March 14, 2017

MEMO TO: IEM-26 File

F R O M: Elle Cochran, Chair
Infrastructure and Environmental Management Committee

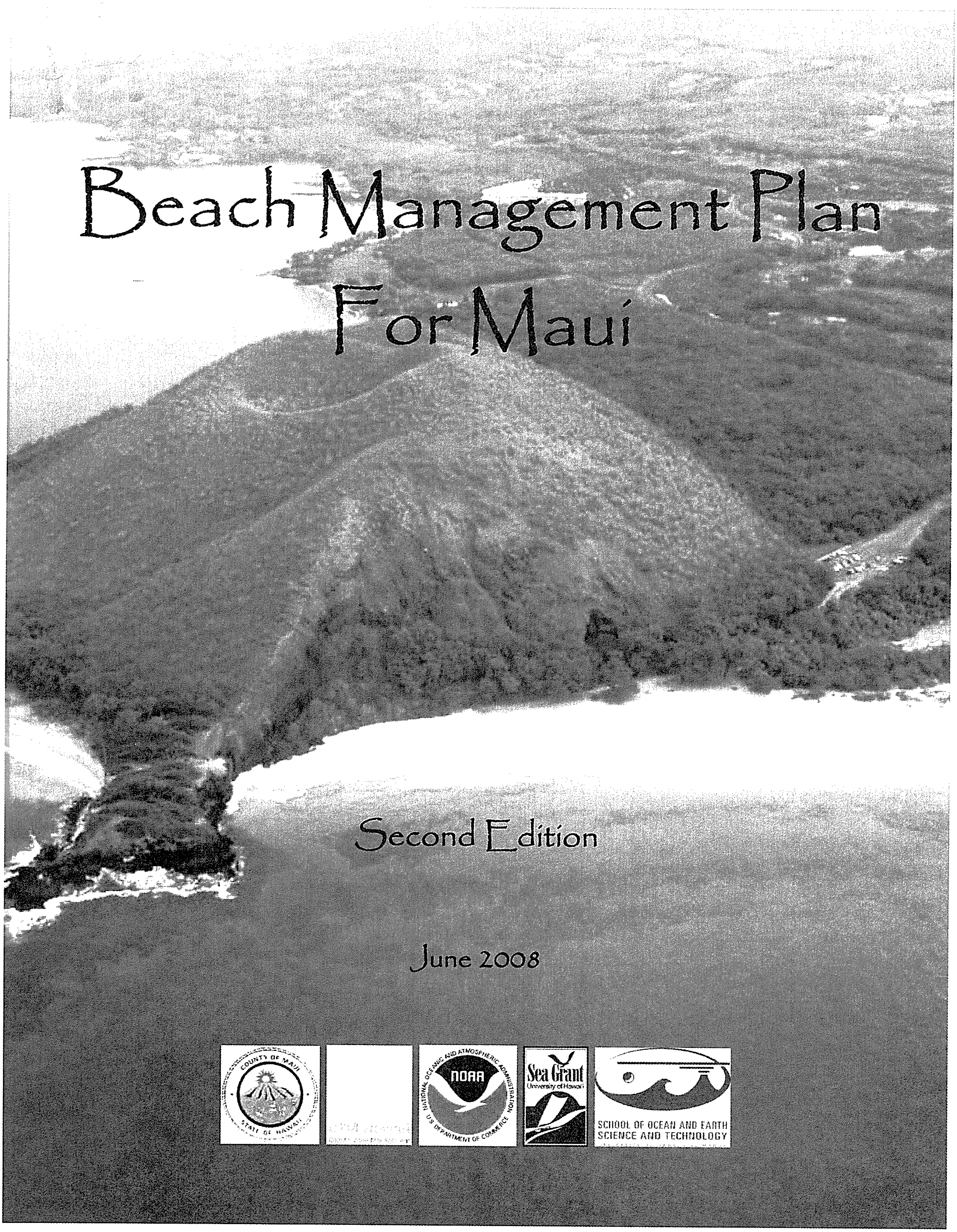
SUBJECT: **TRANSMITTAL OF INFORMATIONAL DOCUMENT RELATING TO BEACH EROSION, SEA LEVEL RISE, STORMS AND FLOODING IMPACTS ON COUNTY INFRASTRUCTURE** (IEM-26)

The attached informational document pertains to Item 26 on the Committee's agenda.

iem:ltr:026amc01:grs

Attachment

Beach Management Plan For Maui



Second Edition

June 2008

School of Ocean and Earth Science and Technology

Supported by:

Coastal Zone Management Program
State of Hawaii Office of Planning

County of Maui
Department of Planning

The *Beach Management Plan for Maui* is funded in part by a grant/cooperative agreement from the National Oceanic and Atmospheric Administration, Project # 39.A/AS-1 which is sponsored by the University of Hawai'i Sea Grant College Program, SOEST, under Institutional Grant No. NA05OAR4171048 from NOAA Office of Sea Grant, Department of Commerce. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies. UNIHI-SEAGRANT-BA-07-01.

The authors would like to thank the individuals who assisted with reviews and contributions to the report, for their helpful comments and suggestions. The individuals are listed in Appendix B.

Second Edition Authors (2008):

Zoe Norcross-Nu'u
University of Hawaii
Sea Grant College Program
norcross@hawaii.edu

Dr. Charles Fletcher
University of Hawaii
Department of Geology and Geophysics
fletcher@soest.hawaii.edu

Thorne Abbott
County of Maui
Department of Planning
Thorne.Abbott@co.maui.hi.us

First Edition Authors (1997):

Robert Mullane
University of Hawaii
Sea Grant College Program

Daren Suzuki
County of Maui
Department of Planning

Cover photograph by Andrew Short

Table of Contents

Executive Summary

Maui's coastal environments are subject to converging forces: intense development pressure to push the uses of coastal lands seaward (makai), and ongoing natural processes such as coastal erosion, sea-level rise, and island subsidence that push the sea landward (mauka). The beach, it seems, is caught in the middle of these forces.

The result is too often beach loss, which local resource management agencies struggle to manage by balancing protection of the public's natural resources with oceanfront landowner's rights to protect private property. On Maui's beaches, these problems have escalated to a crisis condition. With public beaches steadily disappearing and the continued reliance on private shoreline protection structures for erosion control, management authorities are constantly challenged to find new tools and innovative management concepts. Too often, historical approaches lack effectiveness and enforcement of existing tools is fruitless when the political will to protect the public trust is compromised. The current case-by-case approach, in which individual property rights are pitted against the larger public domain resource, is not working. In order to better manage competing public and private interests, it is necessary to view the shoreline in a new manner, using innovative tools and approaches that treat the beach system as a whole, rather than as individually segmented properties. Further, careful regard must be given to the significance of economic, cultural, recreational and environmental resources for each beach system.

The *Beach Management Plan for Maui* seeks to introduce a new set of concepts and tools that are necessary to move away from ad-hoc, permit-by-permit, reactionary management characterizing coastal zone administration on Maui. The Plan also provides information regarding traditional shoreline management issues and practices that are, or could be effective, if properly implemented with political will and true determination to protect the public trust. Ultimately, the Plan seeks to promote beach preservation and sustainable development of the coastal zone. It is intended to serve as a guiding policy document in the style of "COEMAP", the Hawaii Coastal Erosion Management Plan adopted by shoreline administrators in the Hawaii Department of Land and Natural Resources. The Maui Plan offers specific recommendations and mechanisms for balancing competing interests that must be implemented as minimum criteria for any decisions made for public domain oceanfront lands.

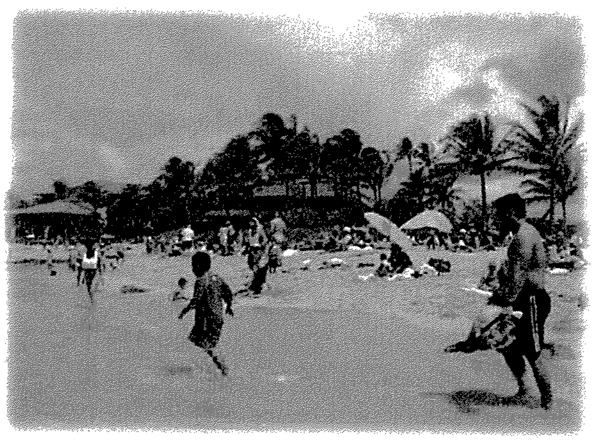
The first edition of the *Beach Management Plan for Maui* was published in 1997 and was subsequently adopted as a guidance document by the Maui County Council. The report has been widely used as an educational resource and reference tool. Some of the report's most important recommendations have been carried out, including the adoption of erosion rate-based setbacks for construction and revisions to the Maui County Code in order to protect coastal dunes. However, many of the report's original recommendations have not yet been implemented. Unlike the first edition which merely offered guidance, the second edition of the Beach Management Plan is intended to have the force of law pursuant to the anticipated adoption of the updated Maui County General Plan and the Maui Island Plan, as well as the State legislatively-adopted Hawaii Ocean Resource Management Plan.

This second edition of the *Beach Management Plan for Maui* reflects changes in coastal zone management strategies that have evolved over the last decade. These changes are the product of a number of sources, including: pilot studies, recent scientific publications, new and emerging environmental issues, changes in legislation, performance analyses of various shore protection devices and the results of implementing policy. A significant improvement in the scientific understanding of coastal process has resulted from the Maui County's support of cutting-edge research conducted by the University of Hawaii and Planning Department staff.

The *Beach Management Plan* identifies thirteen (13) areas to focus on in order to be more effective in managing Maui's beaches and shoreline resources. Each area has a short introduction followed by a statement of objectives and specific recommendations. Although the sections are numbered, they are not ordered by priority or importance. The recommendations should be implemented concurrently to maximize effectiveness. The implementation of the second edition of the *Beach Management Plan for Maui* will stimulate another wave of improvements in the policies and procedures relating to the protection of Maui's coastal resources. However, unlike the first edition which served merely as a guidance document, the second edition offers specific strategies to avoid degradation of our beach, sand and shoreline resources. Failure to implement the plan will lead to the foreclosure of planning options and will erode our opportunities to be responsive in the future. Accordingly, the recommendations and actions presented in the second edition of the Beach Management Plan serve as the pathway to protecting one of Maui's most critical and vital resources: clean, natural, accessible, sandy shorelines.

Introduction

The natural beauty of Maui's sandy beaches and **shoreline** is a highly valued resource by residents as well as visitors from throughout the world. Beaches are vital environmental, cultural, recreational, and economic resources. The **beach** supports habitat for many marine and terrestrial organisms including endangered native Hawaiian plants and animals. Healthy beaches are central to the health and vitality of the shoreline area and coastal waters. Beaches and **dunes** buffer groundwater discharge into the coastal zone as well as discharge from septic systems and cesspools, and provide protection by absorbing the impact of high surf, storms and tsunami.



Beaches also offer diverse cultural opportunities including religious activities and traditional ceremonies. Recreational activities tied directly or indirectly to the beach include windsurfing, surfing, snorkeling, sunbathing, meditating, walking/jogging, swimming, canoe and kayak paddling, and picnicking, to mention a few. Furthermore, this unique attraction with diverse opportunities drives the economy by supporting numerous jobs and providing services to maintain Hawaii's thriving visitor industry.

Unfortunately, many of our sandy beaches are disappearing as a result of natural processes, ill-advised development, shoreline **hardening**, and other human impacts. Recognizing the importance of Maui's beach resources, it is imperative that they be preserved, protected and restored where possible.

Management of coastal resources falls jointly under the jurisdiction of Maui County and the State of Hawaii, with the division of responsibility falling at the location of the shoreline. In most cases, state responsibility falls seaward of the shoreline and county responsibility falls landward. For more information on Maui's Coastal Zone Management (CZM) Program, please visit the Maui Planning Department website at http://www.mauicounty.gov/departments/Planning/czmp/intro.htm. For the State of Hawaii Coastal Zone Management program, please visit http://www.hawaii.gov/dbedt/czm. For the Hawaii Department of Land and Natural Resources (DLNR) Office of Conservation and Coastal Lands (OCCL), please visit http://www.hawaii.gov/dlnr/occl.

This document, the *Beach Management Plan for Maui*, focuses specifically on shoreline issues for the Island of Maui and is intended as a statement of the Maui County Planning Department's long-term commitment to preserve beach resources through effective beach management practices. Additionally, basic information on coastal ecosystems, processes and **erosion** is provided in Appendix A. Maui citizens can benefit from this plan by better understanding coastal processes, potential causes of negative impacts to beaches, and the reasons why certain management practices are favored over others.

