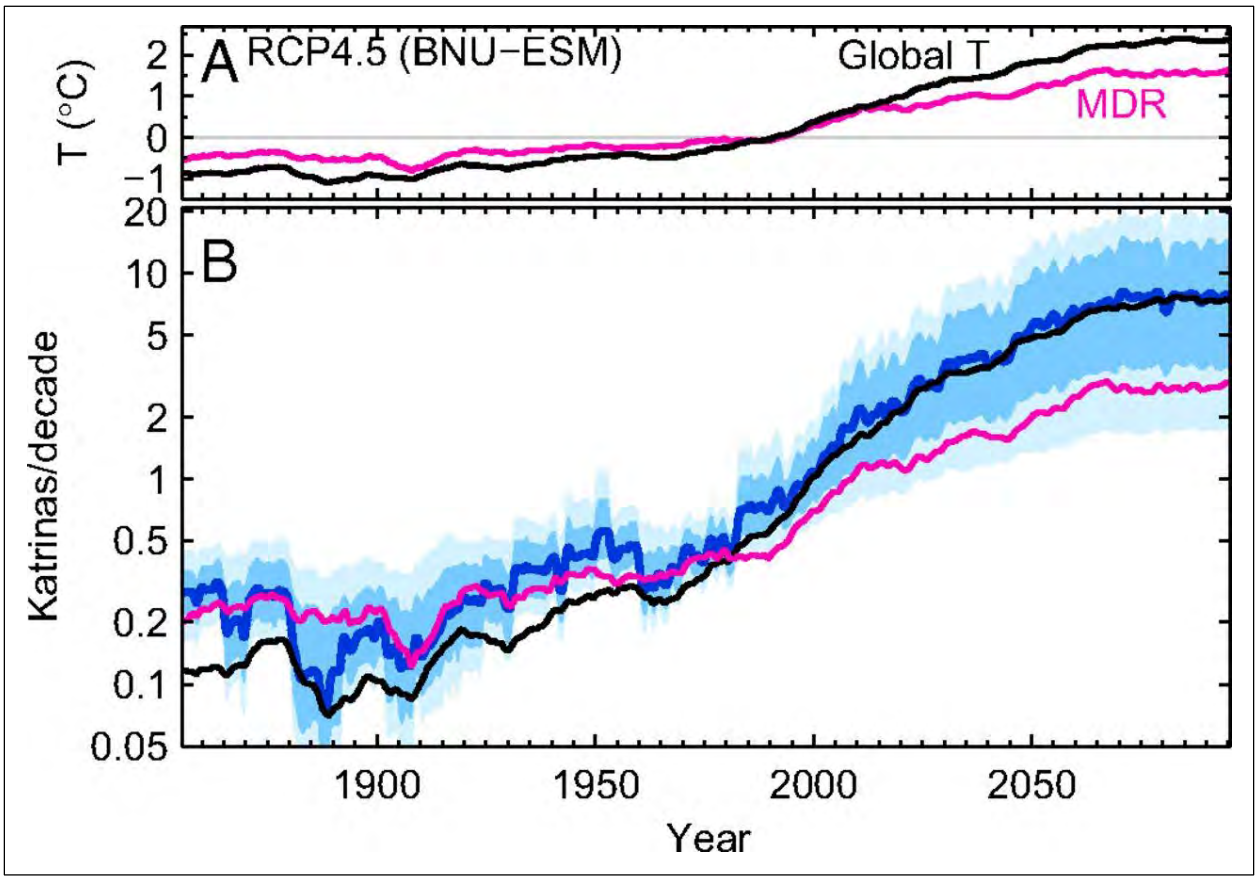


FIGURE 15-11. SURGE EVENT FREQUENCY OVER TIME AND CLIMATE CHANGES

The projected increase in sea level rise has the potential to increase risk of storm surge-related flooding along the coast; expand areas at-risk of coastal flooding; increase vulnerability of energy facilities located in coastal areas; flood transportation and telecommunication facilities; and cause saltwater intrusion into some freshwater supplies near the coasts. High water levels, strong winds, and heavy precipitation resulting from severe coastal storms already cause billions of dollars in damages and disrupt transportation and utility distribution systems. Sea level rise will lead to more frequent and extensive coastal flooding. Warming ocean waters raise sea level through thermal expansion and have the potential to strengthen the most powerful tropical cyclones.

15.2.7 Secondary Hazards

The main threat of tropical cyclones is storm surge and high wind speed. Other factors regularly associated with tropical cyclones cause secondary hazards including landslides, flooding, coastal erosion, storms, and high surf.

15.3 Exposure

15.3.1 Population

It is assumed that the entire County's resident and visitor population is exposed to this storm hazard, though the impact of a severe storm on life, health and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided.

15.3.2 Property

All property in the planning area is exposed to the tropical cyclone hazard. Exposure is particularly severe along the coastline and in areas prone to riverine flooding and or high wind gusts.

15.3.3 Critical Facilities and Assets

All critical facilities and assets within the planning area are exposed to the tropical cyclone hazard.

15.3.4 Onshore and Offshore Natural Environment

All areas of the environment are exposed to the tropical cyclone hazard.

15.4 Vulnerability

15.4.1 Population

The planning area is densely populated along its coastal shores and thus vulnerable to storm surge. Economically disadvantaged populations are exposed to this hazard because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most exposed because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention that may not be available due to isolation during a storm event.

Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Furthermore, there are estimated to be 54,233 visitors in Maui County on any given day. This visitor population would also be considered to be vulnerable to tropical cyclone hazards.

Impacts on persons and households in the planning area were estimated for the 50-year, 100-year and 500-year tropical cyclone events through the Level 2 Hazus-MH analysis. Table 15-2 summarizes the results. It is important to note that these sheltering estimates are for the wind-only hazard. Therefore, additional households may be displaced and require shelter due to other impacts such as flooding and storm surge.

TABLE 15-2.
ESTIMATED TROPICAL CYCLONE IMPACT ON PERSONS AND HOUSEHOLDS

	Number of Displaced	Number of Persons Requiring Short-Term Shelter		
Earthquake Event	**Households**	**Residents**	**Visitors**	**Total**
50-Year Tropical Cyclone	210	51	54,233	54,284
100-Year Tropical Cyclone	1864	427	54,233	54,660
500-Year Tropical Cyclone	12,980	2,988	54,233	57,221

15.4.2 Property

Property losses were estimated through the Level 2 Hazus-MH analysis for the 50-year, 100-year and 500-year tropical cyclone events. Wind-only impacts from a severe storm are reported based on the probabilistic hurricane runs in Hazus-

MH. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with a tropical cyclone. Table 15-3 and Table 15-4 show the results for two types of property loss:

- Structural loss, representing damage to building structures
- Non-structural loss, representing the value of lost contents.

The total of the two types of losses is also shown in the tables. A summary of the property-related loss results is as follows:

- For the 50-year probabilistic tropical cyclone, the estimated damage potential is $357.3 million, or less than 1 percent of the total replacement cost value for the planning area. The estimated peak gust wind speeds for this event equate to a Category 1 hurricane.
- For the 100-year probabilistic tropical cyclone, the estimated damage potential is $1.6 billion, or less than 3.6 percent of the total replacement cost value for the planning area. The estimated peak gust wind speeds for this event equate to a Category 2 hurricane.
- For the 500-year probabilistic tropical cyclone, the estimated damage potential is $11.9 billion, or nearly 26 percent of the total replacement cost value for the planning area. The estimated peak gust wind speeds for this event equate to a Category 5 hurricane.

The Hazus-MH analysis also estimated the amount of wind damage-caused debris in the planning area for the 50-, 100- and 500-year tropical cyclone events, as summarized in Table 15-5.

TABLE 15-3.
LOSS ESTIMATES FOR 50-YEAR PROBABILISTIC TROPICAL CYCLONE

	Estimated Loss Associated with Tropical Cyclone		
Community Planning Area	**Structure**	**Contents**	**Total**
Hana	$4,391,069	$1,525,523	$5,916,592
Kihei-Makena	$18,538,597	$2,537,197	$21,075,794
Lanai	$2,045,805	$253,549	$2,299,354
Makawao-Pukalani-Kula	$46,211,796	$15,888,905	$62,100,702
Molokai	$83,778,636	$30,903,714	$114,682,350
Paia-Haiku	$5,821,828	$1,654,019	$7,475,847
Wailuku-Kahului	$25,388,620	$4,717,508	$30,106,129
West Maui	$99,135,143	$14,533,168	$113,668,311
Total	**$285,311,494**	**$72,013,585**	**$357,325,078**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 15-4.
LOSS ESTIMATES FOR 100- AND 500-YEAR PROBABILISTIC TROPICAL CYCLONE

Community Planning Area	Estimated Loss Associated with Tropical Cyclone					
	100- Year Tropical Cyclone			500- Year Tropical Cyclone		
	Structure	Contents	Total	Structure	Contents	Total
Hana	$87,911,044	$40,685,252	$128,596,296	$33,746,786	$14,176,983	$47,923,769
Kihei-Makena	$435,605,441	$109,789,639	$545,395,079	$2,114,461,045	$847,725,830	$2,962,186,875
Lanai	$256,158	$35,597	$291,755	$129,172,822	$56,248,784	$185,421,606
Makawao-Pukalani-Kula	$511,364,810	$225,644,468	$737,009,278	$974,222,967	$426,240,677	$1,400,463,645
Molokai	$613,597	$133,978	$747,576	$232,076,735	$106,732,093	$338,808,827
Paia-Haiku	$101,933,961	$35,334,852	$137,268,812	$253,028,638	$97,662,149	$350,690,787
Wailuku-Kahului	$37,493,421	$6,211,467	$43,704,888	$1,695,303,968	$742,157,226	$2,437,461,194
West Maui	$32,547,909	$4,997,208	$37,545,117	$2,851,417,838	$1,293,319,537	$4,144,737,375
Total	**$1,207,726,341**	**$422,832,461**	**$1,630,558,802**	**$8,283,430,800**	**$3,584,263,278**	**$11,867,694,078**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 15-5.
WIND DAMAGE-CAUSED DEBRIS

	Structure Debris to Be Removed (tons)	Tree Weight (tons)	Eligible Tree Volume (cubic yards)
50-Year Tropical Cyclone	27,042,000	221,475	127,155
100-Year Tropical Cyclone	118,743,000	442,452	209,246
500-Year Tropical Cyclone	771,745,000	770,517	540,904

15.4.3 Critical Facilities and Assets

Hazus-MH estimates the probability that critical facilities and assets may sustain damage as a result of 50-year, 100-year, and 500-year MRP wind-only events. Additionally, Hazus-MH estimates the loss of use for each facility in number of days. Table 15 7 through Table 15 9 summarize the estimated impacts on critical facilities and assets for the 50-, 100-, and 500-year events.

Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to storm surge and cascading effects such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs.

Utility structures could suffer damage associated with falling tree limbs or other debris. Such impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to citizens (including the young and elderly, who are particularly vulnerable to temperature-related health impacts).

15.4.4 Onshore and Offshore Natural Environment

In general, the environmental vulnerabilities include direct and secondary hazard effects from the tropical cyclone hazard. Direct effects include those caused by a tropical cyclone's associated wind speed velocity. High wind speed causes storm surge on Maui County's coastline, exacerbating the rate in which the coast erodes. While natural processes replenish and revitalize the damaged coastline, a series of tropical cyclones have the potential to permanently change the topography of Maui County's beaches. Additionally, high winds speeds affect natural vegetation within the planning area. Effects include downed trees and blocked waterways. Severity of the effect of downed debris depends on the location and magnitude of material. Tropical cyclones can also significantly add to the acidification problems currently being suffered by coral reefs as the carbon dioxide content of the oceans continues to increase. The change in salinity and PH levels of the ocean is not short-lived after a tropical cyclone and not only affects living coral reefs but can dissolve the existing coral structure, which are the skeletons of past coral generations (Tripp, 2013).

Indirect effects of tropical cyclones on the environment mainly deal with flooding, which has the potential to upset the natural balance of the County's ecosystems. This is of particular concern when dealing with the compounding effects of multiple events in a single season.

TABLE 15-6.
DAMAGE TO CRITICAL FACILITIES FROM 50-YEAR TROPICAL CYCLONE

Category[a]	Average Loss of Use in Days	No Damage or Minor Damage	Moderate Damage	Severe Damage	Complete Damage
Emergency Services	7	43	1	0	0
Government[b] and Services	4	92	0	0	0
Critical Infrastructure and Lifelines	-	-	-	-	-
Other Important Assets	1	3	0	0	0
Total	**4**	**138**	**1**	**0**	**0**

a. Vulnerability not estimated for all facilities and assets due to lack of established damage functions for these type facilities.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

TABLE 15-7.
DAMAGE TO CRITICAL FACILITIES FROM 100-YEAR TROPICAL CYCLONE

Category[a]	Average Loss of Use in Days	No Damage or Minor Damage	Moderate Damage	Severe Damage	Complete Damage
Emergency Services	29	41	1	2	0
Government[b] and Services	11	87	0	5	0
Critical Infrastructure and Lifelines	-	-	-	-	-
Other Important Assets	1	3	0	0	0
Total	**14**	**131**	**1**	**7**	**0**

a. Vulnerability not estimated for all facilities and assets due to lack of established damage functions for these type facilities.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

TABLE 15-8.
DAMAGE TO CRITICAL FACILITIES FROM 500-YEAR TROPICAL CYCLONE

Category[a]	Average Loss of Use in Days	No Damage or Minor Damage	Moderate Damage	Severe Damage	Complete Damage
Emergency Services	92	26	12	5	1
Government[b] and Services	83	10	16	66	0
Critical Infrastructure and Lifelines	-	-	-	-	-
Other Important Assets	256	0	0	3	0
Total	**144**	**36**	**28**	**74**	**1**

a. Vulnerability not estimated for all facilities and assets due to lack of established damage functions for these type facilities.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

15.4.5 Economic Impact

Hurricanes also impact the economy, including: loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. Hazus-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building.

For the 50-year MRP wind only event, Hazus-MH estimates $27.7 million in business interruption losses for the planning area, which includes loss of income, relocation costs, rental costs and lost wages. For the 100-year MRP wind event, Hazus-MH estimates $140.7 million in business interruption costs. For the 500-year MRP wind only event, Hazus-MH estimates $1.3 billion in business interruption losses.

15.5 Future Trends in Development

There is no single reference documenting the historic criteria used for wind design of structures in each county of Hawaii, however, Hawaii design wind pressures have changed over the years through different editions of the Uniform Building Code (UBC) and more recently the International Building Code (IBC). In the case of the IBC, design wind pressures have changed through different editions of the referenced American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7) standard. The design vintage can be used as an indicator of a building's susceptibility to wind damage. Design wind pressures, typical construction type (single or double wall), and use of hurricane uplift resistance can all be determined by the year built based on the corresponding version of the UBC or IBC in effect at the time (County of Maui, 2010a).

The current Maui building code includes specific provisions for future development regarding hurricane-resistant construction.

15.6 Scenario

A worst case scenario event would be a direct hit to Maui County by a category 3 or stronger hurricane. An event of such magnitude would result in widespread damages to private and public property including critical facilities and assets. Long-term power outages would be expected, which may result in loss of utilities such as potable water and wastewater systems. Loss of transportation facilities such as the harbor and airport would exasperate the magnitude of the event by taxing already limited resources and further isolating the islands from response and recovery resources. Many facilities and structures would require months or years to return to pre-event functionality. Long-terms impacts to tourism, supporting industries and the local tax base would be expected.

15.7 Issues

Important issues associated with the tropical cyclone hazard include but are not limited to the following:

- **Emergency Shelter Wind speed Capability Assessment**—Because of the secondary hazards associated with tropical cyclones, emergency shelters are often needed to house residents displaced by collapsing houses or rising flood waters. The County should begin making efforts to test their emergency shelters to ensure that they can withstand sustained wind speeds comparable to a Category 2 hurricane.
- **SLOSH Data—** NOAA is currently developing an updated sea, lake, and overland surges from hurricane (SLOSH) dataset. This data should be incorporated into future plan updates.

Chapter 16. Tsunami

16.1 Hazard Description

A tsunami consists of a series of high-energy waves that radiate outward like pond ripples from an area where a generating event occurs. The waves arrive at shorelines over an extended period.

DEFINITIONS

Tsunami—A series of traveling ocean waves of extremely long wavelength usually caused by displacement of the ocean floor and typically generated by seismic or volcanic activity or by underwater landslides.

Tsunamis are typically classified as local or distant. Locally generated tsunamis have minimal warning times, leaving few options except to run to high ground. They may be accompanied by damage resulting from the triggering earthquake due to ground shaking, surface faulting, liquefaction or landslides. Distant tsunamis may travel for hours before striking a coastline, giving a community a chance to implement evacuation plans.

In the open ocean, a tsunami may be only a few inches or feet high, but it can travel with speeds approaching 500 miles per hour. As a tsunami enters the shoaling waters near a coastline, its speed diminishes, its wavelength decreases, and its height increases greatly. The first wave usually is not the largest. Several larger and more destructive waves often follow the first one. As tsunamis reach the shoreline, they may take the form of a fast-rising tide, a cresting wave, or a bore (a large, turbulent wall-like wave). The bore phenomenon resembles a step-like change in the water level that advances rapidly (from 10 to 60 miles per hour).

The configuration of the coastline, the shape of the ocean floor, and the characteristics of advancing waves play important roles in the destructiveness of the waves. Offshore canyons can focus tsunami wave energy and islands can filter the energy. The orientation of the coastline determines whether the waves strike head-on or are refracted from other parts of the coastline. A wave may be small at one point on a coast and much larger at other points. Bays, sounds, inlets, rivers, streams, offshore canyons, islands, and flood control channels may cause various effects that alter the level of damage. It has been estimated, for example, that a tsunami wave entering a flood control channel could reach a mile or more inland, especially if it enters at high tide.

The first visible indication of an approaching tsunami may be recession of water (draw down) caused by the trough preceding the advancing, large inbound wave crest. Rapid draw down can create strong currents in harbor inlets and channels that can severely damage coastal structures due to erosive scour around piers and pilings. As the water's surface drops, piers can be damaged by boats or ships straining at or breaking their mooring lines. The vessels can overturn or sink due to strong currents, collisions with other objects, or impact with the harbor bottom.

Conversely, the first indication of a tsunami may be a rise in water level. The advancing tsunami may initially resemble a strong surge increasing the sea level like the rising tide, but the tsunami surge rises faster and often does not break as a normal wave. Additionally, this surge of water does not stop at the shoreline and pushes above normal sea level tidal reach. This phenomenon is called "run-up" (Figure 16-1).

Even if the run up appears to be small, 3 to 6 feet for example, the strength of the accompanying surge can be deadly. Waist-high surges can cause strong currents that float cars, small structures, and other debris. Boats and debris are often carried inland by the surge and left stranded when the water recedes.

Source: UNESCO, n.d.

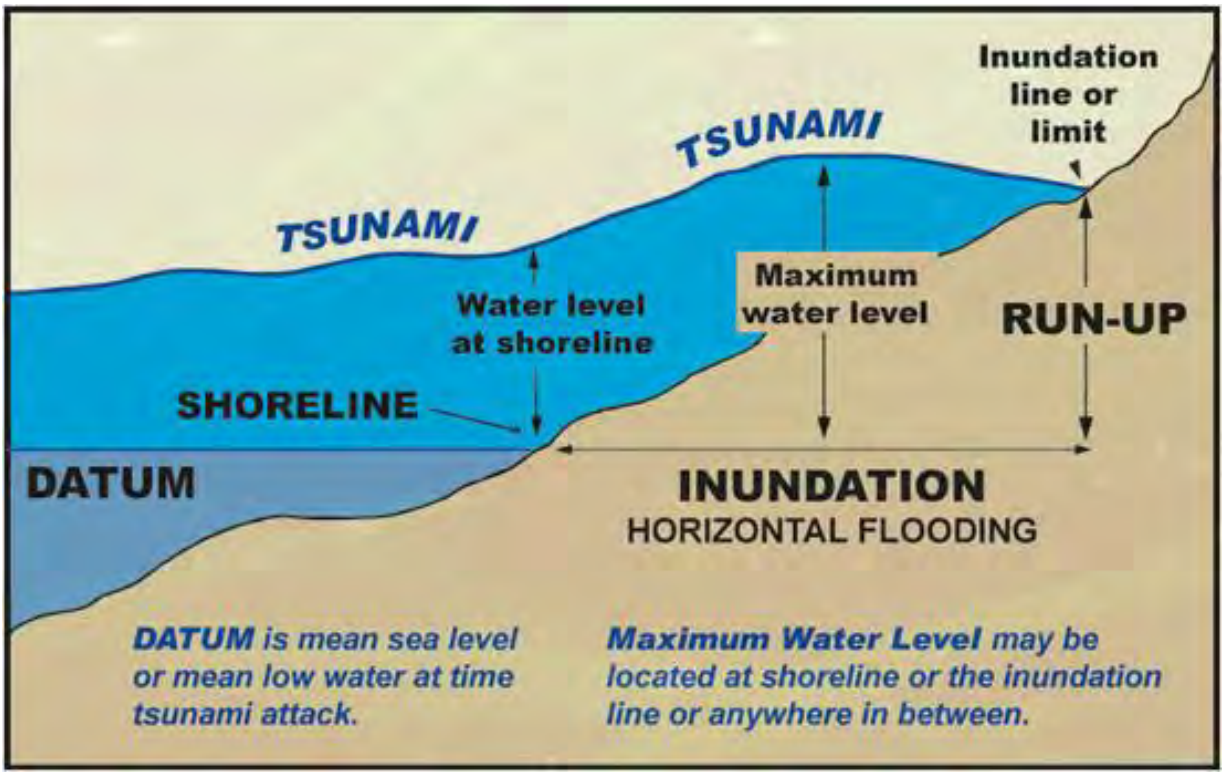


FIGURE 16-1. RUN-UP DISTANCE AND HEIGHT IN RELATION TO THE DATUM AND SHORELINE

At some locations, the advancing turbulent front will be the most destructive part of the tsunami. In other situations, the greatest damage will be caused by the outflow of water back to the sea between crests, sweeping all before it and undermining roads, buildings, bulkheads, and other structures. This outflow action can carry enormous amounts of highly damaging debris with it, resulting in further destruction. Ships and boats, unless moved away from shore, may be dashed against breakwaters, wharves, and other craft, or be washed ashore and left grounded after the withdrawal of the seawater.

Typical signs of a tsunami hazard are earthquakes and/or sudden and unexpected rise or fall in coastal water. The large waves are often preceded by coastal flooding and followed by a quick recession of the water. Tsunamis are difficult to detect in the open ocean because waves are often less than 3 feet high. The tsunami's size and speed, as well as the coastal area's form and depth, affect the impact of a tsunami; wave heights of 50 feet are not uncommon. In general, scientists believe it requires an earthquake of at least a magnitude 7 to produce a tsunami.

16.1.1 Sources of Tsunamis

Tsunamis can be categorized according to their source into three common types: tsunamis induced by earthquakes, tsunamis induced by landslides, and tsunamis induced by submarine volcanic explosions. Figure 16-2 illustrates the

three most common types of tsunamis. All three tsunami types will be discussed in the following sections (County of Maui, 2010a).

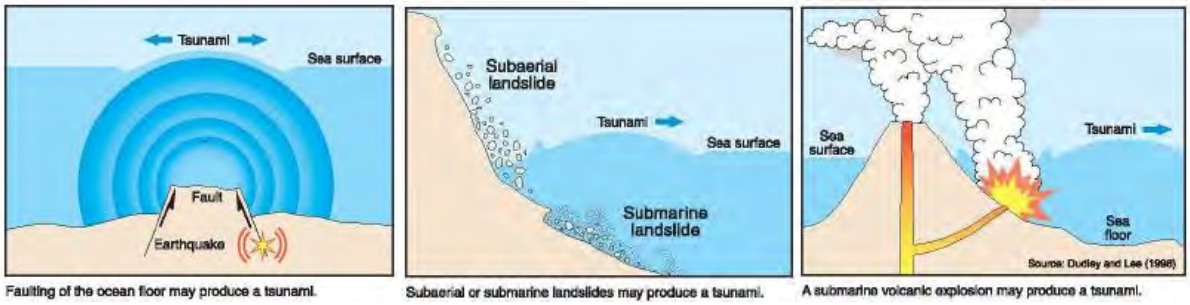


FIGURE 16-2. COMMON SOURCES OF TSUNAMIS

Tsunamis Induced by Earthquakes

The earthquakes associated with tsunamis are referred to as "tsunamigenic earthquakes." The association between earthquakes and tsunamis results from the fact that both are generated by the tectonic displacement of the earth's crust. 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 (County of Maui, 2010a).

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 feature 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 (County of Maui, 2010a).

Tsunamis Induced by Landslides

The second most common cause of tsunamis is landslides. 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 cause tsunamis 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 (County of Maui, 2010a).

Submarine landslides often occur during a large earthquake. 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. For example, the Hawaiian island chain is flanked by at least 20 large submarine landslides. Marine deposits found 230 feet above sea level in the Island of Molokai must have been deposited by tsunamis caused by one of these landslides. Deposition in association with higher sea levels is ruled out since the Hawaiian Islands have probably experienced long-term subsidence instead of uplift (County of Maui, 2010a).

Additional sedimentary evidence of landslide-induced tsunamis in Hawaiian Islands is believed to have been found approximately 200 feet above sea level on the flanks of the Kohala volcano in the northern tip of the Island of Hawaii (County of Maui, 2010a).

Sub-aerial (above water) landslides, on the other hand, disturb the water from above the surface. Similar to submarine landslides, sub-aerial landslides typically occur during large earthquakes. A particular type of tsunami generated by sub-aerial landslides is the type that originates from the collapse of the flanks of volcanic islands. For instance, evidence suggests that a major slope failure on the Island of Hierro in the Canary Islands between 17 and 13 thousand years before present time may have generated a very destructive tsunami in the Atlantic Ocean (County of Maui, 2010a).

Tsunamis Induced by Submarine Volcanic Explosions

At the present time, three island volcanoes are the subject of controversial studies pertaining to their potential to generate very destructive tsunamis following the collapse of their flanks: Cumbre Vieja volcano on the Island of La Palma in the Canary Islands, and Mauna Loa and Kilauea volcanoes on the Island of Hawaii in the Hawaiian Islands. Review of submarine geology around Mauna Loa volcano on the Island of Hawaii shows evidence of past landslides along the volcano's southwestern flank (County of Maui, 2010a).

16.2 Hazard Profile

16.2.1 Past Events

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. The cause of tsunamis was not generally known, nor was the origin in terms of whether the tsunami was the result of a seismic event in a distant source such as the Aleutian Islands of Alaska or a local submarine landslide in the Hawaiian Islands. Toward the end of the 19th century, seismological stations became available to record and locate earthquakes. Through the instruments in these stations, it became easier to associate distant earthquakes with tsunamis in Hawaii. The establishment of the Hawaii Volcano Observatory in 1912 brought the expertise needed to accurately determine the origin and causes of local earthquakes and tsunamis in the islands. After the 1946 tsunami, the Tsunami Warning System was established and a group of experts was constituted to track and document origin, wave heights, and other data pertinent to tsunamis (County of Maui, 2010a).

Up to May 2010, 27 tsunamis with run-up heights greater than 3.3 feet (1 meter) have made landfall in the Hawaiian Islands during recorded history and 8 have had significant damaging effects on Maui, Molokai or Lanai (Fletcher et al., 2002). In fact, tsunamis in the Hawaiian Archipelago have commutatively killed the largest number of people of all natural hazards affecting the islands. The last destructive tsunami to affect the Hawaiian Islands occurred in 1975 (County of Maui, 2010a).

Tsunamis reaching the islands of Maui, Molokai, and Lanai have exhibited tremendous variability in terms of their run-up heights, inundation distances, and the damage they have inflicted. Figure 16-3 through Figure 16-5 show maps of these islands (courtesy of the Tsunami Memorial Institute) indicting historic tsunami run-up heights. As can be seen on the maps, during the April 1, 1946 tsunami, run-up heights within only a few miles along the south shore of the Island of Maui varied by over 10 feet between Huakini Bay (run-up of 10 feet) and Mokuia Point (run-up of 21 feet). The same

tsunami on Molokai had run-up heights of 7 and 44 feet on the east and west sides of the Kalaupapa Peninsula, respectively (County of Maui, 2010a).

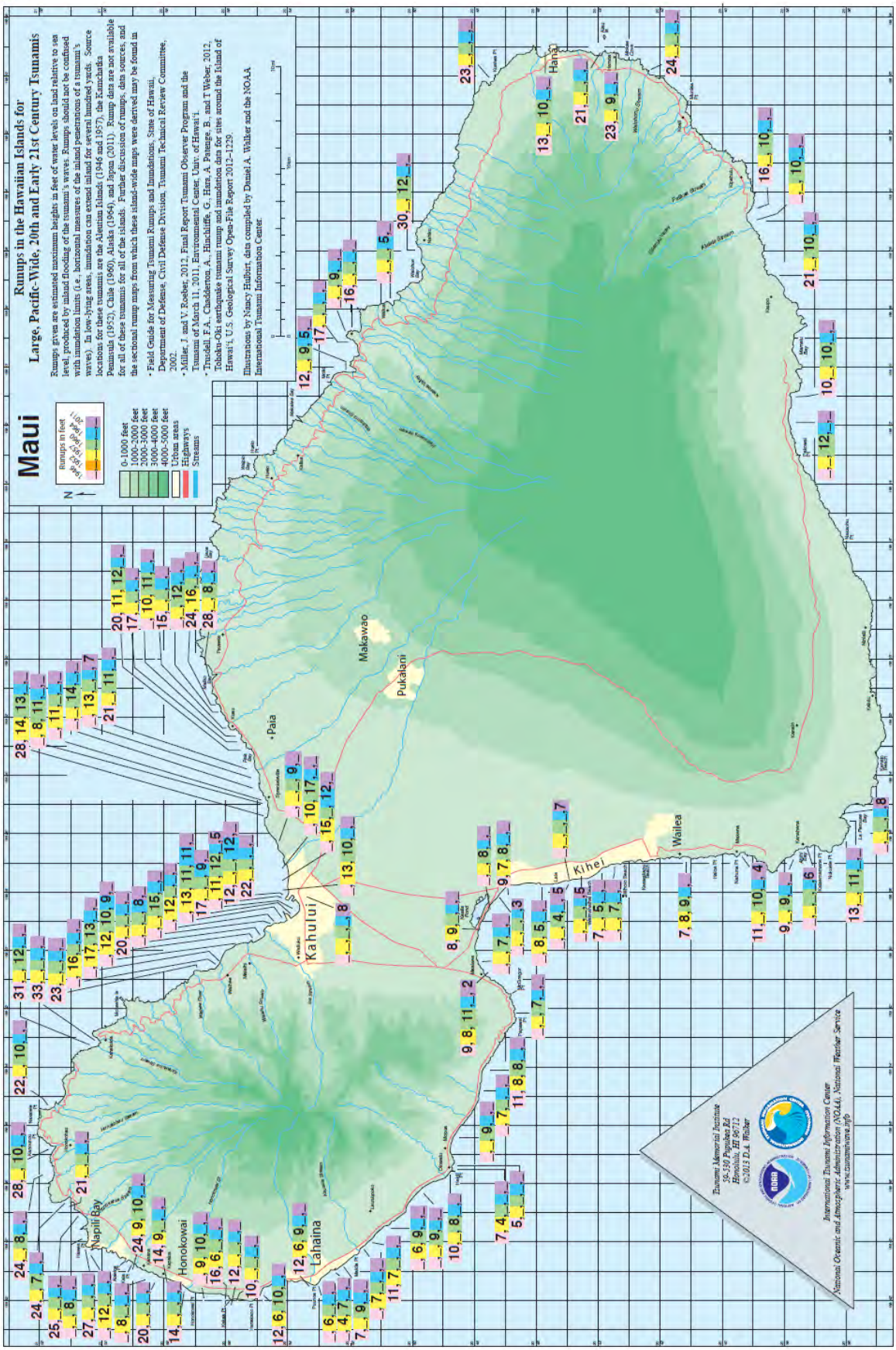


FIGURE 16-3. ISLAND OF MAUI – RUN-UPS HISTORY

Source: ITIC, 2013

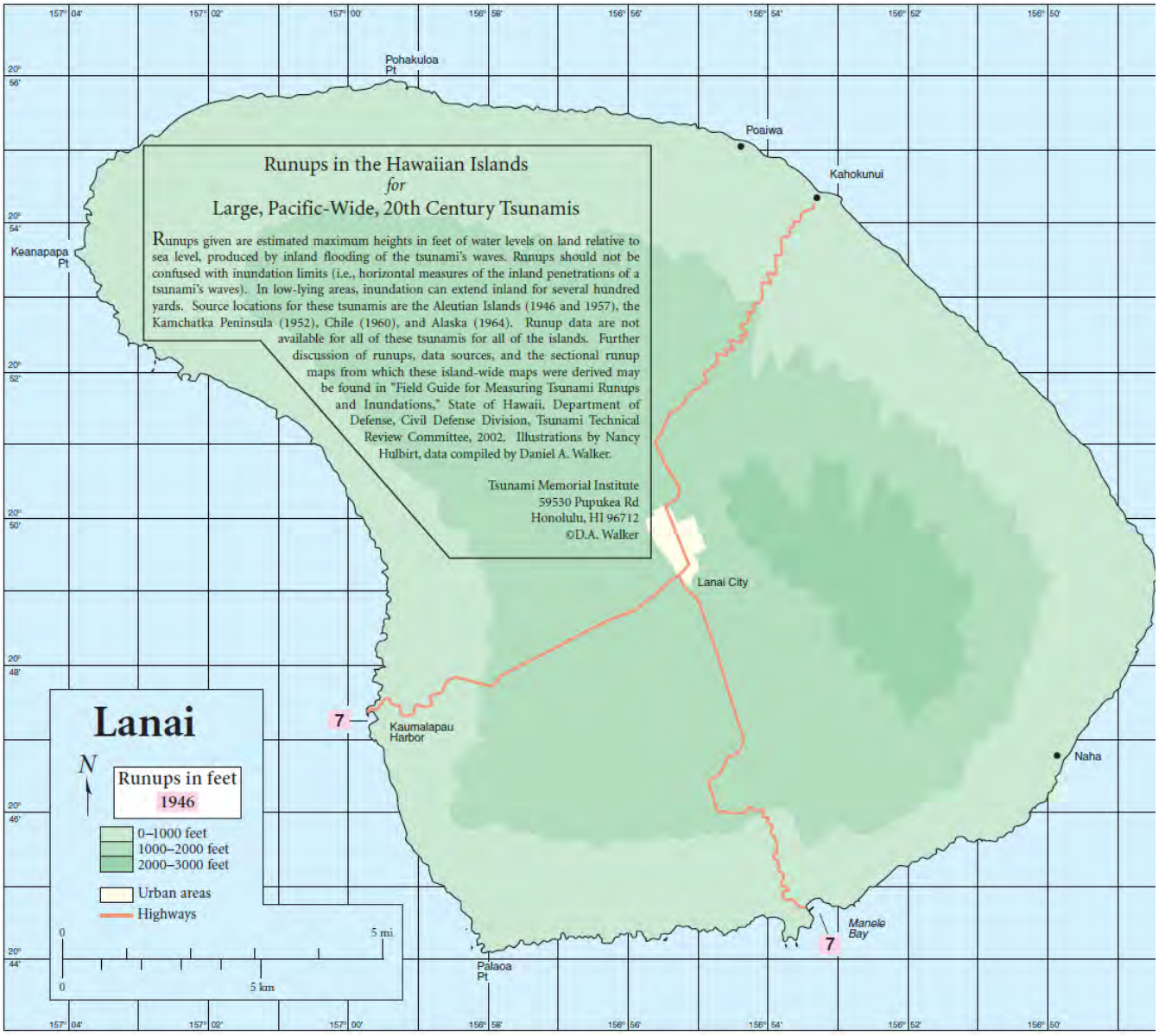


FIGURE 16-4. ISLAND OF LANAI – RUN-UP HISTORY

Source: ITIC, 2013

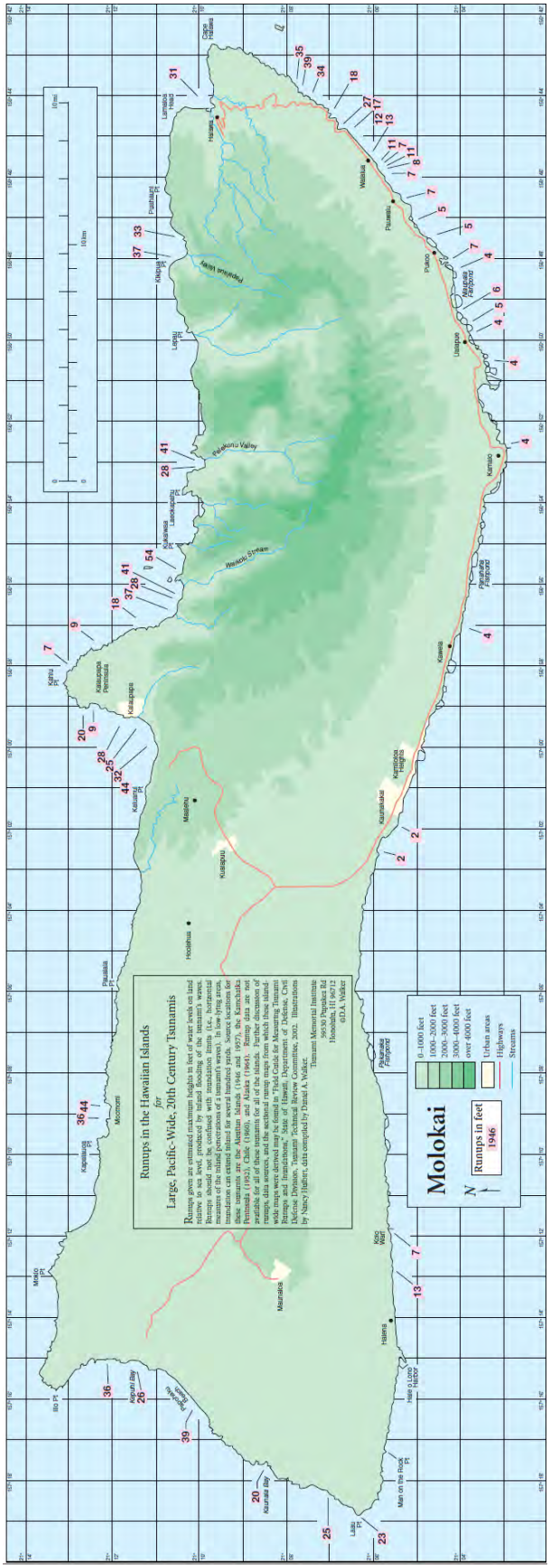


FIGURE 16-5. ISLAND OF MOLOKAI – RUN-UP HISTORY

Source: ITIC, 2013

The highest run-ups on the Island of Maui during the April 1946 tsunami occurred at Kahakuloa on the northern coast of the island. Waves up to 33 feet tall struck the shores of this community and destroyed three homes situated at about 20 feet above sea level. At Honolua and Honokohau, 24 to 28-foot waves destroyed homes, roads, and bridges. The May 1960 tsunami (generated by the magnitude 9.5 Great Valdivia Earthquake in Chile) 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 much less destructive tsunami hit the Island of Maui in March 1964 (generated by the magnitude 9.2 Great Alaskan Earthquake) with a recorded maximum run-up at Kahului of 12 feet and doing estimated $53,000 (1964 dollars) damage (County of Maui, 2010a). Although not destructive, the latest tsunami to hit the Hawaiian Islands occurred in 2010. This tsunami—generated by a magnitude-8.8 tsunami offshore of the Region of Maule in Chile—arrived on the Island of Hawaii approximately at noon on February 27, 2010. Although very similar in nature to the May 22 tsunami generated by the Valdivia Earthquake also in Chile, the 2010 tsunami did not cause any damage to property, injury, or loss of life because its run-ups were much lower than those of the 1960 tsunami (County of Maui, 2010a).

16.2.2 Location

Tsunamis affecting Maui County may be induced by geologic events of local origin, or earthquakes at a considerable distance, such as in Alaska or South America (see hazard description section above). Most tsunamis originate in the Pacific Ocean, where tsunami waves triggered by seismic activity can travel at up to 500 miles per hour, striking distant coastal areas in a matter of hours (see Figure 16-6).

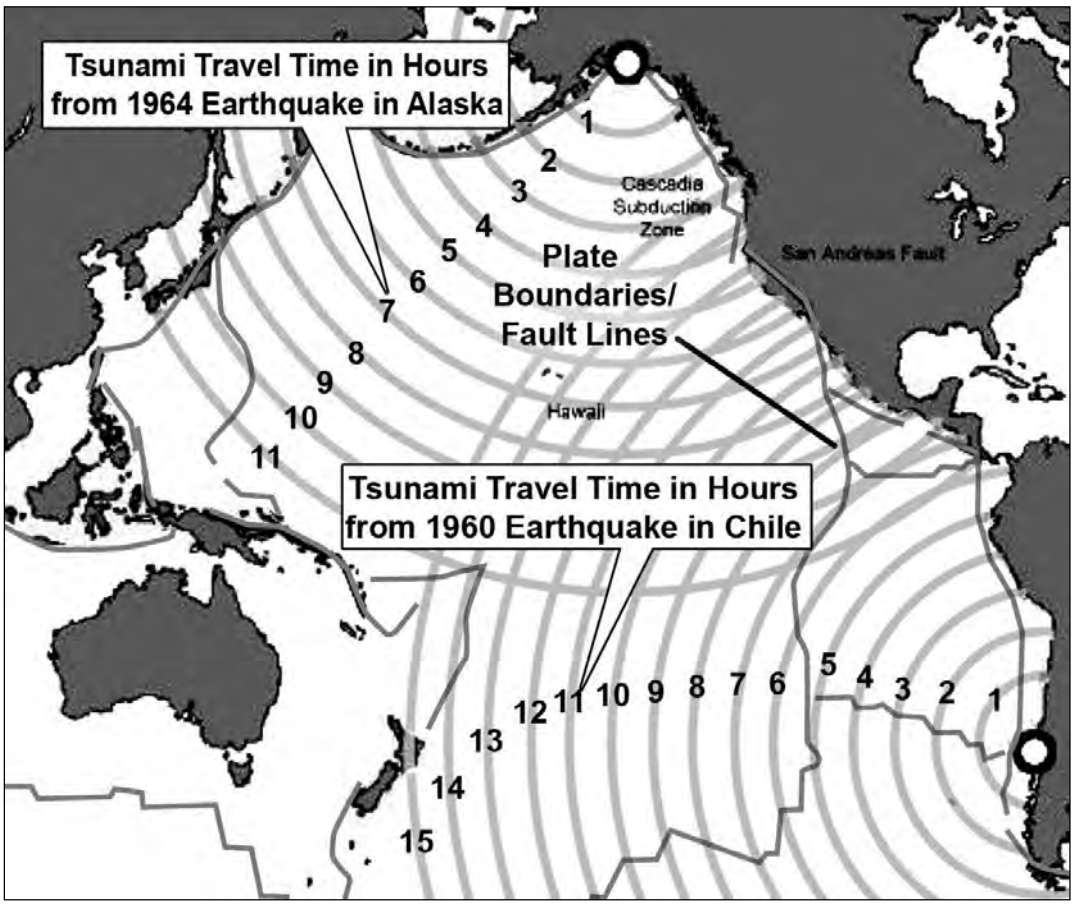


FIGURE 16-6. POTENTIAL TSUNAMI TRAVEL TIMES IN THE PACIFIC OCEAN

According to a document titled *U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*, Hawaii as a whole is classified as a "high hazard" area due to the number of run-ups, frequency of occurrence, and the large number of experienced earthquakes with magnitudes greater than 3.0. Additionally, the state as a whole experienced the highest number of tsunami –associated deaths in the country (Dunbar and Weaver, 2008).

The Maui County Civil Defense Agency and County of Maui GIS division maintain maps of tsunami evacuation zones, as shown on Figure 16-7 through Figure 16-9. These maps were recently updated using more recent scientific techniques and technology, and were produced in conjunction with Maui County Public Safety Officials. These maps are available to the public online (http://www.co.maui.hi.us/index.aspx?NID=261 and form the basis for the risk and vulnerability analysis described in later section of this chapter.

16.2.3 Frequency

The frequency of tsunamis is related to the frequency of the events that cause them, so it is similar to the frequency of seismic or volcanic activities or landslides. Generally four or five tsunamis occur every year in the Pacific Basin, and those that are most damaging are generated in the Pacific waters off South America rather than in the northern Pacific.

16.2.4 Severity

Historic investigation shows that extreme tsunami events, or mega-tsunamis, are possible in the region. The geologic evidence for mega-tsunami in the Hawaiian Islands was recognized first on Lanai and Molokai, where typically ocean-found coral and lava deposits are found as high as 155 meters above sea level. This interpretation has been debated in numerous papers that argue that these high-stand deposits are the result of island uplift. No other data suggest that Lanai is, or has been, uplifted, however, and evidence to the contrary has been gleaned from drowned reefs south of Lanai (Clague and Sherrod, 2014).

16.2.5 Warning Time

The Pacific Tsunami Warning System evolved from a program initiated in 1946. It is a cooperative effort involving 26 countries along with numerous seismic stations, water level stations and information distribution centers. The National Weather Service operates two regional information distribution centers: one located in Ewa Beach, Hawaii; and the other in Palmer, Alaska. The Ewa Beach center also serves as an administrative hub for the Pacific warning system.