Shoreline processes are the net result of many interrelated systems. Effective management of shoreline resources requires input from several different fields of study. The *Beach Management Plan for Maui* has been reviewed by a diverse group of experts (Appendix B), and their comments and suggestions have been incorporated in this report.

Objectives and Recommendations

The *Beach Management Plan for Maui* seeks not only to provide information regarding traditional shoreline management issues and practices, but to introduce a new set of concepts and tools that are necessary to move away from ad-hoc, permit-by-permit, reactionary management characterizing coastal zone administration on Maui. This plan ultimately seeks to promote beach preservation and sustainable development of the coastal zone. It is intended to be a guiding policy document in the style of "COEMAP", the Hawaii Coastal Erosion Management Plan adopted by shoreline administrators in the Hawaii Department of Land and Natural Resources. The Maui Plan offers specific recommendations that may best be implemented through revisions of existing rules and regulations.

1. Development of individual management plans for each shoreline segment

Maui's beaches have unique economic, cultural, recreational and environmental characteristics. Each beach is unique and therefore should be managed with specific characteristics in mind. Addressing erosion problems on a property-by-property basis is exceptionally challenging for decision-makers because impacts on one property can interfere with natural processes at another, potentially affecting an entire beach system. For instance, if one owner erects a **seawall** that impounds sand, erosion may accelerate on neighboring properties, leading to additional seawall construction. The number of remaining pristine beaches on Maui is down to a small handful. These shorelines need to be treated as special management concerns and with different goals and tools than those that are already highly developed. Maui's last healthy beaches should be given the greatest protection possible for the enjoyment of future generations.

Figure 1. This formerly sandy shoreline at Honokowai, Maui, has been lost as a result of extensive seawall construction. *(Photo: Z. Norcross-Nu'u)*

The creation of individual beach management plans for each of Maui's shoreline segments can address this concern by prescribing long-term goals and milestones that address shoreline change, manage **coastal hazards** and coastal development, and that will be consistent across a given shoreline segment. Each segment will represent a continuous region that has largely uniform characteristics in terms of coastal processes, quality of the beach, preservation goals, and land use and value.

One task of individual management plans will be to specify methods of erosion mitigation that are allowed and/or prohibited for each area. These might include approaches such as shoreline **armoring**, beach replenishment, dune construction and conservation, managed retreat, emergency shore protection, or a combination. Such "**littoral cell** planning" will greatly enhance consistency and remove the tremendous pressure on planners and decision makers who currently attempt to address these issues on a property-by-property basis. Coastal processes such as erosion and **accretion** take place on a scale that does not reflect nor respect individual property lines, and as such the issues associated with coastal zone management are most effectively addressed on the scale of a littoral cell (a shoreline segment governed by contiguous physical processes).

While many of Maui's sandy shorelines have undergone heavy development (Figure 1), others are lightly developed and a very few remain undeveloped (Figure 2). Some beaches are in excellent condition while others are suffering from degradation. While recent improvements in Maui's setback rules and grading ordinance assist in the short-term protection of coastal resources, there exists a need to protect the few remaining pristine beaches and adjoining dune systems in perpetuity. Coastal decision-making regarding development, shore protection, and erosion mitigation should consider the condition of the beach and upland development. In other words, a highly valuable public beach resource with little to no development warrants higher prioritization for protection over areas that are heavily developed or where the quality of the shoreline has been impacted. For Maui's few remaining pristine beaches, a commitment should be made to protect them from any negatively impacting human activities.

To assist with the development of individual beach management plans, a quantitative beach ranking tool similar to the shoreline assessment model (SAM) currently under development by the DLNR OCCL can be developed. The SAM uses Geographic Information System (GIS) layers to create maps associated with a database of existing and new information relating to the quality and value of beach and land resources. Maui's shoreline can be divided into approximately 30 shoreline segments, roughly corresponding with the 30 existing erosion rate maps created by the University of Hawaii. These segments represent contiguous regions that have largely uniform characteristics in terms of coastal processes, beach quality, and land use and value.

Objective

1.1) To improve coastal zone management on Maui by considering the scale of unique economic, cultural, and environmental characteristics on each shoreline segment.

Figure 2. Baldwin Beach is one of the few remaining pristine beaches on Maui. *(Photo: Z. Norcross-Nu'u)*

Recommendations

1.1a) Sponsor a study to develop a shoreline assessment model to classify shoreline segments based on factors such as extent of upland development, recreational opportunities, cultural significance, environmental quality, and water quality.

1.1b) Develop individual (littoral cell) management plans for each of Maui's shoreline segments that take into consideration the factors mentioned in 1.1a).

2. Guidelines for Shoreline Protection Measures

When **coastal erosion** threatens property, coastal landowners are often not familiar with the various types of coastal protection measures that are available, or of the associated environmental concerns and permitting requirements of each. Since conventional **coastal protection structures** such as seawalls and **revetments** have been shown to cause **beach narrowing** and loss on retreating shorelines (Tait and Griggs, 1990; Fletcher *et al.*, 1997) (Figure 3), Maui County should identify and recommend more environmentally compatible alternatives where possible. Lessons learned from various attempts at shore protection over the last few decades can be used to make more informed decisions with regard to both long-term and emergency measures. Decisions regarding allowable means of shore protection must be based on consistent criteria to ensure fairness and enforceability.

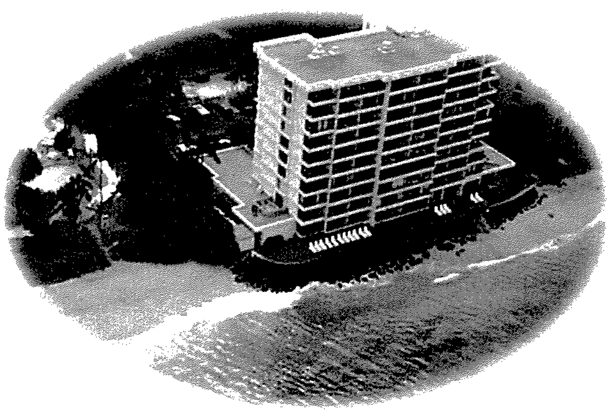


Figure 3. Shoreline armoring has led to the loss of the beach fronting this West Maui building. *(Photo: C. Fletcher)*

For example, the use of conventional sandbags and large **geotextile sandbags** for temporary erosion control became popular over the last few decades, particularly for emergency situations (Figure 4). When filled, sandbags become extremely hard and have a negative impact on adjacent beaches that mimics the effect of a seawall (see **Appendix A** for more information about erosion and the effect of shoreline structures on beaches). Sand is impounded behind and beneath the bags, often leading to erosion on adjacent beaches. The hard surface of sandbags creates wave reflection that scours the beach, exacerbating erosion. The justification for allowing sandbags in the past was that they are easily removed. In reality, geotextile sandbags are rarely removed and there is little to no incentive for removal as most permits have not implemented a "remove-by" date. It is also evident now that geotextile sandbags are highly durable and capable of lasting for many years, possibly decades. Thus, allowing geotextile sandbags is not entirely different from permitting construction of a seawall. In fact, in some ways a rock revetment (Figure 5) has less impact on a beach because the shape of rocks and the high porosity actually absorb wave energy rather than reflecting it as a wall of sandbags is prone to.

Figure 4. Geotextile sandbags have commonly been used for emergency shore protection on Maui. *(Photo: Z. Norcross-Nu'u)*

Figure 5. Revetments sloping walls made of large interlocking boulders - are less reflective to incoming wave energy than geotextile sandbags due to the spaces between the rocks. *(Photo: Z. Norcross-Nu'u)*

Individual beach management plans for shoreline segments, as described above in **Section 1**, will greatly simplify the task of determining the appropriate means of shore protection for a particular location. However, given that it will take several years to create and implement individual beach management plans, there exists a need in the interim to simplify the process of shore protection decision-making. Appropriate shore protection varies from one region to the next because of numerous location-specific factors to be considered. Ideally, interference with natural shoreline processes should be minimized. As such, when a significant and valued building or structure is threatened by a retreating shoreline, the first considerations should be whether the structure is capable of being removed or relocated (Figure 6). If demolition or relocation is not feasible, beach or dune replenishment can offer temporary protection from wave damage by establishing a buffer between the ocean and the land. If sand replenishment is not feasible or reasonable, hard structures such as seawalls, revetments or **groins** or a combination of structures with sand fill may be considered as a last resort. In the case of a chronically retreating shoreline, building a seawall or revetment will result in **beach loss**. Hence, this management option values development above the natural resource.

Despite the numerous negative impacts of shoreline armoring, there are instances where it may be the best alternative. For example, on shorelines that are backed by eroding clay, dirt or rock, with no sandy beach, hardening the shoreline with a seawall or revetment can be beneficial as it stops sediment from entering the water thereby improving water quality. It can even be designed to enhance public access. However, on sandy shorelines experiencing chronic recession, armoring should be a last resort and used only when a significant and valued structure is threatened and can't be moved or removed. In this case the potential for beach loss should be clearly and unequivocally stated in permitting documents so that the trade-off of beach for development is widely understood. Whenever shoreline armoring is pursued for shore protection, it is important to ensure that a means of safe lateral shoreline access is incorporated into the design of the structure or the surrounding area.

A critical parcel purchase program should be established for instances where coastal erosion on a sand-based property has threatened a structure that is not worthy of protection, or where the property owner does not want the expense of shore protection. This would be a particularly valuable option to consider for properties adjacent to well-used public beach areas. The purchase or condemnation of the property would allow the land to continue eroding, which would release sand to the beach and augment the sand budget.

Objectives

2.1) To establish guidelines for determining the most appropriate type of coastal protection for a particular location

2.2) To provide an alternative to owners of eroding coastal properties who do not wish to pursue shore protection measures

Recommendations

2.1a) Encourage hazard avoidance in the form of retreat or relocation where possible

2.1b) Establish a procedure for determining allowable shore protection measures

2.1c) Develop a study to provide technical recommendations for the restoration of sandy shorelines through **beach nourishment**

2.1d) Provide suggestions on alternative coastal protection designs where beach nourishment is not feasible

2.1e) List acceptable structures for emergency (temporary) coastal protection

2.1f) Determine suitable time limits for emergency shore protection measures and ensure that all emergency permits include a time limit and a description of the penalty for failure to remove the temporary shore protection measures by the time limit.

Guidelines for Determining Shore Protection Options for Threatened Structures on Chronically Retreating Sandy Shorelines

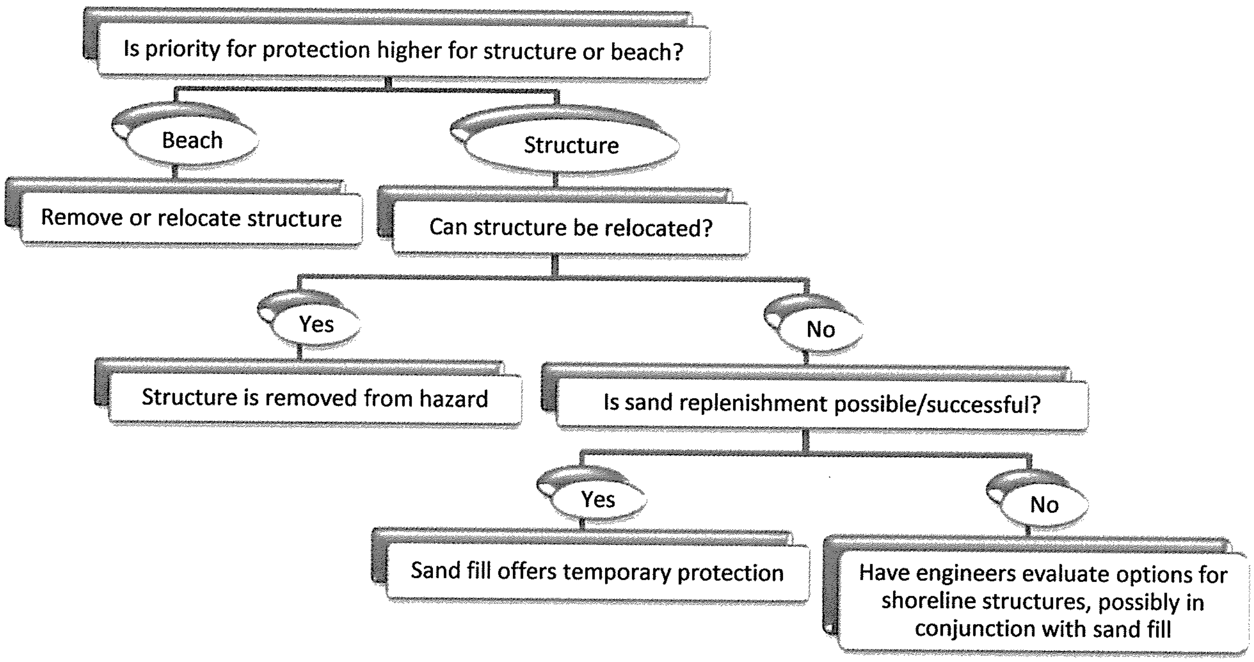


Figure 6. Decision-making guidelines for shore protection alternatives. (*Figure: Z Norcross-Nu'u*)

2.1g) Require compensatory mitigation where lateral access and/or beach resources are lost or impounded by development

2.2a) Establish a critical parcel purchase program to purchase eroding coastal properties that are sand sources for valuable public beach areas

3. Sea-level rise

Recent research highlights the role of anthropogenic global warming in accelerated **sea-level rise** (Church and White, 2006). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) reports "high confidence" that global sea-level rise increased from the 19th to 20th centuries, and that the rate of rise 1961-2003 averaged 1.8 +/-0.5 mm/yr. Satellite data show that from 1993-2003 the rate of sea-level rise averaged 3.3 +/-0.4 mm/yr (Rahmstorf et al., 2007) (Figure 7). While considerable debate remains over how much sea levels will rise by the year 2100 with estimates ranging from 7 inches to 20 feet, the majority of scientists agree that based on projections for atmospheric global warming, sea-level rise will accelerate this century and will continue to rise for centuries to come (Rahmstorf, 2006; Overpeck et al., 2006; IPCC, 2007). Rahmstorf et al. (2007) further conclude that sea level and global mean air temperatures have risen more since 1990 than climate models used in the IPCC predicted, and that IPCC projections may underestimate future sea levels. (See appendix A for more information on sea-level rise.)

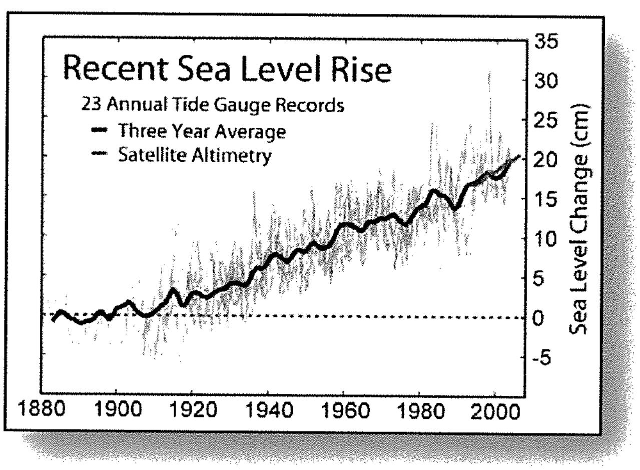


Figure 7. New satellite data suggests the global rate of sea-level rise is 3.4 +/- 0.4 mm/yr. (*Figure: Robert A. Rohde, Global Warming Art Project, http://www.globalwarmingart.com/wiki/Image:Recent_Sea_Level_Rise.png*)

Currently, there are no coastal management tools in Hawaii that take sea-level rise into consideration, and this phenomenon is not being incorporated into planning of developments and infrastructure in coastal and low-lying areas (Figure 8).

Despite the present inability to accurately predict time frames in which various locations will be affected, we do know that low-lying coastal areas including Kahului, Spreckelsville, North Kihei, Ukumehame, Olowalu, Lahaina and Kaanapali face a significant risk of inundation within the lifetime of today's children. As such, it is critical that we begin soon to develop relocation plans for critical infrastructure such as wastewater treatment facilities, power generation facilities, water and waste lines, and roads. These must be situated away from potential inundation in low-lying areas. Further, potential impacts of sea-level rise on new developments and redevelopments in low-lying and coastal areas should be taken into consideration during project review.

To better understand potential impacts of sea-level rise on Maui and in order to identify areas at risk and plan for infrastructure relocation and impact mitigation, it will be critical to have high-accuracy sea-level rise inundation maps showing specific areas that will be affected under a variety of sea-level rise scenarios (Figure 8). This can be accomplished using high-accuracy LIDAR topographic elevation data which Maui County possesses and is currently having processed. Development of these maps should be of the highest priority in order to avoid continued development of areas at risk.

Objective

3.1) To recognize and plan for potential impacts of sea-level rise on low-lying coastal lands

Figure 8. Sea-level rise inundation models, such as this one for Kahului, Maui, are essential tools for long-range planning of low-lying coastal areas. This image illustrates areas likely to become inundated with 1m sea-level rise and 1 month of heavy rainfall (30 cm). (*Figure: U.H. Coastal Geology Group)*

Recommendations

3.1a) Provide funding for the creation of high-accuracy LIDAR-based sea-level rise inundation maps for Maui's low-lying coastal areas.

3.1b) Take sea-level rise into consideration when reviewing development or redevelopment of low-lying and coastal areas.

3.1c) Identify critical infrastructure at risk of sea-level rise inundation and develop relocation plans for this infrastructure.

3.1d) Identify communities and developments at risk of sea-level rise inundation and develop long-term plans to address the associated issues of a rising water table including drainage and leach field failure, flooding, wetland formation and salt-water intrusion into aquifers, as well as coastal erosion and increased susceptibility to damage from storms, **hurricanes**, high surf and tsunami.

3.1e) Encourage and support open space, conservation easements, and decreased development density in low-lying coastal areas

4. Beach Nourishment

Beach nourishment, a technique used to restore an eroding or lost beach, involves the placement of sand fill with or without supporting structures along the shoreline to widen the beach. It is the only management tool that serves the dual purpose of protecting coastal lands and preserving beach resources. Beach nourishment is a common management practice on the U.S. mainland (NATIONAL RESEARCH COUNCIL, 1995). Miami Beach, FL; Myrtle Beach, NC; Ocean City, MD; and several other locations have ongoing beach nourishment projects.

Although Maui has limited experience with beach nourishment, a few small-scale projects have successfully restored lost or eroding beaches and dunes (Figure 9). Most restoration projects that have taken place on Maui were privately funded and carried out without a thorough engineering study under auspices of the Hawaii State Programmatic General Permit for Small-Scale Beach Nourishment (http://www.hawaii.gov/dlnr/occl/nourishment.php).

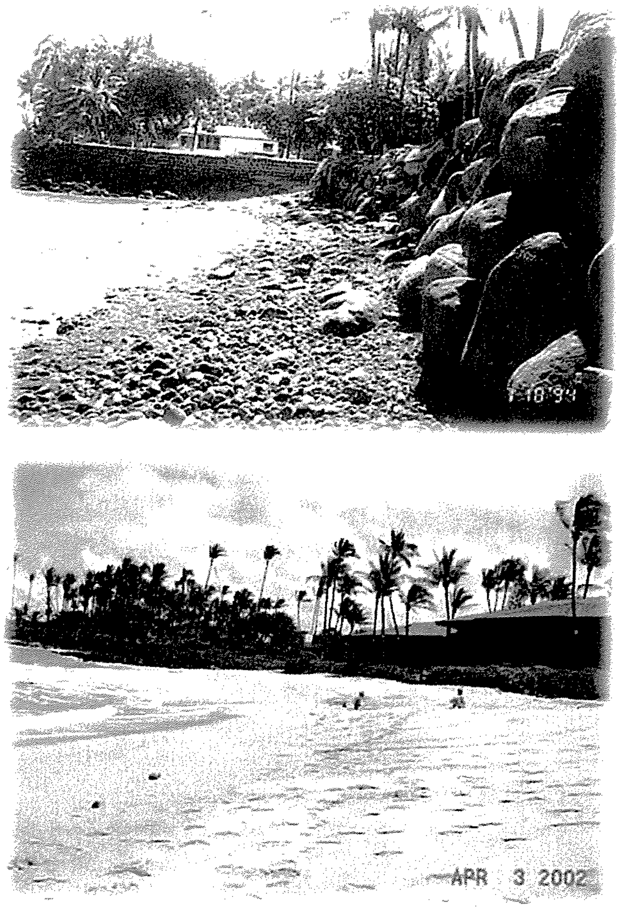


Figure 9. Before and after: A successful small-scale beach nourishment project at Sugar Cove, Spreckelsville, Maui. (*Photos: Barbara Guild*)

While beach nourishment is a favorable method of shore protection, it may not be appropriate at all locations and it is likely to be expensive. First, the chances of beach nourishment success are much higher for embayed shorelines (coves, pocket beaches) than for straight or convex (curved outward) coasts, unless structures such as **groins** are used to simulate the effect of headlands. Second, areas with sensitive marine ecosystems such as coral reefs may be negatively impacted by the addition of sand to the nearshore area. As such, it is necessary to survey the adjacent marine environment for each potential nourishment site in order to determine whether beach replenishment will be appropriate. Additionally, water quality and marine life surveys are important before, during and after sand placement to determine whether any negative impacts arise from the addition of sand. Because of the sensitive nature of marine life, it is also important that sand for beach replenishment is as close as possible in size and composition to existing sand, and that it be as clean, or free from silt and clay, as possible. Silt and clay cause brown sediment plumes to form when they enter the water and can be harmful to marine life. Currently, the State of Hawaii recommends that sand for beach nourishment be the cleanest available.

Beach nourishment requires large volumes of beach-quality sand. The initial nourishment project typically requires thousands of cubic meters of sand per kilometer of shoreline, and most beaches need periodic renourishment. Maui should take measures to effectively manage its limited sources of readily available sand and should build its capacity to tap new, currently unavailable sources of sand.

Sand for nourishment projects is available from a variety of environments. Terrestrial sources of sand include **coastal plains** and **inland sand dunes**. **Offshore** sources include dredge spoil from harbor maintenance, shallow-water sand fields, medium-depth sand channels, and deeper-water sand banks. Harbor spoil can be accessed from land with a clamshell dredge but comprise only a minor portion of Maui's sand resources. Larger sources of sand must be hydraulically dredged with a suction dredge.

To date, most small-scale nourishment and coastal protection projects on Maui have used sand mined from inland dunes (Figure 10). The fine-grained nature of dune sand may not be an ideal match for high energy beaches that typically have coarser sand, but has been shown to work if placed in large volumes such as at Sugar Cove on Maui's north shore. Because some sand dunes contain burial sites, sand should be acquired only from quarries designated free of cultural sites. Inland sand on Maui may also become more expensive as limited inland sand resources become depleted. Sand has been shipped off Maui, primarily to Oahu for use by cement companies for decades (Figure 11). This constitutes a loss of valuable Maui sand that could be used for local beach nourishment projects. A study recently contracted by Maui County determined that inland dune sand may no longer be available in volumes large enough for excavation after 2011 (Hanzawa, 2006).

Figure 10. Inland sand mining operation at Maui Lani.

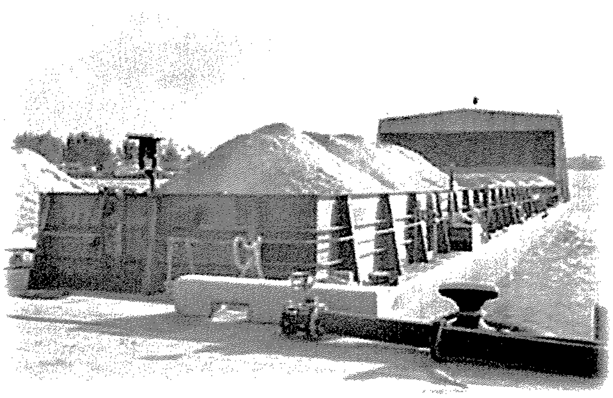


Figure 11. Sand barge leaving Kahului Harbor bound for Oahu. (Photo: Matthew Thayer, Maui News)

Hawaii's white sandy beaches are made of **carbonate sand**, which is derived from skeletal components of marine organisms such as coral, algae and mollusks, and beach nourishment should preferably take place with compatible sand. The sand found in limited supply in inland dune systems is also carbonate sand and as such is frequently compatible for our beaches. Other sources of sand such as crushed rock or imported silica sand are not compatible with existing carbonate beach sand. The construction industry, on the other hand, can use carbonate sand, sand made of crushed rock, or silica sand imported from outside of Hawaii, to make concrete. Thus when the local inland sand resource runs dry, the construction industry will have alternative sand sources to pursue, whereas the only alternative source for beach replenishment will be the much less dependable option of offshore sand supplies. As such, due to their compatibility with Maui's beach sand, the inland resources are extremely valuable for beach replenishment. Accordingly, new legislation should be considered that will protect and provide sand reserves for beach replenishment. This could include a moratorium on sand exports or a requirement that sand excavators stockpile a certain percentage of their excavations for beach replenishment, among other alternatives.