The warning system only begins to function when a Pacific basin earthquake of magnitude 6.5 or greater triggers an earthquake alarm. When this occurs, the following sequence of actions occurs:

- Data is interpolated to determine epicenter and magnitude of the event.
- If the event is magnitude 7.5 or greater and located at sea, a TSUNAMI WATCH is issued.
- Participating tide stations in the earthquake area are requested to monitor their gages. If unusual tide levels are noted, the tsunami watch is upgraded to a TSUNAMI WARNING.
- Tsunami travel times are calculated, and the warning is transmitted to the disseminating agencies and thus relayed to the public.
- The Ewa Beach center will cancel the watch or warning if reports from the stations indicate that no tsunami was generated or that the tsunami was inconsequential.

This system is not considered to be effective for communities located close to the tsunami because the first wave would arrive before the data were processed and analyzed. In this case, strong ground shaking would provide the first warning of a potential tsunami.

In addition, NOAA as part of the U.S. National Tsunami Hazard Mitigation Program, implemented the Deep-ocean Assessment and Reporting of Tsunami (DART) project to ensure detection of tsunamis and to acquire data critical to real-time forecasts. DART systems consist of an anchored seafloor bottom pressure recorder (BPR) and a companion moored surface buoy for real-time communications. An acoustic link transmits data from the BPR on the seafloor to the surface buoy. The surface buoy then delivers data to the national Weather Service Telecommunications Gateway that then distributes the data in real-time to the Tsunami Warning Centers. Figure 16-10 depicts the operation of the DART System (NOAA, 2011).

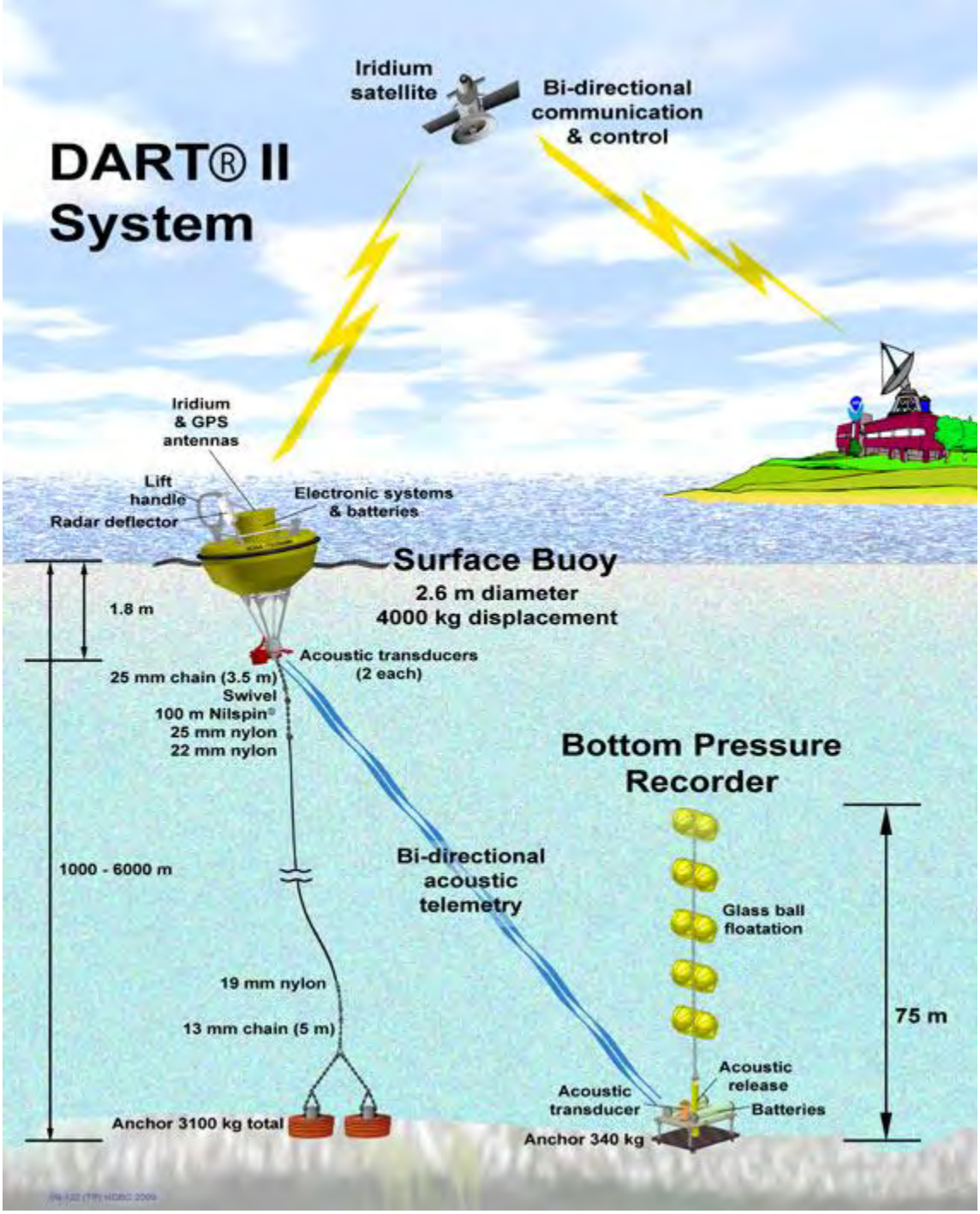
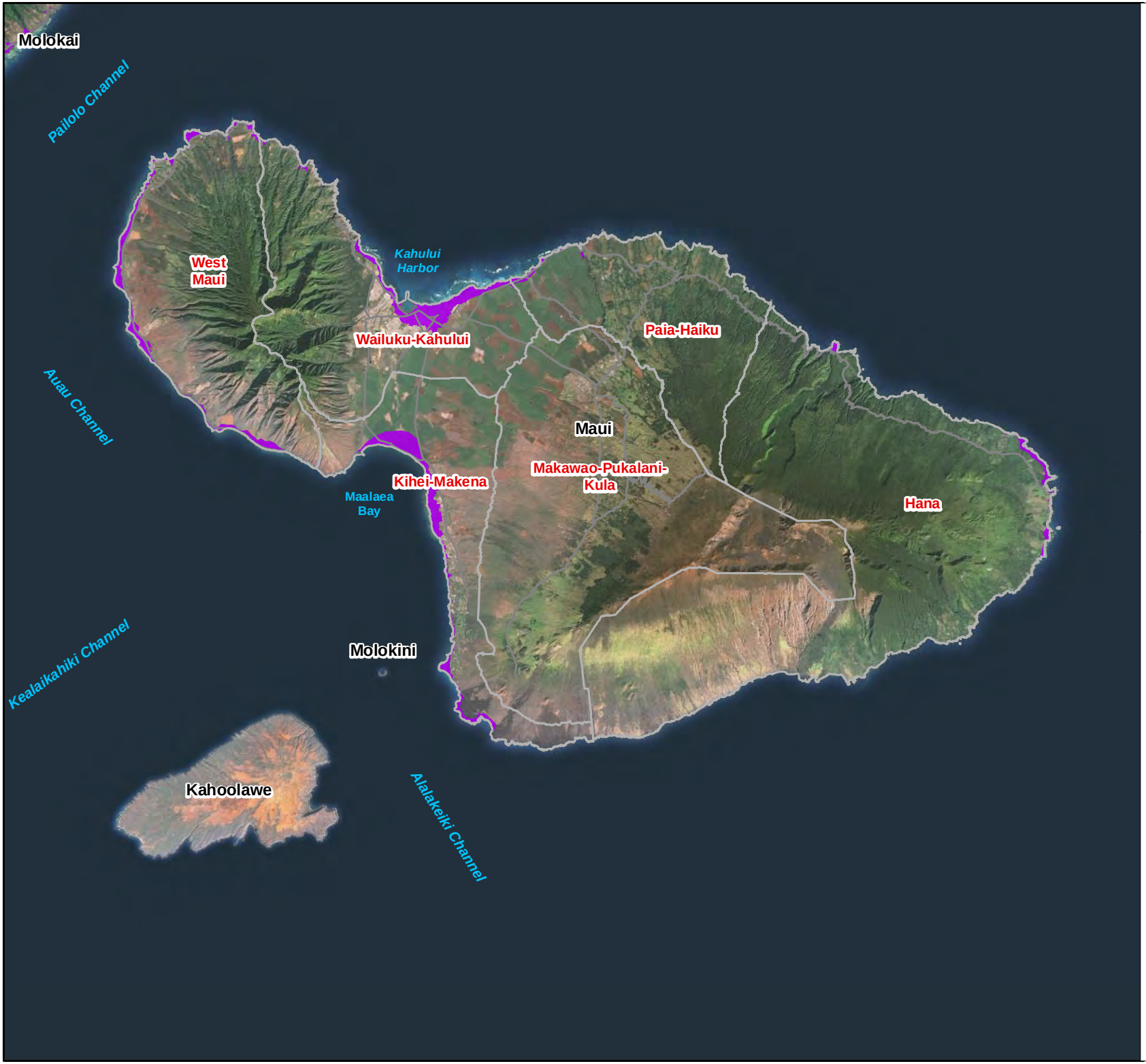


FIGURE 16-7. DART II SYSTEM

Maui County Islands of Maui and Kahoolawe

Tsunami Evacuation Zones



Legend

- Community Plan Boundaries
- Evacuation Zones

Base Map Data Sources:
Maui County, ESRI

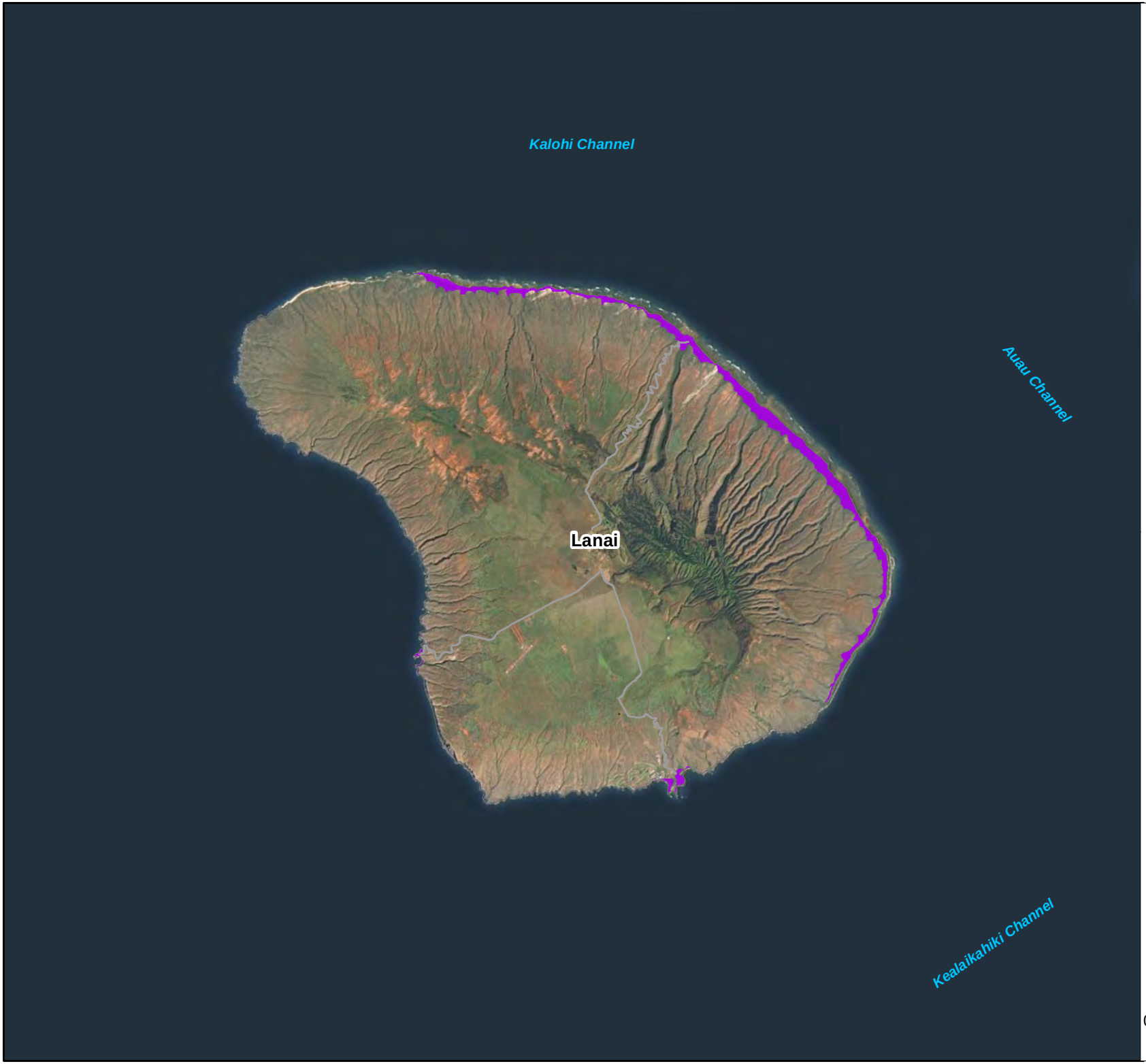
TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Tsunami Evacuation Zones



Legend

Evacuation Zones

Base Map Data Sources:
Maui County, ESRI

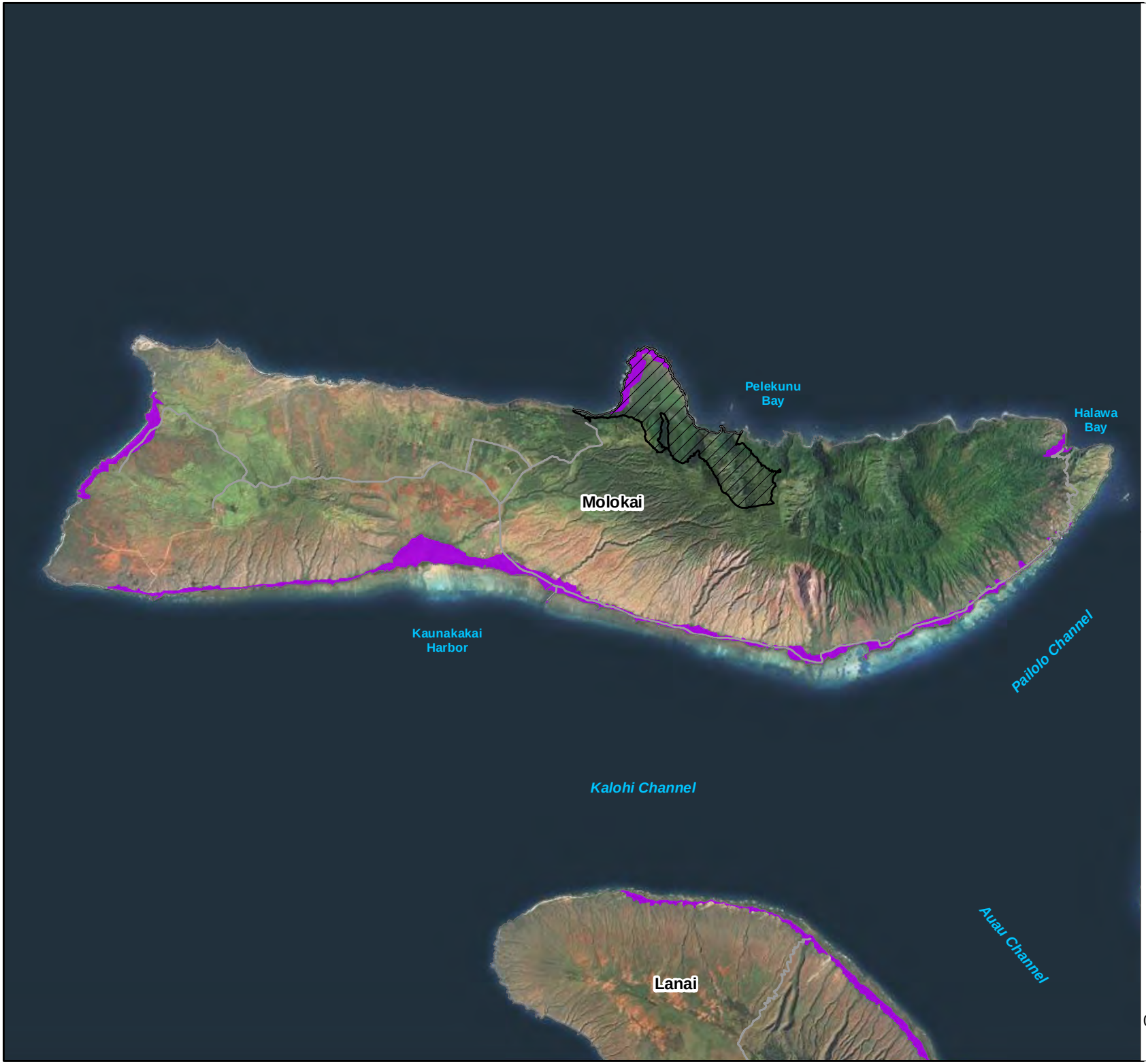
TETRA TECH

N

0 2.5 5 Miles

Maui County Island of Molokai

Tsunami Evacuation Zones



Legend

- Kalawao County
- Evacuation Zones

Base Map Data Sources:
Maui County, ESRI

TETRA TECH

N

0 3.5 7 Miles

16.2.6 Potential Impacts of Climate Change

Any rise is sea level resulting from climate change could increase the risk to coastal communities exposed to the tsunami hazard. Oceanic waves and surge could reach further inland, resulting in more damage to infrastructure and increased life safety concerns.

16.2.7 Secondary Hazards

Floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves.

Port facilities, naval facilities, fishing fleets and public utilities are often the backbone of the economy of the affected areas, and these are the resources that generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and fishing fleets reconstituted, communities may find themselves without fuel, food and employment. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects.

16.3 Exposure

Exposure and vulnerability estimates are based on tsunami evacuation maps.

16.3.1 Population

The population living in tsunami hazard zones was estimated using the percent of buildings within the tsunami evacuation areas for each community planning area and applying this percent to the estimated 2010 population. Using this approach, the estimated resident population living in tsunami risk areas is estimated to be 27,332 or 17.7 percent of the resident population. 34,577 visitors or 63.6 percent of the visitor population are estimated to be staying in tsunami risk areas (see Table 16-1). The populations that would be most exposed to this type of hazard are those along beaches, low-lying coastal areas, tidal flats and stream deltas that empty into ocean-going waters. People recreating in these areas would also be exposed.

TABLE 16-1.
ESTIMATED POPULATION EXPOSURE FOR TSUNAMI EVACUATION AREAS

Community Planning Area	Residents	Visitors	Total
Hana	227	46	273
Kihei-Makena	7,940	6,564	14,504
Lanai	14	0	14
Makawao-Pukalani-Kula	0	0	0
Molokai	2,525	361	2,886
Paia-Haiku	1,385	31	1,416
Wailuku-Kahului	6,115	859	6,974
West Maui	9,126	26,696	35,822
Total	**27,332**	**34,557**	**61,889**

16.3.2 Property

The value of exposed buildings in the tsunami evacuation zone within the planning area was generated by overlaying the evacuation areas on the general building stock and is summarized in Table 16-2. The estimates include the value of both the buildings and their contents. This methodology estimates that that there are 7,766 structures exposed to the tsunami hazard within the planning area, with a replacement value of $13.1 billion.

TABLE 16-2.
EXPOSURE AND VALUE OF STRUCTURES IN TSUNAMI EVACUATION AREAS

	Buildings Exposed	Value Exposed			% of Total Replacement Value
		Structure	Contents	Total	
Hana	109	$24,817,045	$13,297,267	$38,114,313	8.7%
Kihei-Makena	2,154	$1,613,897,226	$916,806,021	$2,530,703,247	26.9%
Lanai	6	$1,015,886	$507,943	$1,523,829	0.2%
Makawao-Pukalani-Kula	0	$0	$0	$0	0.0%
Molokai	1,038	$359,632,956	$216,340,242	$575,973,198	40.3%
Paia-Haiku	528	$156,587,828	$90,839,095	$247,426,922	11.1%
Wailuku-Kahului	1,705	$1,663,139,115	$1,652,634,722	$3,315,773,837	20.1%
West Maui	5,404	$4,166,907,606	$2,272,395,639	$6,439,303,245	64.49%
Total	**7,766**	**$7,985,997,663**	**$5,162,820,928**	**$13,148,818,590**	**28.8%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

Table 16-3 shows the general land use of parcels within the tsunami evacuation areas. The majority of the land area of parcels (58.8 percent) intersecting these areas are agricultural or conservation areas. Residential parcels (apartment and residential) make up 20.8 percent of the total acreage.

TABLE 16-3.
LAND USE IN TSUNAMI EVACUATION AREAS

Land Use	Area in Tsunami Evacuation Area (acres)	% of Total
Agricultural	8,785.81	45.2%
Apartment	367.28	1.9%
Commercial	1,240.47	6.4%
Commercialized Residential	9.45	0.0%
Conservation	2,645.53	13.6%
Hotel/Resort	687.78	3.5%
Industrial	730.37	3.8%
Residential	3,672.23	18.9%
Time Share	11.72	0.1%
Not Classified	1,308.16	6.7%
Total	**19,458.79**	**100.0%**

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified." Acreage includes only areas intersecting mapped hazard layers.

16.3.3 Critical Facilities and Assets

Roads or potential railroads that are blocked or damaged can prevent access throughout the planning area and can isolate residents and emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by tsunami inundation or debris from flood flows also can cause isolation. Water and sewer systems can be flooded or backed up, causing further health problems. Underground utilities can also be damaged during flood events. Table 16-4 provides an estimate of the number and types of critical facilities exposed to the tsunami hazard.

Roads

Roads are an important component in the management of tsunami-related emergencies in that they act is the primary resource for evacuation to higher ground before and during the course of a tsunami event. Roads often act as flood control facilities in low depth, low velocity flood events by acting as levees or berms and diverting or containing flood flows. Hazus-MH indicated that State Routes 30, 31, 310, 311, 32, 3400, 36, 36A, 360, 380, 440, 450 and 460 as well as numerous arterial roads and streets may be impacted by tsunami events. This list of roads should not be misinterpreted as possible evacuation routes for tsunami events. Evacuation routes are identified in emergency response plans.

Bridges

Bridges exposed to tsunami events can be extremely vulnerable due to forces transmitted by the wave run-up and by the impact of debris carried by the wave action. Hazus-MH identified 26 bridges that would be exposed to the tsunami scenario event.

Ports / Fuel Farms

In general, due to their locations, all ports and fuel farms within Maui County are vulnerable to inundation by a tsunami. Depending on the strength and location of the tsunami, ports and fuel farms could sustain damage from water and debris that would render them out of commission for months, exacerbating the disaster.

ABLE 16-4.
CRITICAL FACILITIES AND ASSETS IN TSUNAMI EVACUATION AREAS

Facility Type	Number in Tsunami Evacuation Areas
Emergency Services	
Emergency Operations	0
Police & Fire	6
Community Shelter[a]	0
Medical & Health	0
Government and Services	
Government[b]	-
Schools[a]	21
Critical Infrastructure and Lifelines	
Transportation	36
Water Supply	0
Wastewater	58
Dams	1
Energy	4
Telecommunications	3

ABLE 16-4.
CRITICAL FACILITIES AND ASSETS IN TSUNAMI EVACUATION AREAS

Facility Type	Number in Tsunami Evacuation Areas
Hazardous Materials	3
Other Important Assets	
Financial	32
Tourist Lodging	129
Early Assistance	0
Total	**293**

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.
b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Data sources: See Table 5-1

Water/Sewer/Utilities

Water and sewer systems can be affected by the flooding associated with tsunami events. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing wastes to spill into homes, neighborhoods, rivers and streams. The forces of tsunami waves can impact above-ground utilities by knocking down power lines and radio/cellular communication towers. Power generation facilities can be severely impacted by both the impact of the wave action and the inundation of floodwaters.

Toxic Release Inventory Reporting Facilities

Toxic Release Inventory (TRI) facilities are known facilities that manufacture, process, store or other wise use certain chemicals above minimum thresholds. If damaged by a tsunami, these facilities may potentially release chemicals that cause cancer or other human health effects, significant adverse acute human health effects, significant adverse environmental effects (EPA, 2015). During a tsunami event, containers holding these materials can rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents. Three facilities in the tsunami evacuation area are TRI reporting facility.

16.3.4 Onshore and Offshore Natural Environment

All waterways would be exposed to the effects of a tsunami; inundation of water and introduction of foreign debris could be hazardous to the environment. All wildlife inhabiting the area also is exposed. Depending on the size and associated force of a tsunami event, Maui County's coral reefs may be exposed to increased pressure caused by an incoming tsunami. Additionally, based on how far inland the tsunami reaches, hazardous waste and other materials may be pulled into the ocean by retreating waters, disturbing the natural habitat of the coral reef.

16.4 Vulnerability

16.4.1 Population

The populations most vulnerable to the tsunami hazard are the elderly, disabled and very young who reside or recreate near beaches, low-lying coastal areas, tidal flats and stream or river deltas that empty into ocean-going waters. In addition, visitors recreating in or around inundation areas would also be vulnerable as they may not be as familiar with residents on appropriate responses to a tsunami or ways to reach higher ground. In the event of a local tsunami generated in or near the planning area, there would be little warning time, so more of the population would be vulnerable. The degree of vulnerability of the population exposed to the tsunami hazard event is based on a number of factors:

- Is there a warning system?
- What is the lead time of the warning?
- What is the method of warning dissemination?
- Will the people evacuate when warned?

For this assessment, the population vulnerable to possible tsunami inundation is considered to be the same as the exposed population.

16.4.2 Property

All structures along beaches, low-lying coastal areas, tidal flats and stream or river deltas would be vulnerable to a tsunami, especially in an event with little or no warning time. The impact of the waves and the scouring associated with debris that may be carried in the water could be damaging to structures in the tsunami's path. Those that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound. Because data utilized for this analysis was evacuation areas, rather than inundation areas. No vulnerability analysis was performed. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 16-5 shows the general building stock loss estimates in the tsunami evacuation areas.

TABLE 16-5.
LOSS POTENTIAL FOR TSUNAMI

Community Planning Area	Exposed Value	Estimated Loss Potential from Tsunami		
		10% Damage	30% Damage	50% Damage
Hana	$38,114,313	$3,811,431	$11,434,294	$19,057,157
Kihei-Makena	$2,530,703,247	$253,070,325	$759,210,974	$1,265,351,624
Lanai	$1,523,829	$152,383	$457,149	$761,915
Makawao-Pukalani-Kula	$0	$0	$0	$0
Molokai	$575,973,198	$57,597,320	$172,791,959	$287,986,599
Paia-Haiku	$247,426,922	$24,742,692	$74,228,077	$123,713,461

TABLE 16-5.
LOSS POTENTIAL FOR TSUNAMI

Community Planning Area	Exposed Value	Estimated Loss Potential from Tsunami		
		10% Damage	30% Damage	50% Damage
Wailuku-Kahului	$3,315,773,837	$331,577,384	$994,732,151	$1,657,886,919
West Maui	$6,439,303,245	$643,930,324	$1,931,790,973	$3,219,651,622
Total	**$13,148,818,590**	**$1,314,881,859**	**$3,944,645,577**	**$6,574,409,295**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

16.4.3 Critical Facilities and Assets

There are 293 critical facilities located in the tsunami inundation areas. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from tsunami events should be done to determine if they could withstand impacts of a tsunami.

16.4.4 Onshore and Offshore Natural Environment

The vulnerability of aquatic habit and associated ecosystems would be highest in low-lying areas close to the coastline. Areas near gas stations, industrial areas and hazardous material containing facilities would be vulnerable due to potential contamination from hazardous materials.

Tsunami waves can carry destructive debris and pollutants that can have devastating impacts on all facets of the environment, including onshore and offshore reef habitat. Millions of dollars spent on habitat restoration and conservation in the planning area could be wiped out by one significant tsunami. There are currently no tools available to measure these impacts. However, it is conceivable that the potential financial impact of a tsunami event on the environment could equal or exceed the impact on property. Community planners and emergency managers should take this into account when preparing for the tsunami hazard.

16.4.5 Economic Impact

Economic impact will be largely associated with the location in which tsunami occurred. In such areas, commercial buildings may be completely destroyed or severely damaged, causing a disruption in associated services.

16.5 Future Trends in Development

With historical run-up levels reaching up to 33 feet on the Island of Maui and wave run-up reaching up to 54 feet in Molokai, standard floodplain development regulation may not provide adequate risk protection for new development. Once the data and science can be applied to official mapping with assigned probabilities of occurrence, Maui County may want to consider regulatory provisions for new development in high risk tsunami inundation areas.

16.6 Scenario

A tsunami in Hawaii can be generated by a nearby as well as a distant earthquake or landslide. Several scenarios could create large tsunami events and greatly impact Maui County. One scenario includes a local tsunami event triggered by

a collapse of a flank of Mauna Loa or Kilauea in Hawaii County. Review of submarine geology indicates historical landslides along these flanks have occurred, and the possibility of another flank collapse is possible. This would probably be very damaging, giving little or no warning time. This could result in great loss of life and property and cause severe environmental impacts (Oskin, 2012).

16.7 Issues

The planning team has identified the following issues related to the tsunami hazard for the planning area:

- **Hazard Identification**—To truly measure and evaluate the probable impacts of tsunamis on planning, new hazard mapping based on probabilistic scenarios likely to occur needs to be created. The science and technology in this field are emerging. For tsunami hazard mitigation programs to be effective, probabilistic tsunami mapping will need to be a key component.
- **Building Code Revisions**—Present building codes and guidelines do not adequately address the impacts of tsunamis on structures, and current tsunami hazard mapping is not appropriate for code enforcement.
- **Enhancement of Current Capabilities**—As tsunami warning technologies evolve, the tsunami warning capability within the planning area will need to be enhanced to provide the highest degree of warning.
- **Vulnerable Populations Planning**—Special attention will need to be focused on the vulnerable communities in the tsunami zone and on hazard mitigation through public education and outreach. This may be especially true for visitors to Maui County.

Chapter 17. Volcanic Hazards: Lava Flow and VOG

17.1 Hazard Description

Hazards related to volcanic eruptions are distinguished by the different ways in which volcanic materials and gasses are emitted from the volcano. The molten rock that erupts from a volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles. Ash and fragmented rock material can become airborne and travel far from the erupting volcano to affect distant areas. Additionally, toxic gasses emitted from the volcano vent can travel great distances and cause respiratory distress in those not located in the immediate area of the eruption.

The Hawaiian Islands are geophysically young land masses caused exclusively by the tectonic and volcanic phenomenon within the Pacific Ocean. The volcanoes that created the Hawaiian archipelago were created by a hotspot over which Hawaii County is currently located. This Hawaii hotspot is the most active volcanic hotspot on the world.

DEFINITIONS

Volcano—A vent in the planetary crust from which magma (molten or hot rock) and gas from the earth's core erupts (OSU, n.d.).

Pahoehoe— Basalt lava flow wiith characteristic ropey appearance upon cooling and hardening. During lava flow, pahoehoe can develop a skin which inhibits heat loss. A tear in the skin can change the direction of lava flow through the creation of a lava toe (DGS-Cornell, 2001).

Volcanic Gas (VOG)— VOG is a visible haze comprised of gas and an aerosol of tiny particles and acidic droplets, created when sulfur dioxide (SO_2) and other gases emitted from Kilauea Volcano chemically interact with sunlight and atmospheric oxygen, moisture, and dust (HVO, 2012).

Geologist John Tuzo Wilson created a theory that explains the formation of the Hawaiian Islands. Namely, he theorized that the Hawaii hotspot is a stationary area located under the earth's surface in a mantle plume. Over millions of years, the Pacific tectonic plate has drifted in a northwesterly direction over the plume, resulting in the Hawaiian Islands as we know them today. From the northwest, the Island of Kauai is the oldest of the main islands at about 5 million years old, while the Island of Hawaii is about 700,000 years old (USGS, 1999; Wayman, 2011).

Though true understanding of the formation of the Hawaiian Islands still remains a mystery, Wilson's theory still serves as the most plausible and scientifically accepted explanation, as the Pacific tectonic plate moves approximates 9 centimeters a year in a northwest direction and previously active volcanoes that formed Kauai, Oahu, and the older islands are now considered dormant (NOVA, n.d.).

The volcanoes famously associated with the State of Hawaii and caused by the Pacific Ocean phenomenon are shield volcanoes. Shield volcanoes are the largest volcanoes on earth. Lava that flows from shield volcanoes are composed of mainly basalt materials, resulting in a thick, fluid lava flow, also known as Pahoehoe, which provides shield volcanoes with their characteristically low profile and gently sloping sides (Figure 17-1). Eruptions from shield volcanoes are not typically explosive in nature unless water has entered the vent (OSU, n.d.). Shield volcanoes are prone to flank eruptions in addition to the summit, such as the Puu Oo vent on the eastern rift of the Kilauea Volcano in Hawaii County.

Source: BBC, 2014

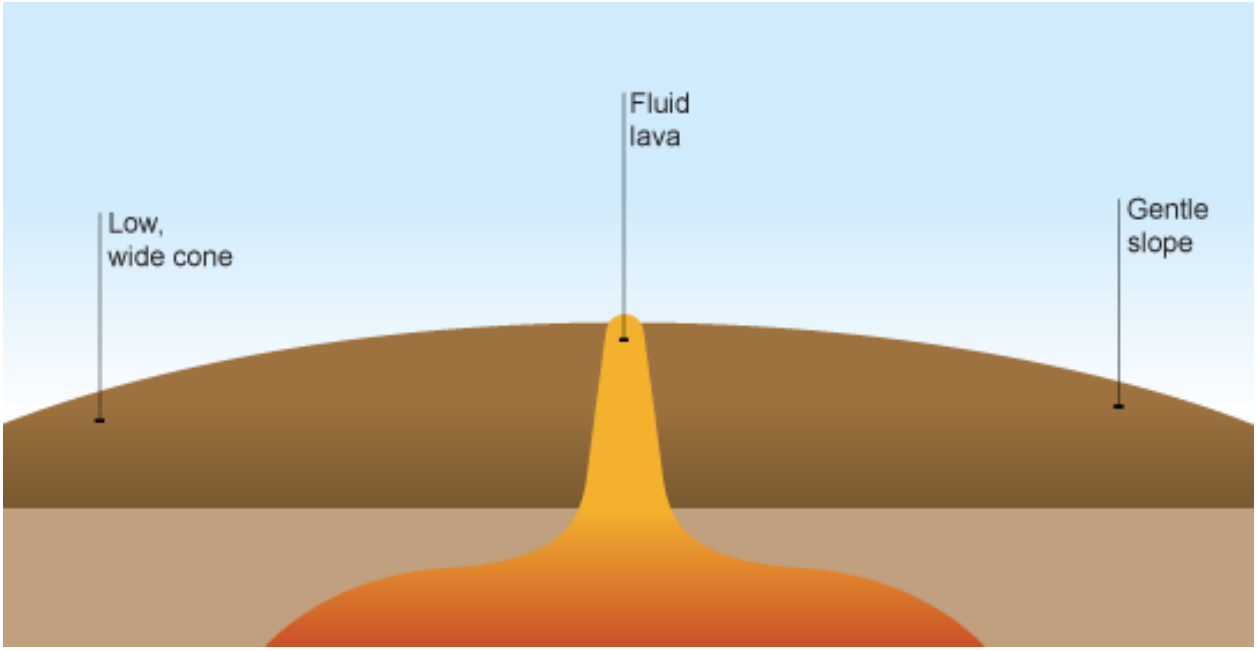


FIGURE 17-1. COMPOSITION OF A SHIELD VOLCANO

Volcanoes are categorized as active, dormant, or extinct. The definitions of these categories have multiple variations throughout the scientific community. Some scientists believe that a volcano with a previous historic eruption 9,000 years ago should be classified as active while others believe that a volcano should be considered dormant with an eruption history that shows a previous eruption as little as 200 years ago. According to the USGS, active volcanoes are generally classified as those currently erupting or showing signs of unrest, such as gas emission and unusual earthquake activity. Dormant volcanoes are not currently active, as described above, but could become restless or erupt again. Extinct volcanoes are those scientists consider unlikely to erupt again. Activity and dormancy vary from region to region and volcano to volcano. For example, Yellowstone caldera in Yellowstone National Park is at least 2 million years old and has not erupted in 70,000 years, yet scientists do not consider Yellowstone extinct. Because the caldera has frequent earthquakes, a very active geothermal system, and rapid rates of ground uplift, many scientists consider it to be very active (USGS, 2009a).

Gasses released by erupting volcanoes can cause undue stress on the respiratory system of those exposed to such toxins. Approximately 99 percent of the gas molecules emitted during a volcanic eruption are water vapor (H_2O), carbon dioxide (CO_2), and sulfur dioxide (SO_2). The remaining one percent is comprised of small amounts of hydrogen sulfide, carbon monoxide, hydrogen chloride, hydrogen fluoride, and other minor gas species (HVO, 2012).

Kilauea volcano, located in Hawaii County, has been continually erupting since 1983. For most of those years, Puu Oo has been emitting around 1,500-2,000 tons of SO_2 daily. Sulfur dioxide is also released at Kilauea's summit. The amount was small—150-200 tons each day—until mid-2007, when SO_2 emission rates at Kilauea's summit began to increase. By the time the new gas vent opened in Halemaumau Crater on March 12, 2008, summit SO_2 emissions had reached 2,000 tons/day—the highest recorded at Kilauea's summit since measurements began in 1979. As of June 2008, summit SO_2 emissions have been fluctuating between 500 and 1,500 tons per day. Near Kilauea's active vents, VOG consists

mostly of SO_2 gas. Along the Kona coast on the west side of Hawaii Island and in other areas far from the volcano, VOG is dominated by an aerosol of sulfuric acid and other sulfate compounds (HVO, 2012).

Volcanic hazards in Hawaii often fall under two broad categories: direct and indirect. Direct volcanic hazards include hazards typically associated with volcanoes, such as lava flows, falling rocks, and drifting gasses. Indirect hazards include geological phenomenon that often accompany volcanic eruptions. These indirect hazards are described in more detail in later sections of this chapter.

Due to the composition of Hawaii's volcanoes, eruption and lava flow on the Island of Maui will be anticipated and planned for, should that time come. Anticipatory seismic activity and other warning signals will alert scientists to the possibility of a future eruption. For VOG, the University of Hawaii recently launched the VOG Measurement and Prediction Project (VMAP). This project is a feasibility study in which scientists evaluate the potential to accurately predict the expected distribution of VOG concentrations as a result of the interaction of emissions and the current and forecasted weather. VMAP intends to forecast up to 60 hours in advance of VOG movement from Kilauea to other areas of the Island of Hawaii and beyond to other portions of the state (VMAP, 2014).

17.2 Hazard Profile

17.2.1 Past Events

Lava Flow

There are no significant historical volcanic lava flows that have affected the islands of Molokai, Lanai, Kahoolawe, or Maui. As was mentioned in the hazard description, the last volcanic activity in these islands was the 1790 south flank eruption of Haleakala in the Island of Maui. During that era, the area affected by Haleakala's eruption was not populated. Even to current days, the southern flanks of the volcano are scarcely populated.

VOG

VOG affects the islands that constitute the County of Maui (specially the Island of Maui) on a frequent basis. Significant VOG occurrences in Maui County have included the following:

- **April 25, 2008**—According to The Maui News, the Island of Maui District Health Office issued an advisory for the residents of the Island of Maui due to VOG originated from Kilauea's summit vent. The advisory urged individuals with respiratory conditions to take precautions. The Hawaiian Volcano Observatory reported that a few days before the advisory for the Island of Maui went in effect, sulfur dioxide levels around the observatory topped 1 ppm for a period of 2 hours.
- **January 2015**—Maui County experienced obscured views and potentially hazardous VOG conditions. A surface ridge sitting over the islands changed the typical trade wind weather pattern, forcing winds to come up from the south, instead, bringing along VOG from Hawaii island's Kilauea Volcano up as far as Kauai. The VOG was so thick, that a kayaker became disoriented while trying to paddle from Maui to Hawaii island and had to be rescued by the Coast Guard 19 miles northeast of Kohala (Nakaso, 2015).

17.2.2 Location

The County of Maui is prone to two different types of volcanic hazards. The first, lava flow, poses a risk only to the Island of Maui, as the volcano of Haleakala could potentially erupt. The second, volcanic smog or VOG, has the potential to affect the entire planning area. While the source of potential lava flow is located immediately on the Island of Maui, the source of VOG is found to the southeast on the Island of Hawaii.

For the purpose of this plan and in keeping the subjectivity of active/dormant categorization in mind as previously stated, the Haleakala shield volcano, located in the eastern portion of the Island of Maui and also known as the East Maui Volcano, will be referred to as a dormant volcano for the following reasons:

- The last suspected eruption was in 1790 at the southern flank (USGS, 2008b).
- The movement of the Pacific tectonic plate in a northwesterly direction has moved the Island of Maui directly off of the Hawaii hotspot, though its proximity could potentially result in additional eruptions.
- Kilauea in the neighboring Island of Hawaii has frequent and long lasting eruptions, with the most current eruption beginning in the 1980s and continuing to present day.
- The regular volcanic activity of Kilauea compared to the over 200 year eruption history of Haleakala indicates that Haleakala is not considered active for the immediate region.

Lava Flow

Because of Haleakala's status as dormant volcano with the potential for future eruption, lava hazard zones similar to those found on the Island of Hawaii have been mapped to show the potential direction and devastation associated with an eruption of the volcano. On the Island of Hawaii, lava-flow hazards are rated on a scale of one through nine, with one being the zone of highest hazard and nine being the zone of lowest hazard. For example, the summits and rift zones of Kilauea and Mauna Loa volcanoes are rated Hazard Zone 1. Using this same scale, preliminary estimates of lava-flow hazard zones on Maui made in 1983 by the U.S. Geological Survey rated the summit and southwest rift zone of Haleakala as Hazard Zone 3. The steep, downslope areas of Kanaio and Kahikinui Ahupuaa and the area north of Hana are rated as Hazard Zone 4. (USGS, 1996).

In 2006, researchers suggested an adjustment of the zones in relation to Haleakala due to the Maui volcano's considerably smaller size than the active volcanoes located on the Island of Hawaii. As a result, these researchers suggested that Maui Zone 1 is roughly equivalent to Hawaii Island Zone 3, Maui Zone 2 is roughly equivalent to Hawaii Island Zone 4, and Maui Zone 3 is roughly equivalent to Hawaii Island Zone 6. In other words, no place on Maui has volcanic hazards equivalent to Lava-Flow Hazard Zones 1 and 2 on Hawaii Island (USGS, 2012b). Figure 17-2 depicts original lava flow zones for the Island of Maui as developed in 1983 (see insert map) versus the current, revised zones developed in 2006. Lava flow hazard maps are not needed for western Maui. Lava inundation areas used as the basis for the exposure and vulnerability assessments are shown in Figure 17-3 through Figure 17-5.

Source: Sherrod et al., 2006

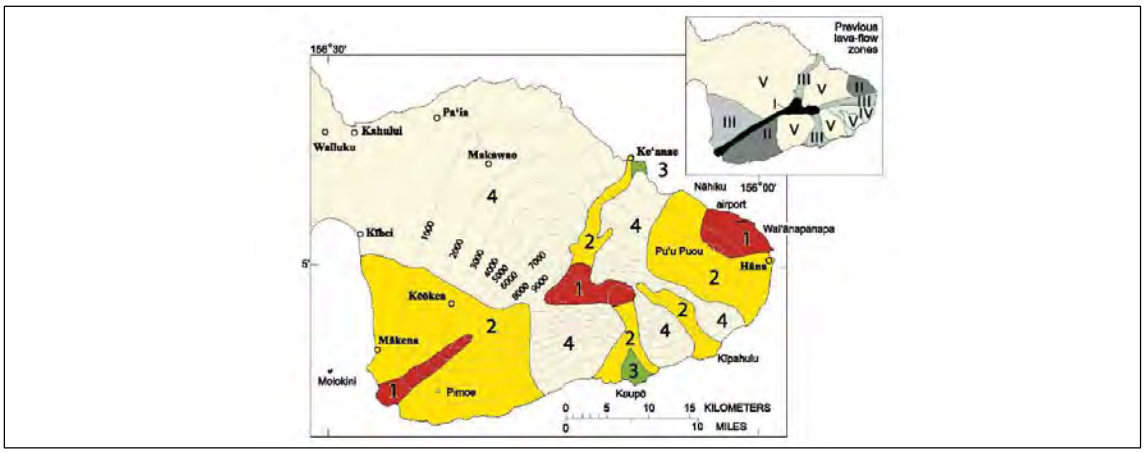
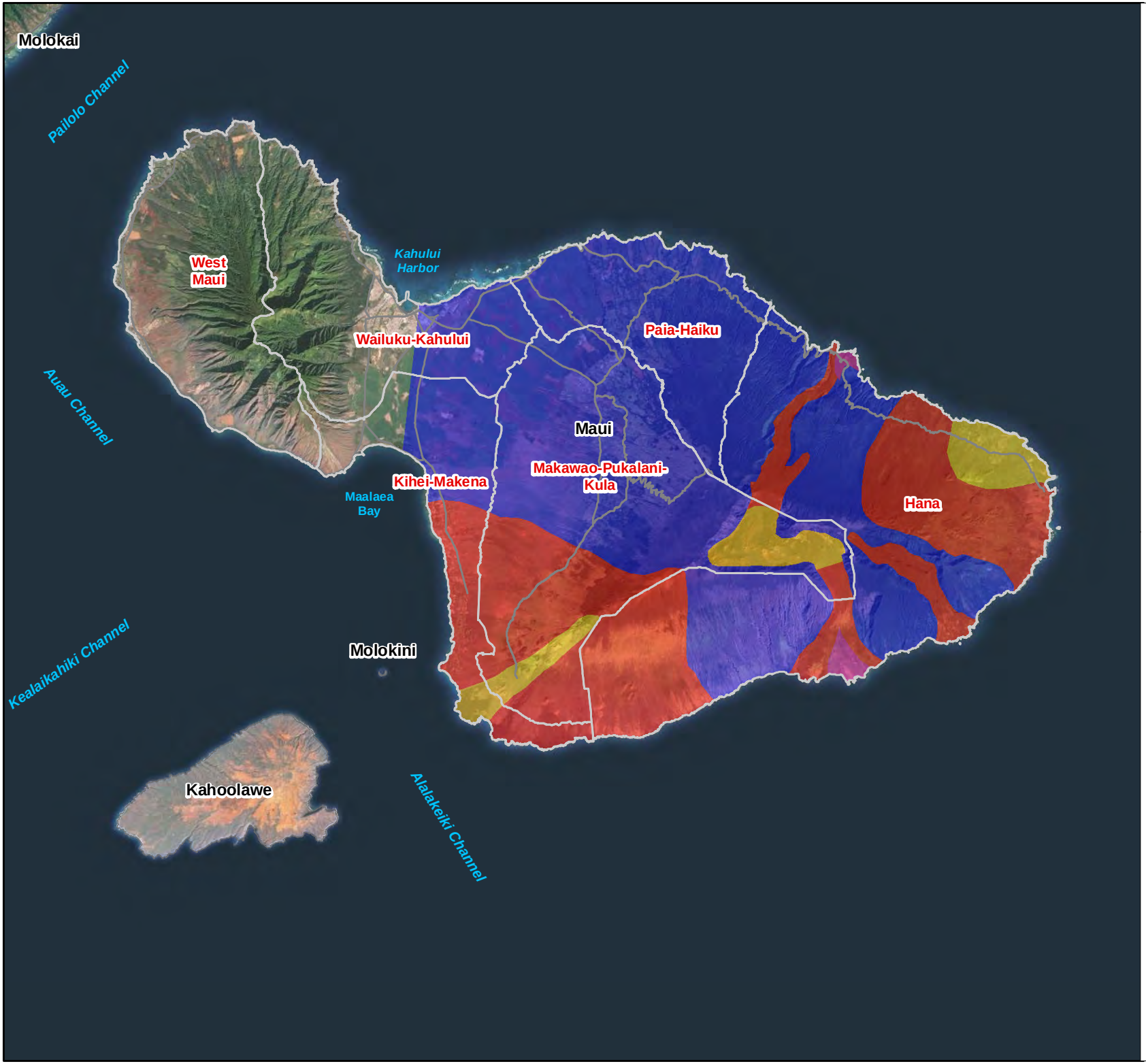


FIGURE 17-2. LAVA FLOW HAZARD ZONES FOR THE ISLAND OF MAUI

Maui County Islands of Maui and Kahoolawe

Lava Inundation Areas



Legend

Community Plan Boundaries

Hazard Zone

- Zone 1
- Zone 2
- Zone 3
- Zone 4

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 4.5 9 Miles

Maui County
Island of Lanai

Lava Inundation Areas

Legend

Hazard Zone

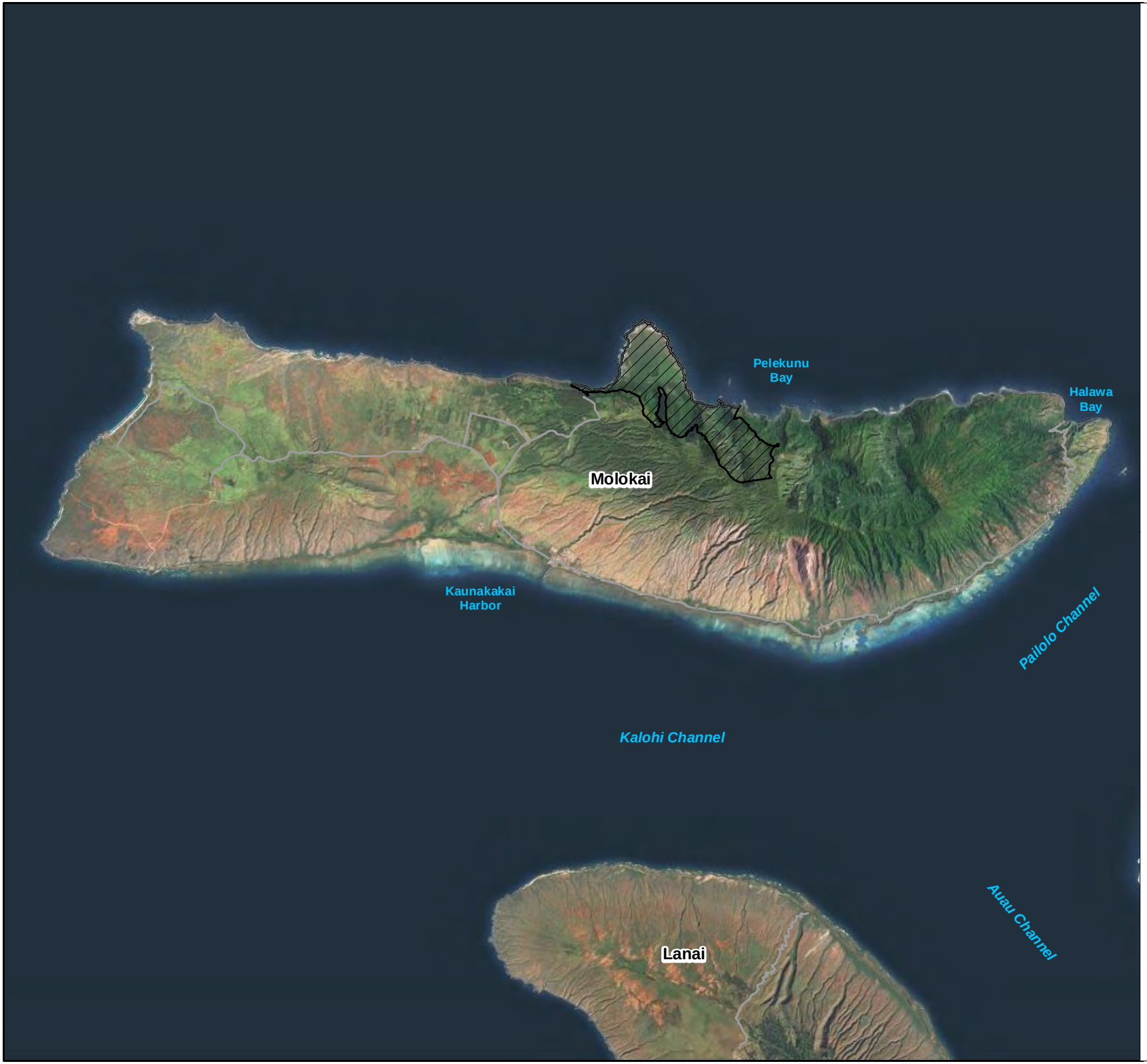
- Zone 1
- Zone 2
- Zone 3
- Zone 4

Base Map Data Sources:
Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 2.5 5 Miles



Maui County Island of Molokai

Lava Inundation Areas

Legend

Kalawao County

Hazard Zone

Zone 1

Zone 2

Zone 3

Zone 4

Base Map Data Sources: Maui County, U.S. Geologic Survey, ESRI

TETRA TECH

N

0 3.5 7 Miles

VOG

In the Hawaiian Archipelago, potential sources of VOG are the dormant volcanoes of Haleakala in the Island of Maui, Mauna Loa, and Hualalai on the Island of Hawaii and the active Kilauea volcano also on the Island of Hawaii. Of these three volcanoes, the first two are potential sources because they have not had any activity in over two centuries. Kilauea's most recent eruption, on the other hand, initiated in 1983 and continues to the present day. In the case of Kilauea, VOG typically originates at the Halemaumau vent (at the volcano's summit), the Puu Oo vent (at the volcano's upper east rift zone), and the ocean entry plume (along the shoreline of the District of Puna). The concentrations of sulfur dioxide gas in VOG are typically greater near the source of the Kilauea volcano. Sulfur dioxide levels are lessened further away or upwind from the vents. VOG mostly affects the Kona coast on the west side of the Island of Hawaii, where the prevailing trade winds blow the VOG to the southwest and southern winds then blow it north up the island's west coast.

During episodes of Kona or non-trade wind conditions, the VOG can diffuse further north towards the Island of Maui. Because of the Island of Maui's unique topography, VOG is funneled through the central valley between Haleakala volcano and the West Maui Mountains. Therefore, the effects of VOG are not limited to urban areas in the island's southern coast like Kihei and Makena but can extend as far as the agricultural areas of central and upcountry Maui and the densely populated areas of Wailuku and Kahului on the island's northern shore. Episodes of VOG of the islands of Lanai and Molokai are much less common because these islands are further away from the sources at the Island of Hawaii. Lanai and Molokai are also shielded from wind-blown VOG by the massive mountains of the Island of Maui (County of Maui, 2010a).

Although the haze caused by VOG may be at times heavy on the west side of the Island of Hawaii and moderate on the south side of the Island of Maui, sulfur dioxide levels at these locations are typically lower than expected due to the geographic distance from the sources. Also, the quantities of sulfur dioxide in the air and the danger they present humans, animals, and plants cannot be directly correlated to the appearance of VOG (sparse, thick, dense, etc.) as sulfur dioxide levels have been measured to be high with only light VOG (County of Maui, 2010a).

As of January 1, 2014, a major change was made at Hawaii Volcano Observatory in the way sulfur dioxide emissions from the Halemaumau vent are reported. The resultant change in emissions values represents a substantial increase in emissions being reported. This does not mean that volcanic emissions have gone up overnight. This change results from long-term observations that suggest that previous estimates were under-reporting emissions. The change in emissions impacts the VOG Model, which uses these emission estimates to generate forecasts (VMAP, 2015). Figure 17-6 illustrates the circulation of VOG in the form of sulfate aerosols and sulfur dioxide across the County of Maui, including the Island of Maui, Lanai, and minimally, Molokai.

17.2.3 Frequency

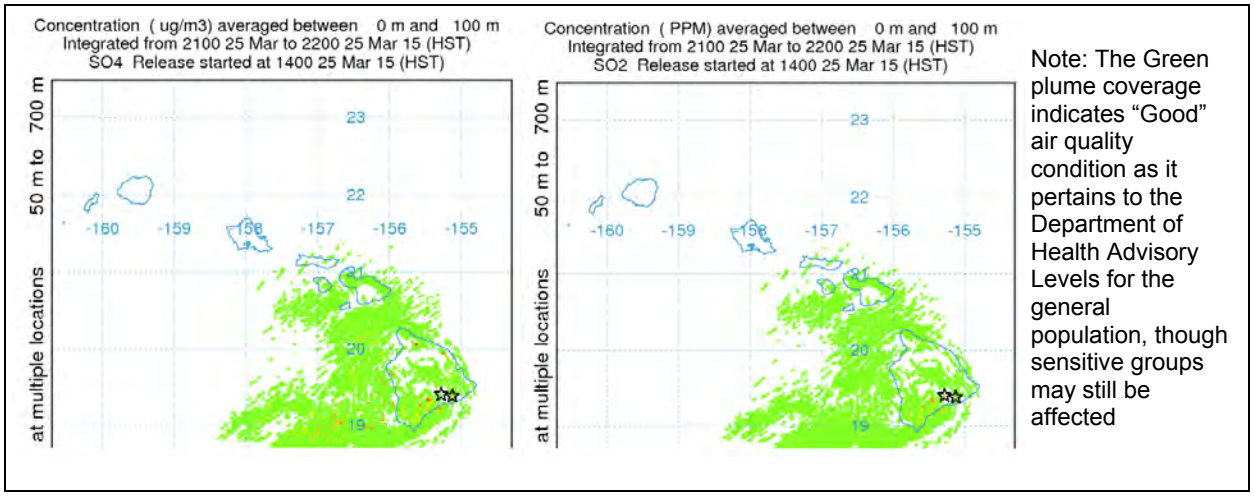
Lava Flow

With the continued eruption of Kilauea in neighboring Hawaii County, a volcanic eruption by Maui's dormant volcano is possible.

VOG

VOG events are expected annually, with higher concentration events dependent on prevailing winds and associated weather phenomenon.

Source: VMAP, 2015



Note: The graphic on the left represents the levels of SO4 (sulfate) in the atmosphere. The right graphic represents the levels of SO2 (sulfide) in the atmosphere.

FIGURE 17-6. CIRCULATION OF VOG ACROSS MAUI COUNTY

17.2.4 Severity

Lava Flow

Since the most recent eruption of the Haleakala occurred in 1790, the severity associated with an eruption is difficult to gage. Recent lava flow events in Hawaii County, however, put into perspective the potential severity of such hazards on the Island of Maui. Based on the flow approaching Pahoa on Hawaii County, an eruption in Maui would result in the loss of property, restriction of areas located in proximity to the lava flow, and a nearly unstoppable hazard with a slow-moving but easily anticipated trajectory.

VOG

Sulfur dioxide is irritating to the eyes, nose, throat and respiratory tract. Short-term exposure to elevated levels of Sulfur Dioxide may cause inflammation and irritation, resulting in burning of the eyes, coughing, difficulty in breathing and a feeling of chest tightness. When it comes to VOG, sensitive populations include children and individuals with pre-existing respiratory conditions such as asthma, emphysema, bronchitis, and chronic lung or heart disease. Individuals who belong to these sensitive populations may respond to very low levels of Sulfur Dioxide in the air. Prolonged or repeated exposure to higher levels may increase the danger. Other common symptoms of VOG exposure include the following (County of Maui, 2010a):

- Headaches
- Breathing difficulties
- Increased susceptibility to respiratory ailments

- Watery eyes
- Sore throat.

Acid aerosols increase corrosion to any exposed metal along the path of the downwind plume including fencing, water lines, water tanks, farm equipment, exposed structural steel structures (i.e. transmission towers, bridges), etc. Even in relatively dry downwind areas, severe corrosion will generate significant economic losses. The most likely process driving the corrosion is dew formation rather than the infrequent rainfall: during the evening hours, as the dew point temperature is approached, the acid aerosols will form an extremely corrosive film on metallic surfaces. With daily replenishment of fresh acid from VOG, and nightly condensation of moisture it is reasonable to anticipate substantially more rapid deterioration of exposed metal surfaces than would occur in similar environments not exposed to the plume acids (County of Maui, 2010a).

17.2.5 Warning Time

The USGS maintains five volcano observatories charged with monitoring and researching active volcanoes within the United States. The Hawaiian Volcano Observatory monitors volcanoes in Hawaii. Since 1790, Haleakala has settled into a pattern of dormancy. However, Haleakala is still monitored by the USGS for the possibility of further large-scale events. As a result of this monitoring, it is likely, although not definite, that warning time ranging from hours to weeks would be available for any event likely to impact Maui County (USGS, 2008a).

There is no VOG monitoring system or warning system for Maui County. The Hawaii Department of Health – Environmental Health does provide private sites such as *AirNow* data to provide daily air quality forecasts. Along with other air pollutants, *AirNow* may take into consideration the sulfur dioxide (SO2) levels due to the Kilauea Volcano on the Island of Hawai'i, but does not solely focus on SO2 levels or VOG.

The County of Hawaii and the Department of Health have worked together to form a color code system to help individuals and groups take protective action based on SO2 levels. The color code is based on a forecast of data and uses volcanic emission levels, weather, wind and historical data into account. Table 17-1 depicts the color coded system.

17.2.6 Potential Impacts of Climate Change

Climate change is not likely to affect the risk associated with volcanoes; however, volcanic activity can affect climate change. The massive outpouring of gases and ash can influence climate patterns for years following a volcanic eruption. The conversion of sulfur dioxide to sulfuric acid is the most significant climate impact from a volcano. The Pinatubo eruption in 1991 was one of the largest volcanic events in the 20th century, injecting 20 million tons of sulfur dioxide into the stratosphere. It ultimately cooled the Earth's surface by as much as 1.3ºF for 3 years after its eruption. In contrast, the carbon dioxide released in recent eruptions has not been shown to lead to a detectable increase in global warming (USGS, 2015b).

17.2.7 Secondary Hazards

Ground movement often accompanies volcanic eruption. Such movement can result in subsidence, surface ruptures, earthquakes, and potentially tsunamis (USGS, 2009b).

Adverse effects of VOG include headaches, breathing difficulties, increased susceptibility to respiratory ailments, water eyes and sore throat. The long-term health effects of VOG are unknown. People with pre-existing respiratory conditions are more prone to these effects (State of Hawaii, 2015b).

TABLE 17-1.
SULFUR DIOXIDE INFORMATION

Condition	Recommended Response
GREEN (Trace)	Sensitive groups[a]: Highly sensitive individuals may be affected at these levels. Everyone else: Potential health effects not expected.
YELLOW (Light)	Sensitive groups: Avoid outdoor activity. Everyone else: Potential health effects not expected, however actions to reduce exposure to VOG may be useful.
ORANGE (Moderate)	Sensitive groups: Avoid outdoor activity and remain indoors. Everyone else: Potential health effects not expected, however actions to reduce exposure to VOG may be useful.
RED (High)	Sensitive groups: Avoid outdoor activity and remain indoors. People experiencing respiratory-related health effects: Consider leaving the area. Everyone else: Avoid outdoor activity
PURPLE (Extreme)	Sensitive groups: Avoid outdoor activity and remain indoors. People experiencing respiratory-related health effects: Leave the area and seek medical help. Everyone: Leave the area if directed by Civil Defense.

a. Sensitive Groups are defined in this instance as children, and individuals with pre-existing respiratory conditions such as asthma, bronchitis, emphysema, lung or heart disease.

Source: State of Hawaii, 2015b

17.2.8 Population

Lava Flow

The eastern portion of the Island of Maui is exposed to potential lava flow should an eruption occur at Haleakala. The population living in lava flow hazard zones was estimated using the percent of buildings within each hazard zone for each community planning area and applying this percent to the estimated 2010 population. Using this approach, the estimated resident population living in lava flow hazard zones is estimated to be 81,809 or 53 percent of the resident population. 20,695 visitors or 38.1 percent of the visitor population are estimated to be staying in lava flow hazard zones (see Table 17-2).

VOG

The entire population of the planning area is exposed to the effects of a VOG event.

17.2.9 Property

Lava Flow

All property in the lava hazard zone areas would potentially be exposed lava flows, depending on the severity of the eruption. The value of exposed buildings in the lava inundation risk areas was generated by overlaying the inundation areas on the general building stock and is summarized in Table 17-3 through Table 17-6. The estimates include the value of both the buildings and their contents. This methodology estimates that that there are 25,023 structures exposed to the lava flow hazard within the planning area, with a replacement value of $21.2 billion.

TABLE 17-2.
ESTIMATED POPULATION EXPOSURE FOR LAVA FLOW INUNDATION AREAS

Community Planning Area	Residents	Visitors	Total
Lava Inundation Zone 1			
Hana	674	0	674
Kihei-Makena	33	0	33
Lanai	0	0	0
Makawao-Pukalani-Kula	59	0	59
Molokai	0	0	0
Paia-Haiku	0	0	0
Wailuku-Kahului	0	0	0
West Maui	0	0	0
Total	765	0	765
Lava Inundation Zone 2			
Hana	1,312	223	1,535
Kihei-Makena	17,502	16,928	34,430
Lanai	0	0	0
Makawao-Pukalani-Kula	1,122	0	1,122
Molokai	0	0	0
Paia-Haiku	0	0	0
Wailuku-Kahului	0	0	0
West Maui	0	0	0
Total	19,935	17,151	37,086
Lava Inundation Zone 3			
Hana	106	0	106
Kihei-Makena	0	0	0
Lanai	0	0	0
Makawao-Pukalani-Kula	0	0	0
Molokai	0	0	0
Paia-Haiku	0	0	0
Wailuku-Kahului	0	0	0
West Maui	0	0	0
Total	106	0	106
Lava Inundation Zone 4			
Hana	200	0	200
Kihei-Makena	9,547	3,369	12,916
Lanai	0	0	0
Makawao-Pukalani-Kula	24,018	144	24,162

TABLE 17-2.
ESTIMATED POPULATION EXPOSURE FOR LAVA FLOW INUNDATION AREAS

Community Planning Area	Residents	Visitors	Total
Molokai	0	0	0
Paia-Haiku	13,122	31	13.153
Wailuku-Kahului	5,979	0	5,979
West Maui	0	0	0
Total	60,283	3,544	63,827
TOTAL FOR ALL ZONES	**81,809**	**20,695**	**102,504**

TABLE 17-3.
EXPOSURE AND VALUE OF STRUCTURES IN LAVA INUNDATION ZONE 1

Community Planning Area	Buildings Exposed	Value Exposed Structure	Value Exposed Contents	Value Exposed Total	% of Total Replacement Value
Hana	324	$84,325,143	$51,165,822	$135,490,965	30.8%
Kihei-Makena	9	$2,927,774	$1,463,887	$4,391,661	0.05%
Lanai	0	$0	$0	$0	0.00%
Makawao-Pukalani-Kula	23	$5,188,677	$2,968,294	$8,156,970	0.17%
Molokai	0	$0	$0	$0	0.00%
Paia-Haiku	0	$0	$0	$0	0.00%
Wailuku-Kahului	0	$0	$0	$0	0.00%
West Maui	0	$0	$0	$0	0.00%
Total	**356**	**$92,441,593**	**$55,598,002**	**$148,039,596**	**0.32%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 17-4.
EXPOSURE AND VALUE OF STRUCTURES IN LAVA INUNDATION ZONE 2

Community Planning Area	Buildings Exposed	Value Exposed Structure	Value Exposed Contents	Value Exposed Total	% of Total Replacement Value
Hana	631	$161,651,147	$96,787,124	$258,438,272	58.65%
Kihei-Makena	4,748	$4,604,441,745	$2,548,282,848	$7,152,724,592	75.99%
Lanai	0	$0	$0	$0	0.00%
Makawao-Pukalani-Kula	441	$135,507,614	$79,282,547	$214,790,161	4.55%
Molokai	0	$0	$0	$0	0.00%
Paia-Haiku	0	$0	$0	$0	0.00%
Wailuku-Kahului	0	$0	$0	$0	0.00%
West Maui	0	$0	$0	$0	0.00%
Total	**5,820**	**$4,901,600,506**	**$2,724,352,519**	**$7,625,953,025**	**16.68%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 17-5.
EXPOSURE AND VALUE OF STRUCTURES IN LAVA INUNDATION ZONE 3

Community Planning Area	Buildings Exposed	Value Exposed Structure	Value Exposed Contents	Value Exposed Total	% of Total Replacement Value
Hana	51	$9,959,570	$5,346,610	$15,306,180	3.47%
Kihei-Makena	0	$0	$0	$0	0.00%
Lanai	0	$0	$0	$0	0.00%
Makawao-Pukalani-Kula	0	$0	$0	$0	0.00%
Molokai	0	$0	$0	$0	0.00%
Paia-Haiku	0	$0	$0	$0	0.00%
Wailuku-Kahului	0	$0	$0	$0	0.00%
West Maui	0	$0	$0	$0	0.00%
Total	**51**	**$9,959,570**	**$5,346,610**	**$15,306,180**	**0.03%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

TABLE 17-6.
EXPOSURE AND VALUE OF STRUCTURES IN LAVA INUNDATION ZONE 4

Community Planning Area	Buildings Exposed	Value Exposed Structure	Value Exposed Contents	Value Exposed Total	% of Total Replacement Value
Hana	96	$20,813,342	$10,587,611	$31,400,954	7.13%
Kihei-Makena	2,590	$1,346,140,762	$734,286,964	$2,080,427,725	22.10%
Lanai	0	$0	$0	$0	0.00%
Makawao-Pukalani-Kula	9,442	$2,910,248,411	$1,583,554,161	$4,493,802,572	95.27%
Molokai	0	$0	$0	$0	0.00%
Paia-Haiku	5,001	$1,435,714,010	$795,019,777	$2,230,733,787	100.00%
Wailuku-Kahului	1,667	$2,289,232,455	$2,313,071,885	$4,602,304,340	27.93%
West Maui	0	$0	$0	$0	0.00%
Total	**18,796**	**$8,002,148,980**	**$5,436,520,398**	**$13,438,669,378**	**29.40%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

Table 17-7 shows the general land use of parcels exposed to lava flow hazard zones in the planning area. Agricultural and conservation land make up the greatest extent of exposed areas.

TABLE 17-7.
LAND USE IN LAVA FLOW INUNDATION ZONES

Land Use	Area in Lava Inundation Areas (acres)	% of Total
Agricultural	204,484.92	57.6%
Apartment	1,106.70	0.3%
Commercial	1,439.71	0.4%
Commercialized Residential	109.10	0.0%

TABLE 17-7.
LAND USE IN LAVA FLOW INUNDATION ZONES

Land Use	Area in Lava Inundation Areas (acres)	% of Total
Conservation	135,651.84	38.2%
Hotel/Resort	594.30	0.2%
Industrial	2,843.29	0.8%
Residential	4,794.38	1.4%
Time Share	8.79	0.0%
Not Classified	3,944.07	1.1%
Total	**354,977.10**	**100.0%**

Source: Summarized from Maui County parcel and tax assessor data. Roads and rights-of-way are categorized as "not classified." Acreage includes only areas intersecting mapped hazard layers.

VOG

All property in the planning area is exposed to VOG, however immediate effects of VOG on property are minimal.

17.2.10 Critical Facilities

Lava Flow

Table 17-8 summarizes the exposed critical facilities in the planning area.

VOG

All infrastructure is exposed to VOG; however, immediate effects of VOG on infrastructure are minimal.

17.2.11 Onshore and Offshore Natural Environment

The environment is highly exposed to the effects of a volcanic eruption. Natural environments and habitat in the path of a lava flow would be subject to destruction and wildlife would be displaced. VOG events expose the local environment to many effects such as lower air quality, and many other elements that could harm local vegetation and water quality. These impacts could be particularly detrimental if areas impacted are critical habitat for endangered or threatened species.

TABLE 17-8.
CRITICAL FACILITIES AND ASSETS IN LAVA INUNDATION ZONES

	Number in Inundation Zones			
Facility Type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Emergency Services				
Emergency Operations	0	0	0	0
Police & Fire	3	4	0	7
Community Shelter[a]	0	1	0	4
Medical & Health	1	1	0	___
Government and Services				
Government[b]	-	-	-	-
Schools[a]	1	8	1	27
Critical Facilities and Lifelines				
Transportation	4	20	1	80

TABLE 17-8.
CRITICAL FACILITIES AND ASSETS IN LAVA INUNDATION ZONES

	Number in Inundation Zones			
Facility Type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Water Supply	3	30	2	64
Wastewater	0	16	0	19
Dams	0	0	0	33
Energy	0	0	0	2
Telecommunications	4	1	0	14
Hazardous Materials	0	0	0	3
Other Important Assets				
Financial	0	10	0	12
Tourist Lodging	0	52	0	24
Early Assistance	0	0	0	0
Total	16	143	4	289

a. All but seven schools are also community shelters. To avoid double counting, they are excluded from the community shelter category and counted only under schools.

b. No government critical facility dataset available at this time. Such information should be incorporated into future updates when available.

Data sources: See Table 5-1

17.3 Vulnerability

17.3.1 Population

Lava Flow

Since there is generally adequate warning time before a volcanic event, the population vulnerable to the lava flow hazard consists of those who choose not to evacuate or are unable to evacuate. The latter includes the elderly, the very young and other populations with access or functional needs.

VOG

The entire population of the planning area is vulnerable to the damaging effects of VOG on an annual basis. The elderly, very young and those who experience ear, nose and throat problems are especially vulnerable to the VOG hazard.

17.3.2 Property

Lava Flow

There are currently no generally accepted damage functions for volcanic hazards in risk assessment platforms such as Hazus-MH. Therefore the planning team was not able to generate damage estimates for this hazard. The most vulnerable structures would be those that are located in Lava Zone 1. Loss estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 17-9 shows the general building stock loss estimates in the lava flow hazard zones.

TABLE 17-9.
LOSS POTENTIAL FOR LAVA FLOW HAZARD ZONES

Community Planning Area	Exposed Value	Estimated Loss Potential from Lava Flow Hazard Zones		
		10% Damage	30% Damage	50% Damage
Hana	$440,636,370	$44,063,637	$132,190,911	$220,318,185
Kihei-Makena	$9,237,543,978	$923,754,398	$2,771,263,193	$4,618,771,989
Lanai	$0	$0	$0	$0
Makawao-Pukalani-Kula	$4,716,749,703	$471,674,970	$1,415,024,911	$2,358,374,852
Molokai	$0	$0	$0	$0
Paia-Haiku	$2,230,733,787	$223,073,379	$669,220,136	$1,115,366,893
Wailuku-Kahului	$4,602,304,340	$460,230,434	$1,380,691,302	$2,301,152,170
West Maui	$0	$0	$0	$0
Total	**$21,227,968,179**	**$2,122,796,818**	**$6,368,390,454**	**$10,613,984,089**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.5 for a discussion of data limitations.

VOG

All of the property exposed to nature in the planning area is exposed to the effects of a VOG. Among these properties, the most vulnerable structures are those that are not as structurally sound and may have experience the compounded acidic effects associated with years of VOG exposure.

17.3.3 Critical Facilities

Lava Flow

All critical facilities that are within the path of lava flow would be vulnerable, unless facilities can be relocated or lava flows diverted. Transportation routes that intersect with the highest risk lava flow zones are most vulnerable, especially depending on their structural stability. Hazus-MH identified 101 bridges that are located in lava flow hazard zones. Additionally, the following major roads in the planning area pass through lava inundation areas and thus are exposed:

- State Highway 31
- State Highway 310
- State Highway 311
- State Highway 32
- State Highway 3500
- State Highway 36
- State Highway 360
- State Highway 365
- State Highway 36A
- State Highway 37
- State Highway 377
- State Highway 378
- State Highway 380

VOG

All transportation routes are exposed to VOG, which could create hazardous, low visibility driving conditions on roads and highways and hinder evacuations and response.

17.3.4 Onshore and Offshore Natural Environment

Besides affecting animals with similar respiratory track health issues as humans can experience, VOG can cause the death of wildlife and livestock because of contaminated food consumption. Wildlife and livestock that graze, for example, can die after ingesting water or grass that has been heavily contaminated by other volcanic particles. Another

effect of VOG on wildlife that has been noted particularly on the Island of Hawaii is the interruption of pollination by bees during heavy VOG fallout (County of Maui, 2010a).

Also of great concern to wildlife and livestock is the deposition of fluoride salts carried by VOG onto forage crops. The scientific literature has documented a number of events where sheep, cattle, and horses have suffered significant losses as a result of acute exposure as well as chronic exposure and accumulation of fluoride salts by grazing animals. Although there have been a few anecdotal reports of symptoms of fluorosis by some ranchers on the Island of Hawaii, further investigations will be necessary to determine whether the forage crops are accumulating sufficient fluoride to be of concern in the downwind communities (County of Maui, 2010a).

Sulfur dioxide and residual acid aerosols have been found to have broad detrimental impacts on non-native and agricultural crop biota. (There is some evidence that native plants have developed a degree of resistance to sulfur dioxide and/or the acid constituents in the plume.) The farming communities in Island of Hawaii's district of Kau have seen extensive defoliation and leaf damage to both edible crops as well as flowering and ornamental plants (tomatoes, lettuce, roses, etc.) (County of Maui, 2010a).

In order for sulfur dioxide to cause damage to vegetation and agricultural crops, it must penetrate the plant's natural openings in leaf surfaces that regulate gas exchange. Once sulfur dioxide enters the moist mesophyll tissue, it combines with water and is converted to sulfuric acid, which burns plant tissue. The general effects of sulfur dioxide exposure to plants may vary and depend upon plant species, age, and the sulfur dioxide dosage; these effects may include (County of Maui, 2010a):

- Reduced seed germination
- Enhanced susceptibility to other diseases
- Foliar necrosis (spots, blight)
- Epicuticular wax erosion
- Rupture of epidermis, plasmolysis
- Reduced chlorophyll content
- Increased membrane permeability of plant leaves
- Decreased plant growth (root length, shoot length, leaf numbers)
- Plant organ or entire plant death.

A further effect of increased loading of acid aerosols produced by VOG onto agricultural lands in the downwind areas will be the accelerated leaching of minerals from the soil column. To date, this process has not been fully researched and, hence, it's difficult to offer an assessment of the long-term impacts of acidification of rainfall on the agriculture communities downwind from the VOG source (County of Maui, 2010a).

17.3.5 Economic Impact

Economic impacts of VOG have both short- and long-term consequences. Due to the respiratory effects of VOG on people, particularly severe occurrences of VOG have the potential to disrupt the tourism industry. Visitors may cut their trips short, or spend more time indoors, causing a temporary dip in the local economy. Long-term effects of VOG include

corrosion of steel structures. Over the years, this corrosion could lead to structural instability that will necessitate remedial action.

17.4 Future Trends in Development

17.4.1 Lava Flow

Lava Zones are mapped in the planning area, as noted previously. As such, development in potentially affected areas remains monitored.

17.4.2 VOG

All future development in the planning area will be susceptible to the potential impacts from VOG. While this potential impact on the built environment is not considered to be significant, the economic impact on industries that rely on machinery and equipment such as agriculture or civil engineering projects could be significant. Since the extent and location of this hazard is difficult to gauge because it is dependent upon many variables, the ability to institute land use recommendations based on potential impacts of this hazard is limited. While the impacts of VOG are sufficient to warrant risk assessment for emergency management purposes, they are not sufficient to dictate land use decisions.

17.5 Scenario

17.5.1 Lava Flow

In the event of a volcanic eruption in the planning area, there would probably not be any loss of life, due to adequate warnings and the generally slow movement of Pahoehoe. However, there could be great loss of property, especially in Lava Zones 1 and 2 and a large and prolonged impact to the local economy. There would also be the possibility of severe environmental impacts due to lava flows in area rivers and streams.

17.5.2 VOG

A large area could be affected by VOG. The most severe impacts would be on individuals, particularly those suffering from respiratory illness. Local hospitals may see an increase in respiratory-related acute illness, potentially causing a surge event. This impact is dependent upon the prevailing wind direction during and after the event. Businesses and non-essential government may be closed during particularly severe VOG events.

17.6 Issues

17.6.1 Lava Flow

- **Public Information Outreach**—Because of the seemingly distant possibility of an eruption of the East Maui Volcano, the public may not be aware of the dire consequences associated with lava flow and the threat to property. Developing public outreach materials ensures that residents are aware that, despite all outward appearances, an eruption is possible.
- **Lava Flow Intersection Mapping**—The Lava Zones for the Island of Maui provide a general guideline for potential lava hazard areas during an eruption. More detailed mapping which shows the intersection of transportation corridors, critical facilities, and private property could serve to develop a focused picture.

17.6.2 VOG

- **Tourism Outreach**—Tourists visiting Maui County may not be immediately aware of the threat that VOG poses to their health. Developing informational pamphlets on VOG facts and safety may assist in minimizing respiratory emergencies from visitors.
- **VOG Action Plan**—The County may consider a VOG Action Plan that delineates specific community actions based on the anticipated level of a severe VOG event. Such plans could include measures for sheltering in place, providing emergency shelter to the County's homeless population, assisting known individuals with disabilities, access, or functional needs that may be exacerbated by VOG.

Chapter 18. Wildfire

18.1 Hazard Description

A wildfire is any uncontrolled fire occurring on undeveloped land that requires fire suppression. Wildfires can be ignited by lightning or by human activity such as smoking, campfires, equipment use, and arson.

Fire hazards present a considerable risk to vegetation and wildlife habitats. Short-term loss caused by a wildfire can include the destruction of timber, wildlife habitat, scenic vistas, and watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and destruction of cultural and economic resources and community infrastructure. Vulnerability to flooding increases due to the destruction of watersheds. The potential for significant damage to life and property exists in areas designated as "wildland urban interface (WUI) areas," where development is adjacent to densely vegetated areas.

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 have 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 (County of Maui, 2010a).

18.1.1 Categories and Types of Wildfire

In general, FEMA defines four categories of wildfires that are experienced throughout the United States. These categories are defined as follows (FEMA, 1997):

- **Wildland Fires**—Wildland fire are fueled almost exclusively by natural vegetation. They typically occur in national forests and parks, where Federal agencies are responsible for fire management and suppression.
- **Interface or Intermix Fires**—Interface fires are urban/wildland fires in which vegetation and the built-environment provide fuel

DEFINITIONS

Conflagration—A fire that grows beyond its original source area to engulf adjoining regions. Wind, extremely dry or hazardous weather conditions, excessive fuel buildup and explosions are usually the elements behind a wildfire conflagration.

Firestorm—A fire that expands to cover a large area, often more than a square mile. A firestorm usually occurs when many individual fires grow together into one. The involved area becomes so hot that all combustible materials ignite, even if they are not exposed to direct flame. Temperatures may exceed 1000°C. Superheated air and hot gases of combustion rise over the fire zone, drawing surface winds in from all sides, often at velocities approaching 50 miles per hour. Although firestorms seldom spread because of the inward direction of the winds, once started there is no known way of stopping them. Within the area of the fire, lethal concentrations of carbon monoxide are present; combined with the intense heat, this poses a serious life threat to responding fire forces. In very large events, the rising column of heated air and combustion gases carries enough soot and particulate matter into the upper atmosphere to cause cloud nucleation, creating a locally intense thunderstorm and the hazard of lightning strikes.

Wildland-Urban Interface (WUI) Area—An area susceptible to wildfires and where wildland vegetation and urban or suburban development occur together. An example would be smaller urban areas and dispersed rural housing in forested areas.

Wildfire—Fires that result in uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property in non-urban areas. Because of their distance from firefighting resources, they can be difficult to contain and can cause a great deal of destruction.

- **Firestorms**—Firestorms are events of such extreme intensity that effective suppression is virtually impossible. Firestorms occur during extreme weather and generally burn until conditions change or the available fuel is exhausted.
- **Prescribed Fires and Natural Burns**—Prescribed fires are intentionally set or selected natural fires that are allowed to burn for beneficial purposes.

According to the National Oceanic and Atmospheric Administration (NOAA), there are four specific types of wildfires: ground wildfires, surface wildfires, crown wildfires, and spotting wildfires. Figure 18-1 illustrates NOAA's wildfire classification (County of Maui, 2010a).

- **Ground Wildfires**—These wildfires burn in natural litter, duff, roots, or sometimes high-organic soils. Once they start, they are very difficult to detect and control. In addition, ground fires my rekindle.
- **Surface Wildfires**—These wildfires burn in grasses and low shrubs (up to 4 feet tall) or in the lower branches of trees. Surface wildfires may move rapidly and the ease of control depends upon the fuel involved.
- **Crown Wildfires**—These wildfires burn on the tops of trees. Once started, they are very difficult to control since wind plays and important role in the spread of this type of wildfire.
- **Spotting Wildfires**—These wildfires can be produced by crown wildfires as well as by wind and atmospheric conditions. A characteristic of spotting wildfires is that large burning embers are thrown ahead of the main fire. Once spotting begins, the wildfire will be very difficult to control.

Source: Maui County, 2010a

FIGURE 18-1. TYPES OF WILDFIRES

18.2 Hazard Profile

18.2.1 Past Events

Island of Maui

The following wildfire events have occurred on the Island of Maui since 1980:

- In 1980, two fires standout. The first was occurred in August and burned 4,087 acres. The second fire was in November and burned 796 acres. Both were in the Haleakala National Park/Kahikinui Forest Reserve area in the south side of the island's east side (County of Maui, 2010a).

- In October 1998, a large wildfire occurred in the Maalaea area on the west side of the Island of Maui. Honoapiilani Highway (State Highway 30) was completely closed to traffic for about twelve and a half hours and alternating from open-to-closed-to-one lane for another fifteen hours. Many structures were threatened but none were lost. At one point all three shifts of the Maui Police Department were on the job (County of Maui, 2010a).
- On January 23, 2001, a wildfire fueled by strong trade winds scorched 800 acres of brush in Launiupoko and stranded hundreds of motorists as authorities were forced to close Honoapiilani Highway (State Highway 30) for more than 7 hours. The blaze, which started at an elevation of approximately 1,200 feet, worked its way down to the coastline in an area east of Launiupoko, between and Launiupoko and Olowalu. Although the Launiupoko fire threatened two homes and a piggery, no damage was reported to these structures. Many firefighters took part in dousing the flames, with three receiving minor injuries. Four water bucket-carrying helicopters were used in containing the fire as well. The cause of the brush fire is unknown (County of Maui, 2010a).
- Another fire occurred in the Olowalu area in July 2002. This time, 225 acres of land were consumed within a few hundred yards of residences. No damage to private or public property was reported (County of Maui, 2010a).
- The next wildfires of significant size occurred in 2005. The first fire, which occurred in early July, burned 120 acres in the Launiupoko area causing the closure of Honoapiilani Highway (State Highway 30) for 3.5 hours. Another July brush fire, this time on the 12th, scorched 200 acres between Maalaea and McGregor Point halted traffic for several hours along Honoapilani Highway (State Highway 30). Smoke from the fire caused much of the problem. Four separate fires along the route merged into one large blaze that took fire fighters many hours to contain and control. County officials believed that the initial fires were intentionally set. There were no reports of serious property damage or injuries (County of Maui, 2010a).
- On July 12, 2005, a wildfire upslope from Lahainaluna High School in leeward West Maui was of unknown origin and burned over 2.5 days. The fire scorched 120 acres of brush and grass land, but for a time threatened native plants and bird habitats. However, no serious injuries or property damage were reported after the blaze was extinguished (County of Maui, 2010a).
- Just a few weeks later, on July 26-27, 2005, a grass and brush fire with a suspicious origin scorched 80 acres near Lahaina in leeward West Maui. The blaze came within 50 yards of homes in the Wahikuli residential area, above Kahoma Street on the slopes of the West Maui Mountains. However, no serious injuries or property damage were reported (County of Maui, 2010a).
- The last two fires of 2005 happened simultaneously in the Lahaina area during the month of October. The blazes, which are suspected to have been arson incidents, burned near Lahainaluna High School. One of the two October 2005 fires charred 200 acres of former sugar cane land (County of Maui, 2010a).
- On September 1, 2006, a large wildfire in the Maalaea area charred approximately 2,000 acres of land. The fire threatened residences and businesses in the town of Maalaea. This Maalaea blaze also posed a significant risk to the Kaheawa Wind Power farm perched in the slopes of the West Maui Mountains above Maalaea. A fire Management Assistance Grant (FMAG) was approved by the Federal Emergency Management Agency (FEMA) to assist the County of Maui and the State of Hawaii in suppressing this fire (County of Maui, 2010a).

- During 2007, a myriad of wildfires affected the Island of Maui. On January 27, 2007, the Upper Waiohuli Wildfire burned approximately 2,300 acres of forested public lands within the Lula Forest Reserve on the western slopes of the Haleakala volcano on the island's east side. The wildfire, which burned for approximately 2 weeks, is believed to have been started by a discarded cigarette, most likely from a hiker. According to a report by the State of Hawaii Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife, in terms of size and intensity, the Upper Waiohuli Wildfire was one of the most devastating to have occurred for many decades in the Hawaiian Islands. Per the same document, approximately 500 acres within the burn unit were subject to relatively lighter fire intensities, and the forest areas therein are anticipated to recover. On the other hand, approximately 1,800 acres within the burn unit were severely burned with little remaining live vegetation (County of Maui, 2010a).
- Shortly after the Upper Waiohuli Wildfire, a wildfire struck the Kauaula Valley in the Lahaina area on February 19, 2007. The conflagration, which started above the Puamana subdivision, burned more than 1,000 acres of former sugar cane fields. According to the Honolulu Star Bulletin, the Kauaula Valley Wildfire also entered the fringe of the Panaewa section of the West Maui Natural Area Reserve system. This reserve area is home to endangered species of plants (County of Maui, 2010a).
- On June 27, 2007, two brushfires on the island's west side forced evacuations in the Lahaina and Olowalu areas. The smaller Lahaina brushfire came within 20 feet of homes at the Wahikulu subdivision forcing evacuations of some homes. The much larger Olowalu fire burned approximately 2,600 acres and destroyed one residence. The fire, which started on the mountain side of Honoapiilani Highway (State Highway 30), spread across the road to the ocean side of the highway severely disrupting traffic along a 2-mile portion of this main arterial road (County of Maui, 2010a).
- Just a few days after the late June 2007 high winds flared up another wildfire in the Lahaina area. The fire, which started on July 3, consumed approximately 180 acres and prompted the evacuation of at least 150 people from a homeless shelter and rental project in the town of Lahaina. The fire also threatened the Lahaina Aquatic Center. The fire is believed to have been sparked by fireworks (County of Maui, 2010a).
- In 2009, several brushfires affected the Maalaea area. On June 21, 2009, a brush fire that started near Maalaea Harbor forced the closing of Honoapiilani Highway (State Highway 30) from the town of Maalaea to the Ukumehame gulch area. The brush fire charred approximately 80 acres, damaged one residence, and fully destroyed another residence. Similarly, on November 2, 2009, another blaze resulted in the closure of Honoapiilani Highway (State Highway 30) from the town of Maalaea to the Ukumehame gulch area. Although small compared to the June blaze, this fire damaged a Hawaiian TelCom's fiber-optic cable line causing service to be disrupted in the area (County of Maui, 2010a).
- In May 2010, a West Maui brushfire burned 1,100 acres in the Olowalu area. Approximately 100 residents were temporarily evacuated from their homes and caused the closure of transportation corridors (Honolulu Advertiser, 2010).
- Shortly after the May fire in June 2010, a brush fire started in the Maalea area of West Maui that resulted in over 6,200 acres catching fire. High winds prevented firefighters from containing the conflagration, with near containment achieved, only to have hotspots reignite (KITV, 2010). The brush fire resulted in the temporary closure of the Honoapiilani Highway and the evacuation of 100 people from nearby areas including Maalaea,

the Kaheawa wind farm and shoreline campers. A subsequent investigation resulted in the classification as "undetermined" regarding the cause of the fire (Maui Now, 2010).