Maui should build its capacity to tap offshore sand resources. Potential offshore borrow sites should be identified, mapped, and sampled (Figure 12). Local scientists and consulting firms have mapped offshore sand resources for O'ahu (SEA ENGINEERING, INC., 1993). Although a similar study was done for Maui and Moloka'i in 1971 (CAMPBELL, ET AL., 1971), this study did not include extensive sampling and should be updated. Sampling is necessary because offshore sand may not be suitable for beach nourishment. A sand nourishment viability study on O'ahu found that offshore sand is often fined-grained and discolored for beach nourishment (SEA ENGINEERING, INC., 1993).

Beach nourishment is the only management tool that protects coastal development without degrading the beach. Preserving or restoring a sandy beach has direct, beneficial impacts on recreational opportunities and property values. Recently, the permit process has become simplified with the adoption of the streamlined Small Scale Beach Nourishment permit system by the State of Hawaii that combines all the necessary state and federal permits into a single application. The demand for beach nourishment on Maui as well as statewide has grown in recent years and will likely continue to grow. The County of Maui should anticipate this growing demand and take the lead

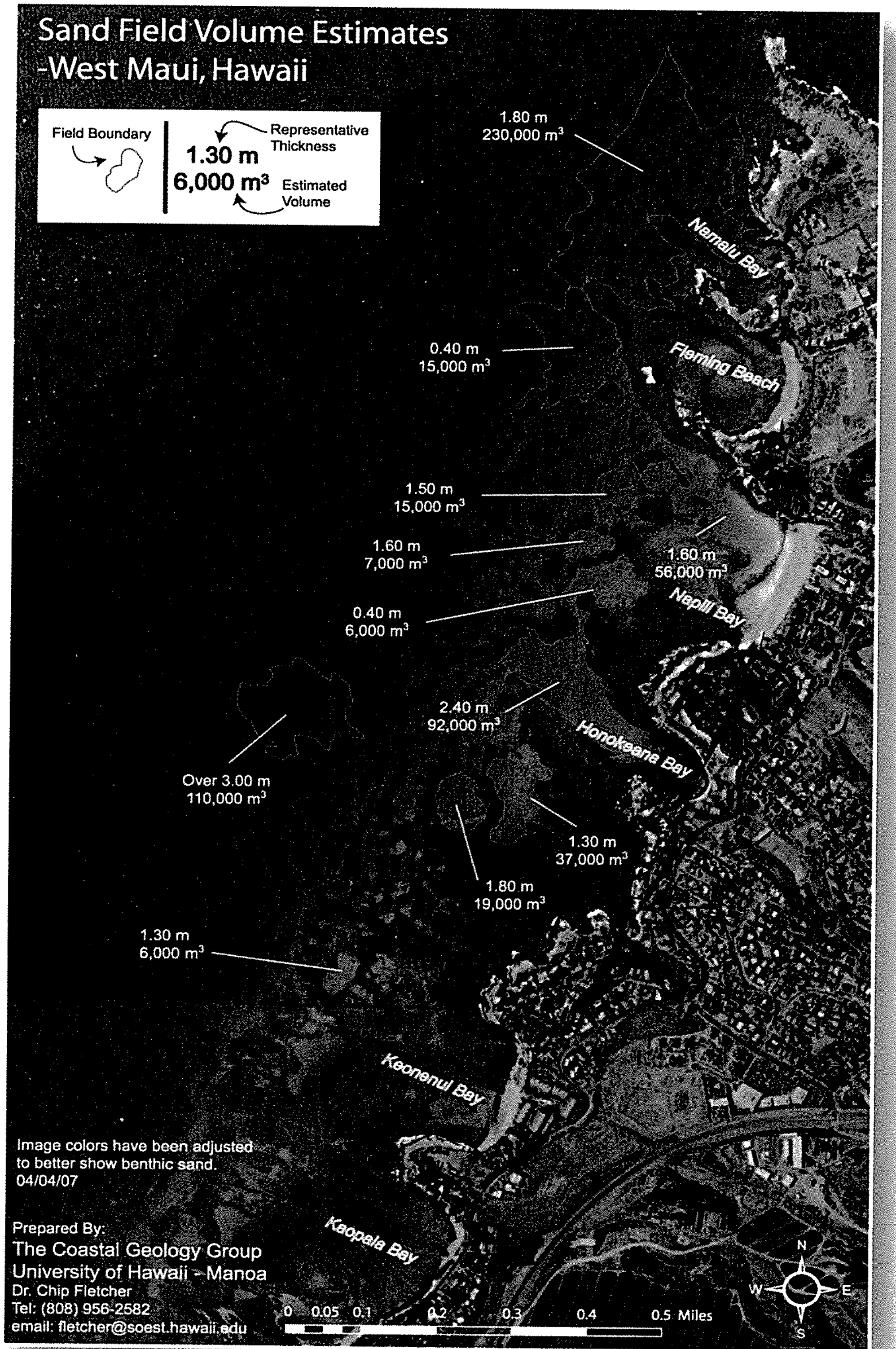


Figure 12. Offshore sand resource inventory for potential beach nourishment sand source, conducted by the University of Hawaii for the Napili Bay and Beach Foundation. (Image: University of Hawaii Coastal Geology Group)

in promoting and facilitating beach nourishment where appropriate.

Objective

4.1) To promote beach nourishment by more effectively managing the limited sources of readily available sand, providing financial incentives for beach nourishment projects, and building a capacity to tap new, currently unavailable (offshore) sources of sand

Recommendations

4.1a) Earmark beach-quality sand that is periodically removed from Maui's harbors for nourishment projects

4.1b) Restrict the export of Maui's dune sand resources, perhaps by introducing new legislation

4.1c) Require a percentage of inland sand excavations to be stockpiled for beach replenishment

4.1d) Limit sand mining to quarries designated free of cultural sites

4.1e) Identify, map, and sample potential offshore borrow sites

4.1f) Establish a County fund for cost matching private beach nourishment projects

4.1g) Purchase a community offshore pump system for rent by private nourishment partners

4.1h) Provide tax incentives to community and commercial associations that participate in beach nourishment projects

5. Dune Preservation and Restoration

Sand dunes are critically important components of the littoral sediment budget that have been largely overlooked in the Hawaii conservation system. Dunes trap sand pushed inland by wind and waves, store excess beach sand, and serve as natural erosion buffers, protecting beach-front property and coastal infrastructure during storms, high-wave events and even tsunami. During such events, the presence of dunes may prevent waves from washing inland and damaging property and structures. Dunes also act as a sacrificial sand source during storms by eroding or releasing sand to the beach and nearshore waters. This causes waves to break further offshore, which reduces the strength of the waves attacking the beach. When gentler winds and waves return, the sand is gradually pushed back onto the beach and the dunes are naturally rebuilt (Figure 13).

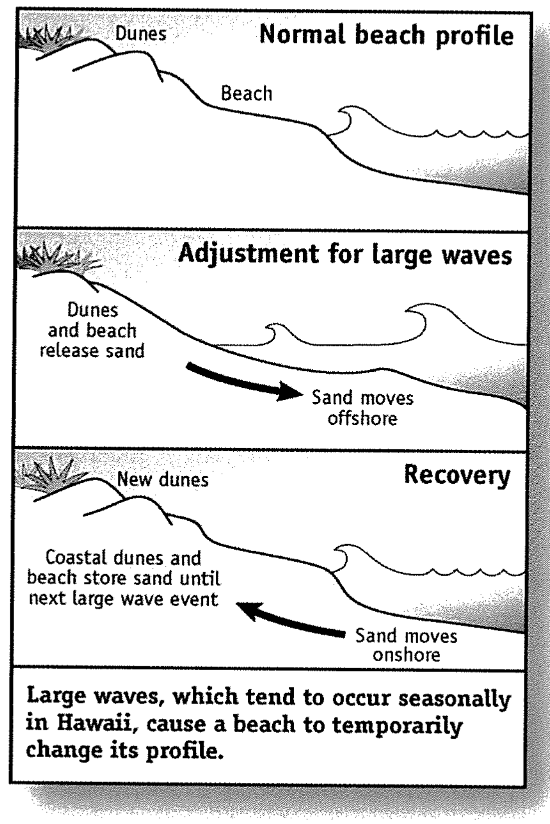


Figure 13. Seasonal beach profile adjustments. (*Figure: University of Hawaii SOEST*)

An unfortunate consequence of coastal development has been the leveling, filling, and landscaping of **coastal dunes** in Hawaii such that they have largely disappeared from most developed lands. Recognizing that dunes are a significant "sub-environment" of the beach, many beach nourishment projects emphasize dune construction for its value in mitigating coastal hazards, and as a sand source to an eroding beach.

Dune construction also potentially reduces the high expense of beach restoration by simplifying permitting and logistics costs.

Pristine dunes are vegetated by native Hawaiian species such as *'aki'aki, 'akulikuli, pohuehue*, and *pohinahina,* which are salt-tolerant and are effective at trapping wind-blown sand (Figure 14). Without vegetation to trap and hold sand in place, sand is blown inland by the wind and is lost from the beach and dune system. For this reason, it is important to prevent unrestricted vehicular and foot traffic across dunes. Access across dunes to the beach should be restricted to designated access paths (Figure 15) and elevated walkways so that vegetation on the dunes is not disturbed.

Figure 14. Coastal dune vegetated with aki aki grass and akulikuli at Kanaha Beach.

Because of the natural erosion buffer that coastal dunes provide, dunes should be preserved and, in some cases, restored. **Dune restoration** projects have taken place at many locations on Maui, including Kamaole I in 1983, Kamaole II in 1984, Mai Poina Oe Iao Beach Park in 1987 and 1998, at the Hawaiian Islands Humpback Whale National Marine Sanctuary (2000-ongoing), Kanaha Beach (2001-ongoing), and at Kamaole III Park (2005-ongoing). All of these restoration projects have been undertaken largely by volunteer efforts and have significantly enhanced the recreational value of the beach and upland areas.

In 2003, the Maui County Code was amended to better protect coastal dunes. The amendment specifies that any grading of the primary **frontal dune** – the first dune encountered mauka of the beach – is prohibited. The amendments also prohibit the grading of any dunes located in the **shoreline setback** area, require a dune delineation for grading permits for coastal properties, and specify that any fill used in the setback area must be beach quality sand.

Figure 15. Moveable walkway constructed of recycled plastic, on the dune at Kaanapali.

Objectives

5.1) To preserve existing sand dunes

5.2) To restore degraded sand dunes

Recommendations

5.1a) Use signs and fencing to restrict beach access to designated pathways

5.1b) Establish moveable **dune walkovers** to provide pedestrian access while preserving dune vegetation

5.1c) Realign beach access paths such that they are not oriented parallel to the prevailing wind direction, in order to minimize wind-blown sand losses

5.1d) Develop educational materials for resorts and schools describing the critical role of dunes in maintaining healthy beach systems and ways to help protect and avoid damaging dunes

5.2a) Encourage and support dune restoration efforts (dune fencing, revegetation, sand nourishment, etc.)

5.2b) Publish a handbook detailing the methodology for future dune restoration projects

6. Coral Reef Ecosystems, Water Quality, and Upland Activities

The health of beaches is closely tied to the health of the coral reef ecosystem, which is itself closely tied to upland land use practices. Hence, effective beach management requires a geographically broader approach known as integrated coastal zone management. Although this plan has focused mainly on the shoreline area—the beach, the dunes, and the coastal plain—we have included some recommendations for more effective protection of the coral reef ecosystem (Figure 16) and better management of land practices throughout the watershed.

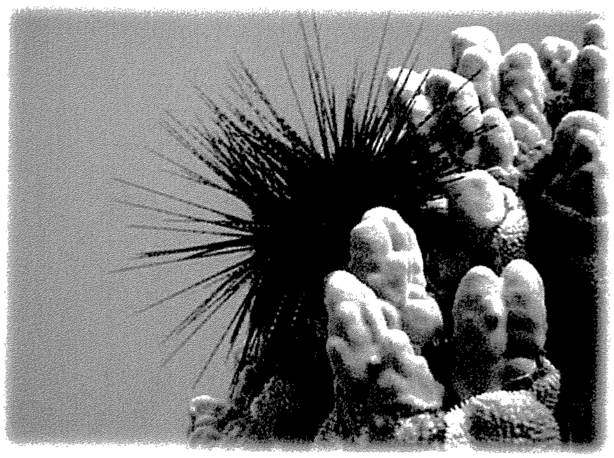


Figure 16. Healthy coral reefs and marine life are dependent on clean water. (*Photo: Donna Brown*)

In many cases, improper control of runoff at agricultural lands and construction sites, even those far from the coast, has degraded the water quality of coastal areas (Figure 17). Suspended materials such as sediment diminish light penetration and eventually settle out on the seafloor. This harms coral (Figure 18) and other marine organisms (e.g., *foraminifera*, an important component of beach sand) and can limit safe and enjoyable ocean recreation. Polluted runoff also transports nutrients, pesticides, and other pollutants to coastal waters compounding the impacts on water quality.