- Two fires caused a 4-hour closure of the Honoapiilani Highway in August 2010. A fire at Ukumehame burned a total of 20 acres, while a separate blaze at Launiupoko burned an estimated 2 acres and burned two utility poles (Osher, 2010).
- Olinda and Kula experienced two simultaneous wildfire events in June 2012. The Olinda fire, located in a difficult area to reach with proper firefighting equipment, burned heavy timber. In Kula, the fire caused damage to three homes. High winds made the conflagrations difficult to control (Meiers, 2012).
- In July 2012, a minor brush fire burned about 5 acres, near the Kuihelani/Honoapiilani Highway intersection. Traffic was not disrupted and the fire was extinguished approximately 4 hours after the initial report (Osher, 2012).
- Finally, wildfire burned approximately 65 acres in Kalupo in July 2013, disrupting traffic on Piilani Highway on the Ulpalakua side of Manawainui Gulch. No injuries were reported and no buildings were in danger (Hawaii News Now, 2013).

Sugarcane Disposal Uncontrolled Fires

In Maui County, sugarcane agriculture serves as a vital economic resource. Each sugarcane field is planted with new cane seedlings only once every8 years. After the first 2-year crop is harvested, the old stalks and root systems are permitted to sprout again. This re-sprouting usually is repeated two more times before the field is plowed under completely and planted again with new seedlings. When a field reaches maturity, the cane is set on fire to get rid of the tons of unwanted vegetation that have accumulated on the cane over the previous 2 years (County of Maui, 2010a).

While sugarcane burning is typically scheduled to take advantage of favorable winds and weather conditions, sudden wind shifts can direct flames in any direction leading to uncontrolled fires. Although uncommon, there have been several recorded instances in the last decades of uncontrolled sugarcane disposal fires in the Island of Maui (County of Maui, 2010a):

- On September 16, 2003, a controlled burn by the Hawaiian Commercial & Sugar Company got out of hand near Waikapu on Maui when the wind carried some of the flames into nearby mountainous terrain. The fire ended up blackening about 1,000 acres of parched grassland, to as high as 2000 feet in elevation in the West Maui Mountains. The blaze forced the evacuation of the Sandalwood and Grand Waikapu golf courses for a few hours during the afternoon of the 16th and all day on the 17th. State and federal firefighters, with the help of four water-carrying helicopters (including a large Chinook from the Hawaii Army National Guard on the Island of Oahu), battled the fire over several days. No serious injuries or property damage were reported during this uncontrolled sugar can burn.
- On September 22, 2009, an uncontrolled sugarcane burning interrupted transit along Haleakala Highway (State Highway 377) in the Island of Maui.

Figure 18-2 shows the locations of all Island of Maui wildfire events between 1998 and 2008 as provided by the Hawaii Wildfire Management Organization through the use of the interactive historical wildfires tool.

Source: HWMO, 2013

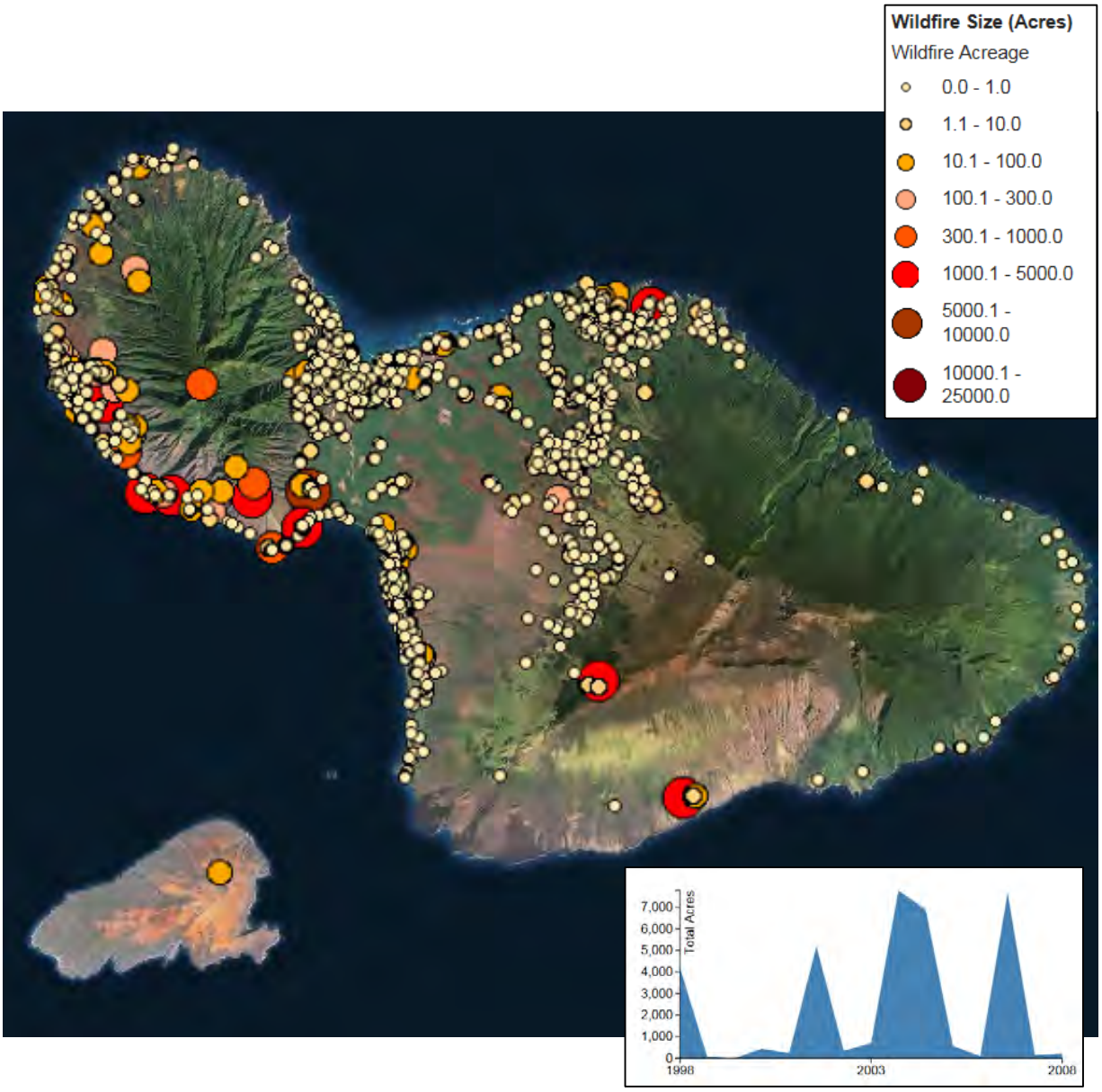


FIGURE 18-2. HISTORY OF WILDFIRES ON THE ISLANDS OF MAUI AND KAHOOLAWE

Island of Kahoolawe

For at least two centuries prior to World War II, the Hawaiian island of Kahoolawe suffered the ravages of periodic wildfires, slash-and-burn agriculture, and sever overgrazing, leaving the island almost barren of vegetation. For this reason, and also because of the absence of human population, wildfires that could threaten the remaining and newly planted vegetation (the island has undergone several land rehabilitation programs with the goal to re-introduce native plant species) are not a common occurrence in the Island of Kahoolawe (County of Maui, 2010a).

Figure 18-2 provides a visual representation of all Island of Kahoolawe wildfire events between 1998 and 2008 a provided by the Hawaii Wildfire Management Organization through the use of the interactive historical wildfires tool.

Island of Lanai

The Island of Lanai has been the safest island in terms of wildfires with only a few consequential fires in the past two decades. In January 1995, one fire burned 1,204 acres and in December 1999, a fire in the Kaluanui Flats area, approximately 2 miles southeast of Lanai City, burned over 2,000 acres. On November 18, 2008, the Palawai Basin wildfire consumed approximately 1,000 acres south of Lanai City. According to County of Maui officials, the Palawai Basin conflagration forced the evacuation of 600 visitors and residents from Manele Bay Hotel and nearby residences (County of Maui, 2010a).

Figure 18-3 provides a visual representation of all Island of Molokai wildfire events between 1998 and 2008 a provided by the Hawaii Wildfire Management Organization through the use of the interactive historical wildfires tool.

Source: HWMO, 2013

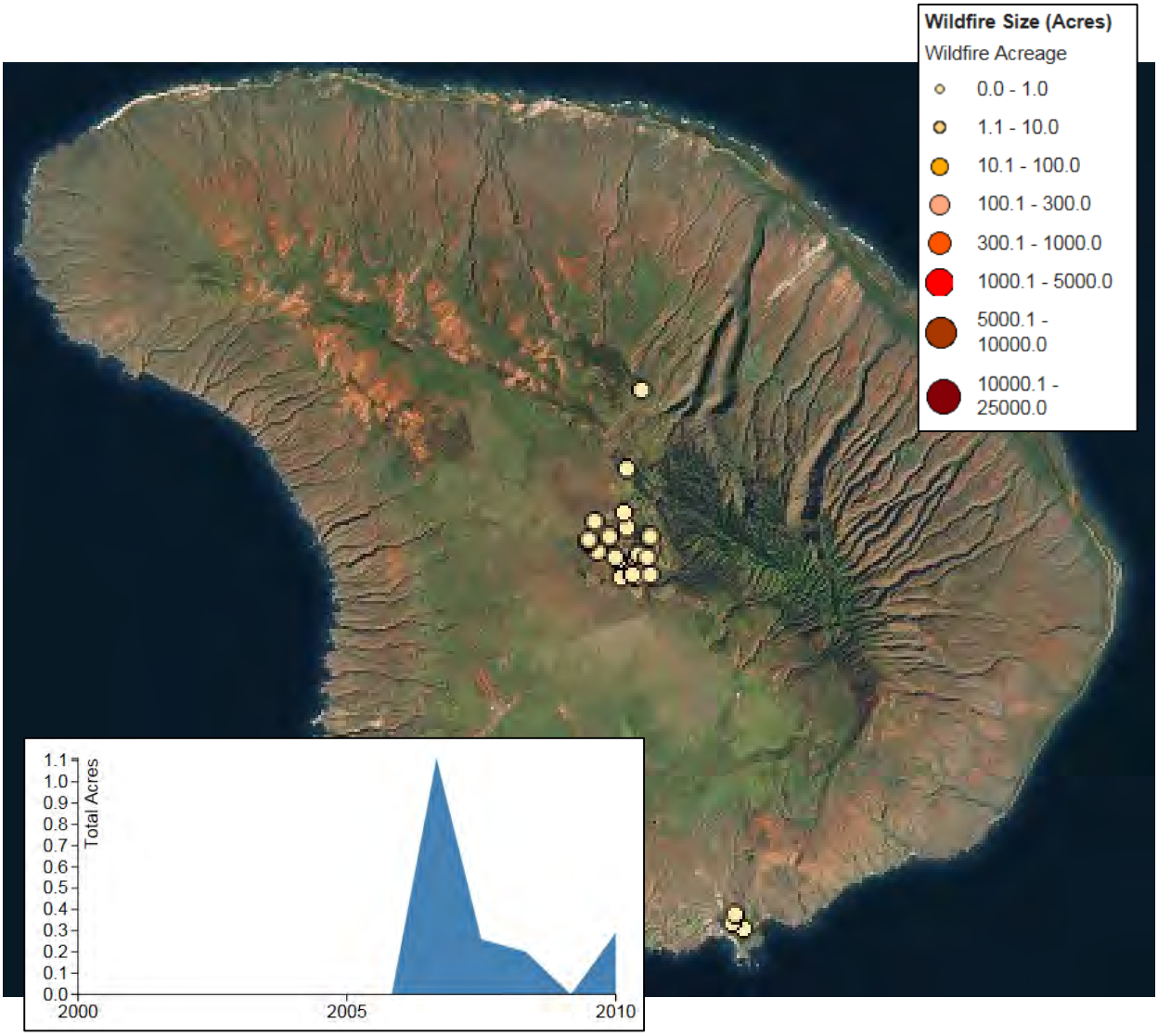


FIGURE 18-3. HISTORY OF WILDFIRES ON THE ISLAND OF LANAI

Island of Molokai

Molokai experienced 9 years on record where at least 1,000 acres were burned. The top years for fires in the Island of Molokai have been 1981, 1991, 1998, 2007 and 2009 (County of Maui, 2010a).

In 1981, a total of 4,913 acres were burned in the Island of Molokai. The eastern half of the island lost 595 acres in two fires while the western half lost 4,186 acres and three structures. In September alone, two fires destroyed 1,955 acres and two structures (County of Maui, 2010a).

In 1991, a total of 12,656 acres were burned on the Island of Molokai. This was almost entirely in one fire in June that burned 12,519 acres. This fire affected the south central area of the island. There were no deaths and only minor property damage; however, several fire fighters did receive minor injuries. Controlling and extinguishing the fire involved 92 people, 14 helicopters, numerous bulldozers and other fire-fighting equipment, and over $500,000 in recovery costs. This cost does not include those absorbed by the U.S. Marines and the National Guard (County of Maui, 2010a).

In 1998, a total of 14,041 acres and one structure were burned in the Island of Molokai. These losses were mostly from one fire in August that burned for 7 days and consumed 12,453 acres with no reports of injuries or structures damaged. The other three large fires to affect the Island of Molokai in 1998 consumed 643, 600, and 300 acres each. These last two fires took place in the month of August. 1998 was also the second year in a row for El Nino.

On July 6, 2005, a fire about 2.5 miles south of Hoolehua Airport burned 200 acres of brush. The cause of the fire was unknown. There were no reports of serious injuries or property damage (County of Maui, 2010a).

In 2007, the Kalua Koi wildfire charred 3,000 acres of bush on the far west end of Molokai. The blaze was first reported on June 7 near mile marker 11 along Maunaloa Highway (State Highway 460). The Kalua Koi wildfire spread quickly on the ocean side of the highway and reached well pass Kalua Koi road. Luckily, the blaze did not pose a threat to any residences (County of Maui, 2010a).

During the last days of August and first days of September 2009, a wildfire consumed approximately 7,800 acres near the town of Kaunakakai on central Molokai. The Kaunakakai fire was first reported on August 29th and burned for 7 days until it was fully contained on September 5th by the combined effort of more than 30 firefighters from the Division of Forestry and Wildlife Management (DOFAW) and the Maui Fire Department (MFD). The fire forced the evacuation of residents from Kalamaula Mauka and threatened 400 primary structures and 80 communication structures (County of Maui, 2010a).

Figure 18-4 provides a visual representation of all Island of Molokai wildfire events between 1998 and 2008 a provided by the Hawaii Wildfire Management Organization through the use of the interactive historical wildfires tool.

Source: HWMO, 2013

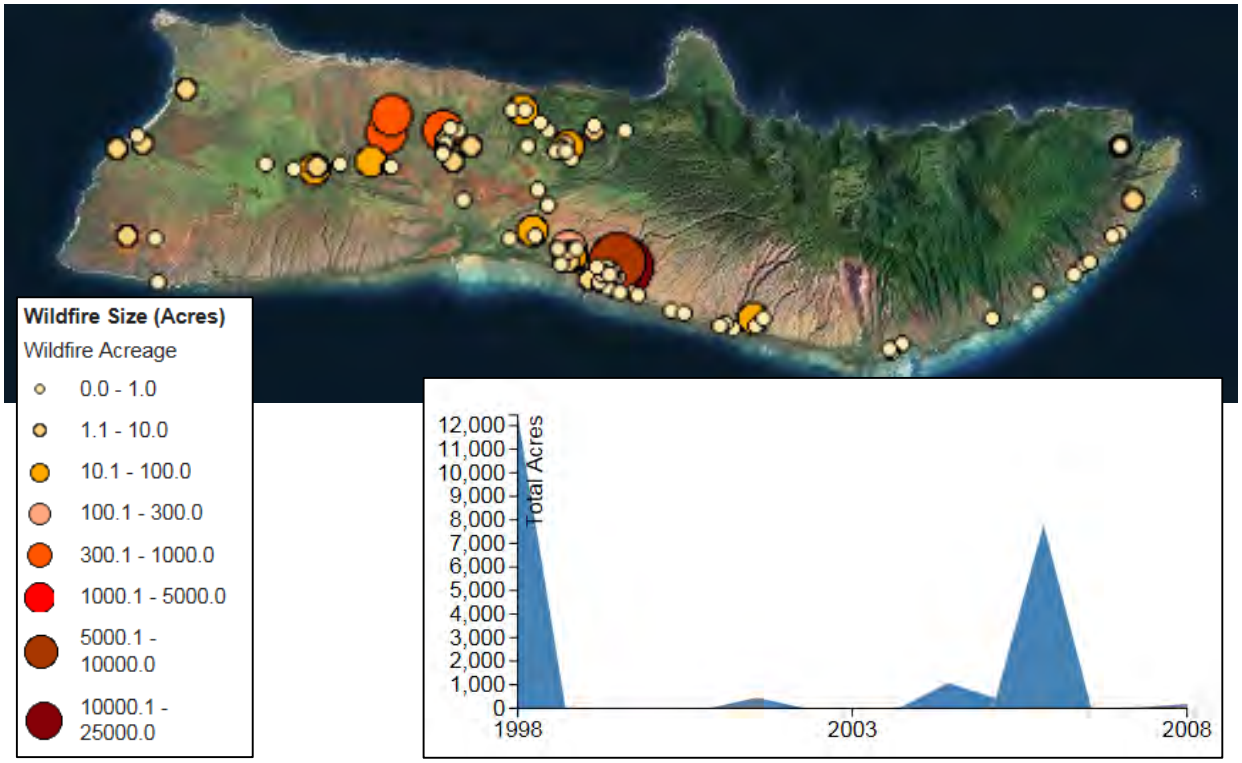


FIGURE 18-4. HISTORY OF WILDFIRES ON THE ISLAND OF MOLOKAI

18.2.2 Location

Areas of the planning area differ in regards to the potential for wildfire. These differences vary depending on the following factors:

- **Fuel**—Fuel may include living and dead vegetation on the ground, along the surface as brush and small trees, and above the ground in tree canopies. Lighter fuels such as grasses, leaves and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs and trunks take longer to warm and ignite. Trees killed or defoliated by forest insects and diseases are more susceptible to wildfire.
- **Weather**—Relevant weather conditions include temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount and duration, and the stability of the atmosphere. Of particular importance for wildfire activity are wind and thunderstorms:
    - **Wind**—Strong, dry winds produce extreme fire conditions. Such winds generally reach peak velocities during the night and early morning hours.
    - **Thunderstorms**—The thunderstorm season typically begins in June with wet storms, and turns dry with little or no precipitation reaching the ground as the season progresses into July and August.
- **Terrain**—Topography includes slope and elevation. The topography of a region influences the amount and moisture of fuel; the impact of weather conditions such as temperature and wind; potential barriers to fire spread, such as highways and lakes; and elevation and slope of land forms (fire spreads more easily uphill than downhill).

Historically, on the Island of Maui, the area between Maalaea and Olowalu are most prone to wildfires due to little precipitation and a frequent history of drought. Additionally, the Lahaina area of the island is susceptible to wildfire events. The areas of the Kula region (from the top of the Haleakala Volcano to the slopes of the West Maui Mountains) are subject to high drought frequency at vulnerable locations and thus have an increased risk of wildfires (County of Maui, 2010a).

On the Island of Molokai, the south-central area of the island has experienced wildfires in the past. Additionally, the low-rainfall area west of Kaunakakai on the Island of Molokai has been consumed by several wildfires in the past. Therefore, this area is at a higher risk of impact (County of Maui, 2010a).

Lanai, the least wildfire-impacts island within the planning area, is most prone to small wildfire in and around Lanai City (County of Maui, 2010a).

18.2.3 Frequency

In Hawaii, the fire season typically runs from the dry months of April through October. However, dry periods or periods of drought can extend the season. The possibility of a naturally-occurring wildfire depends on fuel availability, topography, the time of year, and weather conditions. Nonetheless, because naturally-occurring wildfires are most likely to happen in dry periods or periods of drought, the hazard is often considered as a component of the drought hazard.

According to government authorities however, humans caused the highest percentage of wildfires in the County of Maui either accidentally or intentionally (arson). Major causes of accidentally induced wildfires are debris burning, land clearing (i.e. sugar cane burning), smoking, and campfires. In the County of Maui, wildfires most often start in fields, open areas, transportation areas, or wooded lands. Wildfires are usually extinguished while less than1 acre, but can spread to over thousands of acres. Historically, wildfires started by arson have caused the largest acreage losses, followed by equipment, debris burning, and cigarettes (County of Maui, 2010a).

18.2.4 Severity

Potential losses from wildfire include human life, structures and other improvements, and natural resources. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds.

18.2.5 Warning Time

Humans often cause wildfires, intentionally or accidentally. There is no way to predict when one might break out. Since fireworks often cause brush fires, extra diligence is warranted around the Fourth of July when the use of fireworks is highest. Dry seasons and droughts are factors that greatly increase fire likelihood. Dry lightning may trigger wildfires. Severe weather can be predicted, so special attention can be paid during weather events that may include lightning. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm.

If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

18.2.6 Potential Impacts of Climate Change

Wildfire is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

According to a briefing sheet produced by the University of Hawaii Sea Grant College Program, Hawaii is getting warmer. Data shows a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with stronger warming at high elevations (above 2600 feet). The rate of temperature rise at low elevations (below 2600 feet), 0.16°F per decade, is less than the global rate (about 0.36°F per decade); however, the rate of warming at high elevations in Hawaii, 0.48°F per decade, is faster than the global rate. Most of the warming is related to a larger increase in minimum temperatures compared to the maximum—a net warming about 3 times as large— causing a reduction of the daily temperature range. This response to global warming is consistent with similar trends observed in North America. Despite recent years where the rate of global warming was low, surface temperatures in Hawaii have remained high. As temperatures rise, modeling results indicate to some extent that the State of Hawaii should expect to see decreased rainfall in response to climate change. Studies over the past 20 years have confirmed this phenomenon, as rainfall in throughout the state has steadily declined about 15 percent over the past 20 years (Fletcher, 2010). This increase in temperature coupled with a noticeable decrease in precipitation exacerbates droughts and has the potential to contribute to an increased frequency of wildfire.

18.2.7 Secondary Hazards

Wildfires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable crops and indirect economic losses in reduced tourism. Wildfires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. They strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. Most wildfires burn hot and for long durations that can bake soils, especially those high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

18.3 Exposure

The Hawaii Wildfire Management Organization (HWMO) has conducted detailed mapping and assessment of wildfire risk within Maui County. The extent and location mapping data was unavailable for spatial exposure analysis for this plan update. This data should be incorporated in future plans to better assess risk and vulnerability from the wildfire hazard.

18.3.1 Population

Guided by the National Fire Plan and the Healthy Forests Restoration Act (HFRA), state wildland fire-fighting agencies and their federal and local partners are responsible for identifying communities at risk from wildland fires. Based on the guidelines developed by the National Association of State Foresters in June 2003, the Hawaii Department of Land and Natural Resources DOFAW identified at-risk wildland-urban interface communities in the major Hawaiian Islands and rated each community's risk from wild-land fires. Maui County contains several communities identified as high risk on the islands of Maui and Molokai. Table 18-1 depicts the communities of Maui and identifies their associated wildfire risk rating. Communities at risk from wildfire were categorized as high, medium or low based on such factors such as current vegetation type, climate regimes, and fire history. Although exact definitions for high, medium and low are unavailable these ratings were established to indicate relative risk (Hawaii Statewide Assessment of Forest Conditions and Trends, 2010).

TABLE 18-1.
AT-RISK WILDFIRE COMMUNITES

Community Name	Risk Rating (high, medium, low)	Community Planning Area
Honokowai	High	West Maui
Hoolehua	High	Molokai
Kaanapali	High	West Maui
Kahului	High	Wailuku-Kahului
Kalamaula	High	Molokai
Kaluakoi	High	Molokai
Kaunakakai	High	Molokai
Kawela	High	Molokai
Kihei	High	Kihei-Makena
Lahaina	High	West Maui
Launiupoko	High	West Maui
Maalaea	High	Kihei-Makena
Makena	High	Kihei-Makena
Mauna Loa	High	Molokai
Olowalu	High	West Maui
Wahikuli	High	West Maui
Wailuku	High	Wailuku-Kahului
Camp Maluhia	Medium	Wailuku-Kahului
Honokohua	Medium	West Maui
Kahakuloa	Medium	Wailuku-Kahului
Kahana	Medium	West Maui
Kahikinui	Medium	Hana
Kula Hawaiian Homesteads	Medium	Makawao-Pukalani-Kula
Manele	Medium	Lanai
Napili	Medium	West Maui
Olinda	Medium	Makawao-Pukalani-Kula
Piiholo	Medium	Makawao-Pukalani-Kula
South Kamalo	Medium	Molokai
Waiakoa	Medium	Makawao-Pukalani-Kula
Waiehu	Medium	Wailuku-Kahului

TABLE 18-1.
AT-RISK WILDFIRE COMMUNITES

Community Name	Risk Rating (high, medium, low)	Community Planning Area
Waihee	Medium	Wailuku-Kahului
Waikapu	Medium	Wailuku-Kahului
Haiku	Low	Paia-Haiku
Hailiimaile	Low	Makawao-Pukalani-Kula
Halawa	Low	Molokai
Hamoa	Low	Hana
Hana	Low	Hana
Huelo	Low	Paia-Haiku
Kaeleku	Low	Hana
Kailua	Low	Paia-Haiku
Kalaupapa	Low	Molokai
Keanae	Low	Hana
Kipahulu	Low	Hana
Koali	Low	Hana
Kuau	Low	Paia-Haiku
Kula 200	Low	Makawao-Pukalani-Kula
Lanai City	Low	Lanai
Lower Kula	Low	Makawao-Pukalani-Kula
Makaalae	Low	Hana
Makawao	Low	Makawao-Pukalani-Kula
Nahiku	Low	Hana
Naiwa	Low	Molokai
Paia	Low	Paia-Haiku
Pukalani	Low	Makawao-Pukalani-Kula
Puu O Hoku	Low	Molokai
Spreckelsville	Low	Paia-Haiku
Ulupalakua	Low	Makawao-Pukalani-Kula
Upper Kula	Low	Makawao-Pukalani-Kula
Wahikuli-Keokeo Homesteads	Low	Makawao-Pukalani-Kula
Wailua	Low	Hana
Wailuku Heights	Low	Wailuku-Kahului

Note: Some communities may cross community planning boundaries.

18.3.2 Property

Property damage from wildfires can be severe and can significantly alter entire communities. Structures that were not designed with fire smart principles in mind or located in the wildland urban interface are particularly vulnerable.

18.3.3 Critical Facilities and Assets

There are likely to be several facilities containing hazardous materials exposed to the wildfire hazard. During a wildfire event, these materials could rupture due to excessive heat and act as fuel for the fire, causing rapid spreading and escalating the fire to unmanageable levels. In addition they could leak into surrounding areas, saturating soils and seeping into surface waters, and have a disastrous effect on the environment.

In the event of wildfire, there would likely be little damage to the majority of infrastructure. Most road and railroads would be without damage except in the worst scenarios. Power lines are the most at risk to wildfire because most are made of wood and susceptible to burning. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion.

18.3.4 Onshore and Offshore Natural Environment

Fire is a natural and critical ecosystem process in most terrestrial ecosystems, dictating in part the types, structure, and spatial extent of native vegetation. However, wildfires can cause severe environmental impacts:

- **Damaged Fisheries**—Critical fisheries can suffer from increased water temperatures, sedimentation, and changes in water quality.
- **Soil Erosion**—The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- **Spread of Invasive Plant Species**—Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes, and become difficult and costly to control.
- **Disease and Insect Infestations**—Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active management actions are needed to remove diseased or infested trees.
- **Destroyed Endangered Species Habitat**—Catastrophic fires can have devastating consequences for endangered species.
- **Soil Sterilization**—Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

Many ecosystems are adapted to historical patterns of fire occurrence. These patterns, called “fire regimes,” include temporal attributes (e.g., frequency and seasonality), spatial attributes (e.g., size and spatial complexity), and magnitude attributes (e.g., intensity and severity), each of which has ranges of natural variability. Ecosystem stability is threatened when any of the attributes for a given fire regime diverge from its range of natural variability.

18.4 Vulnerability

Structures, above-ground infrastructure, critical facilities and natural environments are all vulnerable to the wildfire hazard. There is currently no validated damage function available to support wildfire mitigation planning. Except as discussed in this section, vulnerable populations, property, infrastructure and environment are assumed to be the same as described in the section on exposure.

18.4.1 Population

There are no recorded incidents of loss of life from wildfires within the planning area. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal; therefore, injuries and casualties were not estimated for the wildfire hazard.

Smoke and air pollution from wildfires can be a severe health hazard, especially for sensitive populations, including children, the elderly and those with respiratory and cardiovascular diseases. Smoke generated by wildfire consists of visible and invisible emissions that contain particulate matter (soot, tar, water vapor, and minerals), gases (carbon monoxide, carbon dioxide, nitrogen oxides), and toxics (formaldehyde, benzene). Emissions from wildfires depend on the type of fuel, the moisture content of the fuel, the efficiency (or temperature) of combustion, and the weather. Public health impacts associated with wildfire include difficulty in breathing, odor, and reduction in visibility.

Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

18.4.2 Property

Loss estimations for the wildfire hazard are not based on damage functions, because no such damage functions have been generated.

18.4.3 Critical Facilities and Assets

Critical facilities of wood frame construction are especially vulnerable during wildfire events. In the event of wildfire, there would likely be little damage to most infrastructure. Most roads would be without damage except in the worst scenarios. Power lines are the most at risk from wildfire because most poles are made of wood and susceptible to burning. Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. Wildfire typically does not have a major direct impact on bridges, but it can create conditions in which bridges are obstructed. Many bridges in areas of high to moderate fire risk are important because they provide the only ingress and egress to large areas and in some cases to isolated neighborhoods.

Hazardous materials sites located in proximity to wildfires are at particular risk for compounding issues. Hazardous materials facilities often contain large quantities of flammable materials. Should a wildfire reach one of these facilities, the result could be catastrophic.

18.4.4 Onshore and Offshore Natural Environment

Wildfires in Hawaii pose a serious risk to endemic and introduced flora and fauna. Environmental vulnerabilities, therefore, include damage to plant species, damage to animal species, and contamination of hydrological resources.

18.4.5 Economic Impacts

Currently there is no measure in place to quantify the potential economic impacts due to wildfires besides historical data. The risk of wildfires is measured in terms of the hazard's economic, environmental, or social impacts. Economic impacts due to wildfires include costs and losses due to burned agricultural crops, damaged public infrastructure and private property, interrupted transportation corridors, and disrupted communication lines. Economic impacts also

include diminished real property values and thus tax revenues, loss of retail sales, and relocation expenses of temporarily or permanently displaced residents.

18.5 Future Trends in Development

The highly urbanized portions of the planning area have little or no wildfire risk exposure. Urbanization tends to alter the natural fire regime, and can create the potential for the expansion of urbanized areas into wildland areas. The expansion of the wildland urban interface can be managed with strong land use and building codes. The planning area is well equipped with these tools. Land use in the planning area will be directed by the general plan and community plans adopted under state law. The natural hazard elements of the general plans establish standards and policies for the protection of the community from hazards.

18.6 Scenario

A major conflagration in the planning area might begin with a wet spring, adding to fuels already present on the forest floor. Flash fuels would build throughout the spring. The summer could see the onset of insect infestation. A dry summer could follow the wet spring, exacerbated by dry hot winds. Carelessness with combustible materials or a tossed lit cigarette, or a sudden lighting storm could trigger a multitude of small isolated fires.

The embers from these smaller fires could be carried miles by hot, dry winds. The deposition zone for these embers would be deep in the forests and interface zones. Fires that start in flat areas move slower, but wind still pushes them. It is not unusual for a wildfire pushed by wind to burn the ground fuel and later climb into the crown and reverse its track. This is one of many ways that fires can escape containment, typically during periods when response capabilities are overwhelmed. These new small fires would most likely merge. Suppression resources would be redirected from protecting the natural resources to saving more remote subdivisions.

The worst-case scenario would include an active fire season, spreading resources thin. Firefighting teams would be exhausted or unavailable. Many federal assets would be responding to other fires that started earlier in the season. While local fire districts would be extremely useful in the urban interface areas, they have limited wildfire capabilities or experience, and they would have a difficult time responding to the ignition zones. Even though the existence and spread of the fire is known, it may not be possible to respond to it adequately, so an initially manageable fire can become out of control before resources are dispatched.

To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing floodplains and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions of cubic yards of sediment into streams for years, creating new floodplains and changing existing ones. With the forests removed from the watershed, stream flows could easily double. Floods that could be expected every 50 years may occur every couple of years. With the streambeds unable to carry the increased discharge because of increased sediment, the floodplains and floodplain elevations would increase.

18.7 Issues

The major issues for wildfire are the following:

- **WUI Public Information**—Public education and outreach to people living in or near the fire hazard zones should include information about and assistance with mitigation activities such as defensible space, and advance identification of evacuation routes and safe zones.
- **Management of Development**—Future growth into interface areas should continue to be managed with special consideration towards development in the WUI.
- **Continued Responder Training** —Area fire districts need to continue to train on wildland-urban interface events.
- **Vegetation Management Activities**—Such activities would include enhancement through expansion of the target areas as well as additional resources. Controlled burns of sugarcane fields would continue to be monitored to mitigate against potential major uncontrolled conflagrations
- **Responder Qualifications**—Expand certifications and qualifications for fire department personnel. Ensure that all firefighters are trained in basic wildfire behavior, basic fire weather, and that all company officers and chief level officers are trained in the wildland command and strike team leader level.

Chapter 19. Planning Area Risk Ranking

A risk ranking was performed for the hazards of concern described in this plan. This risk ranking assesses the probability of each hazard's occurrence as well as its likely impact on the people, property, and economy of the planning area. The risk ranking methodology and results were reviewed, discussed, and approved by the Steering Committee. When available, estimates of risk were generated with data from Hazus-MH or GIS analysis using methodologies promoted by FEMA. For hazards of concern with less robust datasets, qualitative assessments were used. The results are used in establishing mitigation priorities.

19.1 Probability of Occurrence

The probability of occurrence of a hazard is indicated by a probability factor based on likelihood of annual occurrence:

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—There is no probability of occurrence (Probability Factor = 0).

The assessment of hazard frequency is generally based on past hazard events in the area. Table 19-1 summarizes the probability assessment for each hazard of concern for this plan. For this risk ranking exercise, the two volcanic hazards, lava flow and VOG, are ranked separately. This method was determined because of the significant difference in probability of occurrence for each type of volcanic hazard.

TABLE 19-1.
PROBABILITY OF HAZARDS

Hazard Event	Probability (high, medium, low)	Probability Factor
Coastal Erosion	High	3
Dam and reservoir failure	Low	1
Drought	High	3
Earthquake	High	3
Flood	High	3
High surf	High	3
High wind storm	High	3
Landslide, debris flow and rockfall	High	3
Tropical cyclone	Medium	2
Tsunami	High	3
Volcanic Hazards (Lava flow)	Low	1
Volcanic Hazards (VOG)	High	3
Wildfire	High	3

19.2 Impact

Hazard impacts will be assessed in three categories: impacts on people, impacts on property and impacts on the local economy. Numerical impact factors are assigned as follows:

- **People**—Values are assigned based on the percentage of the total ***population exposed*** to the hazard event. The degree of impact on individuals will vary and is not measurable, so the calculation assumes for simplicity and consistency that all people exposed to a hazard because they live in a hazard zone will be equally impacted when a hazard event occurs. It should be noted that planners could use an element of subjectivity when assigning values for impacts on people. Impact factors were assigned as follows:
  - High—30 percent or more of the population is exposed to a hazard (Impact Factor = 3)
  - Medium—15 percent to 29 percent of the population is exposed to a hazard (Impact Factor = 2)
  - Low—14 percent or less of the population is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the population is exposed to a hazard (Impact Factor = 0).
- **Property**—Values are assigned based on the percentage of the total ***property value exposed*** to the hazard event:
  - High—25 percent or more of the total assessed property value is exposed to a hazard (Impact Factor = 3)
  - Medium—10 percent to 24 percent of the total assessed property value is exposed to a hazard (Impact Factor = 2)
  - Low—9 percent or less of the total assessed property value is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the total assessed property value is exposed to a hazard (Impact Factor = 0).
- **Economy**—Values are assigned based on the percentage of the total ***property value vulnerable*** to the hazard event. Values represent estimates of the loss from a major event of each hazard in comparison to the total assessed value of the property exposed to the hazard. For some hazards, such as wildfire and landslide, vulnerability will be considered to be the same as exposure due to the lack of loss estimation tools specific to those hazards. Loss estimates separate from the exposure estimates will be generated for the earthquake, flood hazards, and tropical cyclones using Hazus-MH.
  - High—Estimated loss from the hazard is 15 percent or more of the total exposed property value (Impact Factor = 3)
  - Medium—Estimated loss from the hazard is 5 percent to 14 percent of the total exposed property value (Impact Factor = 2)
  - Low—Estimated loss from the hazard is 4 percent or less of the total exposed property value (Impact Factor = 1)
  - No impact—No loss is estimated from the hazard (Impact Factor = 0).

The impacts of each category are assigned a weighting factor to reflect its significance: impact on people is given a weighting factor of 3; impact on property is given a weighting factor of 2; and impact on the economy is given a weighting factor of 1. Table 19-1, Table 19-3 and Table 19-4 summarize the impacts for each hazard.

TABLE 19-2.
IMPACT ON PEOPLE FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (3)
Coastal Erosion	Low	1	1 x 3 = 3
Dam and Reservoir Failure[a]	Medium	2	2 x 3 = 6
Drought [b]	Low	1	1 x 3 = 3
Earthquake	High	3	3 x 3 = 9
Flood [c]	Medium	2	2 x 3 =6
High Surf	Low	1	1 x 3 = 3
High Wind Storm	High	3	3 x 3 = 9
Landslide, Debris Flow and Rock Fall	Low	1	1 x 3 = 3
Tropical Cyclone	High	3	3 x 3 = 9
Tsunami	High	3	3 x 3 = 9
Volcanic Hazards (Lava Flow)[d]	Low	1	1 x 3 = 3
Volcanic Hazards (VOG) [e]	Low	1	1 x 3 = 3
Wildfire	Medium	2	2 x 3 = 6

a. Risk ranking is based on the Wailuku Water 6 evacuation zones
b. All people in the planning area would be exposed to drought, but impacts to the health and safety of individuals are expected to be minimal.
c. Although exposure estimates would result in a low ranking, impact was considered medium due to the potential for impacts outside of the mapped floodplains and for impacts to people travelling within and across flooded areas.
d. Risk ranking for impacts on people is based on inundation zone 1.
e. The impacts of VOG on people are not currently well understood. The Steering Committee elected to rate impacts as low until more information is available. Future updates of this plan should revisit and revaluate this impact rating.

TABLE 19-3.
IMPACT ON PROPERTY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)
Coastal Erosion	Medium	2	2 x 2 = 4
Dam and Reservoir Failure[a]	Low	1	1 x 2 = 2
Drought [b]	Low	1	1 x 2 = 2
Earthquake	High	3	3 x 2 = 6
Flood	Medium	2	2 x 2 = 4
High Surf	Low	1	1 x 2 = 2
High Wind Storm	High	3	3 x 2 = 6
Landslide, Debris Flow and Rock Fall	Low	1	1 x 2 = 2
Tropical Cyclone	High	3	3 x 2 = 6
Tsunami	High	3	3 x 2 = 6
Volcanic Hazards (Lava Flow)[c]	Low	1	1 x 2 = 2
Volcanic Hazards (VOG) [d]	Low	1	1 x 2 = 2
Wildfire	Low	1	1 x 2 = 2

TABLE 19-3.
IMPACT ON PROPERTY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)

a. Risk ranking is based on the Wailuku Water 6 evacuation zones
b. All property in the planning area would be exposed to drought, but impacts to structures are expected to be minimal.
c. Risk ranking for impacts on property is based on inundation zone 1 and 2.
d. All property in the planning area would be exposed to VOG, but impacts to structures are expected to be minimal.

TABLE 19-4.
IMPACT ON ECONOMY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (1)
Coastal Erosion[a]	High	3	3 x 1 = 3
Dam and Reservoir Failure[a]	Low	1	1 x 1 = 1
Drought [b]	Low	1	1 x 1 = 1
Earthquake	Low	1	1 x 1 = 1
Flood	Low	1	1 x 1 = 1
High Surf	Low	1	1 x 1 = 1
High Wind Storm	Low	1	1 x 1 = 1
Landslide, Debris Flow and Rock Fall	Low	1	1 x 1 = 1
Tropical Cyclone[a]	High	3	3 x 1 = 3
Tsunami	Medium	2	2 x 1 = 2
Volcanic Hazards (Lava Flow)[c]	Low	1	1 x 1 = 1
Volcanic Hazards (VOG)	Low	1	1 x 1 = 1
Wildfire	Medium	2	2 x 1 = 2

a. Although loss estimates would result in a low ranking, impact was considered medium due to the potential impacts from lost tourism.
b. Risk ranking is based on the Wailuku Water 6 evacuation zones
c. Risk ranking for impacts on property is based on inundation zone 1.

19.3 Risk Rating and Ranking

The risk rating for each hazard was determined by multiplying the probability factor by the sum of the weighted impact factors for people, property and operations, as summarized in Table 19-5.

Based on these ratings, a priority of high, medium or low was assigned to each hazard. The hazards ranked as being of highest concern are tsunami, earthquake and high wind storm. Hazards ranked as being of medium concern are tropical cyclone, flood, wildfire and coastal erosion. The hazards ranked as being of lowest concern are VOG, drought, high surf, landslide, debris flow and rockfall, dam and reservoir failure and lava flow. Table 19-6 shows the hazard risk ranking.

TABLE 19-5.
HAZARD RISK RATING

Hazard Event	Probability Factor	Sum of Weighted Impact Factors	Total (Probability x Impact)
Coastal Erosion	3	3+4+3= 10	30
Dam and Reservoir Failure	1	6+2+1= 9	9
Drought	3	3+2+1= 6	18
Earthquake	3	9+6+1= 16	48
Flood	3	6+4+1= 11	33
High Surf	3	3+2+1= 6	18
High Wind Storm	3	9+6+1= 16	48
Landslide, Debris Flow and Rock Fall	3	3+2+1= 6	18
Tropical Cyclone	2	9+6+3= 18	36
Tsunami	3	9+6+2= 17	51
Volcanic Hazards (Lava Flow)	1	3+2+1= 6	6
Volcanic Hazards (VOG)	3	3+2+1=6	18
Wildfire	3	6+2+2= 10	30

TABLE 19-6.
HAZARD RISK RANKING

Hazard Ranking	Hazard Event	Category
High	Tsunami	51
High	Earthquake	48
High	High Wind Storm	48
Medium	Tropical Cyclone	36
Medium	Flood	33
Medium	Wildfire	30
Medium	Coastal Erosion	30
Low	Volcanic Hazards (VOG)	18
Low	Drought	18
Low	High Surf	18
Low	Landslide, Debris Flow and Rock Fall	18
Low	Dam and Reservoir Failure	9
Low	Volcanic Hazards (Lava Flow)	6

PART 3 —MITIGATION STRATEGY

Chapter 20. Goals and Objectives

Hazard mitigation plans must identify goals for reducing long-term vulnerabilities to identified hazards, as outlined in 44 CFR Section 201.6(c)(3)(i). As part of the plan update process, the Steering Committee reviewed the goals and objectives of the 2010 plan. After discussion, the committee determined that the goals and objectives should be revisited and revised in order to more fully align with other community objectives and priorities. Through several facilitated discussions and exercises, the Steering Committee established an updated set of goals and measurable objectives for the hazard mitigation plan. The resulting goals, objectives and initiatives in this plan update all support each other. Goals were selected based on their relevance and connection to other planning efforts. Objectives were selected that met multiple goals. Mitigation initiatives were prioritized based on the initiative meeting multiple objectives.

20.1 Goals

The following are the mitigation goals for this plan:

1. Protect the life, health, safety and welfare of Maui County residents and visitors.
2. Develop and implement the Maui County Hazard Mitigation Plan based on a comprehensive, multi-hazard risk and vulnerability assessment.
3. Protect property, including but not limited to critical facilities and infrastructure, from the impacts of natural hazards.
4. Promote a sustainable economy and protect the livelihood of the local population.
5. Promote the protection of the County's natural, cultural and historical resources.
6. Promote and increase public awareness on the potential impacts of natural hazards and actions to reduce those impacts.

The effectiveness of a mitigation strategy is replacement by determining how well these goals are achieved.

20.2 Objectives

Each selected objective meets multiple goals, serving as a stand-alone measurement of the effectiveness of a mitigation action, rather than as a subset of a goal. The objectives also are used to help establish priorities. The objectives are as follows:

1. Reduce vulnerability of lifelines, infrastructure, ports of entry and critical facilities to natural hazards (adapted from State HMP).
2. Retrofit, purchase, or relocate structures in high hazard areas, especially those known to be repetitively damaged.
3. Develop and implement appropriate protocols for data collection, information sharing and plan management to ensure the implementation and enhancement of the HMP over the next 5 years (adapted from State HMP).
4. Utilize the best available data, science and technologies to identify and mitigate risk from natural hazards.
5. Promote awareness of the Maui County HMP and the integration of plan elements into other Maui County planning efforts (adapted from State HMP).
6. Promote the regulation of future development in high-risk, natural hazard areas.

7. Incorporate indigenous and resident knowledge into hazard mitigation planning processes (adapted from State HMP).
8. Inform private and public stakeholders on the risk exposure to natural hazards and ways to increase their capability to prepare, respond, recover and mitigate the impacts of these events (adapted from General Plan).
9. Identify and pursue mitigation opportunities and projects that protect natural and cultural resources, promote environmental and cultural stewardship, and enhance the natural environment's ability to withstand impacts from natural hazards.
10. Strengthen planning, coordination, consensus building, and personal and civic engagement in hazard mitigation planning processes (adapted from County Policy Plan).
11. Identify and obtain funding for cost-effective and sustainable projects, critical studies and strategic programs related to the mitigation of natural hazards.
12. Promote and encourage informed, resilient, self-sufficient, and sustainable communities.
13. Integrate the impacts of climate change in mitigation planning and implementation.