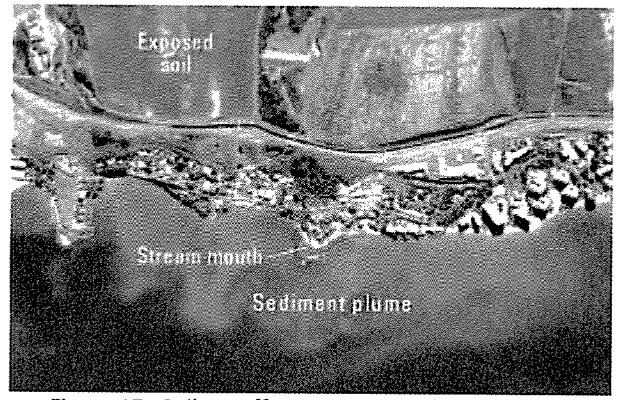


Figure 17. Soil runoff at West Maui. (*Photo: geopubs.wr.usgs.gov/fact-sheet/fs025-02/*)

Golf courses, resorts, residential communities and other urban developments have impacts on water quality through the overuse of fertilizers, pesticides, and the leaching of other pollutants, including chlorine from the drainage of swimming pools. In some cases, **nutrient loading** of coastal waters has led to **algal blooms** (Williams et al., 2007). Workshops should be conducted for landscape design and maintenance personnel so that they may be educated on the benefits of landscaping with native plants, as well as ways to reduce the need for irrigation, fertilizers, herbicides and pesticides. Nutrients are also contributed to nearshore waters by wastewater injection wells. In these locations, if the conditions are right for algae growth, algal blooms can be exacerbated, and can smother and kill coral (Figure 19). Treated wastewater should be used for irrigation of agriculture, parks, resorts and golf courses, for example, which would have the added benefit of reduction of the usage of valuable potable water for landscaping purposes.

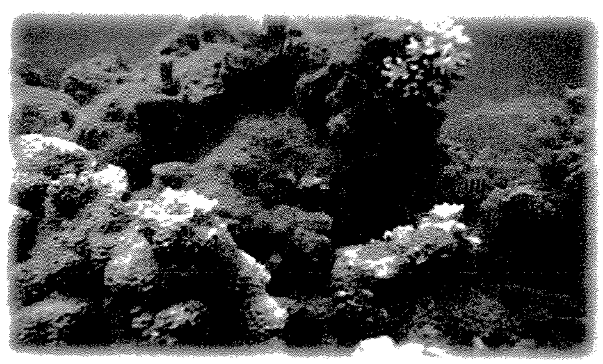


Figure 18. Sediment burying a coral reef. (*Photo: Mike Field*)

Most upland runoff can be prevented from polluting the coastal waters through adherence to the best management practices (BMPs) outlined in the *West Maui Watershed Owners Manual* (WEST MAUI WATERSHED MANAGEMENT ADVISORY COMMITTEE, 1997), which is available to the public from the Hawaii Department of Health. Major recommendations for agriculture and construction are highlighted below. The *West Maui Watershed Owners Manual* also provides recommendations for landscaping.

Figure 19. Algae growth can be harmful and destructive to corals. (*Photo: Russell Sparks*)

According to the *West Maui Watershed Owners Manual*, best management practices for agriculture include, but are not limited to, the following.

- Expanded use of sediment retention basins
- Regular maintenance of sedimentation basins and other erosion control measures
- Use of diversions, terracing, contour farming, and crop residue to intercept and slow sheet flow and stabilize the surface
- Improved water management practices
- Development of precision agriculture in order to ensure efficient application of fertilizer and pesticides based on local soil/crop needs

Best management practices for construction sites include the following.

- Use of detention basins to prevent runoff
- Use of dust suppression measures such as dust screens and watering
- Limiting the surface area of exposed soil and coordinating activities with periods of low rainfall

Other recommendations in the *West Maui Watershed Owners Manual* include

- Providing training and education for contractors, developers, and equipment operators
- Improve inspection of and enforce requirements for erosion control

Upland activities such as landscaping, agriculture, and construction must become more environmentally responsible. Currently, the county Department of Public (DPW) and state Department of Health (DOH) are responsible for enforcing compliance with proper environmental controls at construction sites. Communities and non-governmental organizations can assist DPW and DOH in enforcement by reporting infractions on the Maui County website through the online 'Request For Service' system. Public awareness should also be increased. Contracting firms and developers should attend workshops on environmentally sound construction practices.

Objective

6.1) To reduce impacts to water quality and coral reef ecosystems

Recommendations

6.1a) Continue to educate the public—especially the ocean recreation users such as ocean activity centers and dive/snorkel tour boat operators—on the importance of coral reef ecosystems and how to reduce damage to these resources

6.1b) Support studies to determine the status of Maui's coral reef ecosystems

6.1c) Aim to eliminate the need for wastewater injection wells

6.1d) Ensure that upland construction and agricultural practices become more environmentally responsible by increasing public awareness

6.1e) Provide BMP workshops to contractors at construction sites

6.1f) Improve enforcement of the grading ordinance

6.1g) Implement suggestions of the *West Maui Watershed Owners Manual* including guidelines for the reduction of soil erosion and the development of and adherence to best management practices protective of coastal water quality

6.1h) Review existing water quality standards, testing, and enforcement

6.1i) Support a study of nearshore circulation patterns to help determine environmental impacts of various drainage master plans

6.1j) Evaluate site plans with an eye to minimize both impervious coverage such as pavement and disruption of natural drainage and vegetation. Encourage the use of pervious materials that allow for the infiltration of stormwater.

6.1k) Conduct workshops for landscape designers and landscape maintenance personnel, in particular for resorts and golf courses, on ways to create landscape design and maintenance plans that minimize the need for irrigation, fertilizers, pesticides and herbicides

7. Shoreline Setbacks and Coastal Erosion Hazard Data

The intent of **shoreline setbacks** is to establish a coastal hazard buffer zone to protect beach-front development from high-wave events and coastal erosion. Setbacks that reflect long-term erosion rates provide better protection to beaches because the need for shoreline armoring is minimized when structures are set well back from the shoreline,. Adequate setbacks allow for natural erosion and accretion cycles to occur and help maintain public lateral shoreline access. In many cases, an adequate setback based on historic shoreline positions will allow beach width to be maintained while the shoreline retreats over time. In addition, setbacks provide open space for the enjoyment of the natural shoreline environment (Figure 20).

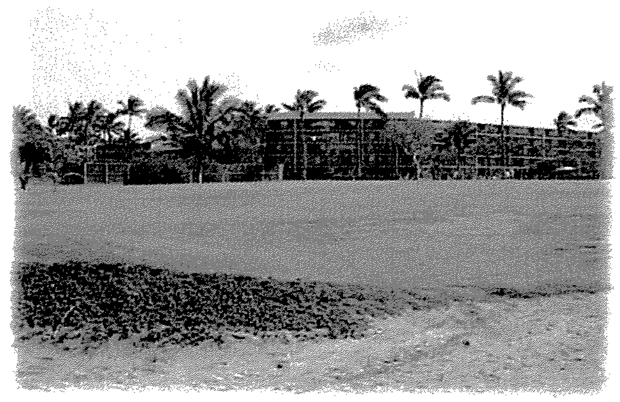


Figure 20. Example of large setback and open space, Kihei. (*Photo: Zoe Norcross-Nu'u*)

Maui's shoreline setback rules were strengthened in 2003 by establishing a variable setback based on historical erosion rates. A University of Hawaii Study determined historical shoreline change rates along the majority of Maui's sandy shorelines for a 100-year period from the early 1900's to 2001. The shoreline was characterized into 30 sections and a map was produced for each section showing rates of shoreline change every 20 meters along the coast (Figure 21). Maui's setbacks are determined by multiplying the annual erosion rate for a given property by 50 years and adding a 25-foot buffer. While this is a marked improvement over the previous lot depth-based setbacks, there is still room for progress.

Essentially, the current setbacks should ensure that a structure will be safe from erosion for 50 years. While this may seem to offer great protection, there are several problems with this scenario. First, it is reasonable to expect that many coastal structures will remain standing for more than 50 years. As such, buildings may need a seawall for protection within their reasonable lifespan; thus the new setback is only delaying the need for shore protection. Second, there is a reasonably strong chance that within the next 50 years, Maui will be impacted by a hurricane or tsunami or an unusually severe high surf event. The 50-year setback does not take these hazards into consideration, thus it should not be falsely assumed that the new setbacks will protect new structures from coastal hazards. Third, the 50-year protection offered by the new setback assumes that the erosion rates will not change. While there is a chance that erosion may slow down or reverse, there is a greater likelihood that erosion rates will increase as global sea level rise accelerates as it is projected to do in response to global warming. For these reasons, **building setbacks** should be increased. The Hawaii Coastal Hazard Mitigation Guidebook (Hwang, 2005) recommends a setback of at least 70 times the erosion rate plus a 40-foot buffer.

Applicants wishing to build on coastal properties should always be encouraged to build as far landward as possible on their property. It is also critical that the county update the erosion hazard maps at least every 5 to 10 years in order to capture changes in erosion rates. The more data is collected, the more statistically robust the erosion rates will be. Setbacks should also consider the type of development and building style. While existing setbacks may be appropriate for smaller post-and-pier structures that can be relocated, deeper setbacks should be required for slab-on-grade construction and large buildings such as hotels and condominiums.

Another urgent issue is that of setbacks for coastal properties located on cliffs or **bluffs**. Currently, there are no established erosion rates for these properties. Unlike the erosion of sandy shorelines that takes place gradually, bluff failure usually occurs catastrophically over short periods of time. In other words, a bluff may appear to not undergo any change for a decade or more, and then suddenly collapse losing tens of feet in an instant. Further, the soil and rock types typical of the Hawaii Islands are particularly susceptible to weathering and erosion. For this reason it is critical that structures on oceanfront bluffs to be set back as far from the edge of the bluff as possible (Figure 22).

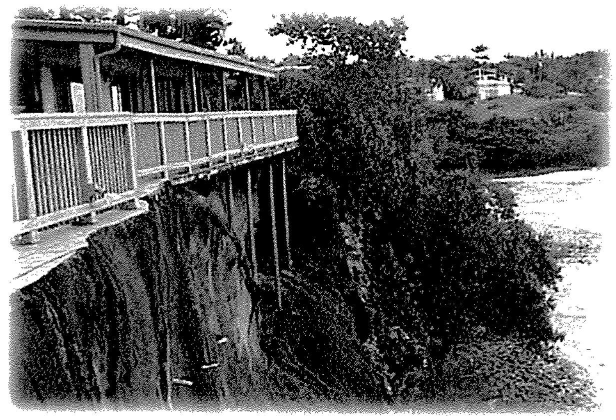


Figure 22. At the time of construction, this home was set back roughly 40 feet from the edge of the bluff. Erosion rates have averaged 1 ft/year. (*Photo: Hawaii County Planning Department*)

Ideally, Maui County should conduct erosion rate studies for bluff areas that are developed and those areas that may be developed in the future. Until this is done, coastal bluff property owners should have an engineering assessment conducted to determine erosion rates at their site, and setbacks should be calculated based on these rates in a manner similar to that of setback calculations for sandy shorelines. A policy should be created with respect to development on coastal bluffs to ensure that development takes place in a safe location.

Objective

7.1) To improve the safety of coastal residents from coastal hazards, improve protection of coastal resources, and provide relevant information for governmental agencies and the coastal community when purchasing shoreline property and/or planning and designing any development along the shoreline

Recommendations

7.1a) Continue to fund updates to Maui's annual erosion hazard maps every 5 to 10 years

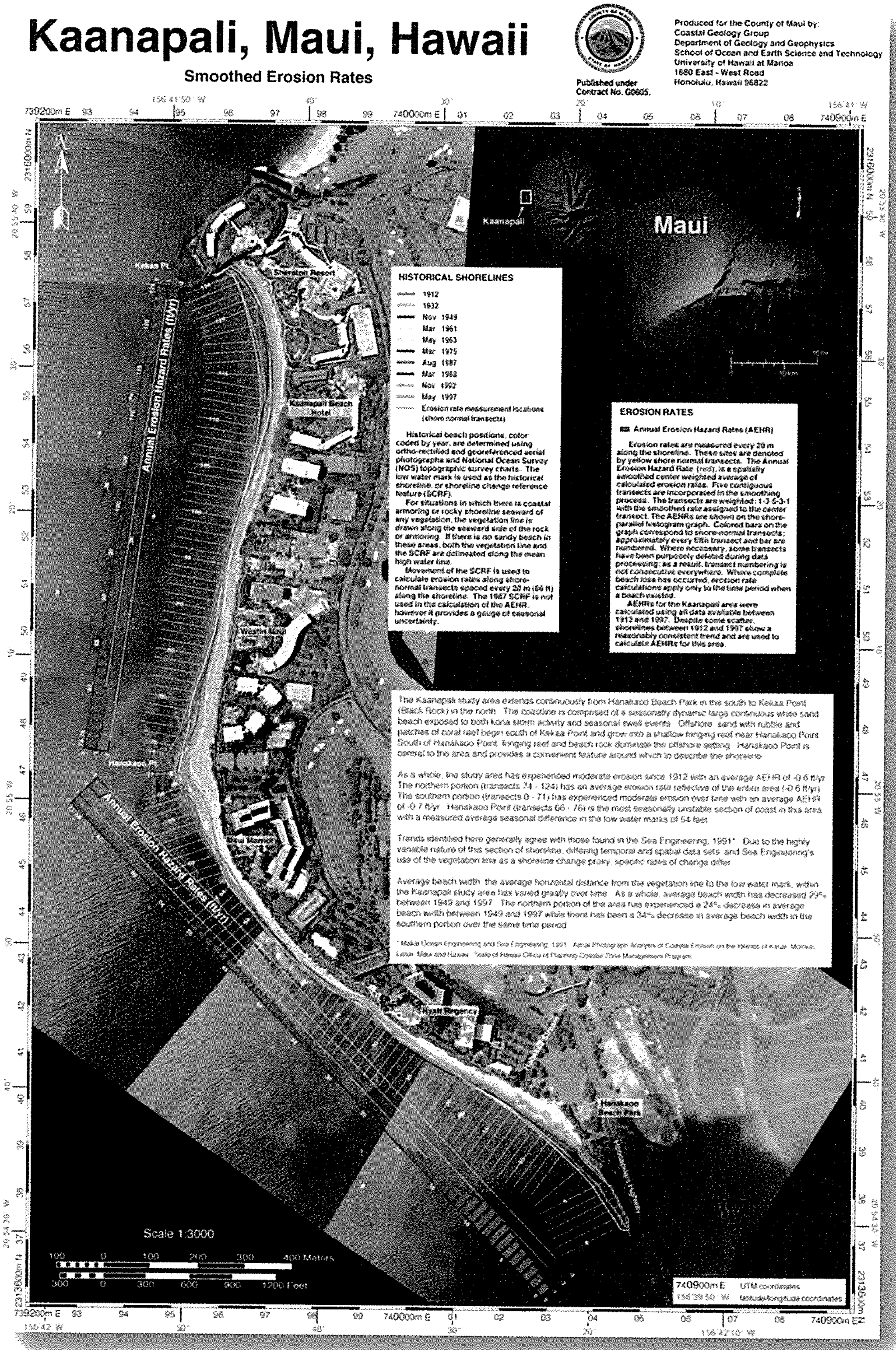


Figure 21. One of Maui's 30 historical shoreline change maps, produced by the University of Hawaii. (*Image: University of Hawaii Coastal Geology Group*)

7.1b) Develop a study to determine high hazard areas for hurricane and tsunami impacts, and incorporate this information into shoreline setback determination, to be no further makai than measured by existing methods

7.1c) Incorporate performance standards (e.g., construction style and estimated lifetime of structure) into the determination of shoreline building setbacks, to be no further makai than measured by existing methods

7.1d) Develop a study of coastal bluff erosion for bluff properties that have been developed and will potentially be developed in the future

7.1e) Develop interim policies for setback requirements on coastal bluff properties

7.1f) For sandy shorelines, increase Maui's shoreline setbacks to 70 times the erosion rate plus a 40-foot buffer for already developed residential lots; to at least 250 feet for undeveloped lots with smaller commercial/residential projects; and to at least 400 feet for undeveloped lots with large commercial projects

7.1g) Amend both the county's Special Management Area (SMA) Rules and Shoreline Rules to extend county jurisdiction to the ocean.

7.1h) Establish a rule and/or ordinance that no certified shoreline shall be located makai of the previous shoreline.

7.1i) Protect accreting lands with a permanent ban on seaward extensions of any improvements other than minor structures permissible under the shoreline rules of the Maui Planning Commission.

8. Proactive Development of Coastal Lands

Proactive management occurs in the planning stages of new developments or redevelopments along the shoreline, well before project layout is finalized. This type of planning is beneficial to coastal landowners and developers who are not always aware of shoreline processes, coastal hazards, and the potential impacts of development on the beach and other nearshore areas. The Hawaii Coastal Hazard Mitigation Guidebook (Hwang, 2005) provides specific recommendations for each stage of development starting from the designation of state land use districts all the way through to the construction of buildings. The permitting agency should request that developers follow the recommendations of the Hawaii Coastal Hazard Mitigation Guidebook during project layout in order to decrease potential adverse impacts of coastal hazards and improve resource protection.

In addition to following recommendations of the Hawaii Coastal Hazard Mitigation Guidebook, developers and landowners should be encouraged to pre-consult with various experts and governmental agencies familiar with coastal hazards in order to get appropriate site-specific recommendations on project design. Developers and landowners should also acknowledge that developments along the shoreline are subject to the risks of coastal erosion and high wave events. Any request to protect structures and property with shoreline armoring is currently approved through a public notification, hearing and decision making process. Approval may occur only on grounds of hardship to the property owner and mitigation of adverse impacts to the environment. More information on coastal processes, coastal hazards, erosion mitigation, insurance, and recommendations for coastal property owners can be found in *Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawaii: A Practical Guide of Common Questions and Answers* (Eversole and Norcross-Nu'u, 2006).

Objectives

8.1) To encourage proactive shoreline developments and increase awareness of coastal hazards

Recommendations

8.1a) Encourage developers and landowners to pre-consult with various experts and governmental agencies familiar with coastal erosion in order to get appropriate recommendations on project design

8.1b) Adopt the recommendations made in the Hawaii Coastal Hazard Mitigation Guidebook for coastal planning and development, and provide these recommendations to developers

8.1c) Make the *Beach Management Plan for Maui* available to developers, contractors, and landowners as a reference guide

8.1d) Encourage greater setbacks for large structures such as hotels and condominiums, and slab-on-grade structures

8.1e) Discourage slab-on-grade construction for coastal properties

8.1f) Encourage minor structures to be non-permanent and portable

8.1g) Encourage developers to construct building additions on the mauka side of the structure

8.1h) Add to best management practices a requirement that lot depth be maximized to avoid shallow oceanfront subdivisions. A minimum 500 ft lot depth should be required in new subdivisions.

8.1i) All new subdivisions and major redevelopments shall restore any existing or recent coastal dune systems to specified standards.

9. Inter-agency Coordination

Coastal resource management is frequently complicated due to continuously migrating and often overlapping administrative jurisdictional boundaries. In most cases, county responsibility falls landward of the shoreline, state responsibility falls seaward of the shoreline, and federal responsibility falls seaward of the high water line. Aspects of the coastal dune – a fragile and critical part of the coastal ecosystem – fall in both state and county jurisdictions, meaning that it is subject to two separate sets of management rules (Figure 23). Given that the position of the shoreline and high water line are constantly changing, it is easy to see how permitting and responsibility for coastal projects can be challenging. Inter-agency communication and education are critically important to more effectively plan for or mitigate coastal hazards and implement more environmentally sound projects. Better inter-agency coordination would also reduce delays, duplications and paperwork. Resource demands for permit processing would result in cost-savings to both permit applicants and governmental agencies.

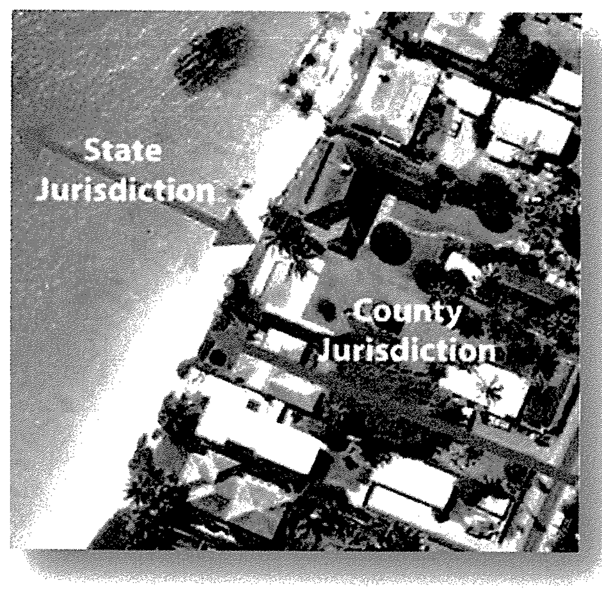


Figure 23. The state shoreline separates the sand-storing dunes from the sand-needing beaches - promoting the demise of each. (*Image: Chip Fletcher*)

Beach nourishment projects and other shore protection measures often fall within two or more jurisdictional boundaries (e.g., Federal and State, State and County, or Federal, State, and County). This leads to jurisdictional conflicts. Each agency is often not fully aware of the other agencies' permitting requirements and the status of pending applications. While sister agencies are usually asked to comment on applications for coastal permits, their advice may conflict with the rules, powers, and political culture of the permitting agency. Some progress has recently been made towards the coordination of county and state shoreline management efforts. Maui County and the State DLNR are discussing the adoption of a cooperation agreement that will ensure that these agencies work together to determine mutually agreeable outcomes for issues that involve both jurisdictions. This will improve consistency and minimize the delivery of conflicting information to applicants.

In one example of successful inter-agency coordination, the State of Hawaii DLNR recently adopted a General Permit for beach nourishment in Hawaii. The purpose of this Small Scale Beach Nourishment (SSBN) permit is to expedite the authorization of projects involving less than 10,000 cubic yards of sand. This permit integrates the beach replenishment requirements of all the necessary state and federal agencies into one application. However, each proposed project must also be separately evaluated through the county's SMA and shoreline rules. It is hoped that this simplified and expedited permit process will encourage coastal property owners to seek beach replenishment rather than shoreline armoring as a means of erosion mitigation. A blanket environmental assessment (EA) was completed for the SSBN permit which means that individual applicants do not need to conduct costly, time-consuming EAs. Activities that do not conform to the provisions and limitations of this permit will still require an individual permit from the USACOE and/or a project-specific DOH Section 401 Water Quality Certification and a Coastal Zone Management (CZM) Federal Consistency determination.

However, more interagency communication is needed. For example, better cooperation between State Parks and the County Parks and Recreation should be sought since many beach parks are maintained by these departments. In addition, discussions should be enhanced with the State Department of Transportation (DOT), because some highway facilities are threatened or will soon be threatened by coastal erosion. In most cases, state highway facilities are the major or only thoroughfare between regions of Maui. Proactive planning of new transportation corridors, highway construction, widening, and realignment could reduce the threat of coastal erosion, high-wave hazards, road closures and beach loss by anticipating future shoreline trends (Figure 24). For example, Maui County is in the process of acquiring land in West Maui to relocate the Honoapiilani Highway away from the ocean, between Ukumehame and Lahaina. One-hundred acres of coastal land has already been obtained toward this purpose through the Ukumehame Subdivision SMA permit approval process.

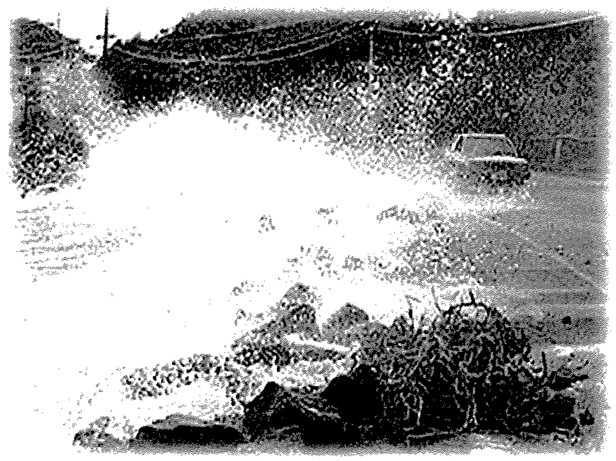


Figure 24. Roads located adjacent to the shoreline are vulnerable to damage and closure during periods of high surf. (*Photo: Honolulu Star-Bulletin*)

Consideration should be given to establishing a new regulatory body or a fully integrated authority responsible for all coastal issues, which presently fall in both state and county jurisdictions. In addition to minimizing cross-jurisdictional conflicts, this would allow for improved management of coastal resources. For instance, coastal dunes, which are extremely valuable from cultural, environmental and shore protection standpoints, often straddle the county-state jurisdictional boundary, making management, protection and restoration of these features complicated. As such, dunes are often overlooked and degraded. Another issue is with seawall permitting. Hawaii's Board of Land and Natural Resources disallows seawalls on conservation lands, but owners can still get permits from county authorities to build seawalls within county jurisdiction in some limited circumstances.