Chapter 21. Identification of Mitigation Initiatives

Hazard mitigation plans must include an action plan, describing how the initiatives identified will be prioritized, implemented, and administered by local jurisdictions (44 CFR §201.6(c)(3)(iii)). In hazard mitigation plan updates, jurisdictions must also review and revise the plan to reflect progress in local mitigation efforts (44 CFR §201.6(d)(3)). This chapter will review the status of the initiatives identified in the 2010 HMP, describe the process utilized to select new mitigation actions and present the initiatives that have been selected for implementation.

21.1 Status of Initiatives from Previous Plan

The 2010 Maui County Hazard Mitigation Plan identified 38 initiatives for implementation. These initiatives were reviewed by the Steering Committee and, as needed, were distributed to other relevant agencies for comment. Identifying and describing progress on initiatives was challenging, as specific lead agencies for each initiative had not been identified in the 2010 plan. Steering committee members and the planning team reviewed the identified initiatives and determined whether or not the initiatives had been completed, were in progress or if no progress had been made. Incomplete initiatives were reviewed to determine if they should be carried over to the 2015 plan or removed from the plan due to a change in priorities, capabilities, or feasibility. In total 11 (29 percent) of the identified initiatives were completed in the performance period of the 2010 plan, 12 (32 percent) showed some progress, and 15 (39 percent) showed no progress. Of the 38 identified initiatives 25 or 66 percent were carried over to the 2015 plan. Many of these carried over actions were reworded to more clearly state the intent of the initiative. Table 21-8 summarizes the initiatives that were recommended in the 2010 hazard mitigation plan and their implementation status at the time this update was prepared.

TABLE 21-1.
PREVIOUS PLAN INITIATIVES: IMPLEMENTATION STATUS

Initiative Description	Action Status: Completed	Action Status: Carry Over to Plan Update	Action Status: Removed; No Longer Feasible	Comments
Natural hazard policies for the General Plan & Community Development Plan		✓		See Initiative AH-10.
Hardening, flood proofing, and bypass alternatives for critical roadways and highways, particularly for communities subject to isolation during a disaster		✓		See Initiative CE-2.
Hardening or relocation of County base yard facilities (e.g., Wailuku base yard)		✓		Monies for Molokai base yard were approved in the FY15 budget. A budget proposal to create a central Maui base yard where all departments (Water, Highways, Environmental Management, and Parks) would be located has been sent to the County Council, but has not been approved. See Initiative AH-2.
NASKA DWS base yard relocation out of potential isolation due to flooding		✓		See Initiative AH-2.
Hardening of fuel storage and distribution to critical facilities		✓		See Initiative AH-2.
Hardening for electrical systems		✓		See Initiative AH-2.
Hardening of water supply facilities (e.g., critical pump stations) for reliability		✓		See Initiative AH-2.
Hardening of wastewater facilities for improved reliability		✓		Ongoing process to the replace aged equipment with updated energy efficient and tsunami hardened equipment. See Initiative AH-2.
Wailuku-Kahului WWRF Tsunami Protection and other hazard mitigation		✓		Ongoing project to provide shoreline protection for critical facilities. Some hardening of concrete structures has been completed. See Initiative AH-2.
County of Maui All-Hazard Assessment of Critical Facilities Retrofits of fire, police, medical, airports.	✓			Critical facilities study conducted in 2010.
Update the building code from the 1997 UBC to the 2006 IBC	✓			Ordinance 3929 effective on 3/19/2012 adopted the IBC 2006 & Ordinance 3928 effective on 3/19/2012 adopted the International Residential Code (IRC) 2006.

TABLE 21-1.
PREVIOUS PLAN INITIATIVES: IMPLEMENTATION STATUS

Initiative Description	Action Status: Completed	Action Status: Carry Over to Plan Update	Action Status: Removed; No Longer Feasible	Comments
Testing of the Seismic and Wind Performance of Single Wall Construction		✓		See Initiative HW-1.
Water Conservation and Watershed Management Education	✓			DWS annually funds and supports Maui's nine watershed partnerships. A portion of the funding is utilized for public outreach programs/activities. DWS has an outreach program on water conservation that includes an annual poster contest, give away of low flow fixtures and native planting guide.
Incentives for homeowners and businesses to retrofit their structures		✓		See Initiative FL-5.
Visitor Industry Disaster Preparation & Training	✓			
Conduct Public Meetings on All Hazards		✓		MCDA meets with individual groups and conducts an annual Preparedness Expo. See Initiative AH-13.
Identify high wind speed areas and vulnerable structures; Adapt Hazus-MH for use with hurricane hazard to Maui County	✓			High wind speed areas have been identified and incorporated into Maui County code. Hazus-MH hurricane model was run for the 2015 HMP update.
Perform a comprehensive screening evaluation of candidate building types and identify the types more suitable for hurricane refuge use		✓		Initiative was partially completed by the critical facilities study that was conducted in 2010 and some initial screenings. A more comprehensive assessment should be performed. See Initiative TC-2.
Emergency shelter evaluation: All-Hazard Assessment of Hurricane Shelters & Identify Effective Retrofits		✓		See Initiative TC-1.
Adapt Hazus-MH or other hazard modeling to Maui County; Develop scenario training and mitigation planning capabilities	✓			The County's Hazus-MH model was updated during the development of the 2015 HMP. Model results and data can be utilized to develop training exercises.
Update the Hazus-MH model to incorporate detailed data on State and County Bridges		✓		See Initiative E-2.
Update debris estimation for post-earthquake recovery planning.	✓			Debris estimation for two scenario events and two probabilistic events were generated during the 2015 update.

TABLE 21-1.
PREVIOUS PLAN INITIATIVES: IMPLEMENTATION STATUS

Initiative Description	Action Status: Completed	Action Status: Carry Over to Plan Update	Action Status: Removed; No Longer Feasible	Comments
Update tsunami evacuation maps	✓			Tsunami zone evacuation zone data were revised, updated, and published in 2013.
UHM SOEST to produce 100-year and 500-year tsunami hazard maps	✓			Tsunami zone evacuation zone data were revised, updated, and published in 2013.
Adopt tsunami design provisions for buildings (to be released in Fall 2010) for new and for evaluating existing buildings.		✓		See Initiative AH-2.
MECO Power Plant Tsunami Inundation Protection Measures		✓		MECO is currently working on the implementation of this action. See Initiative AH-2.
Investigate the differences between the existing and new DFIRM maps, and adapt maps so that tsunami inundation hazard is included along the south and west coasts	✓			The entire coastlines of the Islands or Maui and Molokai were studied in order to establish tsunami inundation limits. 80 percent of the coastline of Lanai has been studied. These data were incorporated into the 2012 effective DFIRM.
Implement rainfall and stream-flow gauging system data tool suitable for real-time flood monitoring		✓		See Initiative FL-10.
Develop Dam Evacuation Maps	✓			The Pacific Disaster Center completed this initiative in November 2010. Evacuation maps were used in the 2015 HMP risk assessment.
Develop additional policies for mitigation of repetitive losses		✓		See Initiative FL-5.
Pump Station flood proofing evaluation (Kihei & other coastal areas)		✓		See Initiative FL-1.
Improve County of Maui rating in the Community Rating System		✓		Maui County has adopted the 2006 IBC and the HMP will be scored as a Floodplain Management Plan. See Initiative FL-7.
Prescribed burns to reduce fuel loads in fire prone areas; Wild land fuel reduction from Maalaea to Lahaina		✓		See Initiative W-2.
Pump Station at Reservoir 40 (Kula Agricultural Park)		✓		See Initiative FL-2.
Construct new 300 Million Gallon Kula Reservoir			✓	No longer feasible.
Kula Agricultural Park Reservoir Relining Project			✓	No longer feasible.
Maui Memorial Hospital and HHSC hospitals		✓		See Initiative AH-2.

TABLE 21-1.
PREVIOUS PLAN INITIATIVES: IMPLEMENTATION STATUS

Initiative Description	Action Status: Completed	Action Status: Carry Over to Plan Update	Action Status: Removed; No Longer Feasible	Comments
Identification of Rockfall / Landslide Hazard zones		✓		See Initiative L-3.

21.2 Potential Mitigation Initiatives

The goals and objectives identified in the previous hazard mitigation plan were reviewed and revised during this plan update process to reflect changes in priorities and to better integrate with other planning mechanisms within the planning area, such as the Maui County General Plan. These revisions, coupled with the updated risk assessment, presented an opportunity for new mitigation initiatives reflecting these changes to be identified and included in the updated plan. The process for identifying new mitigation initiatives included:

- A facilitated brainstorming session focused on identifying mitigation-related strengths, weaknesses, obstacles, and opportunities
- A review of initiatives identified in other planning mechanisms in the County
- A review of the results of public outreach efforts including the public survey
- Several discussions with Steering Committee members and relevant stakeholders.
    - Potential mitigation initiatives were combined into a mitigation catalog that was reviewed and discussed with the Steering Committee and from which new initiatives were chosen. The following sections describe in more detail the process by which potential mitigation initiatives were identified.

21.2.1 Strengths, Weaknesses, Obstacles and Opportunities

The planning team led Steering Committee members through a facilitated brainstorming session to identify and discuss the strengths, weaknesses, obstacles, and opportunities (SWOO) relevant for hazard mitigation in Maui County. The session examined each of the hazards of concern within the context of Maui County specific risks, capabilities, goals and objectives and strived to promote discussion that encompassed all mitigation project typologies (Section 21.3.3). The session was attended by Steering Committee members and, thus, did not include all possible stakeholder perspectives on mitigation planning in the County. However, the unique set of perspectives and resulting discussion established a strong base for the development of mitigation initiatives for the plan update. Appendix D includes the results of the SWOO session.

21.2.2 Review of Initiatives in Relevant Programs

Relevant programs and planning documents were reviewed to identify mitigation initiatives that had been identified. This review encouraged a cohesive and comprehensive assessment of planned or current mitigation initiatives within

the planning area. The following documents and programs were reviewed and mitigation initiatives were included for the Steering Committee's consideration as appropriate:

- State of Hawaii Hazard Mitigation Plan
- Maui Community Plan
- Lanai Community Plan
- Molokai Community Plan
- West Maui Community Wildfire Protection Plan
- Maui Storm Water Management Program Plan
- Maui County General Plan.

21.2.3 Mitigation Catalog Development

The planning team combined initiatives identified through SWOO brainstorming session, with information gathered from reviewing relevant programs and traditional mitigation approaches used in other communities and recommended by FEMA to develop a mitigation catalog. The catalog of hazard mitigation alternatives was developed to present a broad range of alternatives to be considered for use in the planning area, in compliance with 44 CFR (Section 201.6(c)(3)(ii)). The purpose of the catalog was to provide an expansive list of what could be considered to reduce risk from natural hazards within the planning area. Alternatives, not chosen to forward into the Hazard Mitigation Initiative Action Plan, were considered not feasible to implement based on cost, time, political support and applicability. The catalog is available upon request.

21.2.4 Analysis of Mitigation Initiatives

Each recommended initiative was classified based on the hazard it addresses and the type of mitigation it involves. Table 21-2 and Table 21-3 shows the classification based on this analysis. Mitigation types used for this categorization are as follows:

Mitigation Categories:

- **Local Plans and Regulations (LPR)**—These actions include government authorities, policies or codes that influence the way land and buildings are being developed and built.
- **Structure and Infrastructure Project (SIP)**—These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. This could apply to public or private structures as well as critical facilities and infrastructure. This type of action also involves projects to construct manmade structures to reduce the impact of hazards.
- **Natural Systems Protection (NSP)**—These are actions that minimize damage and losses, and also preserve or restore the functions of natural systems.
- **Education and Awareness Programs (EAP)**—These are actions to inform and educate citizens, elected officials, and property owners about hazards and potential ways to mitigate them. These actions may also include participation in national programs, such as StormReady and Firewise Communities.

Community Rating System Categories:

- **Prevention (PR)**—Government, administrative or regulatory actions that influence the way land and buildings are developed to reduce hazard losses. Includes planning and zoning, floodplain laws, capital improvement programs, open space preservation, and stormwater management regulations.
- **Property Protection (PP)**—Modification of buildings or structures to protect them from a hazard or removal of structures from a hazard area. Includes acquisition, elevation, relocation, structural retrofit, storm shutters, and shatter-resistant glass.
- **Public Education and Awareness (PI)**—Actions to inform citizens and elected officials about hazards and ways to mitigate them. Includes outreach projects, real estate disclosure, hazard information centers, and school-age and adult education.
- **Natural Resource Protection (NR)**—Actions that minimize hazard loss and preserve or restore the functions of natural systems. Includes sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.
- **Emergency Services (ES)**—Actions that protect people and property during and immediately after a hazard event. Includes warning systems, emergency response services, and the protection of essential facilities.
- **Structural Projects (SP)**—Actions that involve the construction of structures to reduce the impact of a hazard. Includes dams, setback levees, floodwalls, retaining walls, and safe rooms.

TABLE 21-2.
ANALYSIS OF MITIGATION INITIATIVES

Hazard Type	Total Initiatives[a]	Hazard Type	Total Initiatives[a]
All Hazards	13	High Wind	5
Coastal Erosion	11	Landslide	3
Dam and Reservoir	3	Tropical Cyclone	12
Drought	4	Tsunami	7
Earthquake	4	Volcanic Hazards	2
Flood	24	Wildfire	2
High Surf	6		

a. Total includes hazard identification as both primary and secondary.

TABLE 21-3.
ANALYSIS OF MITIGATION INITIATIVES

Initiative Addressing Hazard, by Mitigation Type[a]						
Mitigation Categories						
	LPR	SIP	NSP	EAP		
Total Initiatives	**13**	**26**	**11**	**13**		
Community Rating System Categories						
	PR	PP	PI	NR	ES	SP
Total Initiatives	**12**	**13**	**9**	**8**	**9**	**7**

a. See Section 21.3.3 for description of mitigation types

21.3 Selected Mitigation Initiatives

Hazard mitigation initiatives recommended in this plan were then selected by the Steering Committee from among the alternatives presented in the mitigation catalog. Some of the initiatives identified in the mitigation catalog were determined not to be feasible or otherwise undesirable based on the selection criteria identified for this plan (e.g. lack of public support, more cost-effective alternative available, etc.). Over several sessions, the Steering Committee reviewed and provided feedback on the catalog ultimately selecting the mitigation initiatives described in detail in the following sections. Those initiatives that have been chosen are backed by a planning process, are consistent with the established goals and objectives, and are within the capabilities of Maui County and its stakeholders to implement.

Table 21.4 and 21.5 describe the type of information detailed in the Hazard Mitigation Initiative Action Plan (Table 21.6). Each mitigation initiative is assigned an index value to indicate the hazard addressed. The hazards are placed in alphabetical order.

TABLE 21-4.
IMPLEMENTATION KEY

Category	Description
Implementation Priority	Implementation priority identified from prioritization exercise described in Section 21.3.2
Mitigation Initiative Description	Title and description on action.
Hazard(s) of Concern Addressed	Type of hazard(s) addressed by the initiative.
Lead Coordinating Agency	The agency that is the primary point of contact for the mitigation initiative and that head coordination.
Support Agency	Supporting entities that will assist in the implementation, funding, or maintenance of the mitigation initiative.
Timeline	Estimation of how long it will take to complete a project; “ongoing” refers to initiatives that are either under way or have no definitive end date.
Possible Funding Source(s)	Possible sources of funding including county budget, state, federal and private grants.
Mitigation Category	The FEMA mitigation action category (Local Plans and Regulations [LPR], Structure and Infrastructure Project [SIP], Natural Systems Protection [NSP], and Education and Awareness Programs [EAP])
CRS Category	The CRS mitigation action category (Prevention [PR], Property Protection [PP], Public Education and Awareness [PI], Natural Resource Protection [NR], Emergency Services [ES], and Structural Projects [SP].
Goals and Objectives	Hazard mitigation goals and objectives addressed by the mitigation initiative.

TABLE 21-5.
FUNDING SOURCE AND AGENCY ABBREVIATIONS

ARC	American Red Cross	HMWG	Hazard Mitigation Working Group
ASCE	American Society of Structural Engineers	HUD	United States Department of Housing and Urban Development
BEACH Act	Beaches Environmental Assessment and Coastal Health Act of 2000	HWMO	Hawaii Wildfire Management Organization
CDBG	Community Development Block Grant	IT	Information Technology
CDBG-DR	Community Development Block Grant-Disaster Recovery	GIS	Geographic Information System
CIP	Capital Improvement Plan	LEPC	Local Emergency Planning Committee
CRS	Community Rating System	LRD	Long Range Division
CWSRF	Clean Water State Revolving Fund	MCDA	Maui County Civil Defense Agency
CZM	Coastal Zone Management	MECO	Maui Electric Company
DAGS	Department of Accounting and General Services	MFD	Maui Fire Department and Public Safety
DBEDT	Hawaii Department of Business, Economic Development, and Tourism	MPD	Maui Police Department
DEM	Department of Environmental Management	NDSP	National Dam Safety Program
DLNR	Hawaii Department of Land and Natural Resources	NFIP	National Flood Insurance Program
DOC	U.S. Department of Commerce	NMFS	National Marine Fisheries Service
DOE	Hawaii Department of Education	NOAA	National Oceanic and Atmospheric Administration
DOI	U.S. Department of Interior	NPS	National Parks Service
DOFAW	Hawaii Division of Forestry and Wildlife	NWS	National Weather Service
DOT	Department of Transportation	OIMT	Hawaii Office of Information and Technology
DWSRF	Drinking Water State Revolving Fund	PA	Public Assistance
EMA	Emergency Management Agency	PDC	Pacific Disaster Center
EPA	U.S. Environmental Protection Agency	PDM	Pre-Disaster Mitigation
FEMA	Federal Emergency Management Agency	PID	Planning Implementation Division
FHWA	Federal Highway Administration	PUC	Public Utilities Commission
FMA	Flood Mitigation Assistance	RL	Repetitive Loss
HAH	Healthcare Association of Hawaii	SRL	Severe Repetitive Loss
Hazmat	Hazardous Materials	UH – Sea Grant	University of Hawaii Sea Grant
HDOA	Hawaii Department of Agriculture	USACE	United Stated Army Corps of Engineers
HDOT	Hawaii Department of Transportation	USDA	U.S. Department of Agriculture
HI-EMA	Hawaii Emergency Management Agency	USGS	United States Geological Survey
HHS	U.S. Department of Health and Human Services	WUDP	Water Use and Development Plan
HMGP	Hazard Mitigation Grant Program		

Table 21.6 lists each selected mitigation initiative and the corresponding implementation factors listed above.

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
AH-1	High	Update and maintain an inventory of critical facilities and lifelines including County buildings.	All Hazards	MCDA	HMWG, GIS, Planning GIS	One year for development, ongoing maintenance	FEMA, Hawaii EMA, Staff Time	EAP	PI, ES	Goals: 1, 2, 3 Objectives: 1, 2, 3, 4, 8
AH-2	Medium	Relocate and/or retrofit vulnerable critical facilities in high hazard areas. Harden these facilities to withstand future natural hazard events. Prioritized facilities include but are not limited to the following: • Pukoo Fire Station – Molokai or other facilities identified in the 2015 Molokai, Lanai Community Plan • MECO power plant • Kaunakakai Waste Water Treatment Facility • Kahului-Wailuku Wastewater Reclamation Facility • Honoapiilani Highway • Wailuku Base Yard • NASKA DWS Base Yard	All Hazards	MCDA	HMWG, Facility Owner	3-5 Years	HMGP, PA - 406	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 8, 11
AH-3	Medium	Acquire, residential and privately owned structures in high hazard areas, including but not limited to those known to be or subject to repetitive damages.	All Hazards	Managing Director, Department of Finance	MCDA	Over 5 Years (for all properties)	FEMA HMGP, PDM, and FMA; HUD CDBG-DR	SIP	PP	Goals: 1, 2, 3, 6 Objectives: 2, 3, 8, 10, 12
AH-4	High	Evaluate existing shelter and other critical facilities needs for redundant power generation. Obtain and install permanent backup power sources for critical facilities and infrastructure not addressed in other proposed projects, and for specific facilities serving functional needs and vulnerable populations. Use of solar or green energy will be considered, where feasible. Initial facilities may include but are not limited to: • War Memorial Gymnasium • Hannibal Tavares Community Center • Velma Santos Community Center • Kihei Community Center (solar off grid?) • Maui High School • Baldwin High School • King Kekaulike High School • Lahainaluna High School • Hana High and Elementary School • Lanai High and Elementary School • Molokai High School • Walter Cameron Center	All Hazards	MCDA	Parks and Recreation, DOE, Office on Aging, ARC, Private Stakeholders	3 Years	HUD CDBG, FEMA HMGP	SIP	PP, SP, ES	Goals: 1, 2, 3, 6 Objectives: 1, 2, 4, 10, 11

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
AH-5	High	Acquire portable emergency generators for identified critical facilities. Initial facilities may include but are not limited to: • Maui Food Bank • War Memorial Gymnasium • Hannibal Tavares Community Center • Velma Santos Community Center • Kihei Community Center • Maui High School • Baldwin High School • King Kekaulike High School • Lahainaluna High School • Hana High and Elementary School • Lanai High and Elementary School • Molokai High School • Walter Cameron Center	All Hazards	MCDA	Facility Owner	2 Years	FEMA HMGP and PDM	SIP	ES	Goals: 1, 2, 3, 6 Objectives: 1, 2, 4, 10, 11
AH-6	High	Develop a Maui, Lanai and Molokai island-wide evacuation routes plan. Create a public awareness campaign to educate the public on evacuation routes and expectations.	All Hazards	MCDA	MPD, MFD, GIS	2 Years	Hawaii Office of Planning, Staff Time	LPR	ES	Goals: 1, 2, 6 Objectives: 3, 5, 7, 8, 10
AH-7	High	Work with telecommunications providers to provide more reliable and continued services during natural hazard events.	All Hazards	MPD Radio Shop	MCDA, IT Services Division	Ongoing	FEMA HMGP, Hawaii OIMT	SIP	ES	Goals: 1, 2, 4 Objectives: 1, 4, 8, 12
AH-8	High	Work with school complexes to develop a hazard awareness component for middle and high school curriculums.	All Hazards	MCDA	DOE	2 Years	Hawaii DOE; Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 1, 5, 7, 8, 10, 12
AH-9	High	Develop and formalize MOUs for emergency barge and ferry service for reaching communities isolated and impacted from disaster. Specifically, Hana, Molokai and Lanai.	All Hazards	MCDA	Planning (LRD), County DOT	2-4 Years	Staff Time	LPR	ES	Goals: 1, 2 Objectives: 1, 4, 8, 12, 13
AH-10	High	Continue to include hazard mitigation initiatives in future Capital Improvements Planning and include hazard mitigation goals and objectives into the General and Community Plans. Consider all hazard mitigation initiatives when developing the County 6-year budget and 20-Year Plan.	All Hazards	CIP Coordinator, Planning (PID), MCDA	Public Works, Water Supply, DEM, Parks and Recreation	Ongoing	Staff Time	LPR	PR	Goals: 1, 2, 3, 4, 5, 6 Objectives: 1, 2, 3, 4, 5, 6, 9, 10, 11, 13
AH-11	High	Develop and annually maintain an updated list of emergency shelters for Maui, Lanai and Molokai. Identify lead operators for each shelter. Ensure list is included in the Maui County Civil Defense Emergency Operations Plan and synchronized to lists in the National Shelter System.	All Hazards	MCDA	ARC, HI-EMA, DOE, Parks and Recreation	1 Year	Staff Time	LPR	PR	Goals: 1, 2, 6 Objectives: 1, 3, 5, 8, 10, 12
AH-12	High	Develop a system (process) for capturing historical data related to hazard events throughout the Maui County and disseminating this information to the relevant planning partners.	All Hazards	MCDA	GIS, PDC, HMWG	1 Year	Staff Time	LPR	PR	Goals: 1, 2, 3 Objectives: 1, 2, 3, 4, 5, 10, 11, 13

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
AH-13	High	Promote and implement existing education and outreach programs on all hazards such as HHARP, CERT, American Red Cross, etc. that build hazard understanding and awareness, and offer tools and information resources to guide mitigation, preparedness, response and recovery.	All Hazards	MCDA	PDC, ARC, UH Sea Grant; MVB	Ongoing	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 1, 5, 7, 8, 10, 12
CE-1	Medium	Realign Honoapiilani Highway outside of coastal hazard area – Initiate a planning process with HDOT; Document planning process steps and timeline; Develop environmental documents showing alternative alignments; Acquire/purchase any additional land needed for realignment; Implement construction for realignment.	Coastal Erosion (P) Flood (S) Tsunami (S) Tropical Cyclone (S)	HDOT, Planning (LRD/PID CZM program)	Parks and Recreation, MCDA, GIS, Managing Director	3 Years for Planning, then ongoing toward implementation	FEMA HMGP, PDM, and FMA; CDBG; Hawaii DOT; Staff Time; FHWA ($800 Million)	SIP	PP	Goals: 1, 2, 3, 4 Objectives: 1, 2, 4
CE-2	Medium	Identify vulnerable coastal roads that are susceptible to destruction from natural hazards, plan for elevating or realigning portions of those roadways and implement identified projects. Identified roads include but are not limited to North Kihei Road, South Kihei Road, and Kamehameha V Highway on Molokai.	Coastal Erosion (P) High Surf (S) Flood (S) Tsunami (S) Tropical Cyclone (S)	HDOT, Planning (LRD/PID CZM program)	Parks and Recreation, MCDA, GIS, Managing Director, Public Works Highways Division	3 Years for Planning, then ongoing toward implementation	FEMA HMGP, PDM, and FMA; CDBG; Hawaii DOT; Hawaii EMA; FHWA	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4
CE-3	High	Expand Beach and Dune Restoration Projects – Identify and prioritize erosion hotspots for mitigation via beach nourishment; Pursue State/County funding for beach nourishment; Work with State regulatory agencies to streamline permitting for beach nourishment.	Coastal Erosion (P) High Surf (S) Flood (S) Tsunami (S) Tropical Cyclone (S)	Planning (CZM)	Parks and Recreation	Immediate and ongoing	NOAA Regional Coastal Resilience Grant, NMFS Ecosystem Restoration Grant, DLNR Beach Fund, Hawaii Tourism Authority, County budget	SIP	NR	Goals: 1, 2, 3, 4, 5 Objectives: 4, 9, 13
CE-4	High	Expand Dune Restoration Projects - Develop and/or update dune restoration guidance. Provide dune restoration training. Develop an outreach initiative to encourage or establish new dune restoration volunteers/stewards. Install ADA compliant dune walkovers in identified locations.	Coastal Erosion (P) High Surf (S) Flood (S) Tsunami (S) Tropical Cyclone (S)	Planning (CZM)	Parks and Recreation, DLNR, UH-Sea Grant	3 Years	NOAA Regional Coastal Resilience Grant, NMFS Ecosystem Restoration Grant, DLNR, Hawaii Tourism Authority, County budget	SIP	NR	Goals: 1, 2, 3, 4, 5 Objectives: 4, 9, 13
CE-5	Medium	Study and/or pilot offshore wave attenuation devices, such as breakwaters, that cause waves to break in open water instead of at the beach.	Coastal Erosion (P) Flood (S)	Planning (CZM Program)	USACE, MCDA, DLNR, UH Sea Grant; State Office of Planning	2 Years	EPA, NOAA Regional Coastal Resilience Grant, FEMA, Hawaii EMA	SIP	NR, PP	Goals: 1, 2, 3, 5 Objectives: 1, 4, 9, 10, 12, 13
CE-6	Medium	Support University of Hawaii sea level rise mapping for all islands that is based on dynamic sea level mapping (increased water level due to sea level rise plus waves or storm surge) rather than "flood the bathtub" mapping.	Coastal Erosion	Planning (CZM)	GIS, MCDA, DLNR, UH Sea Grant, State Office of Planning	1 Year	EPA, NOAA Regional Coastal Resilience Grant, FEMA, Hawaii EMA	NSP	PR	Goals: 1, 2, 5, 6 Objectives: 3, 4, 9, 10, 11, 13
CE-7	Medium	Consider sea level rise impacts on existing and future developments by conducting or commissioning community based vulnerability assessments.	Coastal Erosion	Planning (CZM)	Public Works, MCDA	2-3 Year	EPA, NOAA Regional Coastal Resilience Grant; FEMA, Hawaii EMA, County Funds	NSP	PR	Goals: 1, 2, 5, 6 Objectives: 3, 4, 9, 10, 11, 13

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
CE-8	High	Develop a 5-Year Strategic Plan for integrating coastal erosion mitigation projects into each community plan and County FY budget.	Coastal Erosion (P) Flood (S)	Planning	MCDA, Public Works	1 Year	FEMA, NOAA Regional Coastal Resilience Grant	LPR	NR	Goals: 1, 2, 3, 4, 5, 6 Objectives: 3, 4, 5, 8, 9, 10, 11
CE-9	High	Continue to support a public awareness campaign for residents in and around coastal erosion zones showing what they can do to minimize the impact of coastal erosion. Update as appropriate the UH Sea Grant guidebook titled Purchasing Coastal Real Estate in Hawaii.	Coastal Erosion	MCDA	MFD, Public Works, Parks and Recreation, DEM, Planning (CZM)	1 Year	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 1, 5, 7, 8, 10, 12
CE-10	Low	Expand University of Hawaii shoreline erosion studies to include Molokai and Lanai and continue to update studies for Maui.	Coastal Erosion	Planning (CZM)	MCDA	Ongoing	FEMA, NOAA Regional Coastal Resilience Grant, County Funds	NSP	PR	Goals: 1, 2, 4 Objectives: 3, 4, 5, 8, 9, 10, 11
DR-1	High	As required, support structural and non-structural elements related to the certification and/or re-certification of Kaunakakai levee in federal programs (e.g. United States Army Corps of Engineers Public Law 84-99).	Dam and Reservoir Failure (P) Flood (S)	Public Works Engineering Division	MCDA, Planning, MPD	3-5 Years	FEMA NDSP, Hawaii EMA	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 8, 10, 11
DR-2	High	Develop a public outreach awareness campaign targeting residents located within a dam inundation area. Include information about what to do in an emergency, community Q&A, and where to receive information.	Dam and Reservoir Failure (P) Flood (S)	DLNR, MCDA	Dam Operators, MPD	2-3 Years	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 4, 5, 7, 8, 10, 12
DR-3	Low	Regularly exercise the current emergency action plan focusing on evacuation with participation from police, public/private dam owners and state/federal dam operators.	Dam and Reservoir Failure (P) Flood (S)	MCDA, DLNR	Dam Owners & Operators, MPD	Ongoing	FEMA, Hawaii EMA	EAP	ES	Goals: 1, 2 Objectives: 1, 5, 8, 10, 12
D-1	High	Update the Water Use and Development Plan (WUDP) for all Maui County Islands with a comprehensive monitoring, repair, and replacement strategy.	Drought	Maui County Department of Water Supply	Water Support Management, Water Purveyors on each Island, Commission on Water Resources Management, PUC	5 Years	Staff Time	LPR	PR	Goals: 1, 2, 5, 6 Objectives: 3, 4, 5, 8, 10
D-2	High	Encourage drought-tolerant landscape design such as incorporating drought-tolerant or xeriscaping practices into landscape ordinances to reduce dependence on irrigation, and provide incentives for xeriscaping.	Drought	CWORM, Maui County Department of Water Supply	MCDA	Ongoing	USDA, FEMA, EPA, DOI Bureau of Reclamation, DLNR	NSP	NR	Goals: 1, 2, 3, 5, 6 Objectives: 4, 8, 9, 10, 12
D-3	Low	Coordinate with industry stakeholders to develop alternative sources of irrigation water including wastewater reuse, recycled stormwater runoff, and brackish well water.	Drought	DPW/DEM	Maui Farm Bureau, Parks and Recreation, HDOA Agricultural Resource Management	2 Years	EPA CWSRF	LPR	PR	Goals: 1, 2, 4 Objectives: 4, 7, 8, 9, 10, 12
D-4	High	Explore options and necessary code and regulation changes to allow graywater reuse systems for irrigation and toilet flushing.	Drought	Department of Health	DEM, Public Works	1 Year	EPA CWSRF	LPR	PR	Goals: 1, 2, 3, 4, 5, 6 Objectives: 1, 3, 5, 6, 9, 10, 11, 13
E-1	Medium	Reduce potential damage to critical facilities (including schools, shelters, etc.) and infrastructure from future seismic events through structural retrofits.	Earthquake	Facility Owner, MCDA		3 Years	FEMA HMGP	SIP	PP, ES	Goals: 1, 2, 3 Objectives: 1, 2, 4

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
E-2	Medium	Conduct an engineering survey on all bridges to ensure structural stability during a natural disaster. Implement all structural improvement identified/recommended from survey. Prioritize the implementation of structural improvements to bridges serving potential isolated communities (e.g. East Maui).	Earthquake	Public Works Engineering Division	HDOT	4 Years	HMGP, PA 406	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 10
FL-1	Medium	Flood proof wastewater treatment facilities located in flood hazard areas.	Flood	DEM	MCDA, Maui Floodplain Manager	5 Years	EPA CWSRF, FEMA HMGP, PDM, and FMA, CDBG, Hawaii EMA	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 8, 10, 12
FL-2	Medium	Flood proof water treatment facilities located in flood hazard areas.	Flood	Water Supply	MCDA, Maui Floodplain Manager	5 Years	EPA DWSRF, FEMA HMGP, PDM, and FMA, CDBG, Hawaii EMA	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 8, 10, 12
FL-3	Medium	Inspect, and if necessary, repair stormwater drainage swales and culverts. Implement a program to regularly remove blockages from drains and channels.	Flood	Public Works	Planning	2 Years	FEMA HMGP, PDM, and FMA, CDBG, Hawaii DOT, Hawaii EMA, County Budget	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4
FL-4	Low	Increase drainage and absorption capabilities with detention and retention basins, relief drains, and spillways. Implement a program to regularly remove blockages from basins, drains and spillways.	Flood	Public Works	Planning	3-5 Years	FEMA HMGP, PDM, and FMA, CDBG, Hawaii EMA	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4
FL-5	Medium	Where appropriate, support retrofitting, purchase, or relocation of structures located in hazard-prone areas to protect structures from future damage with repetitive loss and severe repetitive loss properties as priority.	Flood (P) Tsunami (S) High Surf (S)	Maui Floodplain Manager, Managing Director, Department of Finance	Homeowners, County Council	Ongoing	Federal and State Mitigation Grant Programs and local budget (or property owner) for cost share	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 8, 10
FL-6	High	Remain in good standing and in compliance with the NFIP.	Flood	Maui Floodplain Manager	MCDA	Ongoing	Staff Time	LPR	PR	Goals: 1, 2 Objectives: 2, 3, 5, 8, 10, 12
FL-7	High	Continue to participate in the CRS program and continually identify opportunities to improve CRS class.	Flood	Maui Floodplain Manager	Public Works, Planning, MCDA	Ongoing	Staff Time	NSP	PR	Goals: 1, 2 Objectives: 2, 3, 5, 8, 9, 10, 12
FL-8	High	Identify key planning, public works, and/or emergency management personnel who could benefit from advanced knowledge as a Certified Floodplain Manager.	Flood	Maui Floodplain Manager	Planning Department; Public Works; MCDA	1 Year	Staff Time	EAP	PR	Goals: 1, 2, 6 Objectives: 3, 5, 8, 9, 10, 12
FL-9	Low	Develop a Flood Acquisition/Elevation Plan that may be used to identify and prioritize acquisitions and elevation of RL/SRL properties.	Flood	Maui Floodplain Manager	Corps Council, and County Council, Property owner	3-5 Year	FEMA, CDBG, Hawaii EMA	LPR	PP	Goals: 1, 2, 3 Objectives: 1, 2, 3, 4, 5, 6
FL-10	Medium	Identify and place operational stream gauges where needed.	Flood	Maui Floodplain Manager, Water Supply, DLNR	USGS, NWS, NPS	1 Year	FEMA HMGP, PDM, and FMA; Hawaii EMA, DLNR	NSP	NR	Goals: 1, 2, 3, 4, 5 Objectives: 4, 10, 12

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
FL-11	High	Identify potential areas for open space that could double as detention basins during major flooding events.	Flood	Maui Floodplain Manager, Planning (LRD)	Public Works, Parks and Recreation	1 Year	Staff time	NSP	NR	Goals: 1, 2, 5 Objectives: 4, 5, 7, 9, 10
FL-12	High	Seek community information on possible hazardous waste sites, not identified by the LEPC. Investigate, and use remediation when needed.	Flood (P) Earthquake (S)	Maui Fire Hazmat, LEPC	DEM	5 Years	FEMA HMGP, EPA	NSP	NR	Goals: 1, 2, 3, 6 Objectives: 3, 4, 5, 7, 8, 10, 12
FL-13	High	Harden the Island Petroleum Fuel Pipeline at the Molokai Kaunakakai Wharf in a trench with grating cover.	Flood (P) High Surf (S) Tropical Cyclone (S)	Planning (CZM)	Island Petroleum Fuel Pipeline	5 Years	FEMA HMGP, PDM, and FMA; CDBG; Hawaii EMA	SIP	SP	Goals: 1, 2, 3 Objectives: 1, 2, 4, 10, 12
HW-1	Medium	Encourage retrofit of identified critical facilities and infrastructure through mechanisms such as: a) Improve roof coverings (e.g., no pebbles, remove ballast roof systems). b) Install hurricane shutters or other protective measures. c) Anchor roof-mounted heating, ventilation, and air conditioning units. d) Retrofit buildings with load-path connectors to strengthen structural frames. e) e. Harden traffic lights and other traffic control lights.	High Wind (P) Tropical Cyclone (S)	MCDA	Facility Owner or Responsible Party, DOT Highways	5 Years	FEMA HMGP and PDM, CDBG, Hawaii EMA, PA - 406	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4
HW-2	High	Encourage (and if funding is available implement) the following types of modification or retrofits to **residential** buildings: a) Install hurricane shutters, safe rooms, reinforced garage doors or other protective measures b) Replace existing non-ductile infrastructure with ductile c) Retrofit building with load-path connectors to strengthen structural frames d) d. Inspect and retrofit roofs, gable end walls to adequate standards to provide wind resistance	High Wind (P) Tropical Cyclone (S)	MCDA, Homeowners	Public Works, UH Sea Grant	Ongoing	FEMA HMGP and PDM, CDBG, Hawaii EMA	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4
HW-3	High	Develop a public outreach initiative that illustrates the benefits of steel utility poles for communities that opted out of new poles.	High Wind (P) Tropical Cyclone (S)	MCDA	MECO	1 Year	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 3, 5, 8, 10, 12
L-1	Medium	Install concrete foundations for rockfall barrier fences in areas prone to landslides and rockfalls. Ensure foundations are designed to include rock anchors for overturning.	Landslide	HDOT-Highways, Public Works		5 Years	FEMA HMGP and PDM, CDBG, Hawaii EMA, DLNR	SIP	PP	Goals: 1, 2, 3, 5 Objectives: 1, 2, 4, 9
L-2	Medium	Improve drainage opportunities along steeps areas that are prone to fail due to soil saturation.	Landslide	HDOT – Highways, Public Works	Parks and Recreation	1 Year	FEMA HMGP and PDM, CDBG, Hawaii EMA, DLNR	SIP	PP	Goals: 1, 2, 3, 5 Objectives: 1, 2, 4, 9
L-3	Medium	Identify areas at risk for rockfall and acquire/install netting to minimize impact.	Landslide	HDOT – Highways, Public Works	Parks and Recreation	1-3 Years	FEMA HMGP and PDM, CDBG, Hawaii EMA, DLNR	NSP	NR	Goals: 1, 2, 3, 5 Objectives: 1, 2, 4, 9

TABLE 21-6. MITIGATION INITIATIVE ACTION PLAN

Index	Implementation Priority[a]	Mitigation Initiative Description	Hazards	Lead Coordinating Agency	Support Agency(ies)	Timeline	Funding Sources	Mitigation Category	CRS Category	Goals and Objectives
TC-1	Medium	Harden emergency shelters throughout the planning area to ensure that they are able to withstand Category 3 hurricane force wind speeds (111-129mph).	Tropical Cyclone (P); High Wind (S)	DOE, Parks and Recreation	MCDA	5 Years	FEMA HMGP and PDM, CDBG, Hawaii EMA, DLNR	SIP	PP, ES	Goals: 1, 2, 3 Objectives: 1, 2, 4
TC-2	Medium	Conduct engineering surveys on the ability of emergency shelters and potential emergency shelters to withstand hurricane force wind speed.	Tropical Cyclone (P); High Wind (S); Flood (S); Earthquake (S)	MCDA, HI-EMA, DOE	DAGS, ARC, ASCE	2 Years	FEMA HMGP and PDM, CDBG, Hawaii EMA	SIP	ES	Goals: 1, 2, 3 Objectives: 1, 4, 8, 10
TC-3	High	Develop joint MOUs with private sheltering facilities to continue working together towards a common emergency sheltering goal for tropical cyclone evacuation.	Tropical Cyclone (P); Flood (S)	ARC, Mayor	MCDA	1 Year	Staff Time	LPR	ES	Goals: 1, 2, 3, 4, 6 Objectives: 1, 3, 5, 8, 10
TC-4	Medium	Prioritize and pursue activities identified as unmet needs in the project led by Maui County planning department titled Post Disaster Reconstruction Guidelines and Protocols project.	Tropical Cyclone, Coastal Erosion, Flooding, High Surf	Planning (CZM)	MCDA, UH Sea Grant, HI-EMA	1-5 Years	Staff time, NOAA resiliency grant	NSP	PP	Goals: 1, 2, 3, 4, 5 Objectives: 4, 7, 8, 9, 10, 11, 12
T-1	Medium	Install signage delineating tsunami evacuation routes and tsunami hazard zones (entering/leaving).	Tsunami	MCDA	Public Works, HDOT	2-3 Years	FEMA HMGP, PDM, and FMA; EPA; Hawaii EMA	EAP	PI	Goals: 1, 2, 3, 6 Objectives: 1, 2, 4, 8, 10, 12
T-2	High	Develop an outreach plan on the development and distribution of tsunami awareness materials. Develop and distribute educational materials regarding information about tsunamis and what to do if a tsunami is imminent (i.e. what to do, where to go, etc.).	Tsunami	MCDA	GIS, HI-EMA, MVB	1 Year	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 5, 8, 10, 12
VH-1	High	Develop a public outreach program for both residents and visitors informing them about VOG - what it is and how to protect yourself.	Volcanic Hazards	Department of Health, MCDA	MCDA, MVB, Planning	5 Years	Staff Time	EAP	PI	Goals: 1, 2, 6 Objectives: 5, 8, 10, 12
VH-2	High	Work with the University of Hawaii - VOG Measurement and Prediction Project (VMAPP) to develop danger levels and trigger points for Maui County VOG exposure, and track high level, measurable VOG patterns in Maui County. Install air quality monitoring instruments that allow for the measurement of sulfur dioxide.	Volcanic Hazards	Department of Health, NPS, NOAA, USGS Volcano Observatory	MCDA	5 Years	FEMA, EPA, Hawaii EMA, USDA	NSP	ES	Goals: 1, 2 Objectives: 4, 5, 6, 7, 8, 10
W-1	Medium	Retrofit at-risk County structures with ignition-resistant materials.	Wildfire	Facility Owner, MFD Prevention Bureau	DLNR, HWMO, Molokai and West Maui Fire Task Force	5 years	FEMA HMGP and PDM, EPA, DLNR	SIP	PP	Goals: 1, 2, 3 Objectives: 1, 2, 4
W-2	Medium	Implement mitigation action items as identified in the Western Maui Community Wildfire Protection Plan (CWPP). Implement mitigation action items from Molokai CWPP and Central Maui CWPP once the plans are finalized.	Wildfire	HWMO, DLNR, MFD	MFD, Maui Farm Bureau, Watershed Partners, DNLR, DOFAW	3 years	FEMA HMGP and PDM, EPA, USDA, DLNR, EPA	NSP	PP	Goals: 1, 2, 3, 4, 5 Objectives: 4, 7, 8, 9, 10, 11, 12
W-3	High	Revitalize the Firewise Program.	Wildfire	DOFAW, MFD	MCDA, West Maui Fire Task Force, Molokai Wildfire Task Force, MCDA, HWMO	5 Year	Staff Time	EAP	ES	Goals: 1, 2, 6 Objectives: 3, 5, 8, 10, 12

a. Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these initiatives. The ratings of high, medium and low are qualitative based solely on the comparison of one initiative to another. Implementation of an initiative should not be dissuaded based on its identification as a low priority.

21.3.1 Benefit/Cost Review

According to plan development requirements, the initiative plan must be prioritized according to a benefit/cost analysis of the proposed initiatives and their associated costs, outlined in 44 CFR, Section 201.6(c)(3)(iii). The benefits of proposed initiatives were weighed against estimated costs as part of the initiative prioritization process. The benefit/cost analysis was not of the detailed variety required by FEMA for project grant eligibility under the Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) grant program. A less formal approach was used because some initiatives may not be implemented for up to 10 years, and associated costs and benefits could change dramatically in that time. Therefore, a review of the apparent benefits versus the apparent cost of each initiative was performed. Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these initiatives. The ratings of high, medium and low are qualitative based solely on the comparison of one initiative to another. Implementation of an initiative should not be dissuaded based on its identification as a low priority. All of the initiatives identified in the Hazard Mitigation Initiative Action Plan are and should be considered important steps to alleviate hazard impacts towards the people, property and economy of Maui County.

Cost ratings were defined as follows:

- **High**—Existing funding will not cover the cost of the initiative; implementation would require new revenue through an alternative source (for example, bonds, grants, and fee increases).
- **Medium**—The initiative could be implemented with existing funding but would require a re-apportionment of the budget or a budget amendment, or the cost of the initiative would have to be spread over multiple years.
- **Low**—The initiative could be funded under the existing budget. The initiative is part of or can be part of an ongoing existing program.

Benefit ratings were defined as follows:

- **High—**Initiative will provide an immediate reduction of risk exposure for life and property.
- **Medium—**Initiative will have a long-term impact on the reduction of risk exposure for life and property, or initiative will provide an immediate reduction in the risk exposure for property.
- **Low—**Long-term benefits of the initiative are difficult to quantify in the short term.

Using this approach, initiative with positive benefit versus cost ratios (such as high over high, high over medium, medium over low, etc.) are considered cost-beneficial and are prioritized accordingly.

For many of the strategies identified in this initiative plan, Maui County may seek financial assistance under the HMGP or PDM programs, both of which require detailed benefit/cost analyses. These analyses will be performed on projects at the time of application using the FEMA benefit-cost model. For projects not seeking financial assistance from grant programs that require detailed analysis, Maui County reserves the right to define “benefits” according to parameters that meet the goals and objectives of this plan.

21.3.2 Initiative Plan Prioritization

Implementation Prioritization

Table 21-7 lists the implementation priority of each initiative, using the same parameters used in selecting the initiatives. A qualitative benefit-cost review was performed for each of these initiatives. The priorities are defined as follows:

- **High Priority**—An initiative that meets multiple objectives, has benefits that exceed cost, has funding secured or is an ongoing project and meets eligibility requirements for a grant program. High priority initiative s can be completed in the short term (1 to 5 years). The key factors for high priority initiatives are that they have funding secured and can be completed in the short term.
- **Medium Priority**—An initiative that meets goals and objectives, that has benefits that exceed costs, and for which funding has not been secured but that is grant eligible. Initiative can be completed in the short term, once funding is secured. Medium priority projects will become high priority projects once funding is secured. The key factors for medium priority initiatives are that they are eligible for funding, but do not yet have funding secured, and they can be completed within the short term.
- **Low Priority**—An initiative that will mitigate the risk of a hazard, that has benefits that do not exceed the costs or are difficult to quantify, for which funding has not been secured, that is not eligible for grant funding, and for which the time line for completion is long term (1 to 10 years). Low priority initiatives may be eligible for grant funding from other programs that have not yet been identified. Low priority projects are "blue-sky" projects. Financing is unknown, and they can be completed over a long term.

Grant Funding Prioritization

Table 21-7 also lists the grant funding priority of each initiative. The priorities are defined as follows:

- **High Priority**—An initiative that has been identified as meeting grant eligibility requirements, assessed to have high benefits, is listed as high or medium priority, and where local funding options are unavailable or where dedicated funds could be utilized for projects that are not eligible for grant funding.
- **Medium Priority**—An initiative that has been identified as meeting grant eligibility requirements, assessed to have medium or low benefits, is listed as medium or low priority, and where local funding options are unavailable.
- **Low Priority**—An initiative that has not been identified as meeting grant eligibility requirements, or has low benefits.
    - Those initiatives identified as high-priority grant funding initiatives should be closely reviewed for consideration when grant funding opportunities arise.

TABLE 21-7.
PRIORITIZATION OF MITIGATION INITIATIVES

Initiative #	# of Objectives Met	Benefits	Costs	Do Benefits equal or exceed Costs?	Is project Grant eligible?	Can Project be funded under existing programs/ budgets?	Implementation Priority	Grant Funding Priority
AH-1	5	High	Low	Yes	Yes	Yes	High	Low
AH-2	5	High	High	Yes	Yes	No	Medium	High
AH-3	5	High	Medium	Yes	Yes	Yes	Medium	Medium
AH-4	5	Medium	Medium	Yes	Yes	No	High	High
AH-5	5	Medium	Medium	No	Yes	No	High	High
AH-6	5	Low	Low	Yes	Yes	Yes	High	Low
AH-7	4	Medium	Medium	Yes	Yes	Yes	High	Low
AH-8	6	Low	Low	Yes	Yes	Yes	High	Low
AH-9	5	Medium	Medium	Yes	Yes	Yes	High	Low
AH-10	10	Low	Low	Yes	No	Yes	High	Low
AH-11	6	Low	Low	Yes	No	Yes	High	Low
AH-12	8	Low	Low	Yes	No	Yes	High	Low
AH-13	6	Low	Low	Yes	No	Yes	High	Low
CE-1	3	High	High	Yes	Yes	No	Medium	High
CE-2	3	High	High	Yes	Yes	No	Medium	High
CE-3	3	Medium	Medium	Yes	Yes	Yes	High	Low
CE-4	3	Medium	Medium	Yes	Yes	Yes	High	Medium
CE-5	6	Low	High	No	Yes	No	Medium	Medium
CE-6	6	Low	Medium	No	Yes	Yes	Medium	Medium
CE-7	6	Low	Medium	No	Yes	Yes	Medium	Medium
CE-8	7	Low	Medium	No	Yes	Yes	High	Low
CE-9	6	Low	Low	Yes	No	Yes	High	Low
CE-10	7	Low	High	No	Yes	No	Low	High
DR-1	6	High	High	Yes	Yes	No	High	High
DR-2	6	Low	Low	Yes	Yes	Yes	High	Low
DR-3	5	Medium	High	No	Yes	No	Low	Medium
D-1	5	Low	Medium	No	Yes	Yes	High	Low
D-2	5	Medium	Medium	Yes	Yes	Yes	High	Medium
D-3	6	Low	Medium	No	Yes	Yes	Low	Low
D-4	8	Medium	Low	Yes	Yes	Yes	High	Medium
E-1	3	High	High	Yes	Yes	No	Medium	High
E-2	4	High	High	Yes	Yes	No	Medium	High
FL-1	6	High	High	Yes	Yes	No	Medium	High
FL-2	6	High	High	Yes	Yes	No	Medium	High
FL-3	3	High	Medium	Yes	Yes	No	Medium	High
FL-4	3	Medium	High	No	Yes	No	Low	High
FL-5	5	High	High	Yes	Yes	No	Medium	High
FL-6	6	Medium	Low	Yes	No	Yes	High	Medium
FL-7	7	Medium	Low	Yes	No	Yes	High	Medium
FL-8	6	Low	Low	Yes	No	Yes	High	Low
FL-9	6	Low	Medium	No	No	Yes	Low	Low

TABLE 21-7.
PRIORITIZATION OF MITIGATION INITIATIVES

Initiative #	# of Objectives Met	Benefits	Costs	Do Benefits equal or exceed Costs?	Is project Grant eligible?	Can Project be funded under existing programs/ budgets?	Implementation Priority	Grant Funding Priority
FL-10	3	High	High	Yes	Yes	No	Medium	High
FL-11	5	High	Medium	Yes	Yes	Yes	High	Low
FL-12	7	Low	Low	Yes	No	Yes	High	Low
FL-13	5	High	Medium	Yes	No	Yes	High	Low
HW-1	3	High	High	Yes	Yes	No	Medium	High
HW-2	3	Medium	Medium	Yes	Yes	No	High	Medium
HW-3	5	Low	Low	Yes	Yes	Yes	High	Low
L-1	4	High	High	Yes	Yes	No	Medium	High
L-2	4	High	High	Yes	Yes	No	Medium	High
L-3	4	High	High	Yes	Yes	No	Medium	High
TC-1	3	High	High	Yes	Yes	No	Medium	High
TC-2	4	Medium	Low	Yes	Yes	Yes	Medium	Medium
TC-3	5	Low	Low	Yes	No	Yes	High	Low
TC-4	7	High	High	Yes	Yes	No	Medium	High
T-1	6	Medium	Medium	Yes	Yes	No	Medium	Medium
T-2	4	Low	Low	Yes	Yes	Yes	High	Low
VH-1	4	Low	Low	Yes	Yes	Yes	High	Low
VH-2	6	Medium	Medium	Yes	Yes	Yes	High	Medium
W-1	3	High	High	Yes	Yes	No	Medium	High
W-2	7	High	High	Yes	Yes	No	Medium	High
W-3	5	Low	Low	Yes	No	Yes	High	Low

a. Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these initiatives. The ratings of high, medium and low are qualitative based solely on the comparison of one initiative to another. Implementation of an initiative should not be dissuaded based on its identification as a low priority.

Note: For explanation of table results, see Section 21.3.1 and 21.3.2

Chapter 22. Plan Adoption

A hazard mitigation plan must document that it has been formally adopted by the governing body of the jurisdiction requesting federal approval of the plan, as outlined in 44 CFR Section 201.6(c)(5). Disaster Mitigation Act of 2000 (DMA) compliance and its benefits cannot be achieved until the plan is adopted. This plan will be submitted for a pre-adoption review to Hawaii State Civil Defense, Federal Emergency Management Agency (FEMA) Region IX, and the Insurance Services Office prior to adoption. Once pre-adoption approval has been provided, Maui County will formally adopt the plan. A copy of the resolution is provided in Figure 22-1.

ALAN M. ARAKAWA
MAYOR

KEITH A. REGAN
MANAGING DIRECTOR

OFFICE OF THE MAYOR

Ke'ena O Ka Meia
COUNTY OF MAUI – Kalana O Maui

August 26, 2015

Memo To: Keith Regan, Managing Director
Anna M. Foust, Emergency Management Officer
All Department Directors and Deputies

From: Alan M. Arakawa, Mayor, County of Maui

Subject: County of Maui Multi-Hazard Mitigation Plan 2015

The Maui Multi-Hazard Mitigation Plan is a master plan for the County that identifies the hazards and risks posed by natural and technological disasters, identifies hazard mitigation actions and activities to reduce losses form such disaster and establishes priorities and a long-term sustained process to implement those actions.

Natural disasters have inflicted significant property losses and resulted in death and injury to residents and visitors in the County of Maui. Since 1955, there have been over 24 major disaster declarations in the State of Hawaii due to tropical cyclones, earthquakes, landslides, lava flows and tsunamis.

Beyond direct costs attributed to natural disasters, indirect costs also need to be considered in calculating the total cost of natural disasters. Disaster recovery efforts divert available public and private resources, adversely impacting the productivity of the economy.

The County of Maui Multi-Hazard Mitigation Plan represents the County of Maui's commitment to reduce risks from natural hazards and serves as a guide for decision makers as resources are committed in an effort to reduce the effects of natural hazards.

In accordance with the Disaster Mitigation Act of 2000, Public Law 106-390 this Plan is hereby approved and implemented.

The Maui Civil Defense Agency is responsible for annual maintenance and updates of the Plan and advising all county agencies on its implementation.

200 South High Street, Wailuku, Hawai'i 96793-2155 Telephone (808) 270-7855 Fax (808) 270-7870 e-mail: mayors.office@mauicounty.gov

Chapter 23. Plan Implementation and Maintenance Strategy

This section presents a plan implementation and maintenance process—outlined in CRS Step 10 and 44 CFR Section 201.6(c)(4)—that includes the following:

- A section describing how Maui County will implement the recommendations of this plan over its 5-year performance period
- A process by which Maui County will incorporate the requirements of the mitigation plan into other planning mechanisms, such as general or capital improvement plans, when appropriate
- A section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan over the 5-year cycle
- A discussion on how the community will continue public participation in the plan maintenance process.

Maui County did not integrate elements of the 2010 HMP into other planning mechanisms or annually review/update the plan based on best available data. This was primarily due to a lack of personnel dedicated to mitigation planning before, during and after the 2010 HMP planning process. Unlike the 2010 planning process, Maui County reached out to multiple stakeholders to participate in the 2015 plan update. This section details the formal process that will ensure that the Maui County Hazard Mitigation Plan remains an active and relevant document and that the County maintains its eligibility for applicable funding sources. It includes a the establishment of a Hazard Mitigation Working Group and a schedule for monitoring and evaluating the plan annually and producing an updated plan every 5 years. The plan's format allows sections to be reviewed and updated when new data become available, resulting in a plan that will remain current and relevant.

23.1.1 Plan Implementation

The effectiveness of the hazard mitigation plan depends on its implementation and the incorporation of its action items into existing local plans, policies and programs. Together, the action items in the Plan provide a framework for activities that Maui County can implement over the next 5 years. The planning team and the Steering Committee have established goals and objectives and have prioritized mitigation initiatives that will be implemented through existing plans, policies, and programs. The Maui County Civil Defense Agency will have lead responsibility for overseeing the plan implementation and maintenance strategy; however, plan implementation and evaluation will be a shared responsibility among all agencies identified as lead agencies in the mitigation action plan.

Incorporation into Other Planning Mechanisms

The information on hazard, risk, vulnerability, and mitigation contained in this plan is based on the best science and technology available at the time this plan was prepared. The Maui County General Plan is considered to be an integral part of this plan. Maui County, through adoption of a general plan and zoning ordinance, has planned for the impacts of natural hazards. The plan development process provided the opportunity to review and expand on policies in these planning mechanisms. The general plan documents and the hazard mitigation plan are complementary documents that

work together to achieve the goal of reducing risk exposure. An update to a general plan may trigger an update to the hazard mitigation plan.

Maui County will create a linkage between the hazard mitigation plan and the general plan documents by identifying a mitigation initiative as such and giving that initiative a high priority. Other planning processes and programs to be coordinated with the recommendations of the hazard mitigation plan may include the following:

- Emergency response plans
- Natural hazard elements of community plans
- Capital improvement programs
- Municipal codes
- Community design guidelines
- Landscape design guidelines
- Stormwater management programs
- Water system vulnerability assessments
- Any additional plans as they are reviewed and updated during the performance period of this plan.

Some action items do not need to be implemented through regulation. Instead, these items can be implemented through the creation of new educational programs, continued interagency coordination, or improved public participation. As information becomes available from other planning mechanisms that can enhance this plan, that information may be incorporated via the update process.

In order to promote incorporation of 2015 planning elements into the above planning mechanisms/programs individuals who are responsible for these programs, or closely associated with the responsible parties were invited to sit on the Steering Committee for the 2015 update. As a result, greater awareness of hazard mitigation and the planning elements was accrued by both Maui County and private non-governmental stakeholders. In addition, numerous mitigation initiatives were also identified to ensure the incorporation of mitigation elements in other planning mechanisms. Steering Committee members along with the lead coordinating agencies identified in the Hazard Mitigation Initiative Action Plan will serve on the Hazard Mitigation Working Group over the next 5 years. Having a working group comprised of individuals responsible for the review and update of the above programs, especially members from the Maui County Planning Department and Public Works, will help ensure integration and eliminate duplication of efforts.

23.1.2 Hazard Mitigation Working Group

The hazard mitigation Steering Committee was a total volunteer body that oversaw the development of the Plan and made recommendations on key elements of the Plan, including the implementation and maintenance strategy. It was the Steering Committee's position that an oversight committee with representation similar to that of the Steering Committee should have an active role in the Plan implementation and maintenance. Therefore, it is recommended that a hazard mitigation working group be formed to remain a viable body involved in key elements of the Plan implementation and maintenance strategy. This working group should strive to include representation from stakeholders in the planning area as well as identified lead agencies. The hazard mitigation working group will work toward fulfilling the following three responsibilities:

- Coordinating project implementation
- Reviewing the annual progress report
- Providing input to the Maui County Civil Defense Agency on possible enhancements to be considered at the next update.

Future plan updates will be overseen by a working group similar to the one that participated in this plan development process, so keeping an interim working group intact will provide a head start on future updates.

Implementation Coordination

It is anticipated that upon completion of this plan, there will be interest among the lead agencies identified in the action plan in pursuing grant funding under FEMA hazard mitigation grant programs and other relevant programs. Given the competitive nature of these programs, coordination and careful planning among the agencies will ensure the highest degree of success in seeking grant funding.

In order to clarify responsibilities and to streamline efforts, the Steering Committee chose to elect a Plan Implementation Lead. The Plan Implementation Lead will strive to:

- Coordinate with lead agencies and stakeholders in identifying and developing opportunities for implementation of mitigation projects through existing mechanisms
- Monitor grant funding opportunities identified in this plan
- Notify lead agencies when such funding opportunities become available.

For the duration of this plan's performance period, Maui County Civil Defense will act as the Plan Implementation Lead.

The Plan Implementation Lead will coordinate implementation planning sessions as needed and with enough lead time to plan for pursuing Hazard Mitigation Assistance funds, which typically open in March or April. Several meetings may be held throughout the year, with at least one meeting held to coordinate with the annual mitigation grant cycle. All working group members will be invited to participate. The objectives of these sessions will be to:

- Identify and refine projects that are recommendations of this plan so that eligible, well-planned, vetted projects can be submitted for consideration when funding opportunities arise
- Identify and develop strategies for incorporating mitigation projects into existing budgets, schedules, and planning mechanisms
- Provide input for the annual progress report regarding the actions and decisions of the committee.

Annual Progress Report

The hazard mitigation working group will also convene an annual working group meeting to evaluate the progress on the action plan during a 12-month performance period. This review will include items such as the following:

- Summary of any hazard events that occurred during the performance period and the impact these events had on the planning area
- Review of mitigation success stories
- Review of continuing public involvement

- Brief discussion about why targeted strategies were not completed
- Reevaluation of the action plan to determine if the timeline for identified projects needs to be amended (such as changing a long-term project to a short-term project because of new funding)
- Recommendations for new projects
- Changes in or potential for new funding options (grant opportunities)
- Impact of any other planning programs or initiatives that involve hazard mitigation.

The planning team has created a template for preparing a progress report (see Appendix F). The hazard mitigation working group will provide feedback to the planning team on items included in the template. The planning team will then prepare a formal annual report on the progress of the plan. This report should be used as follows:

- Posted on the Maui County website page dedicated to the hazard mitigation plan
- Provided to the local media through a press release
- Presented to the Maui County Council and Mayor to inform them of the progress of mitigation initiatives implemented during the reporting period
- Provided as part of the CRS annual re-certification package. The CRS requires an annual recertification to be submitted by October 1 of every calendar year for which the community has not received a formal audit. To meet this recertification timeline, the planning team will strive to complete progress reports between June and September each year.

Annual progress reporting is credited under CRS Step 10.

23.1.3 Plan Update

Maui County intends to update the hazard mitigation plan on a 5-year cycle from the date of initial plan adoption (CRS Step 10). This cycle may be accelerated to less than 5 years based on the following triggers:

- A federal disaster declaration that impacts the planning area
- A hazard event that causes loss of life
- A comprehensive update of the Maui Countywide Policy Plan portion of the general plan.

It will not be the intent of future updates to develop a complete new hazard mitigation plan for the planning area. The update will, at a minimum, include the following elements:

- The update process will be convened through a steering committee.
- The hazard risk assessment will be reviewed and, if necessary, updated using best available information and technologies.
- The action plan will be reviewed and revised to account for any initiatives completed, dropped, or changed and to account for changes in the risk assessment or new policies identified under other planning mechanisms (such as the general plan).
- The draft update will be sent to appropriate agencies and organizations for comment.
- The public will be given an opportunity to comment on the update prior to adoption.
- The Maui County Mayor will adopt the updated plan.

23.1.4 Opportunities for Public Access

The public will continue to be apprised of the plan's progress through the hazard mitigation plan website and by providing copies of annual progress reports to the media. The website will not only house the final plan, it will become the one-stop shop for information regarding the plan and plan implementation. Copies of the plan will be distributed to the Maui County library system. Upon initiation of future update processes, a new public involvement strategy will be initiated based on guidance from a new Steering Committee. This strategy will be based on the needs and capabilities of Maui County at the time of the update. At a minimum, this strategy will include the use of local media outlets within the planning area

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APPENDICES

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APPENDIX A. ACRONYMS AND DEFINITIONS

Appendix A.
Acronyms and Definitions

Acronyms

%g	Percent acceleration force of gravity
44 CFR	Code of Federal Regulations, Title 44
AMBER	Areal Mean Basin Estimated Rainfall
BEACH Act	Beaches Environmental Assessment and Coastal Health Act of 2000
cfs	Cubic feet per second
CIP	Capital Improvement Plan
CO_2	Carbon dioxide
CRS	Community Rating System
DAR	Division of Aquatic Resources
DFIRM	Digital Flood Insurance Rate Maps
DHS	U.S. Department of Homeland Security
DLNR	Department of Land and Natural Resources
DMA	Disaster Mitigation Act of 2000
DOFAW	Division of Forestry and Wildlife Management
EAP	Emergency Action Plan
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIS	Geographic Information System
H_2O	Water vapor
HAR	Hawaii Administrative Rules
Hazmat	Hazardous materials
Hazus-MH	Hazards U.S.-Multi Hazard

HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
IBC	International Building Code
IRC	International Residential Code
LiMWA	Limit of Moderate Wave Action
MCDA	Maui County Civil Defense Agency
MFD	Maui Fire Department
MM	Modified Mercalli Scale
NEHRP	National Earthquake Hazards Reduction Program
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PDI	Palmer Drought Index
PDM	Pre-Disaster Mitigation Grant Program
PGA	Peak Ground Acceleration
PIRCA	Pacific Islands Regional Climate Assessment
ppm	Parts per million
SFHA	Special Flood Hazard Area
SHELDUS	Special Hazard Events and Losses Database for the US
SLOSH	Sea, lake, and overland surges from hurricane
SO_2	Sulfur dioxide
SPI	Standardized Precipitation Index
STAPLEE	Social, technical, administrative, political, legal, environmental, and economic
SWOO	Strengths, weaknesses, obstacles, and opportunities
TRI	Toxic Release Inventory
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VMAP	VOG Measurement and Prediction Project

VOG	Volcanic gas
WUI	Wildland urban interface

Definitions

100-Year Flood: The term "100-year flood" can be misleading. The 100-year flood does not necessarily occur once every 100 years. Rather, it is the flood that has a 1 percent chance of being equaled or exceeded in any given year. Thus, the 100-year flood could occur more than once in a relatively short period of time. The Federal Emergency Management Agency (FEMA) defines it as the 1-percent annual chance flood, which is now the standard definition used by most federal and state agencies and by the National Flood Insurance Program (NFIP).

Acre-Foot: An acre-foot is the amount of water it takes to cover 1 acre to a depth of 1 foot. This measure is used to describe the quantity of storage in a water reservoir. An acre-foot is a unit of volume. One acre foot equals 7,758 barrels; 325,829 gallons; or 43,560 cubic feet. An average household of four will use approximately 1 acre-foot of water per year.

Asset: An asset is any man-made or natural feature that has value, including, but not limited to, people; buildings; infrastructure, such as bridges, roads, sewers, and water systems; lifelines, such as electricity and communication resources; and environmental, cultural, or recreational features such as parks, wetlands, and landmarks.

Base Flood: The flood having a 1-percent chance of being equaled or exceeded in any given year, also known as the "100-year" or "1-percent chance" flood. The base flood is a statistical concept used to ensure that all properties subject to the National Flood Insurance Program (NFIP) are protected to the same degree against flooding.

Basin: A basin is the area within which all surface water flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains, and ridges. Basins are also referred to as "watersheds" and "drainage basins."

Benefit: A benefit is a net project outcome and is usually defined in monetary terms. Benefits may include direct and indirect effects. For the purposes of benefit-cost analysis of proposed mitigation measures, benefits are limited to specific, measurable, risk reduction factors, including reduction in expected property losses (buildings, contents, and functions) and protection of human life.

Benefit/Cost Analysis: A benefit/cost analysis is a systematic, quantitative method of comparing projected benefits to projected costs of a project or policy. It is used as a measure of cost effectiveness.

Building: A building is defined as a structure that is walled and roofed, principally aboveground, and permanently fixed to a site. The term includes manufactured homes on permanent foundations on which the wheels and axles carry no weight.

Capability Assessment: A capability assessment provides a description and analysis of a community's current capacity to address threats associated with hazards. The assessment includes two components: an inventory of an agency's mission, programs, and policies, and an analysis of its capacity to carry them out. A capability assessment is an integral

part of the planning process in which a community's actions to reduce losses are identified, reviewed, and analyzed, and the framework for implementation is identified. The following capabilities were reviewed under this assessment:

- Legal and regulatory capability
- Administrative and technical capability
- Fiscal capability.

Community Rating System (CRS): The CRS is a voluntary program under the NFIP that rewards participating communities (provides incentives) for exceeding the minimum requirements of the NFIP and completing activities that reduce flood hazard risk by providing flood insurance premium discounts.

Critical Area: An area defined by state or local regulations as deserving special protection because of unique natural features or its value as habitat for a wide range of species of flora and fauna. A sensitive/critical area is usually subject to more restrictive development regulations.

Critical Facility: Facilities and infrastructure that are critical to the health and welfare of the population. These become especially important after any hazard event occurs. For the purposes of this plan, critical facilities include:

- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic and/or water reactive materials
- Hospitals, nursing homes, and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for disaster response before, during, and after hazard events
- Public and private utilities, facilities and infrastructure that are vital to maintaining or restoring normal services to areas damaged by hazard events
- Government facilities.

Cubic Feet per Second (cfs): Discharge or river flow is commonly measured in cfs. One cubic foot is about 7.5 gallons of liquid.

Dam: Any artificial barrier or controlling mechanism that can or does impound 10 acre-feet or more of water.

Dam Failure: Dam failure refers to a partial or complete breach in a dam (or levee) that impacts its integrity. Dam failures occur for a number of reasons, such as flash flooding, inadequate spillway size, mechanical failure of valves or other equipment, freezing and thawing cycles, earthquakes, and intentional destruction.

Debris Avalanche: Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph.

Debris Flow: Dense mixtures of water-saturated debris that move down-valley; looking and behaving much like flowing concrete. They form when loose masses of unconsolidated material are saturated, become unstable, and move down slope.

Debris Slide: Debris slides consist of unconsolidated rock or soil that has moved rapidly down slope. They occur on slopes greater than 65 percent.

Disaster Mitigation Act of 2000 (DMA); The DMA is Public Law 106-390 and is the latest federal legislation enacted to encourage and promote proactive, pre-disaster planning as a condition of receiving financial assistance under the Robert T. Stafford Act. The DMA emphasizes planning for disasters before they occur. Under the DMA, a pre-disaster hazard mitigation program and new requirements for the national post-disaster hazard mitigation grant program (HMGP) were established.

Drainage Basin: A basin is the area within which all surface water flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains and ridges. Drainage basins are also referred to as **watersheds** or **basins**.

Drought: Drought is a period of time without substantial precipitation from one year to the next. Drought can also be defined as the cumulative impacts of several dry years or a deficiency of precipitation over an extended period of time, which in turn results in water shortages for some activity, group, or environmental function. A hydrological drought is caused by deficiencies in surface and subsurface water supplies. A socioeconomic drought impacts the health, well being, and quality of life or starts to have an adverse impact on a region. Drought is a normal, recurrent feature of climate and occurs almost everywhere.

Earthquake: An earthquake is defined as a sudden slip on a fault, volcanic or magmatic activity, and sudden stress changes in the earth that result in ground shaking and radiated seismic energy. Earthquakes can last from a few seconds to over 5 minutes, and have been known to occur as a series of tremors over a period of several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties may result from falling objects and debris as shocks shake, damage, or demolish buildings and other structures.

Exposure: Exposure is defined as the number and dollar value of assets considered to be at risk during the occurrence of a specific hazard.

Extent: The extent is the size of an area affected by a hazard.

Fire Behavior: Fire behavior refers to the physical characteristics of a fire and is a function of the interaction between the fuel characteristics (such as type of vegetation and structures that could burn), topography, and weather. Variables that affect fire behavior include the rate of spread, intensity, fuel consumption, and fire type (such as underbrush versus crown fire).

Fire Frequency: Fire frequency is the broad measure of the rate of fire occurrence in a particular area. An estimate of the areas most likely to burn is based on past fire history or fire rotation in the area, fuel conditions, weather, ignition sources (such as human or lightning), fire suppression response, and other factors.

Flash Flood: A flash flood occurs with little or no warning when water levels rise at an extremely fast rate

Flood Insurance Rate Map (FIRM): FIRMs are the official maps on which the Federal Emergency Management Agency (FEMA) has delineated the Special Flood Hazard Area (SFHA).

Flood Insurance Study: A report published by the Federal Insurance and Mitigation Administration for a community in conjunction with the community's Flood Insurance rate Map. The study contains such background data as the base

flood discharges and water surface elevations that were used to prepare the FIRM. In most cases, a community FIRM with detailed mapping will have a corresponding flood insurance study.

Floodplain: Any land area susceptible to being inundated by flood waters from any source. A flood insurance rate map identifies most, but not necessarily all, of a community's floodplain as the Special Flood Hazard Area (SFHA).

Floodway: Floodways are areas within a floodplain that are reserved for the purpose of conveying flood discharge without increasing the base flood elevation more than 1 foot. Generally speaking, no development is allowed in floodways, as any structures located there would block the flow of floodwaters.

Floodway Fringe: Floodway fringe areas are located in the floodplain but outside of the floodway. Some development is generally allowed in these areas, with a variety of restrictions. On maps that have identified and delineated a floodway, this would be the area beyond the floodway boundary that can be subject to different regulations.

Fog: Fog refers to a cloud (or condensed water droplets) near the ground. Fog forms when air close to the ground can no longer hold all the moisture it contains. Fog occurs either when air is cooled to its dew point or the amount of moisture in the air increases. Heavy fog is particularly hazardous because it can restrict surface visibility. Severe fog incidents can close roads, cause vehicle accidents, cause airport delays, and impair the effectiveness of emergency response. Financial losses associated with transportation delays caused by fog have not been calculated in the United States but are known to be substantial.

Freeboard: Freeboard is the margin of safety added to the base flood elevation.

Frequency: For the purposes of this plan, frequency refers to how often a hazard of specific magnitude, duration, and/or extent is expected to occur on average. Statistically, a hazard with a 100-year frequency is expected to occur about once every 100 years on average and has a 1 percent chance of occurring any given year. Frequency reliability varies depending on the type of hazard considered.

Fujita Scale of Tornado Intensity: Tornado wind speeds are sometimes estimated on the basis of wind speed and damage sustained using the Fujita Scale. The scale rates the intensity or severity of tornado events using numeric values from F0 to F5 based on tornado wind speed and damage. An F0 tornado (wind speed less than 73 miles per hour (mph)) indicates minimal damage (such as broken tree limbs), and an F5 tornado (wind speeds of 261 to 318 mph) indicates severe damage.

Goal: A goal is a general guideline that explains what is to be achieved. Goals are usually broad-based, long-term, policy-type statements and represent global visions. Goals help define the benefits that a plan is trying to achieve. The success of a hazard mitigation plan is measured by the degree to which its goals have been met (that is, by the actual benefits in terms of actual hazard mitigation).

Geographic Information System (GIS): GIS is a computer software application that relates data regarding physical and other features on the earth to a database for mapping and analysis.

Hazard: A hazard is a source of potential danger or adverse condition that could harm people and/or cause property damage.

Hazard Mitigation Grant Program (HMGP): Authorized under Section 202 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the HMGP is administered by FEMA and provides grants to states, tribes, and local governments to implement hazard mitigation actions after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to disasters and to enable mitigation activities to be implemented as a community recovers from a disaster

Hazards U.S. Multi-Hazard (Hazus-MH) Loss Estimation Program: Hazus-MH is a GIS-based program used to support the development of risk assessments as required under the DMA. The Hazus-MH software program assesses risk in a quantitative manner to estimate damages and losses associated with natural hazards. Hazus-MH is FEMA's nationally applicable, standardized methodology and software program and contains modules for estimating potential losses from earthquakes, floods, and wind hazards. Hazus-MH has also been used to assess vulnerability (exposure) for other hazards.

Hydraulics: Hydraulics is the branch of science or engineering that addresses fluids (especially water) in motion in rivers or canals, works and machinery for conducting or raising water, the use of water as a prime mover, and other fluid-related areas.

Hydrology: Hydrology is the analysis of waters of the earth. For example, a flood discharge estimate is developed by conducting a hydrologic study.

Intensity: For the purposes of this plan, intensity refers to the measure of the effects of a hazard.

Inventory: The assets identified in a study region comprise an inventory. Inventories include assets that could be lost when a disaster occurs and community resources are at risk. Assets include people, buildings, transportation, and other valued community resources.

Landslide: Landslides can be described as the sliding movement of masses of loosened rock and soil down a hillside or slope. Fundamentally, slope failures occur when the strength of the soils forming the slope exceeds the pressure, such as weight or saturation, acting upon them.

Lightning: Lightning is an electrical discharge resulting from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt," usually within or between clouds and the ground. A bolt of lightning instantaneously reaches temperatures approaching 50,000ºF. The rapid heating and cooling of air near lightning causes thunder. Lightning is a major threat during thunderstorms. In the United States, 75 to 100 Americans are struck and killed by lightning each year (see http://www.fema.gov/hazard/thunderstorms/thunder.shtm).

Liquefaction: Liquefaction is the complete failure of soils, occurring when soils lose shear strength and flow horizontally. It is most likely to occur in fine grain sands and silts, which behave like viscous fluids when liquefaction occurs. This situation is extremely hazardous to development on the soils that liquefy, and generally results in extreme property damage and threats to life and safety.

Local Government: Any county, municipality, city, town, township, public authority, school district, special district, intrastate district, council of governments (regardless of whether the council of governments is incorporated as a

nonprofit corporation under State law), regional or interstate government entity, or agency or instrumentality of a local government; any Indian tribe or authorized tribal organization, or Alaska Native village or organization; and any rural community, unincorporated town or village, or other public entity.

Magnitude: Magnitude is the measure of the strength of an earthquake, and is typically measured by the Richter scale. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Mass movement: A collective term for landslides, mudflows, debris flows, sinkholes and lahars.

Mitigation: A preventive action that can be taken in advance of an event that will reduce or eliminate the risk to life or property.

Mitigation Actions: Mitigation actions are specific actions to achieve goals and objectives that minimize the effects from a disaster and reduce the loss of life and property.

Objective: For the purposes of this plan, an objective is defined as a short-term aim that, when combined with other objectives, forms a strategy or course of action to meet a goal. Unlike goals, objectives are specific and measurable.

Peak Ground Acceleration: Peak Ground Acceleration (PGA) is a measure of the highest amplitude of ground shaking that accompanies an earthquake, based on a percentage of the force of gravity.

Preparedness: Preparedness refers to actions that strengthen the capability of government, citizens, and communities to respond to disasters.

Presidential Disaster Declaration: These declarations are typically made for events that cause more damage than state and local governments and resources can handle without federal government assistance. Generally, no specific dollar loss threshold has been established for such declarations. A Presidential Disaster Declaration puts into motion long-term federal recovery programs, some of which are matched by state programs, designed to help disaster victims, businesses, and public entities.

Probability of Occurrence: The probability of occurrence is a statistical measure or estimate of the likelihood that a hazard will occur. This probability is generally based on past hazard events in the area and a forecast of events that could occur in the future. A probability factor based on yearly values of occurrence is used to estimate probability of occurrence.

Repetitive Loss Property: Any NFIP-insured property that, since 1978 and regardless of any changes of ownership during that period, has experienced one of the following:

- Four or more paid flood losses in excess of $1000.00
- Two paid flood losses in excess of $1000.00 within any 10-year period since 1978
- Three or more paid losses that equal or exceed the current value of the insured property.

Return Period (or Mean Return Period): This term refers to the average period of time in years between occurrences of a particular hazard (equal to the inverse of the annual frequency of occurrence).

Riverine: Of or produced by a river. Riverine floodplains have readily identifiable channels. Floodway maps can only be prepared for riverine floodplains.

Risk: Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. Risk measures the likelihood of a hazard occurring and resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to occurrence of a specific type of hazard. Risk also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment: Risk assessment is the process of measuring potential loss of life, personal injury, economic injury, and property damage resulting from hazards. This process assesses the vulnerability of people, buildings, and infrastructure to hazards and focuses on (1) hazard identification; (2) impacts of hazards on physical, social, and economic assets; (3) vulnerability identification; and (4) estimates of the cost of damage or costs that could be avoided through mitigation.

Risk Ranking: This ranking serves two purposes: (1) to describe the probability that a hazard will occur, and (2) to describe the impact a hazard will have on people, property, and the economy. Risk estimates are based on the methodology used to prepare the risk assessment for this plan. The following equation shows the risk ranking calculation:

Risk Ranking = Probability + Impact (people + property + economy)

Robert T. Stafford Act: The Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 100-107, was signed into law on November 23, 1988. This law amended the Disaster Relief Act of 1974, Public Law 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

Sinkhole: A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

Special Flood Hazard Area: The base floodplain delineated on a Flood Insurance Rate Map. The SFHA is mapped as a Zone A in riverine situations and zone V in coastal situations. The SFHA may or may not encompass all of a community's flood problems

Stakeholder: Business leaders, civic groups, academia, non-profit organizations, major employers, managers of critical facilities, farmers, developers, special purpose districts, and others whose actions could impact hazard mitigation.

Stream Bank Erosion: Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. However, it is important to remember that a stream is a dynamic and constantly changing system. It is natural for a stream to want to meander, so not all eroding banks are "bad" and in need of repair. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses

from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

Steep Slope: Different communities and agencies define it differently, depending on what it is being applied to, but generally a steep slope is a slope in which the percent slope equals or exceeds 25 percent. For this study, steep slope is defined as slopes greater than 33 percent.

Sustainable Hazard Mitigation: This concept includes the sound management of natural resources, local economic and social resiliency, and the recognition that hazards and mitigation must be understood in the largest possible social and economic context.

Thunderstorm: A thunderstorm is a storm with lightning and thunder produced by cumulonimbus clouds. Thunderstorms usually produce gusty winds, heavy rains, and sometimes hail. Thunderstorms are usually short in duration (seldom more than 2 hours). Heavy rains associated with thunderstorms can lead to flash flooding during the wet or dry seasons.

Tornado: A tornado is a violently rotating column of air extending between and in contact with a cloud and the surface of the earth. Tornadoes are often (but not always) visible as funnel clouds. On a local scale, tornadoes are the most intense of all atmospheric circulations, and winds can reach destructive speeds of more than 300 mph. A tornado's vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long.

Vulnerability: Vulnerability describes how exposed or susceptible an asset is to damage. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power. Flooding of an electric substation would affect not only the substation itself but businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Watershed: A watershed is an area that drains downgradient from areas of higher land to areas of lower land to the lowest point, a common drainage basin.

Wildfire: These terms refer to any uncontrolled fire occurring on undeveloped land that requires fire suppression. The potential for wildfire is influenced by three factors: the presence of fuel, topography, and air mass. Fuel can include living and dead vegetation on the ground, along the surface as brush and small trees, and in the air such as tree canopies. Topography includes both slope and elevation. Air mass includes temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount, duration, and the stability of the atmosphere at the time of the fire. Wildfires can be ignited by lightning and, most frequently, by human activity including smoking, campfires, equipment use, and arson.

Windstorm: Windstorms are generally short-duration events involving straight-line winds or gusts exceeding 50 mph. These gusts can produce winds of sufficient strength to cause property damage. Windstorms are especially dangerous in areas with significant tree stands, exposed property, poorly constructed buildings, mobile homes (manufactured housing units), major infrastructure, and aboveground utility lines. A windstorm can topple trees and power lines; cause damage to residential, commercial, critical facilities; and leave tons of debris in its wake.

Zoning Ordinance: The zoning ordinance designates allowable land use and intensities for a local jurisdiction. Zoning ordinances consist of two components: a zoning text and a zoning map.

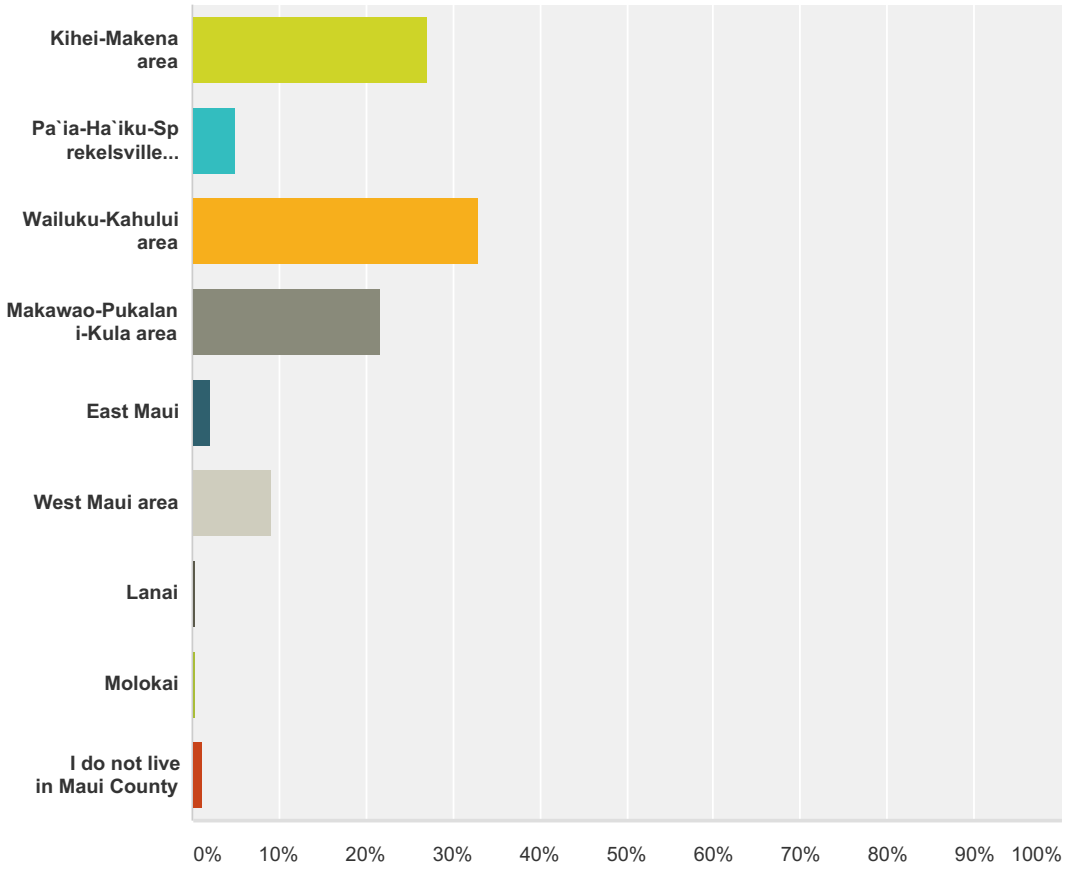
Maui County

Hazard Mitigation Plan Update

APPENDIX B. HAZARD MITIGATION PUBLIC SURVEY RESULTS

Q1 Where in Maui County do you live?

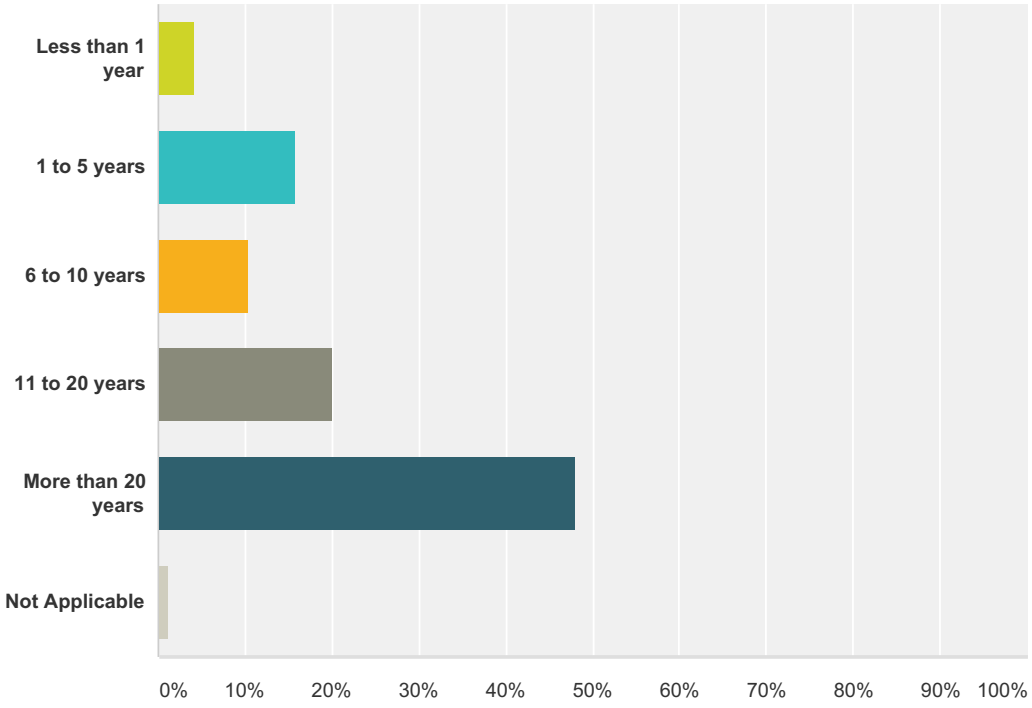
Answered: 240 Skipped: 0



Answer Choices	Responses	
Kihei-Makena area	**27.08%**	65
Pa`ia-Ha`iku-Sprekelsville area	**5.00%**	12
Wailuku-Kahului area	**32.92%**	79
Makawao-Pukalani-Kula area	**21.67%**	52
East Maui	**2.08%**	5
West Maui area	**9.17%**	22
Lanai	**0.42%**	1
Molokai	**0.42%**	1
I do not live in Maui County	**1.25%**	3
Total		**240**

Q2 How long have you lived in Maui County?