An example to look to is the California Coastal Commission, which is an independent state agency that was established by voter initiative in 1972 and later made permanent by the Legislature through adoption of the California Coastal Act of 1976. The Coastal Commission, in partnership with coastal cities and counties, plans and regulates development activities and the use of land and water in the coastal zone. On land the coastal zone varies in width from several hundred feet in highly urbanized areas up to five miles in certain rural areas, and offshore the coastal zone includes a three-mile-wide band of ocean. Development activities are broadly defined by the Coastal Act to include (among others) construction of buildings, divisions of land, and activities that change the intensity of use of land or public access to coastal waters.

Objectives

9.1) To enhance coordination with federal, state, and other governmental agencies with jurisdiction over shoreline management — Army Corps of Engineers, Natural Resource Conservation Service, State and County Parks Departments, the State Department of Transportation (Highways and Harbors Division) the State Department of Land and Natural Resources, State Department of Health, and the County Department of Public Works

9.2) To develop an atmosphere that allows communities to act proactively to meet demands for shore protection and preservation

Recommendations

9.1a) Maintain ongoing discussions and improve coordination on shoreline matters with other agencies in order to avoid duplication, streamline permit processing, and encourage more environmentally sensitive shoreline protection measures

9.1b) Support the establishment of an independent state agency charged with managing the entire coastal zone

9.1c) Expand Maui's Shoreline Rules or augment SMA boundaries to include all primary dunes

9.1d) Clarify and strengthen the role of sister agency comments so that they are more than just advisory in nature

9.1e) Establish a bimonthly coastal council of permitting agency representatives and advisory personnel to discuss and resolve the disposition of coastal applications.

9.2a) Proactively plan highway construction, park improvements, and other infrastructure projects with input from sister agencies with overlapping purview.

9.2b) Agencies with coastal projects should be required to seek pre-consultation with sister agencies and solicit expert opinions when proposing new projects in the coastal zone

10. Beach Management Districts

Figure 25. Napili and Kapalua Bay resort and condominium associations are working together to protect their beautiful sandy beaches. (*Photo: Kristen N. Staples)*

Beach management districts should be established on a neighborhood scale to help maintain or restore nearby beaches and other shoreline areas. A beach management district (BMD) is a special designation for a group of neighboring coastal properties that provides a mechanism for implementing erosion mitigation projects at multi-property scales. BMDs streamline the permitting requirements for beach preservation and restoration projects and facilitate cost sharing between the group of neighborhood owners and county, state, and federal agencies. Further details about establishing beach management districts and the advantages and challenges of establishing them are thoroughly discussed in a 1992 report entitled *Beach Management Plan with Beach Management Districts* by Hwang and Fletcher.

Certain beach management projects (e.g., large beach restorations) affect several beachfront properties. The formation of a beach management district allows a group of adjacent landowners to address shoreline issues as a unit rather than as individual property holders (HWANG AND FLETCHER, 1992). As a beach management district, the group can pool its resources and streamline the permitting process for such projects. Occasionally, county, state, and federal agencies will participate in cost sharing for a particular project, if it benefits the public.

Beach management districts can lobby for specific conditions that are consistent with and enhance the intent of existing laws. For instance, a neighborhood fearful of new development might push local authorities for a locally applied condition preventing seaward creep of new development. Another might want a condition encouraging redevelopment projects to retreat from the shoreline as a measure to reduce hazard vulnerability and promote environmental sustainability.

Some condominium associations and neighborhood boards already act as *de facto* beach management districts. For example, several condominiums and resorts in Napili and Kapalua joined together to create the Napili Bay and Beach Foundation, a not-for-profit organization into which tax-deductible donations can be made to support sand replenishment of Napili and Kapalua Bays (Figure 25). By creating this foundation, the condominiums and resorts have simplified the task of project and financial management for beach nourishment involving multiple properties and owners. Private homeowners in Spreckelsville are also in the process of establishing a not-for-profit organization for the same purpose.

Objective

10.1) To encourage and implement beach management districts in order to coordinate beach management on a neighborhood scale

Recommendations

10.1a) Establish beach management districts at locations experiencing **chronic erosion**, as well as other types of coastal settings, especially those proposing to implement beach restoration projects

10.1b) Set up a mechanism at the county and/or state levels for evaluating petitions to form a beach management district

10.1c) Encourage the formation of not-for-profit organizations to facilitate beach nourishment for multi-property projects and communities.

11. Public Awareness and Education

Coastal and marine environments are greatly influenced by human activities. Increasing public awareness of the sensitivity of coastal environments is a first step in significantly decreasing human impacts. Policy makers and agency personnel should be provided with guidance for more effective beach management practices. Equally important is increasing awareness and education of the general public (Figure 26). Although Maui has many well-informed individuals with stewardship attitudes, both the private sector and the public need to become more aware of coastal and marine resource issues.

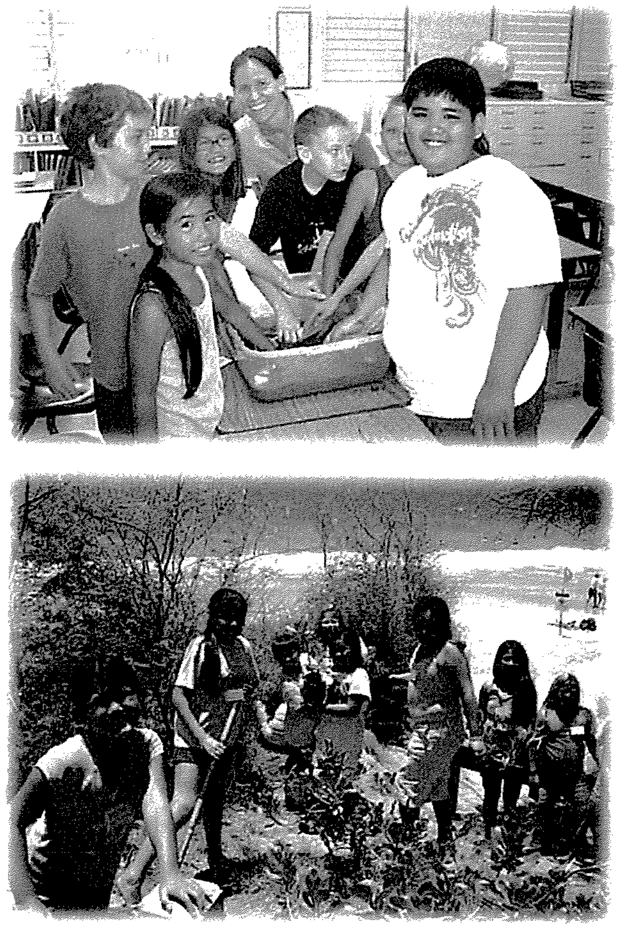


Figure 26. Kihei Elementary School students experimenting with the effects of seawalls on beaches (left) and working on dune restoration at Kamaole III Beach Park (right). (*Photos: Sue Forbes*)

Policy makers and agency personnel rotate and are replaced on a regular schedule tied to political changes. The constant influx of new personnel in key decision-making positions requires an education mechanism guaranteeing that decisions of new personnel are environmentally and economically responsible. The same applies to developers and contractors, especially those working at shoreline properties. A better informed public will support decisions that need to be made.

Hawaii Sea Grant and Maui Community College should develop a public awareness and education program on coastal and marine resource issues. Sea Grant should team up with local scientists and environmental groups to sponsor K-12 teacher training workshops. Maui Community College can support post-secondary education and research by continuing to offer marine science courses through its Marine Option Program. Offering a bachelor's degree program in Marine Science should be a longer-term goal at Maui Community College.

Public awareness can also be increased through educational presentations to various groups (e.g., community associations, schools, neighborhood boards, rotary clubs, ocean activity owners and county commissions). Other ways to increase awareness include creating a web site on coastal processes and development guidelines, issuing press releases, publishing information in booklets, and giving presentations at conferences and symposiums.

Objective

11.1) To increase public and private sector awareness and education on coastal and marine resource protection

Recommendations

11.1a) Identify key target audiences (e.g., schools, community associations, neighborhood boards, rotary clubs, developers and contractors, ocean activity owners, county commissions, etc.)

11.1b) Continue disseminating information by issuing press releases, publishing booklets and posters, and giving presentations at conferences and to key user groups

11.1c) Sponsor the creation of a web site on coastal processes, development guidelines, and beach management

11.1d) Partner with local scientists and environmental groups to sponsor K-12 teacher training workshops

11.1e) Create a Maui Environmental Education Fund using monies generated by land development projects

12. Research

Several University of Hawaii research projects have focused on Maui County's coastal and marine resources. These projects have greatly increased our knowledge of the coastal and marine environments and processes and have led to improved management of the coastal zone. Further research is necessary to increase our understanding of coastal and marine science and to ensure the effective and efficient management of the coastal zone.

Hawaii Sea Grant can help identify new projects and potential funding partnerships. The most likely partners would be Sea Grant, DLNR, DOH, the Hawaii Coastal Zone Management Program, the United States Geological Survey (USGS), the Environmental Protection Agency, the Federal Emergency Management Agency, the National Park Service, and NOAA's Hawaiian Island Humpback Whale National Marine Sanctuary.

An important component of research is **monitoring**. Monitoring involves the periodic collection of data to study changes in an environment through time. Three important studies relevant to beach management include the monitoring of beaches, marine life and water quality before, during and after beach replenishment projects (Figure 27); monitoring algal blooms; and the regular collection of high-resolution aerial photographs for monitoring shoreline change.

High-resolution vertical aerial photographs of the shoreline provide valuable information to coastal zone planners and developers. In particular, current aerial photographs are critical for determining the annual erosion hazard rates on which the shoreline setbacks are based. Aerial photographs may also become an important component in the shoreline certification process, and for the determination of rates of bluff erosion. The database of coastal aerial photographs should be updated at least every 5 years, and no longer than every 10 years, in order to keep the annual erosion hazard rate information and shoreline setback determinations up to date.

Figure 27. Water quality monitoring for a beach replenishment project at Maalaea, Maui. (*Photo: Zoe Norcross-Nu'u*)

Objective

12.1) To continue to help fund research in coastal and marine science and marine policy

12.2) To continue to closely monitor shoreline trends such as coastal erosion and beach loss as well as algal blooms

Recommendations

12.1a) Commission new research projects in coastal and marine science and marine policy on all scales

12.1b) Fund studies that seek to better understand site-specific causes of coastal erosion and beach loss

12.1c) Sponsor a study on the incorporation of the impacts of episodic events such as hurricanes and tsunami into shoreline setbacks

12.1d) Sponsor a study on bluff erosion

12.1e) Sponsor a study on sea-level rise inundation hazard areas

12.1f) Sponsor a study on locating offshore sand resources with potential for beach replenishment

12.1g) Encourage Maui Community College to take a more active role in marine science education and research by further developing its Marine Option Program

12.1h) Seek participation in research on marine issues from other universities, ocean user groups, and other government agencies

12.1i) Create a Maui Environmental Research Fund with funds generated by a combination of new development projects, tourism, and major resource users

12.2a) Update the County's database of coastal aerial photographs at least every five years and no longer than every 10 years so that county planners can make informed decisions with reasonably up-to-date information on shoreline development

12.2b) Help support the continued collection of data on water quality and algal blooms

13. Funding Mechanisms

Two tools for managing coastal erosion and beach loss are beach nourishment and acquisition of coastal lands. Additionally, research in coastal and marine science are necessary to establish long-term trends and plan for resource protection and hazard mitigation. Large beach nourishment projects and the purchase of shoreline properties can cost millions of dollars. Furthermore, ongoing research requires continuous funding.

Several mechanisms should be investigated for funding these activities including grants from outside agencies (e.g., federal and state agencies, Sea Grant, the DLNR, and the Hawaii Coastal Zone Management Program) and leveraging seed monies provided by the County. Monetary and in-kind support from non-governmental organizations and environmental groups should also be sought.