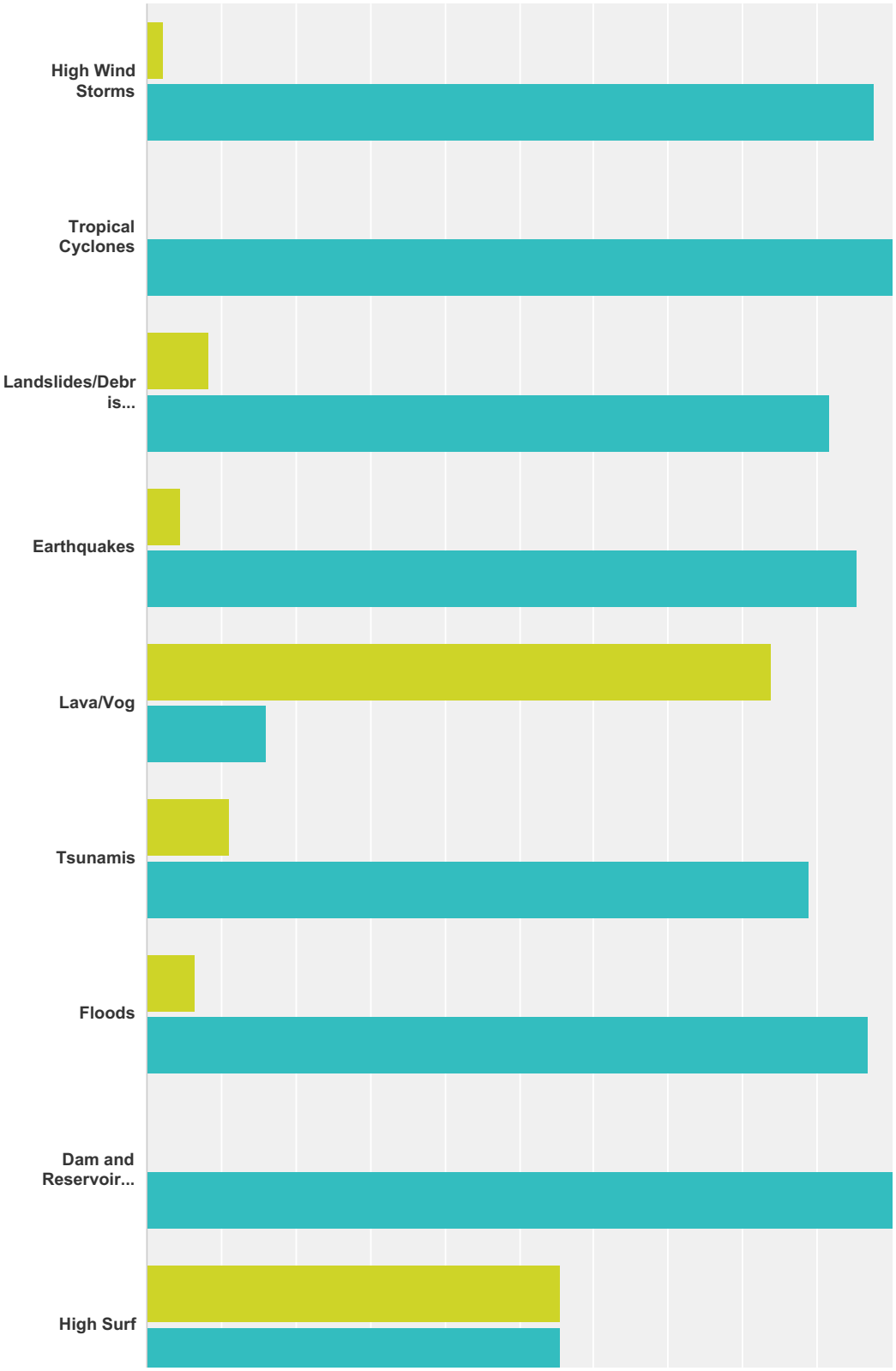
Answered: 239 Skipped: 1

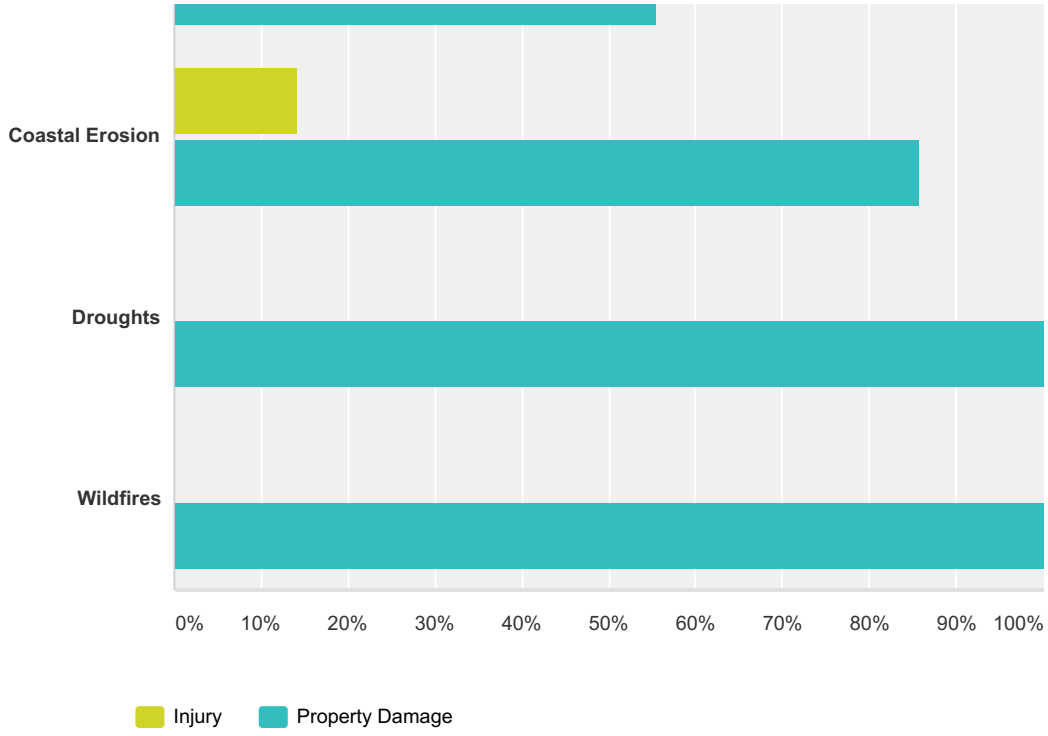


Answer Choices	Responses	
Less than 1 year	**4.18%**	10
1 to 5 years	**15.90%**	38
6 to 10 years	**10.46%**	25
11 to 20 years	**20.08%**	48
More than 20 years	**48.12%**	115
Not Applicable	**1.26%**	3
Total		**239**

Q3 In the past 20 years, have any of the following hazards impacted you, a member of your household or your property? (Check all that apply)

Answered: 110 Skipped: 130

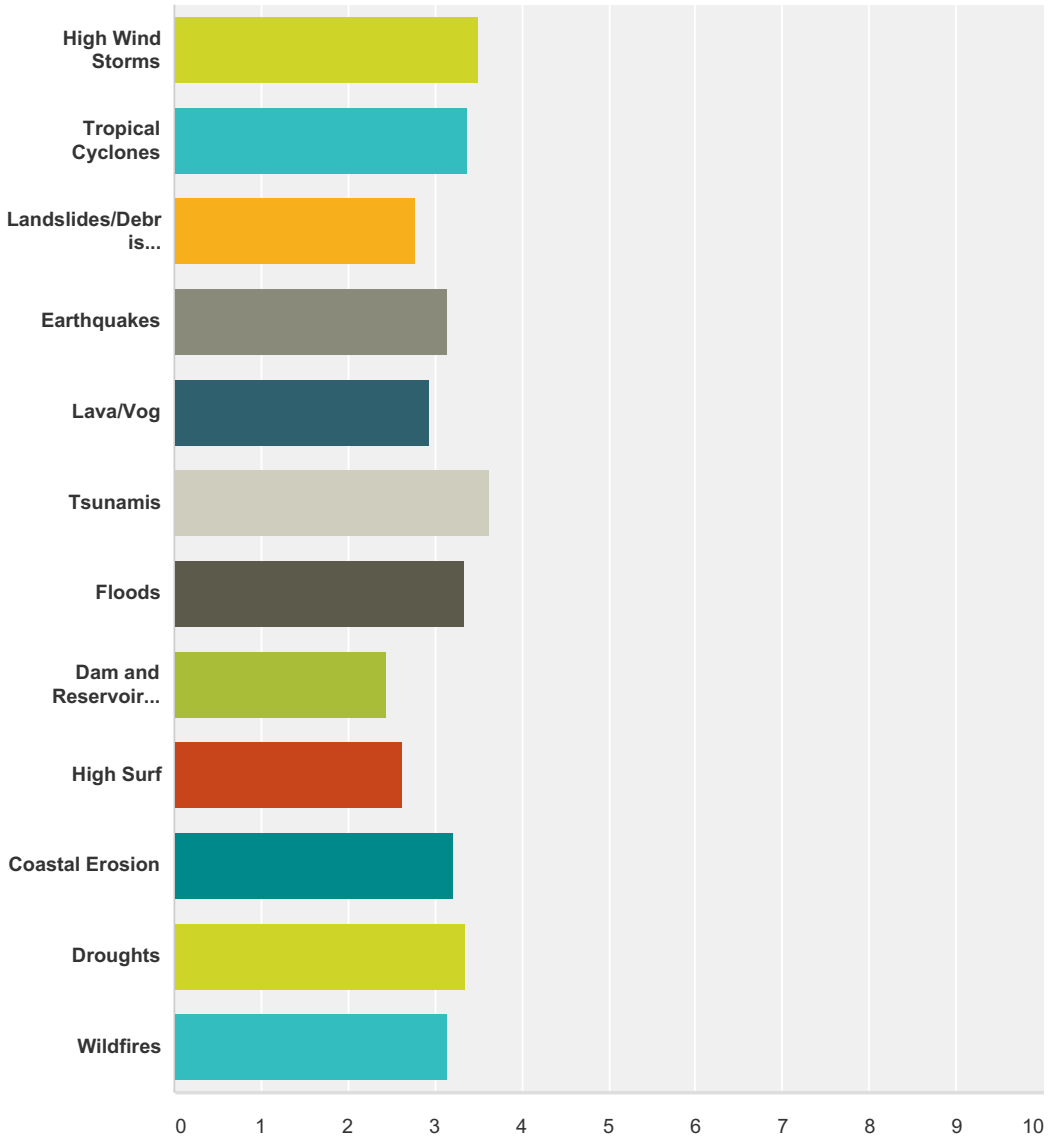




	Injury	Property Damage	Total Respondents
High Wind Storms	**2.33%** 2	**97.67%** 84	86
Tropical Cyclones	**0.00%** 0	**100.00%** 17	17
Landslides/Debris Flows/Rockfalls	**8.33%** 1	**91.67%** 11	12
Earthquakes	**4.55%** 1	**95.45%** 21	22
Lava/Vog	**83.87%** 26	**16.13%** 5	31
Tsunamis	**11.11%** 1	**88.89%** 8	9
Floods	**6.45%** 2	**96.77%** 30	31
Dam and Reservoir Failures	**0.00%** 0	**100.00%** 1	1
High Surf	**55.56%** 5	**55.56%** 5	9
Coastal Erosion	**14.29%** 1	**85.71%** 6	7
Droughts	**0.00%** 0	**100.00%** 11	11
Wildfires	**0.00%** 0	**100.00%** 5	5

Q4 How concerned are you about the following hazards' potential to impact people and property in Maui County?

Answered: 202 Skipped: 38

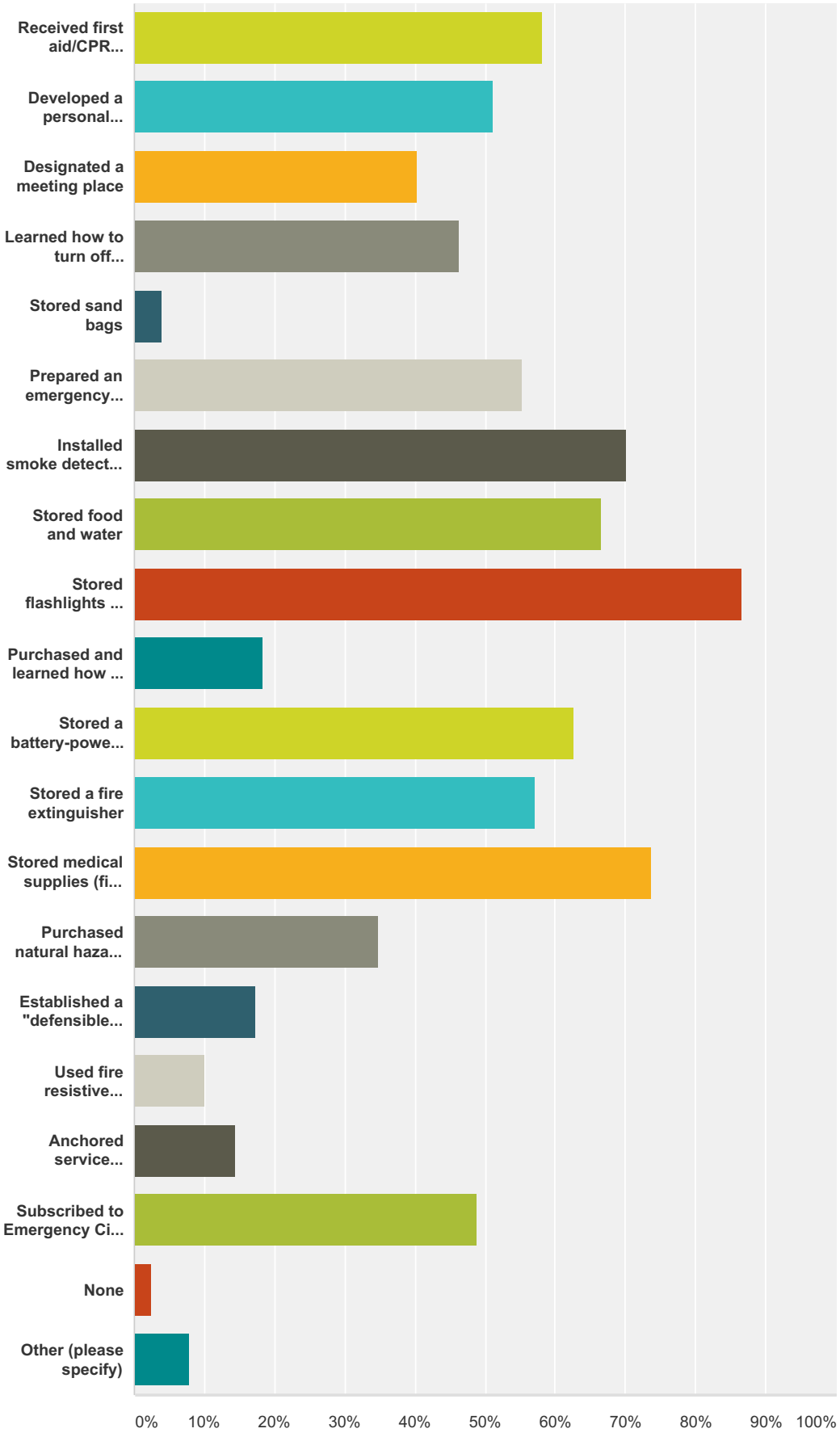


	Not concerned	Somewhat concerned	Concerned	Very concerned	Extremely concerned	Total	Weighted Average
High Wind Storms	**2.03%** 4	**13.71%** 27	**34.01%** 67	**31.98%** 63	**18.27%** 36	197	3.51
Tropical Cyclones	**8.47%** 16	**13.23%** 25	**29.63%** 56	**29.10%** 55	**19.58%** 37	189	3.38
Landslides/Debris Flows/Rockfalls	**16.09%** 28	**25.86%** 45	**31.61%** 55	**16.67%** 29	**9.77%** 17	174	2.78
Earthquakes	**6.99%** 13	**19.35%** 36	**38.71%** 72	**20.43%** 38	**14.52%** 27	186	3.16

Lava/Vog	**16.11%** 29	**22.22%** 40	**28.33%** 51	**17.78%** 32	**15.56%** 28	180	2.94
Tsunamis	**4.17%** 8	**14.06%** 27	**24.48%** 47	**29.17%** 56	**28.13%** 54	192	3.63
Floods	**5.46%** 10	**15.30%** 28	**35.52%** 65	**27.87%** 51	**15.85%** 29	183	3.33
Dam and Reservoir Failures	**29.94%** 50	**25.15%** 42	**22.75%** 38	**14.37%** 24	**7.78%** 13	167	2.45
High Surf	**18.18%** 32	**31.25%** 55	**30.11%** 53	**10.80%** 19	**9.66%** 17	176	2.63
Coastal Erosion	**10.06%** 18	**18.44%** 33	**27.93%** 50	**27.37%** 49	**16.20%** 29	179	3.21
Droughts	**7.69%** 14	**15.38%** 28	**30.77%** 56	**24.73%** 45	**21.43%** 39	182	3.37
Wildfires	**9.50%** 17	**21.23%** 38	**32.40%** 58	**17.88%** 32	**18.99%** 34	179	3.16

Q5 Which of the following steps has your household taken to prepare for a hazard event? (Choose all that apply)

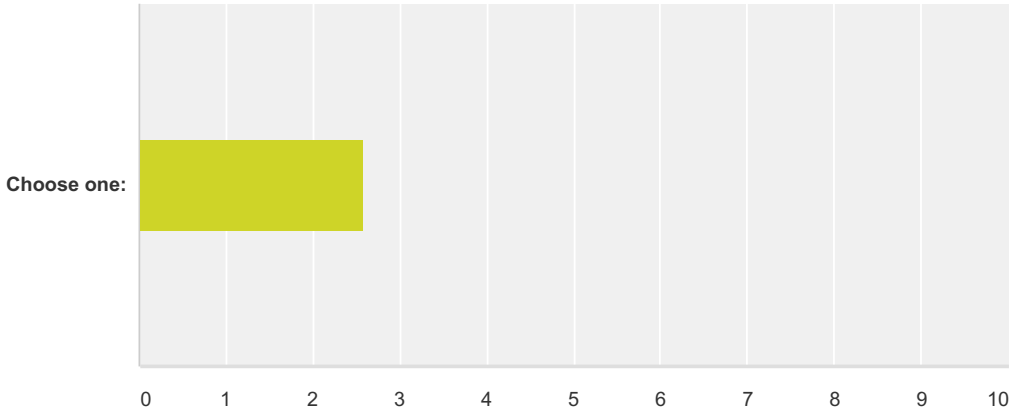
Answered: 201 Skipped: 39


Received first aid/CPR...
Developed a personal...
Designated a meeting place
Learned how to turn off...
Stored sand bags
Prepared an emergency...
Installed smoke detect...
Stored food and water
Stored flashlights ...
Purchased and learned how ...
Stored a battery-powe...
Stored a fire extinguisher
Stored medical supplies (fi...
Purchased natural haza...
Established a "defensible...
Used fire resistive...
Anchored service...
Subscribed to Emergency Ci...
None
Other (please specify)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Answer Choices	Responses	
Received first aid/CPR training	**58.21%**	117
Developed a personal preparation plan	**51.24%**	103
Designated a meeting place	**40.30%**	81
Learned how to turn off utilities, such as natural gas	**46.27%**	93
Stored sand bags	**3.98%**	8
Prepared an emergency survival kit	**55.22%**	111
Installed smoke detectors on each level of the house	**70.15%**	141
Stored food and water	**66.67%**	134
Stored flashlights and batteries	**86.57%**	174
Purchased and learned how to program a NOAA Weather Radio	**18.41%**	37
Stored a battery-powered radio	**62.69%**	126
Stored a fire extinguisher	**57.21%**	115
Stored medical supplies (first aid kit, medications)	**73.63%**	148
Purchased natural hazard insurance (Flood, Earthquake, Wildfire)	**34.83%**	70
Established a "defensible space" (area free from vegetation and combustible materials) around your home	**17.41%**	35
Used fire resistive landscaping (the use of plants that do not catch fire easily)	**9.95%**	20
Anchored service utilities to your home (water heater, furnace, wood stove, etc.)	**14.43%**	29
Subscribed to Emergency Civil Defense Alerts	**48.76%**	98
None	**2.49%**	5
Other (please specify)	**7.96%**	16
Total Respondents: 201		

Q6 Please rank how prepared you feel that you and your household are for the probable impacts of natural hazard events likely to occur in Maui County (e.g. disruption in basic services for one week or longer, such as bank and grocery store closures, water service disruption, etc.).

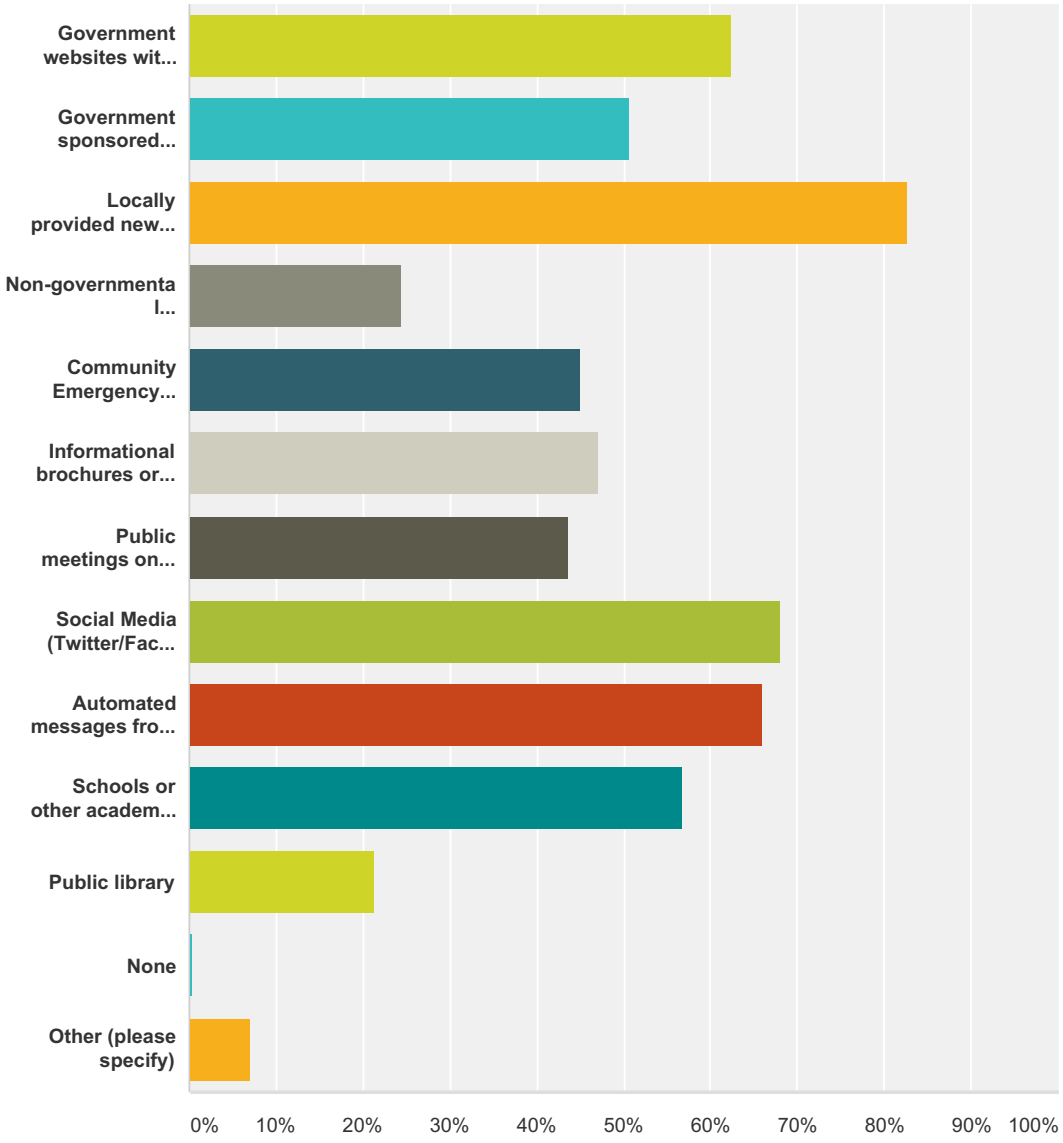
Answered: 196 Skipped: 44



	Not at all prepared	Somewhat prepared	Adequately prepared	Well prepared	Very well prepared	I am not sure	Total	Weighted Average
Choose one:	**10.71%** 21	**45.92%** 90	**22.96%** 45	**15.31%** 30	**4.59%** 9	**0.51%** 1	196	2.59

Q7 Which of the following do you think are the best ways to provide information about preparing for or responding to natural hazard events? (Choose all that apply)

Answered: 197 Skipped: 43

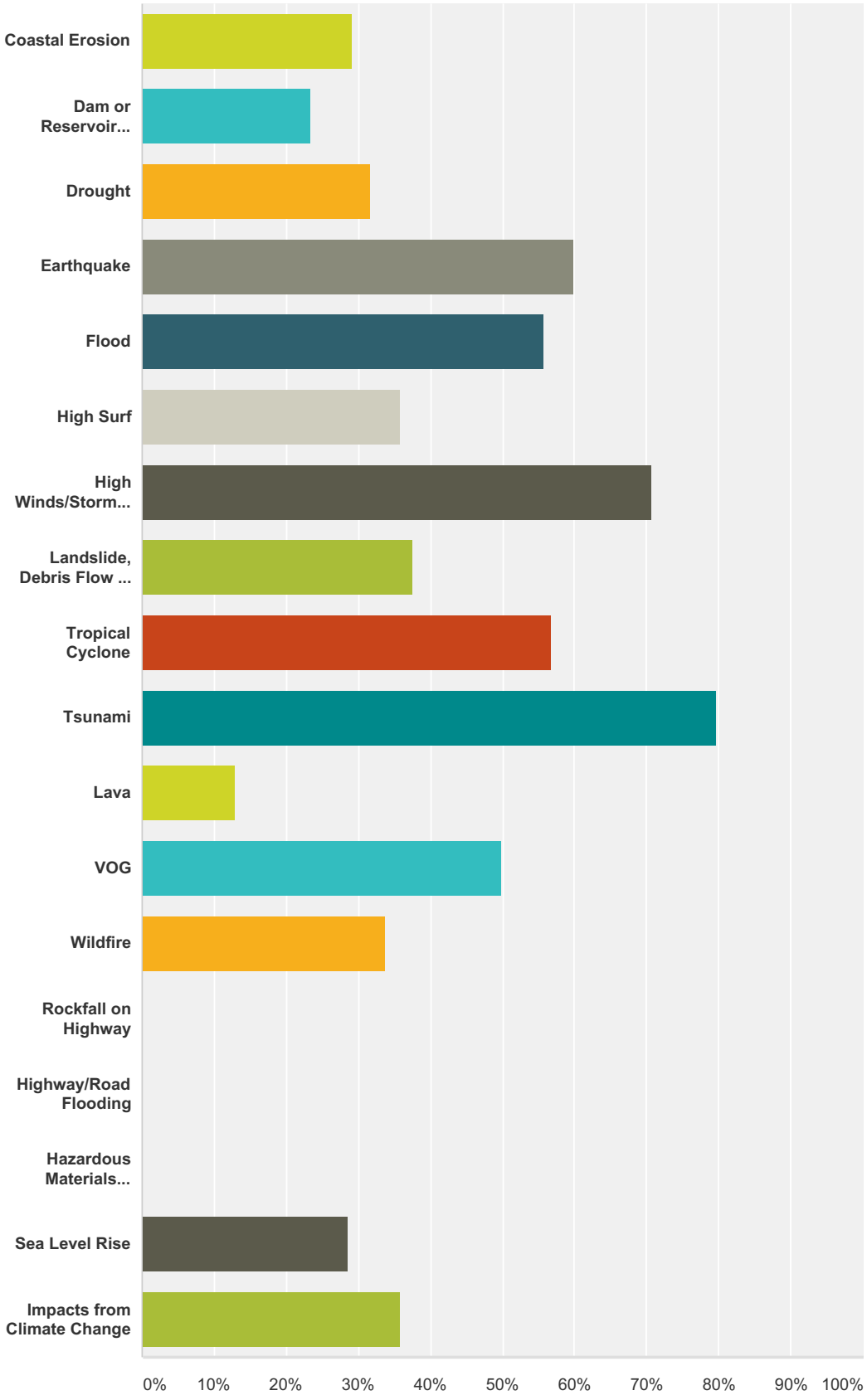


Answer Choices	Responses	
Government websites with emergency preparedness information	**62.44%**	123
Government sponsored public awareness campaigns	**50.76%**	100
Locally provided news or other media information (Radio, TV, Newspaper)	**82.74%**	163
Non-governmental organizations, such as faith-based institutions	**24.37%**	48
Community Emergency Response Team training (CERT) classes	**45.18%**	89

Informational brochures or other print materials	**47.21%**	93
Public meetings on disaster preparedness topics	**43.65%**	86
Social Media (Twitter/Facebook)	**68.02%**	134
Automated messages from Civil Defense	**65.99%**	130
Schools or other academic institutions	**56.85%**	112
Public library	**21.32%**	42
None	**0.51%**	1
Other (please specify)	**7.11%**	14
Total Respondents: 197		

Q8 For which hazards should information be more readily available? (check all that apply)

Answered: 192 Skipped: 48

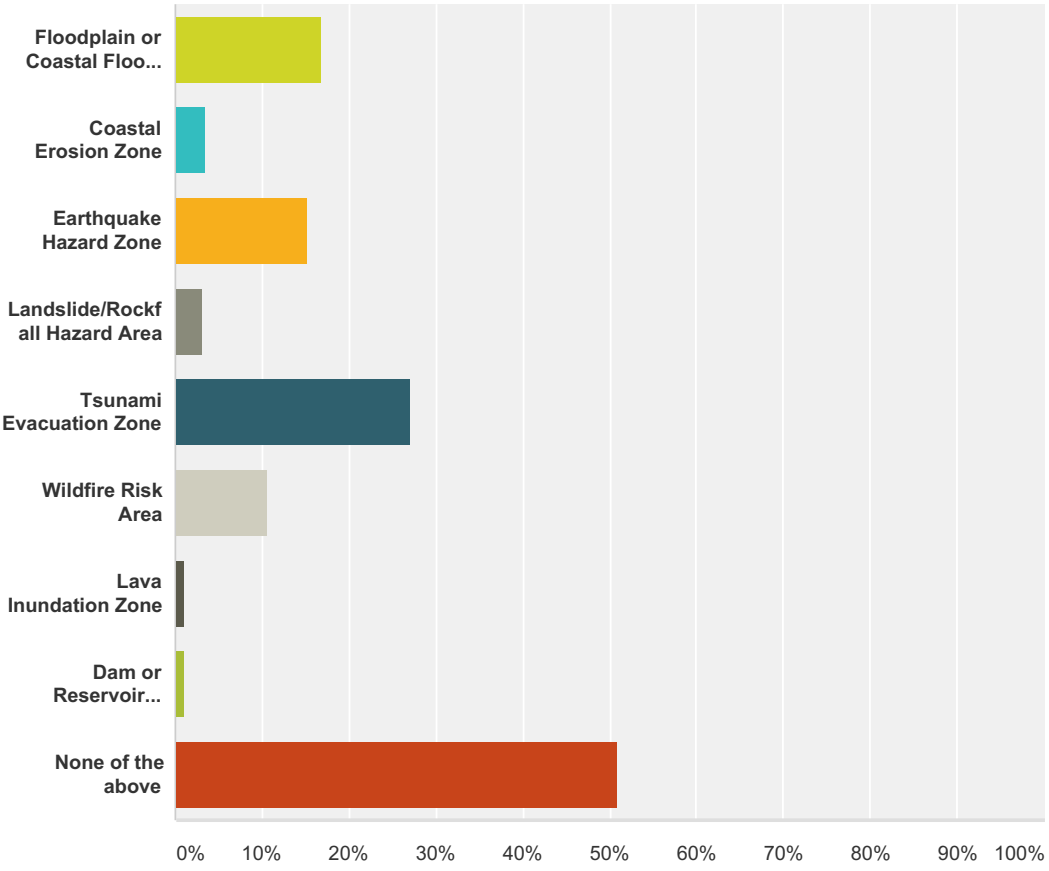


Answer Choices	Responses	
Coastal Erosion	**29.17%**	56

Dam or Reservoir Failure	**23.44%**	45
Drought	**31.77%**	61
Earthquake	**59.90%**	115
Flood	**55.73%**	107
High Surf	**35.94%**	69
High Winds/Storm Damage	**70.83%**	136
Landslide, Debris Flow or Rock Fall	**37.50%**	72
Tropical Cyclone	**56.77%**	109
Tsunami	**79.69%**	153
Lava	**13.02%**	25
VOG	**50.00%**	96
Wildfire	**33.85%**	65
Rockfall on Highway	**0.00%**	0
Highway/Road Flooding	**0.00%**	0
Hazardous Materials Spill/Release	**0.00%**	0
Sea Level Rise	**28.65%**	55
Impacts from Climate Change	**35.94%**	69
Total Respondents: 192		

Q9 To the best of your knowledge, is your home located within any of the following natural hazard areas (please choose all that apply):

Answered: 196 Skipped: 44

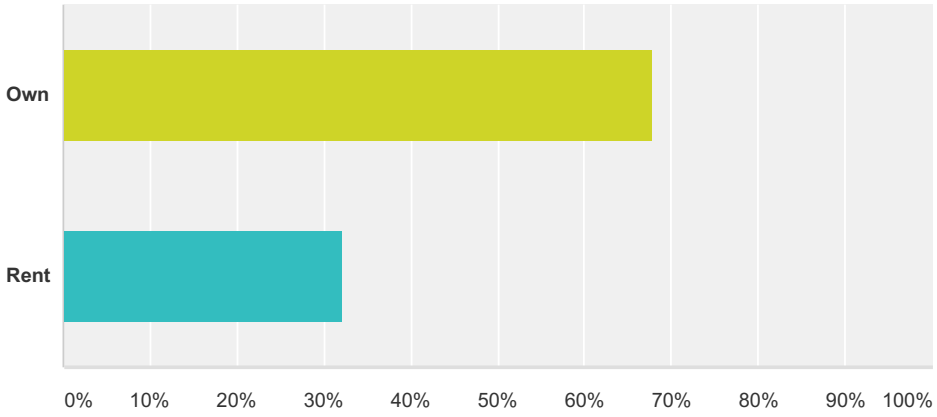


Answer Choices	Responses	
Floodplain or Coastal Flood Zone	**16.84%**	33
Coastal Erosion Zone	**3.57%**	7
Earthquake Hazard Zone	**15.31%**	30
Landslide/Rockfall Hazard Area	**3.06%**	6
Tsunami Evacuation Zone	**27.04%**	53
Wildfire Risk Area	**10.71%**	21
Lava Inundation Zone	**1.02%**	2
Dam or Reservoir Failure Inundation Zone	**1.02%**	2
None of the above	**51.02%**	100

Total Respondents: 196	

Q10 Do you own or rent your home?

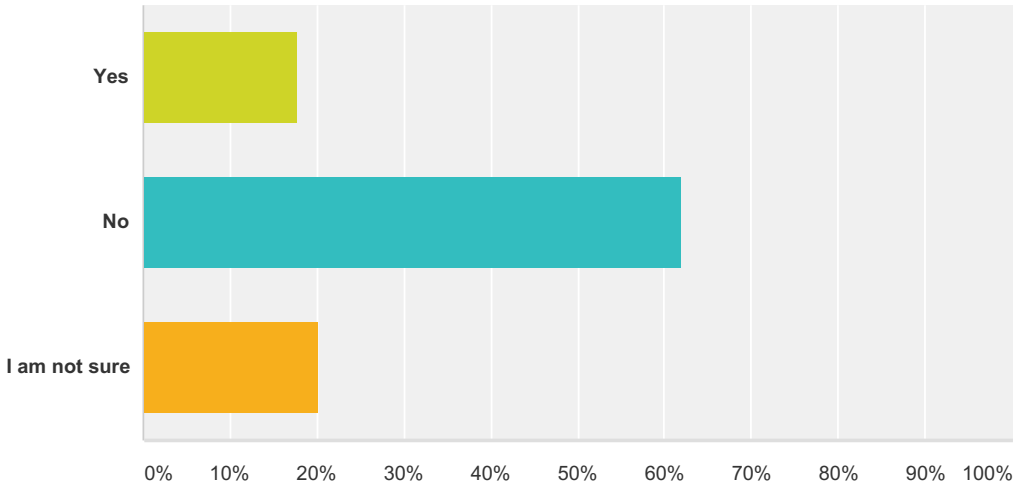
Answered: 196 Skipped: 44



Answer Choices	Responses	
Own	**67.86%**	133
Rent	**32.14%**	63
Total		**196**

Q11 Did a real estate agent, seller or landlord tell you if your home was in or near a hazard risk zone before you moved into or purchased your home (i.e. dam failure zone, flood zone, tsunami evacuation zone, landslide hazard area, high fire risk area)?

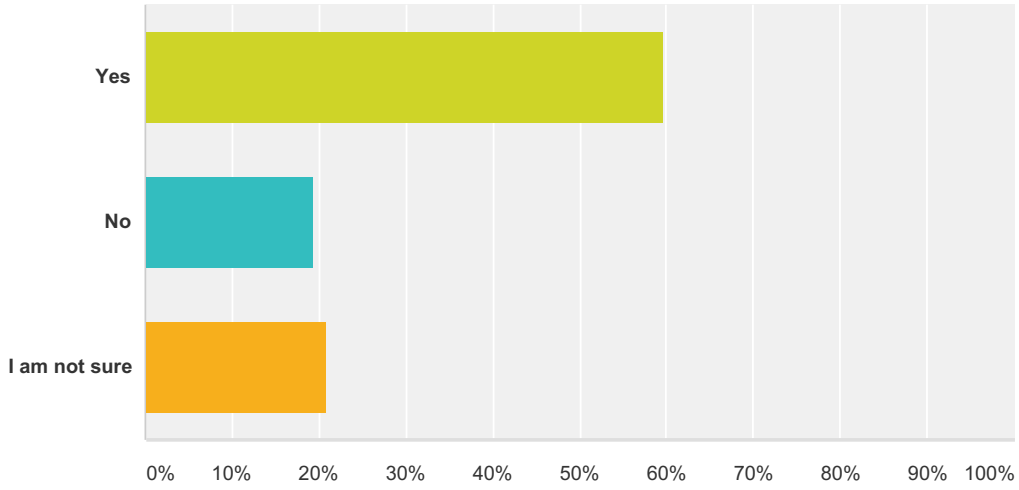
Answered: 192 Skipped: 48



Answer Choices	Responses	
Yes	**17.71%**	34
No	**61.98%**	119
I am not sure	**20.31%**	39
Total		**192**

Q12 If you were told this type of hazard risk information, would it influence your decision to buy or rent a home?

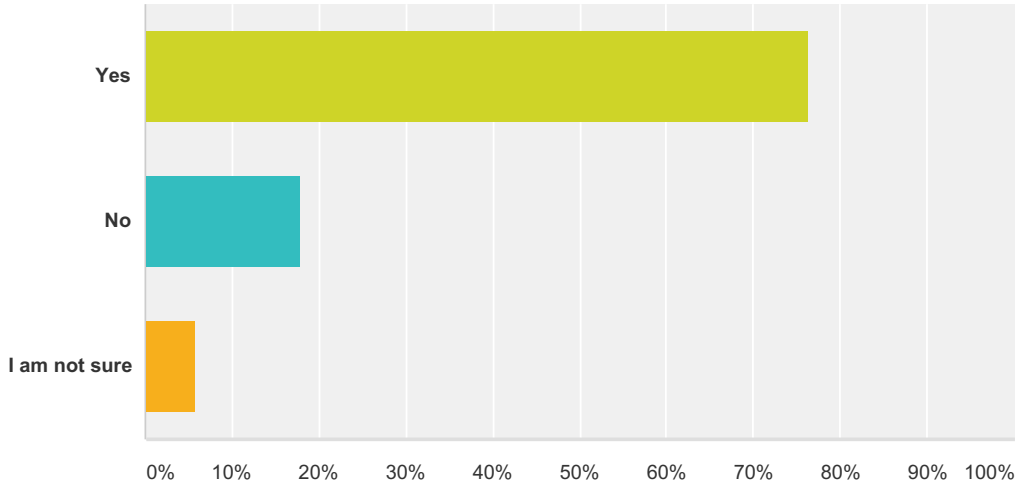
Answered: 186 Skipped: 54



Answer Choices	Responses	
Yes	**59.68%**	111
No	**19.35%**	36
I am not sure	**20.97%**	39
Total		**186**

Q13 Do you have homeowners or renters insurance for your property?

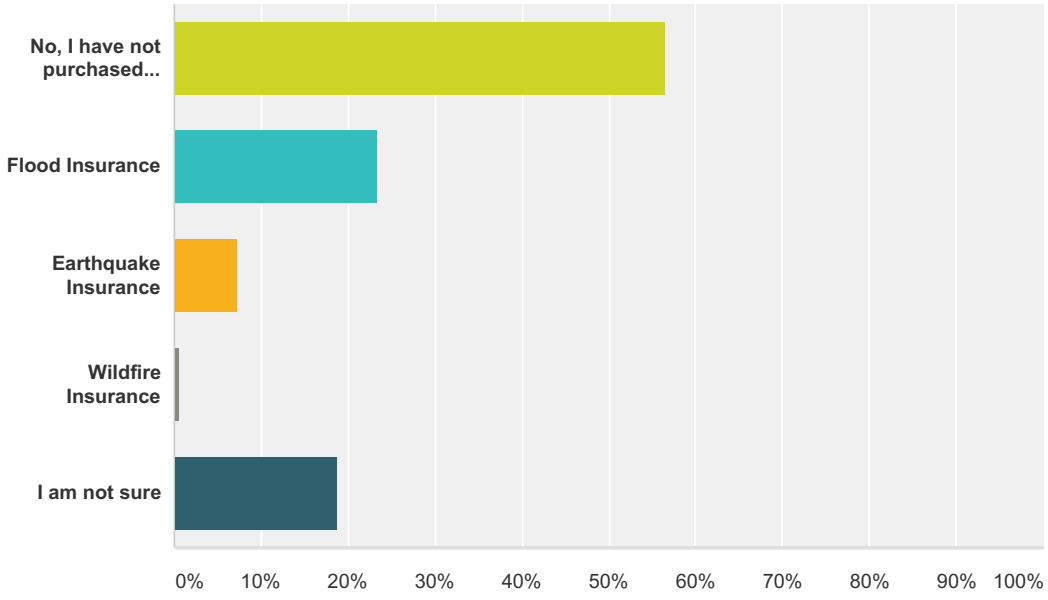
Answered: 190 Skipped: 50



Answer Choices	Responses	
Yes	**76.32%**	145
No	**17.89%**	34
I am not sure	**5.79%**	11
Total		**190**

Q14 Have you purchased any specialty insurance policies that will provide coverage for losses from hazards not usually covered by homeowners' insurance policies (i.e. floods, landslides, wildfires, earthquakes)? Please choose from the choices below.

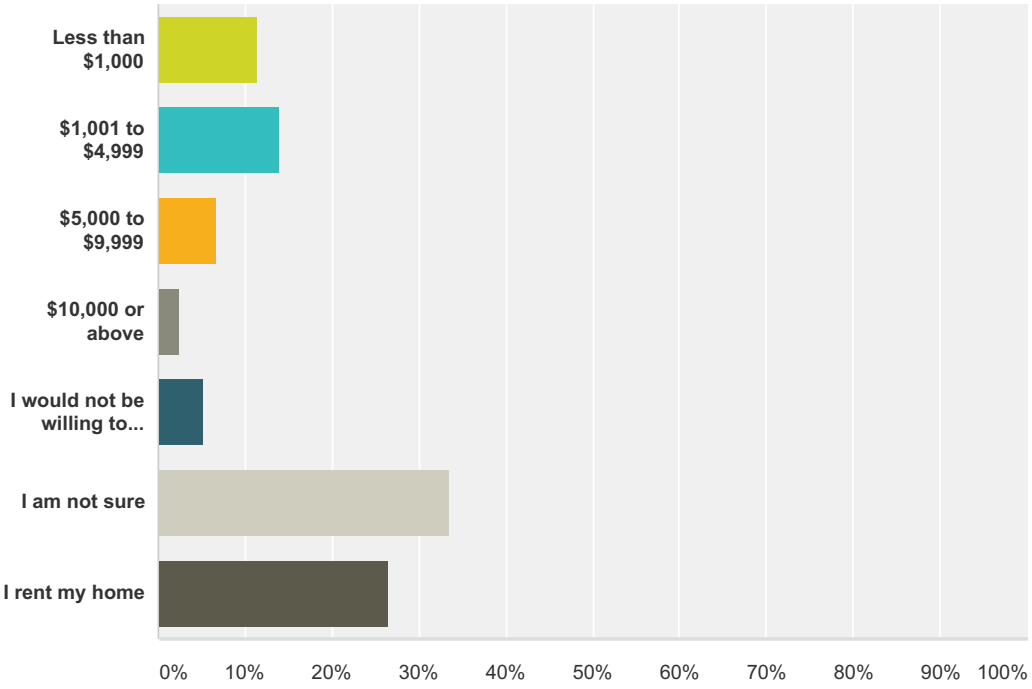
Answered: 180 Skipped: 60



Answer Choices	Responses	
No, I have not purchased specialty insurance coverage	**56.67%**	102
Flood Insurance	**23.33%**	42
Earthquake Insurance	**7.22%**	13
Wildfire Insurance	**0.56%**	1
I am not sure	**18.89%**	34
Total Respondents: 180		

Q15 How much money are you willing to spend to make your home more disaster resilient (i.e. retrofit, elevate, perform seismic upgrades, etc.)?

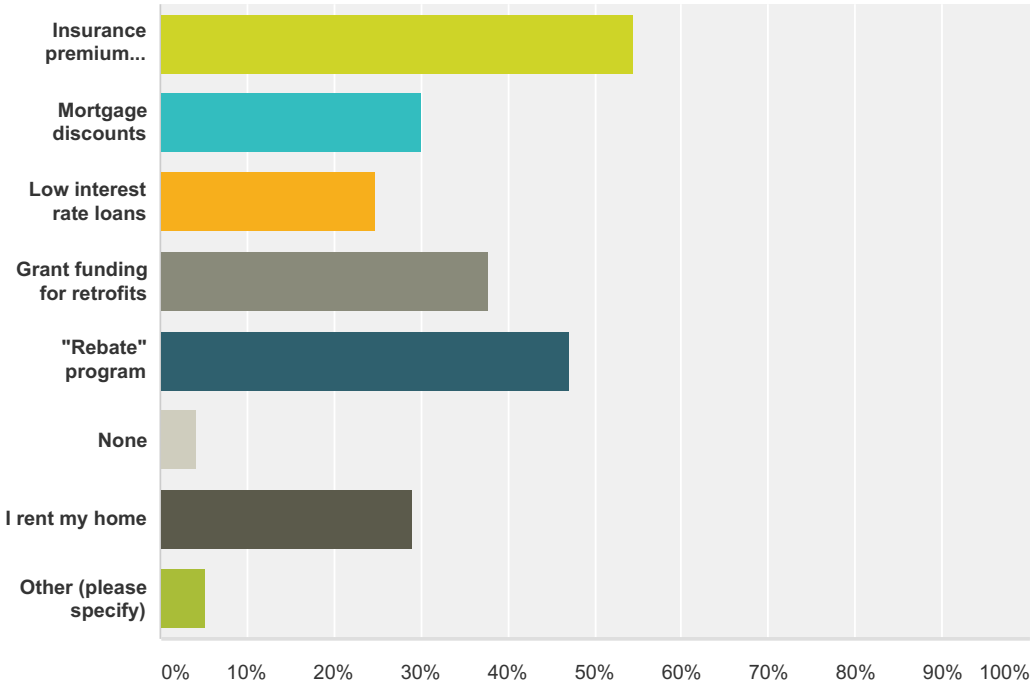
Answered: 193 Skipped: 47



Answer Choices	Responses	
Less than $1,000	**11.40%**	22
$1,001 to $4,999	**13.99%**	27
$5,000 to $9,999	**6.74%**	13
$10,000 or above	**2.59%**	5
I would not be willing to spend any money	**5.18%**	10
I am not sure	**33.68%**	65
I rent my home	**26.42%**	51
Total		**193**

Q16 Which of the following incentives would motivate you to take additional steps to better protect your home from a natural disaster? (check all that apply)

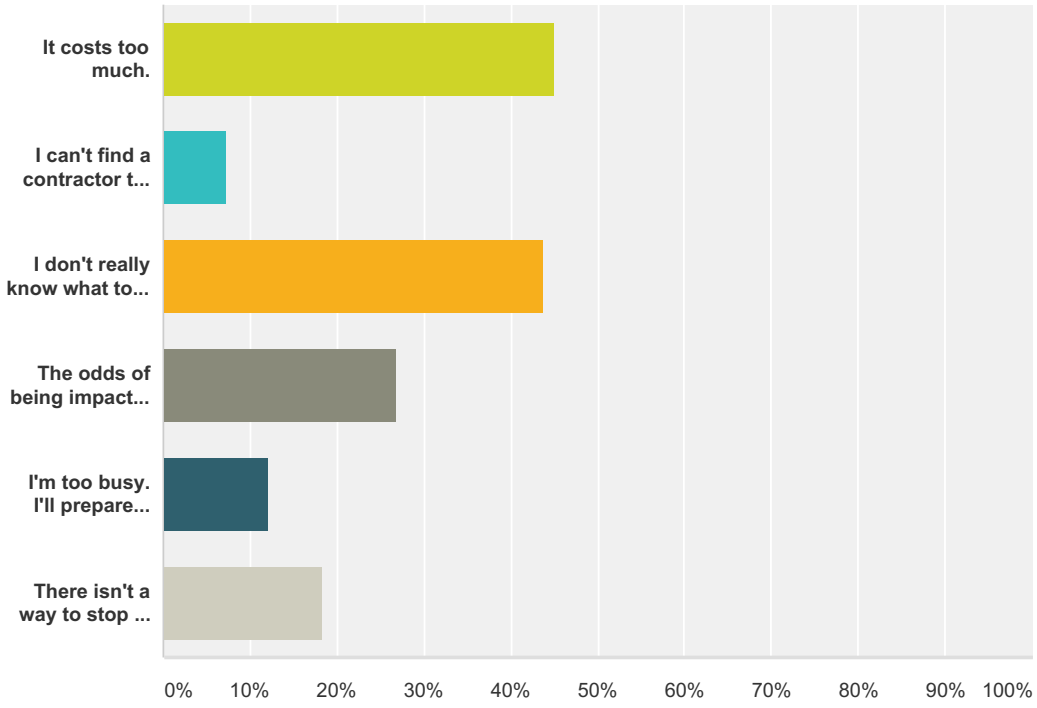
Answered: 193 Skipped: 47



Answer Choices	Responses	
Insurance premium discounts	**54.40%**	105
Mortgage discounts	**30.05%**	58
Low interest rate loans	**24.87%**	48
Grant funding for retrofits	**37.82%**	73
"Rebate" program	**47.15%**	91
None	**4.15%**	8
I rent my home	**29.02%**	56
Other (please specify)	**5.18%**	10
Total Respondents: 193		

Q17 Which of the following obstacles prevent you in strengthening your home for the next disaster? (check all that apply)

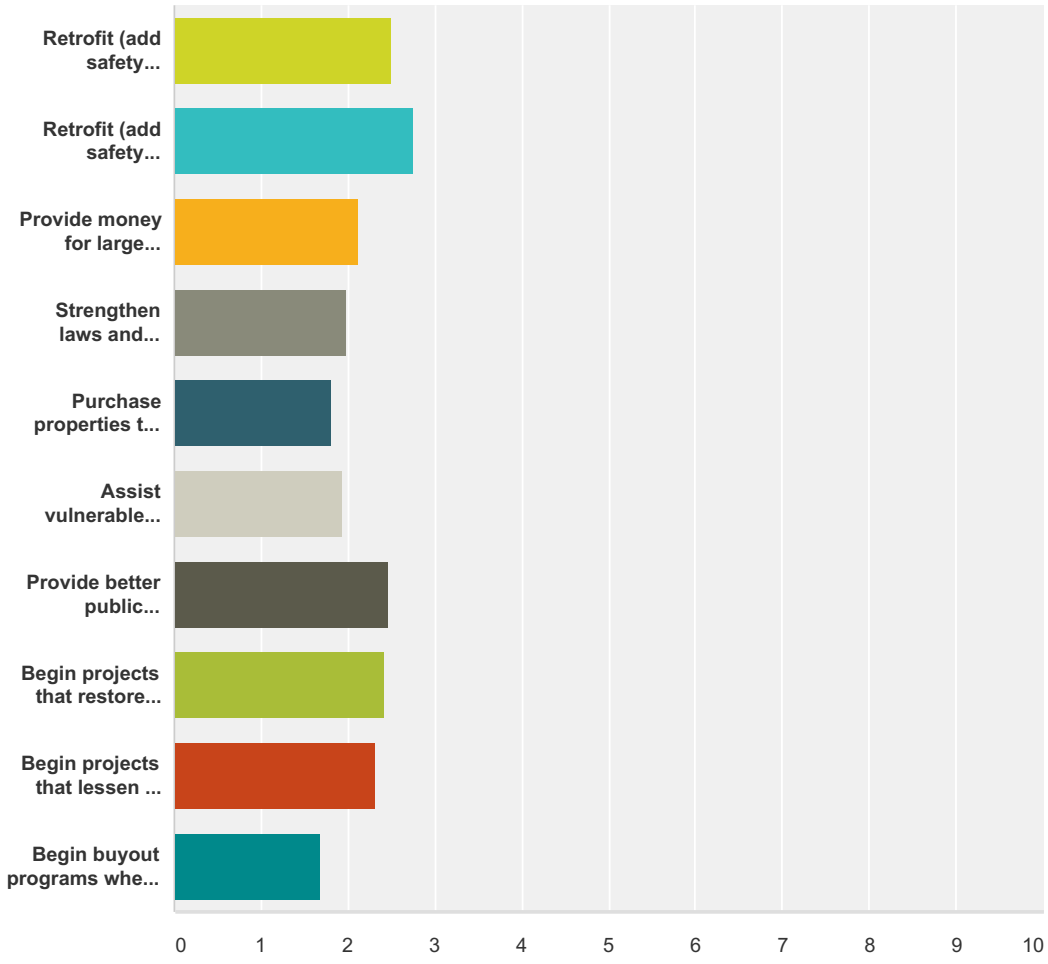
Answered: 164 Skipped: 76



Answer Choices	Responses	
It costs too much.	**45.12%**	74
I can't find a contractor to do the work.	**7.32%**	12
I don't really know what to do or how to do it.	**43.90%**	72
The odds of being impacted are too remote to justify the cost.	**26.83%**	44
I'm too busy. I'll prepare if there's any warning.	**12.20%**	20
There isn't a way to stop the hazard and damage.	**18.29%**	30
Total Respondents: 164		

Q18 What types of projects do you believe the County, State or Federal agencies should be doing in order to reduce damage and disruption from hazard events within Maui County? Please rank each option as a low, medium or high priority.

Answered: 187 Skipped: 53



	Low	Medium	High	Total	Weighted Average
Retrofit (add safety improvements) and strengthen essential facilities such as police and fire stations, schools and hospitals.	**6.04%** 11	**37.91%** 69	**56.04%** 102	182	2.50
Retrofit (add safety improvements to) infrastructure, such as harbors, roads, bridges, drainage facilities, levees, water supply systems, waste water systems and power supply facilities.	**0.53%** 1	**22.46%** 42	**77.01%** 144	187	2.76
Provide money for large projects, such as dams, levees, flood walls, drainage improvements and bank stabilization projects.	**19.44%** 35	**48.33%** 87	**32.22%** 58	180	2.13
Strengthen laws and regulations to include higher regulatory standards in hazard areas, such as floodplains.	**26.11%** 47	**48.33%** 87	**25.56%** 46	180	1.99

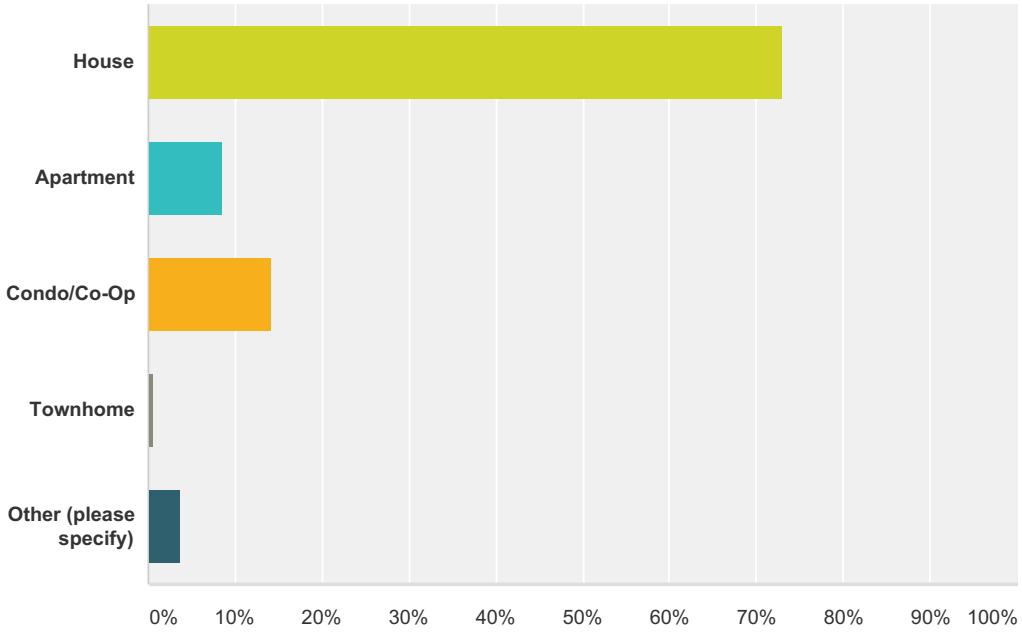
Purchase properties that are in danger to natural hazards and maintain them as open space or parks.	**40.33%** 73	**37.57%** 68	**22.10%** 40	181	1.82
Assist vulnerable property owners with finding funding for reducing the risk from hazards.	**28.02%** 51	**48.90%** 89	**23.08%** 42	182	1.95
Provide better public information about risk, and the exposure to hazards within the area.	**5.00%** 9	**43.33%** 78	**51.67%** 93	180	2.47
Begin projects that restore the natural environment's ability to absorb the impacts from natural hazards, such as rain gardens.	**8.89%** 16	**39.44%** 71	**51.67%** 93	180	2.43
Begin projects that lessen the potential impacts from climate change.	**17.13%** 31	**34.81%** 63	**48.07%** 87	181	2.31
Begin buyout programs where homes or properties located in designated "high hazard" or areas that are repeatedly damaged are purchased from their owners.	**46.89%** 83	**36.72%** 65	**16.38%** 29	177	1.69

Q19 At this time, what actions do you plan on taking to better prepare or protect your family and home from the next disaster?

Answered: 86 Skipped: 154

Q20 Please indicate the type of property where your home is located:

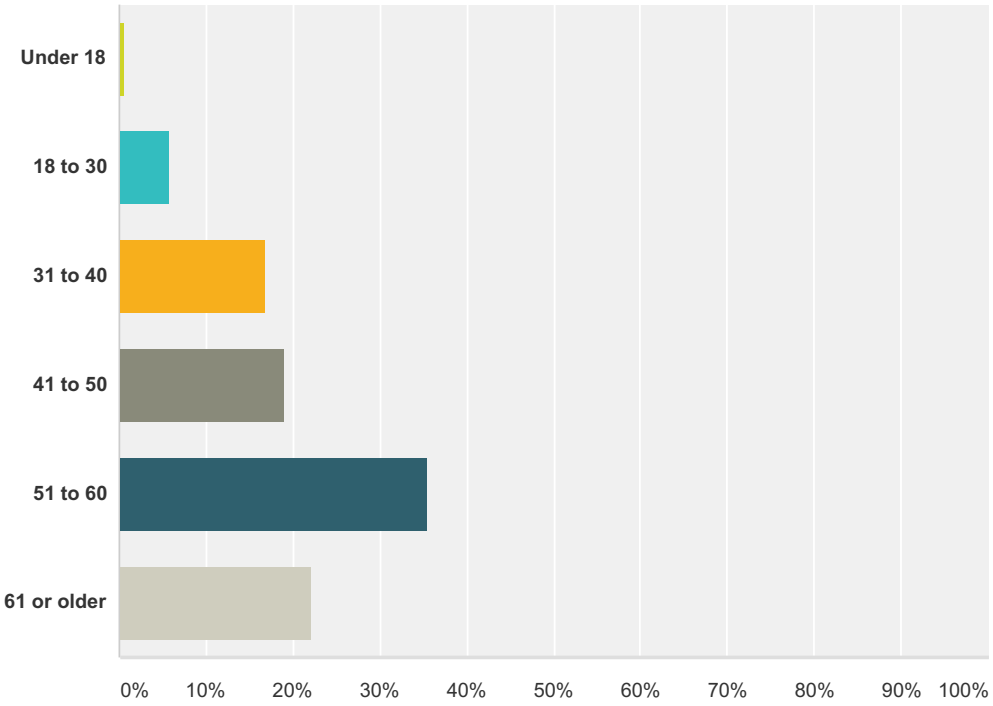
Answered: 189 Skipped: 51



Answer Choices	Responses	
House	**73.02%**	138
Apartment	**8.47%**	16
Condo/Co-Op	**14.29%**	27
Townhome	**0.53%**	1
Other (please specify)	**3.70%**	7
Total		**189**

Q21 Please indicate your age range.

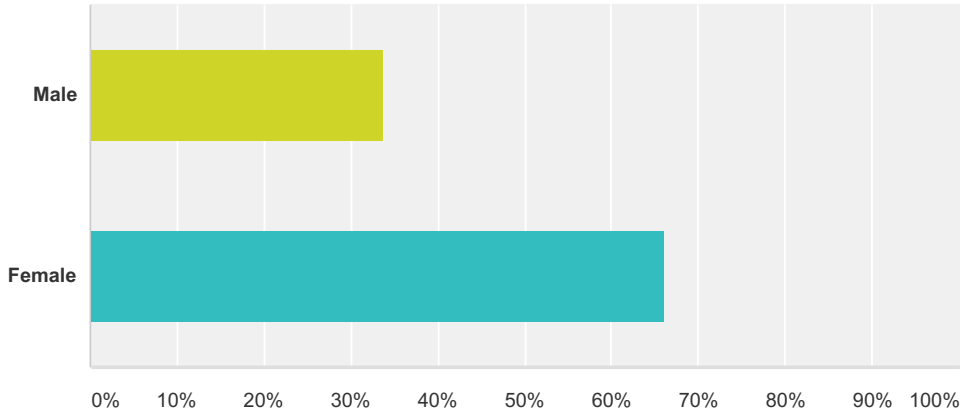
Answered: 189 Skipped: 51



Answer Choices	Responses	
Under 18	**0.53%**	1
18 to 30	**5.82%**	11
31 to 40	**16.93%**	32
41 to 50	**19.05%**	36
51 to 60	**35.45%**	67
61 or older	**22.22%**	42
Total		**189**

Q22 Please indicate your gender.

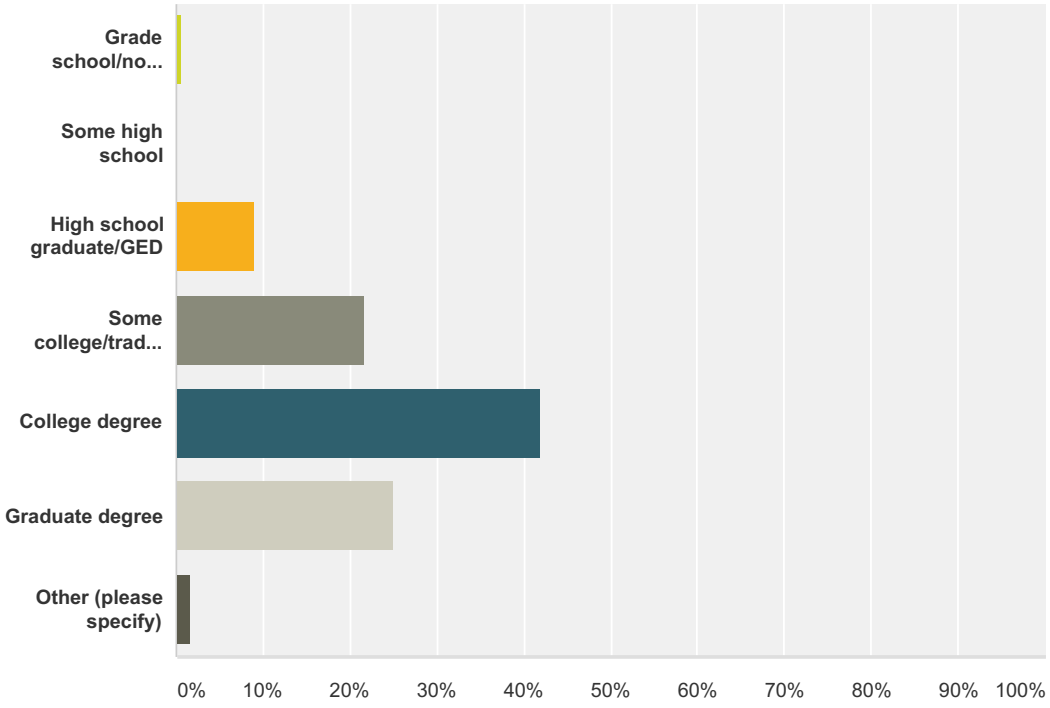
Answered: 186 Skipped: 54



Answer Choices	Responses	
Male	**33.87%**	63
Female	**66.13%**	123
Total		**186**

Q23 Please indicate your highest level of education.

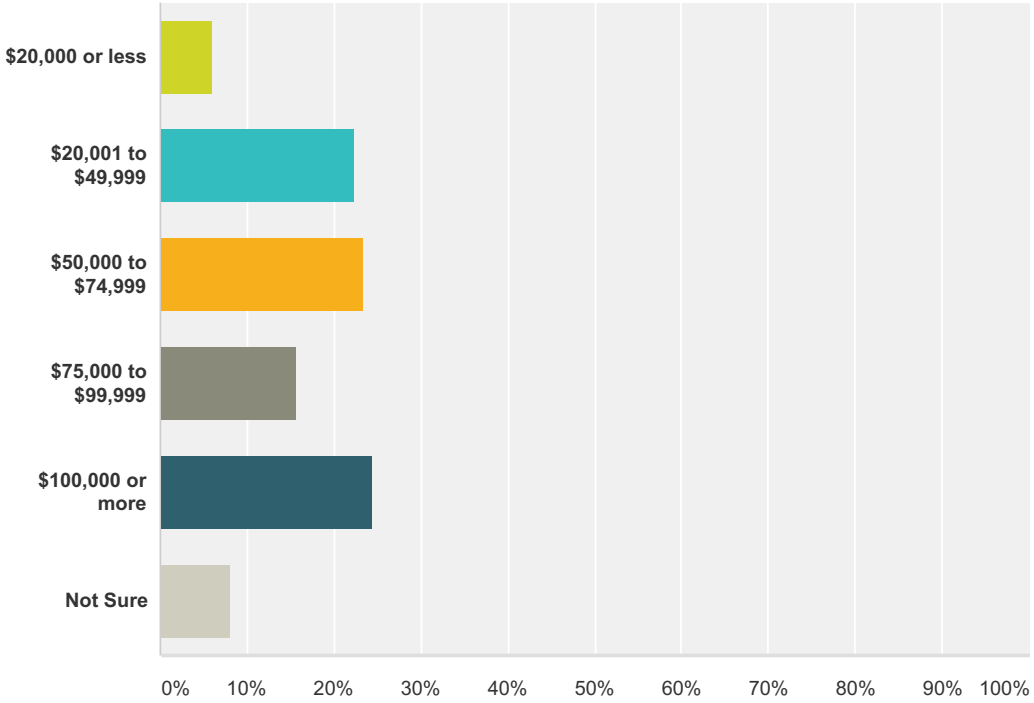
Answered: 188 Skipped: 52



Answer Choices	Responses	
Grade school/no schooling	**0.53%**	1
Some high school	**0.00%**	0
High school graduate/GED	**9.04%**	17
Some college/trade school	**21.81%**	41
College degree	**42.02%**	79
Graduate degree	**25.00%**	47
Other (please specify)	**1.60%**	3
Total		**188**

Q24 What is your gross, annual household income? (Income before taxes or other deductions)

Answered: 184 Skipped: 56



Answer Choices	Responses	
$20,000 or less	**5.98%**	11
$20,001 to $49,999	**22.28%**	41
$50,000 to $74,999	**23.37%**	43
$75,000 to $99,999	**15.76%**	29
$100,000 or more	**24.46%**	45
Not Sure	**8.15%**	15
Total		**184**

Q25 If you have additional information you would like to share about your knowledge and experience regarding local natural hazard events in Maui County, we invite you to provide that information below. This survey and your comments are completely confidential. For resources and information about hazard mitigation, please visit: http://www.co.maui.hi.us/index.aspx?NID=1832Mahalo for your time and feedback.

Answered: 23 Skipped: 217

Maui County

Hazard Mitigation Plan Update

APPENDIX C. DATA SOURCES FOR HAZARD MAPPING

Appendix C.
Data Sources for Hazard Mapping

Earthquake Mapping

National Earthquake Hazard Reduction Program Soil Classification

The NEHRP soils data were generated using the USGS Geologic Map of the State of Hawaii data and the County of Maui Probable Site Classes map in the 2013 Hawaii State Mitigation Plan. Data was recreated from static sources, as GIS data files were unavailable. This methodology has resulted in a rather coarse resolution that is limited in applicability to planning purposes.

Probabilistic Peak Ground Acceleration Maps

Probabilistic Peak Ground Acceleration data are generated by Hazus-MH 2.1. In Hazus-MH's probabilistic analysis procedure, the ground shaking demand is characterized by spectral contour maps developed by the United States Geological Survey (USGS) as part of a 2008 update of the National Seismic Hazard Maps. USGS probabilistic seismic hazard maps are revised about every 6 years to reflect newly published or thoroughly reviewed earthquake science and to keep pace with regular updates of the building code. Hazus-MH includes maps for eight probabilistic hazard levels: ranging from ground shaking with a 39-percent probability of being exceeded in 50 years (100-year return period) to the ground shaking with a 2-percent probability of being exceeded in 50 years (2,500-year return period). Earthquake mapping for this plan used the 100-year and 500-year probabilistic events.

Shake Maps

A shake map is designed as a rapid response tool to portray the extent and variation of ground shaking throughout the affected region immediately following significant earthquakes. Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on both estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. For this plan, shake maps were prepared for two earthquake scenarios:

- A Magnitude-7.0 event approximately 5 miles north of the Island of Lanai in the Kalohi Channel (Scenario Earthquake 1)
- A Magnitude-7.0 event approximately 32 miles northeast east of Kahului (Scenario Earthquake 2).

Flood Mapping

Flood hazard areas are mapped as depicted on draft FEMA Digital Flood Insurance Rate Maps.

Repetitive flood loss data were provided by FEMA as of April 30, 2015. Property addresses were geocoded and then mapped.

Landslide Mapping

A dataset for landslide probability areas was created by intersecting slope data with NEHRP soils data. Three landslide probability classifications were created: high (greater than 30 percent slope, D type soils), moderate (15-30 percent slope, D type soils), and low (0-15 percent slope, D type soils). The slope data were generated from the USGS 10-meter DEM. The NEHRP soils data were generated using the USGS Geologic Map of the State of Hawaii data and the County of Maui Probable Site Classes map in the 2013 Hawaii State Mitigation Plan. This cursory assessment of landslide risk areas was conducted at an extremely coarse resolution. It is likely that this assessment either greatly over- or understates risk in each classification and is only valid for planning purposes.

Tropical Cyclone Mapping

Probabilistic maximum wind gust data are generated by Hazus-MH 2.1 and displayed at the census tract level. The wind speeds shown are the estimated maximum 3-second gusts in open terrain at 10m above ground at the centroid of each census tract.

Tsunami Evacuation Zone Mapping

- Tsunami evacuation zone data were provided by Maui County GIS.

Volcanic Hazards (Lava Flow) Mapping

Lava inundation zones data were obtained from the USGS Cascade Volcano Observatory.

Maui County

Hazard Mitigation Plan Update

APPENDIX D. STRENGTHS, WEAKNESSES, OBSTACLES, AND OPPORTUNITIES BRAINSTORMING SESSION NOTES

Appendix D.
Strengths, Weaknesses, Obstacles and Opportunities Brainstorming Session Notes

Coastal Erosion

Strengths

- Have erosion rates
- Have erosion based setbacks
- Shoreline rules and regulations
- Enforcement in the planning department
- There is a permitting process for beach nourishment in place.

Weaknesses

- Setbacks need updating
- Relocation of some highways are needed, but there are political and economic issues with moving forward
- Many failing sea walls
- Wastewater treatment facility currently building a revetment, ongoing because of coastal erosion.

Obstacles

- A lot of threatened infrastructure, some critical and there are a lot of emergency hardening, when it is not an emergency
- Sea level rise
- Existing development and highways and big condos are where most of the issues are located
- Many regulatory and financial hurdles to overcome before being able to pursue coastal erosion projects.

Opportunities

- These setbacks need updating
- Many requests for new seawalls
- Rather than walling in the islands, perhaps focus on regional and small scale beach nourishment projects
- Opportunity for public/private partnership
- Off shore wave engineering
- Demonstration projects
- UH studies sandy shoreline and how erosion will respond to sea level.

Dam and Reservoir Failure

Strengths

- Evacuation by police (plan in place)
- New emergency alert system where notifications can be pushed out
- 911 data and subscribers can be set up before hand
- NWS will issue a flash flood warning with dam specific language if a failure is imminent.

Weaknesses

- EAPs are available, but are not published
- Inundation and evacuation maps are not published
- EAPs are not reviewed annually
- No public notice to residents in dam inundation
- Misunderstanding about reservoirs and dams.

Obstacles

- Carrier service is not consistent.

Opportunities

- No public notice to residents in dam inundation.

Drought

Strengths

- Mitigation committee and plan is in place
- Ranchers to move cattle into particular areas.

Weaknesses

- None identified.

Obstacles

- None Identified.

Opportunities

- None identified.

Earthquake

Strengths

- Communications are down, but appropriate people generally know to report without a call out
- Plans for inspections of bridges and infrastructure
- Communication plans in place for each agency
- Communication towers are hardened
- Statewide shared, blended system
- County-wide communication is coordinated.

Weaknesses

- Old bridges could be structurally dangerous
- Potential for number of isolated communities
- Limited liquefaction data
- Need more generators for telephone service.

Obstacles

- Hawaii air national guard is no longer a communications unit.

Opportunities

- Strong ham operator community
- Need to diversify energy generation for generators.

Flood

Strengths

- In the CRS program
- Flash flood advisories
- Honolulu office has great notifications
- Very strong relationship with NWS
- Get a watch, sometimes even days ahead of time
- Strong disclosure law
- FHAT – Flood hazard assessment tool
- Use information on areas prone to flooding on website and pushed out to the news media
- Public works has master plan strategies for drainage basins
- Stormwater management rules have recently been passed
- Good examples of managed retention systems
- Flood control project underway
- Watershed partnerships.

Weaknesses

- Visitor population is inexperienced
- Disclosure law implementation is weak
- After action report for major events, not really for urban drainage issues
- Need more stream gauges
- Need more retention basins
- Flood management
- No overall flood management strategy.

Obstacles

- Flash flooding can be very isolated
- Resident population may not know they are in a floodplain, although there is a disclosure requirement
- Social obstacle of being aware of hazards, but not caring and moving forward with development
- Lack funding source for Master Plan implementation, often put back on the developer
- Uncontrolled invasive species
- Current land use is problematic for proper management.

Opportunities

- Improve CRS class
- Need signage in places where flooding is an issue
- Charge for disclosure statements
- New permit system could produce the report revenue for mitigation projects
- GIS work determining where future development can go and not be exposed to hazards
- Engage with stakeholders early on to get buy-in on these actions
- IMT established, but no mechanism to activate
- Need more stream gauges

- Dashboard on flood events including dam safety
- Need more retention basins
- The West Maui Ridge to Reef project with USACE
- Public outreach campaign (re: invasive species).

High Wind Storm

Strengths

- Requirements for all new construction.

Weaknesses

- Power outage is the biggest issue.

Obstacles

- None identified.

Opportunities

- None identified.

Landslide, Debris Flow, and Rockfall

Strengths

- State and County coordination
- High volume of netting.

Weaknesses

- Most landslide risk areas are undeveloped other than roads.

Obstacles

- Problematic for evacuation and emergency response and can create isolated communities
- Exasperating of other hazards.

Opportunities

- Need mapping
- Could use more netting for rockfalls.

Tropical Cyclone

Strengths

- Warning systems and work very closely with NOAA
- Very early warning, have a few days to prepare
- Have catastrophic plan linked and trained, annual state-wide exercise
- Best community outreach (and tsunami)
- Public is knowledgeable on where to go (shelters)
- Some critical facilities are hardened
- Community voted to have new poles put in after power outage
- New South Maui High School will provide opportunity for a shelter and South Maui Parks Gymnasium.

Weaknesses

- Shelters not up to appropriate standards
- People don't know what to bring to shelters
- Only evacuating the shoreline
- Evacuation routes are not pre-identified
- Some critical facilities still need hardening
- Utilities may not be hardened and two power plants are in tsunami inundation zones
- Have strengthened distribution lines in some areas, but lots of power interest in moving forward in MECO
- Other communities have elected to not put in new power poles
- Generators are not present at every shelter.

Obstacles

- East side – isolated communities, no mandatory evacuation, not fast or easy
- There are other islands that have few resources and need to get them there
- Reaching out does not necessarily translate into action
- Have not had a hurricane in anyone's lifetime.
- Many high wind, high surf, storm events (don't get named or tracked)
- Some shelters are not owned by the County.

Opportunities

- Need signage on which way to drive
- Need to emphasize 7 day messaging for personal preparation
- County could harden County-owned facilities
- Adopt recommendations that were made by the building council
- Opportunity to address in building code
- Capital improvement managers as part of the Steering Committee for the hazard mitigation plan and use as matching funds for grant opportunities.

Tsunami

Strengths

- Warning system, Tsunami warning system in place
- Maps are accessible and interactive maps are available on-line
- Recently updated maps
- Evacuation can happen quickly
- Tsunami post event perishable data capture, international tsunami observers volunteers
- Number of studies recently done
- Evacuation route signs.

Weaknesses

- Evacuation – need more information on where to go
- Water and wastewater is affected as they are shut off so as to not damage.

Obstacles

- Have had events in recent past, but very minor.

Opportunities

- In the middle of a warning system modernization
- Hotel and Resort Security very active in preparedness
- Looking at working doing some things that the big island is doing, such as entering and leaving inundation zones
- State Civil Defense grants (earthquake and tsunami)
- Hawaii Hazards and Resiliency – dependent of community involvement.

Volcanic Hazards

Strengths

- VOG is mapped and where it will be, shown on the news
- Ongoing active area of research.

Weaknesses

- Most people have never heard of VOG
- No air quality measuring instrument.

Obstacles

- Currently no long-term way to predict severity of VOG occurrences.

Opportunities

- Currently, no index for danger level or trigger points
- May currently be installing air quality measuring instruments
- Track episodes, when it is measureable
- No consistent notification.

Wildfire

Strengths

- CWPPs in place and in progress
- Active task forces in Molokai and West Maui
- Quarterly meetings to discuss wildfire
- Coordination and planning already in place
- Fire department not has a PIO
- Maui Watch, Maui Now, Maui 24/7, lots of warning through social media
- Fuel management is big and there is coordination with grazing and drought
- Fire department does wildfire training and has a specialized team
- Fire handles evacuation, the fire and police come in and notify, EOC would activate
- Strong MOAs between County, State and National parks.

Weaknesses

- Firewise is not as strong as it used to be
- Interface, road blockages.

Obstacles

- Most are human-caused

- Tend to happen in areas that only have one route.

Opportunities

- Red flag advisories, but no formal warning system, and people might not know what it means
- Fire prevention bureau sends out notices for overgrowth, but is a tool that is available and not widely used.

Note: The high surf hazard was not discussed as a standalone hazard; however, strengths, weaknesses, obstacles and opportunities were discussed within the context of related hazards such as coastal erosion and flood.

Maui County

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APPENDIX E. PROGRESS REPORT TEMPLATE

Appendix E.
Summary of Mitigation Initiative Action Plan Funding Sources

Federal Emergency Management Agency (FEMA)

Flood Mitigation Assistance (FMA)

The FMA program supports the National Flood Insurance Act of 1968 by providing funding to states and local governments for mitigation activities. Activities must demonstrate the reduction or elimination of flood-specific risks and damages in the community. FMA funds are released annually. More information on this program is available through http://www.fema.gov/flood-mitigation-assistance-grant-program.

Hazard Mitigation Grant Program (HMGP)

HMGP funds are awarded following a Presidentially-declared disaster. These funds are designed to support a wide variety of hazard mitigation activities and are one of the most well-known of the FEMA mitigation grant assistance programs. Further information is available at http://www.fema.gov/hazard-mitigation-grant-program.

Pre-Disaster Mitigation (PDM)

The PDM program was authorized under the Stafford Disaster Relief and Emergency Assistance Act, and it is designed to assist communities in implementing natural hazard mitigation activities prior to the occurrence of a hazard event. Funds are issued annually by FEMA to the state, and then are further distributed to local governments. PDM funds support a wide variety of risk-reduction activities. Further information can be found at http://www.fema.gov/hazard-mitigation-grant-program.

As the FMA, HMGP, and PDM programs all support mitigation activities, FEMA has developed a reference tool for local officials which distinguishes eligible activities by program type. This chart is available at http://www.fema.gov/hazard-mitigation-assistance-mitigation-activity-chart.

Other FEMA Funding

Public Assistance (PA)

The PA Grant Program provides financial assistance to state, tribal, and local governments, as well as certain nonprofit organizations, to facilitate community recovery after a Presidentially-declared disaster event. This supplemental disaster grant assistance provides communities funding to ensure debris removal, emergency protective measures, and the repair, replacement, or restoration of certain damaged facilities. Further information on this program can be located at http://www.fema.gov/public-assistance-local-state-tribal-and-non-profit/.

National Dam Safety Program (NDSP)

The NDSP is a federal program focused on reducing the threat of dam failure and on protecting Americans from the impacts of such failures, when they occur. The primary way in which the NDSP supports its mission is through the provision of financial assistance to states. States can then use these funds towards dam safety training, dam inspections, submittal and testing of Emergency Action Plans, timely review and issuance of permits, coordination with emergency preparedness personnel, identification of dams in need of repair/removal, and dam safety awareness workshops. More information on this program can be found at https://www.fema.gov/about-national-dam-safety-program.

National Oceanic and Atmospheric Administration (NOAA)

Regional Coastal Resilience Grant

This grant program promotes the development or implementation of activities which will enhance the resilience of coastal regions, communities, and economic sectors when impacted by extreme weather events, climate hazards, and changing ocean conditions. Supported activities include, but are not limited to, identifying data, information, and priority gaps; developing science-based tools to support regional efforts for a resilient ocean and coastal community; understanding the impact of changing ocean conditions on coastal economy; and supporting the development of sustainable recovery, redevelopment, and adaptation plans and programs to reduce risk and increase resilience. Further information on this program can be located at http://coast.noaa.gov/resilience-grant/ or http://www.federalgrants.com/Regional-Coastal-Resilience-Grants-Program-2015-51402.html.

U.S. Department of Housing and Urban Development (HUD)

Community Development Block Grant (CDBG)

CDBG funds are issued to address a wide range of unique community development needs. Specifically, the program seeks to ensure that the country's more vulnerable populations, e.g., low-to-moderate income (LMI) residents, have sufficient access to affordable housing, necessary services, and employment opportunities. Eligible activities must benefit LMI populations, prevent or eliminate slums and blight, or address community development needs having a particular urgency and threat to the community's health and welfare. Further information on this program can be located at http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs.

Community Development Block Grant-Disaster Recovery (CDBG-DR)

CDBG-DR funds are issued by HUD to assist local and state governments in the recovery process after a Presidentially-declared disaster. CDBG-DR funds have similar criteria to general CDBG funds but focus specifically on aiding communities in rebuilding affected areas and starting the recovery process. CDBG-DR funds serve as a funding source for those communities and neighborhoods that otherwise might not recover due to limited resources. Further information on this program can be located at https://www.hudexchange.info/programs/cdbg-dr/.

U.S. Department of Interior

Bureau of Reclamation

Although not associated with a specific grant program, the Bureau of Reclamation provides water resource management assistance. It is most active in the western half of the United States; however, the Bureau of Reclamation has previously partnered with the State of Hawaii to study potential opportunities to reclaim stormwater runoff and to extend the state's freshwater supplies. Further information on this study can be located at http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=13701, while general information on the Bureau of Reclamation is available through http://www.usbr.gov/.

U.S. Environmental Protection Agency (EPA)

BEACH Act Grant

The Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act) became federal law in October 2000, and it has contributed to significant improvements for beach monitoring programs across the country. Associated federal grant funds are issued to assist eligible coastal communities (i.e., state, tribal, or local governments) in implementing coastal recreation water monitoring and public notification programs. Although funds are limited to recreational coastal areas only, the EPA typically issues almost $10 million in funding annually through this program. Further information on this program is available at http://www2.epa.gov/beach-tech/beach-grants.

Clean Water State Revolving Fund (CWSRF)

The CWSRF offers low-cost funding options for projects focused on improving water quality, the renewal of wastewater infrastructure, and support of local economies. This fund serves as the nation's largest water quality financing source and is designed to help communities comply with Clean Water Act requirements. Further information on this program can be located at http://water.epa.gov/grants_funding/cwsrf/cwsrf_index.cfm.

Drinking Water State Revolving Fund (DWSRF)

Similar to the CWSRF, the DWSRF provides funds to improve drinking water infrastructure. The DWSRF is made available to support the Safe Drinking Water Act. It additionally promotes fund distribution to small and disadvantaged communities, as well as programs that use pollution prevention as a tool to ensure safe drinking water. Further information on this program is available at http://water.epa.gov/grants_funding/dwsrf/index.cfm.

Maui County

Hazard Mitigation Plan Update

APPENDIX F. PROGRESS REPORT TEMPLATE

Appendix F.
Progress Report Template

Maui County
Hazard Mitigation Plan
Annual Progress Report

Reporting Period: *(Insert reporting period)*

Background: Maui County developed a hazard mitigation plan to reduce risk from natural hazards by identifying resources, information, and strategies for risk reduction. The federal Disaster Mitigation Act of 2000 requires state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. To prepare the plan, Maui County organized resources, replacement risks from natural hazards, developed planning goals and objectives, reviewed mitigation alternatives, and developed an initiative action plan to address probable impacts from natural hazards. By completing this process, Maui County maintained compliance with the Disaster Mitigation Act, achieving eligibility for mitigation grant funding opportunities afforded under the Robert T. Stafford Act. The plan can be viewed on-line at:

http://www.co.maui.hi.us/index.aspx?NID=1832

Summary Overview of the Plan's Progress: The performance period for the Hazard Mitigation Plan became effective on ____, 2015, with the final approval of the plan by FEMA. The initial performance period for this plan will be 5 years, with an anticipated update to the plan to occur before _____, 2020. As of this reporting period, the performance period for this plan is considered to be __-percent complete. The Hazard Mitigation Plan has targeted 62 hazard mitigation initiatives to be pursued during the 5-year performance period. As of the reporting period, the following overall progress can be reported:

- __ out of __ initiatives (__%) reported ongoing action toward completion.
- __ out of __ initiatives (__%) were reported as being complete.
- __ out of __ initiatives (___%) reported no action taken.

Purpose: The purpose of this report is to provide an annual update on the implementation of the initiative action plan identified in the Maui County Hazard Mitigation Plan. The objective is to ensure that there is a continuing and responsive planning process that will keep the Hazard Mitigation Plan dynamic and responsive to the needs and capabilities of Maui County. This report discusses the following:

- Continued public outreach related to hazard mitigation that has occurred within the last year
- Natural hazard events that have occurred within the last year
- Changes in risk exposure within the planning area (all of Maui County)
- Review of any hazard mitigation grant funding opportunities pursued within the last year
- Mitigation success stories
- Review of the initiative action plan and incorporation of new initiatives
- Changes in capabilities that could impact plan implementation

- Recommendations for changes/enhancement.

The Hazard Mitigation Plan Working Group: The Hazard Mitigation Plan Working Group, made up of stakeholders within the planning area, reviewed and approved this progress report at its meeting held on _____, 201_. It was determined through the plan's development process that a working group would remain in service to oversee the implementation and maintenance of the plan. At a minimum, the working group provides technical review and oversight on the development of the annual progress report. It is anticipated that there will be turnover in the membership annually, which will be documented in the progress reports. For this reporting period, the working group membership is as indicated in Table 1.

TABLE 1.
HAZARD MITIGATION WORKING GROUP MEMBERS

Name	Title	Jurisdiction/Agency

- **Continued Hazard Mitigation Public Outreach in the Planning Area:** During the reporting period, the following events in the planning area contributed to furthering continued public involvement in hazard mitigation in the planning area:

- _____
- _____

Natural Hazard Events within the Planning Area: During the reporting period, there were __ natural hazard events in the planning area that had a measurable impact on people or property. A summary of these events is as follows:

- _____
- _____.

Changes in Risk Exposure in the Planning Area: *(Insert brief overview of any natural hazard event in the planning area that changed the probability of occurrence or ranking of risk for the hazards addressed in the hazard mitigation plan)*

Pursuit of Mitigation Grant Opportunities: *(Insert brief overview of any grant funding that was pursued for mitigation initiatives during the reporting period)*

Mitigation Success Stories: *(Insert brief overview of mitigation accomplishments during the reporting period)*

Review of the Action Plan: Table 2 reviews the action plan, reporting the status of each initiative. Reviewers of this report should refer to the Hazard Mitigation Plan for more detailed descriptions of each initiative and the prioritization process.

Address the following in the "status" column of the following table:

- Was any element of the initiative carried out during the reporting period?
- If no action was completed, why?
- Is the timeline for implementation for the initiative still appropriate?
- Is the priority for the initiative still appropriate?
- If the initiative was completed, does it need to be changed or removed from the action plan?

TABLE 2.
INITIATIVE ACTION PLAN MATRIX

Action Taken? (Yes or No)	Time Line	Priority	Comments	Status (N, X, O,✓)
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				

TABLE 2.
INITIATIVE ACTION PLAN MATRIX

Action Taken? (Yes or No)	Time Line	Priority	Comments	Status (N, X, O,✓)
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				
Initiative #__ — _____ [description]				

TABLE 2.
INITIATIVE ACTION PLAN MATRIX

Action Taken? (Yes or No)	Time Line	Priority	Comments	Status (N, X, O,✓)
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				
Initiative #__—_____[description]				

Completion status legend:

✓= Project Completed
O = Action ongoing toward completion
X = No progress at this time
N = New initiative added

Changes That May Impact Implementation of the Plan: *(Insert brief overview of any significant changes in the planning area that would have a profound impact on the implementation of the plan. Specify any changes in technical, regulatory and financial capabilities identified during the plan's development)*

Recommendations for Changes or Enhancements: Based on the review of this report by the Hazard Mitigation Plan Working Group, the following recommendations will be noted for future updates or revisions to the plan:

- _____
- _____
- _____
- _____
- _____
- _____.

Public review notice: *The contents of this report are considered to be public knowledge and have been prepared for total public disclosure. Copies of the report have been provided to the Maui County Council and to local media outlets and the report is posted on the Maui County Hazard Mitigation Plan website. Any questions or comments regarding the contents of this report should be directed to:*

Insert Contact Info Here

Maui County

Hazard Mitigation Plan Update

APPENDIX G. FEMA CROSSWALK

Appendix G.
FEMA CrossWalk

To be completed.