In addition, the County should establish a dedicated beach management fund. This fund would help pay for coastal land acquisition, beach nourishment, shoreline access and dune restoration projects as well as research and monitoring needs. Some of the money for this fund could be gathered from CZM-related permit processing fees both for regular as well as after-the-fact SMA and Shoreline Setback permits,. Moreover, penalties and fines collected from SMA and shoreline violations should be directed to the beach management fund. Further, any funds resulting from County-initiated, SMA-related settlement agreements, as well as additional funds for coastal resource protection and hazard mitigation allocated in the County budget, should be directed to the beach management fund. Even a small, perhaps voluntary, visitor donation for beach preservation ranging from as little as $0.50 per person per day to a $5.00 or $10.00 per visit donation could generate millions annually. Mechanisms for collecting such a donation could be developed through in-flight services prior to landing or departure, hoteliers during check-in / check-out, and the visitor service industry.

The State Coastal Zone Management Act (CZMA) provides a mechanism to fund the replacement and/or restoration of damaged or lost beaches, dunes and shoreline access. CZMA policies allow for monetary compensation when coastal or recreational resources will be unavoidably damaged by development or when shoreline access is lost from private actions (see HRS 205A-2(c)(1)(B)(ii)). One market-based mechanism to mitigate these losses is **land banking** or so-called mitigation banking. Wetland, land and endangered species mitigation banks are well described in federal and state policy and have been successfully implemented to foster habitat protection and conserve valuable ecological functions.

Mitigation banks are designed to create, restore and/or enhance large, ecologically important tracts of land. The bank is authorized by the county to receive payment as compensatory mitigation to offset impacts from private landowners whose projects will result in the unavoidable loss of shoreline access or beach sand. These funds are then used to acquire and maintain portions of predetermined, publicly-valued, sandy coastal land to be protected for public use in the long term. This market-based funding method would allow some shoreline areas to be armored, but would compensate for this by having private landowners fund the protection of valued beaches for long-term use by the public.

Mitigation banking has potential to be a useful tool in certain cases. However, care should be exercised to avoid it being used in a way that is inconsistent with conservation goals. Hence, the tool should only be used in coordination with governing rules designed to reduce hazard vulnerability and enhance coastal ecosystem preservation and conservation. Mitigation banking should only be an option for compensation of access and beach loss on shorelines that are already degraded.

Objectives

13.1) To sharply increase government funding for beach management, coastal land acquisition, and coastal research and monitoring

13.2) To seek funding from non-governmental, community and environmental groups for beach management, coastal land acquisition, and coastal research and monitoring

Recommendations

13.1a) Allocate a portion of the annual budget to a dedicated beach management fund, which would be used for land banking, shoreline access and beach and dune restoration projects as well as continued coastal zone research and monitoring

13.1b) Pass an ordinance to direct revenue from fees, fines, penalties, regular as well as after-the-fact SMA and shoreline permits, violations and county-initiated settlement agreements to a revolving fund for coastal land acquisition and beach, dune, and shoreline access restoration

13.1c) Identify strategies for generating more revenue earmarked for beach management

13.1d) More effectively pursue matching funds from outside agencies

13.1e) Conduct a pilot beach mitigation banking program pursuant to HRS 205A to provide a market-based mechanism that compensates the public for lost shoreline access on impaired coastlines by purchasing publicly-valued, intact sandy shorelines for long-term conservation and public use.

13.2a) Build relationships with and between non-governmental, community and environmental groups to raise funds, coordinate land acquisition, and carry out coastal research and monitoring

13.2b) Support and recognize volunteer efforts of non-governmental, community and environmental groups who are active in coastal stewardship

Glossary

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

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

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

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

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

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

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

Beach loss – see **Beach erosion**

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

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

Beach nourishment - the technique of placing sand fill along the shoreline to widen the beach and enhance its capacity to protect inland areas from wave damage.

Berm - a physical feature usually located near mid-beach and characterized by a break in slope, separating the flatter backshore from the seaward-sloping foreshore. Can also be used to describe a terrace formed by wave action, or a mound or accumulation of sand.

Blowout – an area on a dune where an absence of vegetative groundcover allows wind activity to funnel sand over and out of the dune system, causing scouring of the dune and accelerating beach loss. Frequently occurs at shoreline access paths and drainage outlets that are aligned parallel with the prevailing wind direction.

Bluff – a high steep bank or slope usually formed by erosion.

Building setback - see **Shoreline setback**

Carbonate sand – sand composed primarily of calcium carbonate that has formed by precipitation and organic secretion in the ocean. Carbonate sand in Hawaii is frequently made up of skeletal remains of marine organisms such as coral, mollusks foraminifera and algae, and is usually found close to its location of origin. The other main classification of sand is siliciclastic, composed primarily of quartz, a mineral which is eroded from rocks on land such as granite. Beaches on the continental United State are primarily made up of siliciclastic sand.

Chronic erosion – long-term erosion or shoreline retreat resulting from local sand shortage, human impacts and/or sea level rise. See also **Coastal erosion**.

Coastal dune - mounds or ridges of unconsolidated sand contiguous and parallel to the beach. See also **Dune** and **Inland dune**.

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

Coastal hazard - natural or human-influenced events that threaten lives, property, and the health of coastal environments. This includes, but is not limited to hurricanes, tsunami, erosion, and coastal storms.

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

Coastal protection structure – usually refers to seawalls, revetments, or geotextile sandbags used to stop the loss of land from erosion

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

Deflation - a lowering of the beach profile, often in response to erosion.

Downdrift - in the direction of net longshore sediment transport.

Dune - a ridge or mound of unconsolidated sand, often vegetated. See also **Coastal dune** and **Inland dune.**

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

Dune walkover - light construction such as a walkway or bridge made of wood or recycled plastic that provides pedestrian access to the beach without trampling dune vegetation.

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

Erosion - the loss of sand or other sediment, often indicated by the landward retreat of the shoreline.

Frontal dune – the first dune encountered landward of the beach. See also **Dune** and **Coastal dune.**

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

Geotextile sandbags - large sand-filled tubes made of highly durable synthetic fabric, used for both temporary and long-term coastal erosion control projects.

Groin – a wall that extends perpendicular from the shoreline into the ocean. Groins are designed to trap and accumulate sand that is carried along the beach by waves and currents, but may lead to erosion on the down-current side of the groin.

Hardening - see **Armoring.**

Hurricane – a storm characterized by a cyclonic (circulating) air mass with wind speeds greater than 75 miles per hour.

Inland sand dune – A naturally-formed mound or ridge of sediment located inland from the coast. Inland dunes can be found miles from the coastline and usually indicate that the area in which they are found was formerly submerged.

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

Littoral cell – a stretch of shoreline in which sediment transport occurs without significant interruption. Usually contains both sediment sources (ie. dunes or offshore sand fields) and sediment sinks or accretion terminals (ie. sand spits, sand channels).

Littoral sediment budget - the sediment (usually sand) budget of the littoral cell consisting of sources (influx of sediment) and sinks (loss of sediment).

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

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

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

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

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

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

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

Revetment - a sloping wall usually constructed from large, interlocking boulders that are not cemented together. Revetments are designed to stop the erosion of the land into the ocean and tend to have a rougher (less reflective) surface but larger footprint than seawalls.

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

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

Sea-level rise – a rise in the surface of the sea due to increased water volume of the ocean and/or sinking of the land. Sea level rise in Hawaii results from a combination of globally occurring sea level increases and **subsidence** of the Hawaiian islands.

Seasonal erosion – temporary erosion caused by seasonal wind and/or wave conditions. Recovery from seasonal erosion often takes place during the opposite season (ie. recovery from winter erosion often takes place during the summer).

Seawall - a vertical or near-vertical wall parallel to the ocean, most often built of concrete or grouted rocks. Seawalls are designed to stop the erosion of land into the ocean and are often located at the interface between land and sea.

Sediment plume – particles of silt or clay suspended in the water column, causing a discoloration of the water.

Shoreline – a location represented by the highest annually recurring reach of the waves. This is sometimes roughly represented by the vegetation line, or by a line of debris during the season of high surf.

Shoreline area – all of the land between the shoreline and the shoreline setback line.

Shoreline setback - the boundary seaward of which building may not take place. Setback requirements are established by the individual counties, and may be arbitrary distances based on lot depth, or variable distances based on erosion rates.

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

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

Swell – ocean waves built by winds. Can travel across entire oceans with little energy loss. Cause breaking waves in shallow water.

Subsidence – sinking. In reference to the Hawaiian Islands, the islands are sinking at different rates due to geologic activity taking place in the earth's crust.

Zooxanthellae - unicellular, symbiotic algae living within coral polyps that produce food for their hosts by photosynthesis and help efficiently recycle low-levels of nutrients.

REFERENCES

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

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

CALHOUN, R.S., FLETCHER, C.H., AND HARNEY, J.N., (2002) A budget of marine and terrigenous sediments, Hanalei Bay, Kauai, Hawaiian Islands. Sedimentary Geology, 150, 1-2, 61-87.

CHURCH, J.A., AND WHITE, N.J., 2006. A 20th Century Acceleration in Global Sea-Level Rise. *Geophysical Research Letters,* Vol. 33, L01602.

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

EVERSOLE, D., AND NORCROSS-NU'U, Z., 2006. *Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawaii: A Practical Guide of Common Questions and Answers.* University of Hawaii Sea Grant Publication UNIHI-SEAGRANT-BA-06-03. 26p.

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

FLETCHER, C.H., ROONEY, J., BARBEE, M., LIM, S.-C., AND RICHMOND, B., 2003. Mapping Shoreline Change Using Digital Orthophotogrammetry on Maui, Hawaii. *Journal of Coastal Research,* 38, 106-124.

HANZAWA, 2006. *Maui Inland Sand Resource Quantification Study*. Prepared for the County of Maui Department of Public Works & Environmental Management. Prepared by SSFM International, Inc. 23p.

HARNEY, J.N., AND FLETCHER, C.H. (2003) A budget of carbonate framework and sediment production, Kailua Bay, Oahu, Hawaii. Journal of Sedimentary Research, v. 73, no. 6, p. 856-868.

HARNEY, J.N., GROSSMAN, E.E., RICHMOND, B.M., AND FLETCHER, C.H. (2000) Age and composition of carbonate shoreface sediments, Kailua Bay, Oahu, Hawaii: Coral Reefs, v. 19, pg. 141-154.

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

HWANG, 2005. *Hawaii Coastal Hazard Mitigation Guidebook*. A publication of the Hawaii Coastal Zone Management Program, Office of Planning, Department of Business, Economic Development & Tourism, State of Hawaii. 216p.

IPCC, 2007. Climate *Change 2007: The Physical Science Basis, Summary for Policymakers.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 21p.

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

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

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

OVERPECK, J.T., OTTO-BLIESNER, B.L., MILLER, G.H., MUHS, D.R., ALLEY, R.B., AND KIEHL, J.T., 2006. Paleoclimatic Evidence for Future Ice Sheet Instability and Rapid Sea-Level Rise . *Science,* 311: 1747-1750.

RAHMSTORF, S., 2006. A Semi-Empirical Approach to Projecting Future Sea-Level Rise. *Science (Sciencexpress 14 December 2006)*, 1-10.

RAHMSTORF, S., CAZENAVE, A., CHURCH, J.A., HANSEN, J.E., KEELING, R.F., PARKER, D.E., AND SOMERVILLE, R.C.J., 2007. Recent Climate Observations Compared to Projections. *Science,* 316: 709.

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

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

WEST MAUI WATERSHED MANAGEMENT ADVISORY COMMITTEE, 1997. *West Maui Watershed Owners Manual*. 92 p.

Williams, I., Sparks, R., and Smith, C., 2007. Status of Maui's Coral Reefs. Two-page report supported by the Hawaii Department of Land and Natural Resource, Division of Aquatic Resources, and the Hawaii Coral Reef Initiative.

Appendix A

Background information on beaches, reefs, erosion, water quality, and human impacts on coastal ecosystems.

Coastal Ecosystems

Beaches

A beach is defined as an accumulation of sediment—usually sand or gravel—that occupies a portion of the coast. The **active beach**, the area of loose sediment subject to transport by wind, waves, and currents, is divided into three regions: the **backshore** and dune, the **foreshore**, and the offshore, as shown in Figure a. The active beach is backed by the **coastal upland**, which can be a dune field, a cliff, a rocky substrate, a soil embankment, a fossil **berm**, or an engineering structure such as a seawall or a revetment. Common geomorphic features of the beach include dunes, berms, **scarps**, and offshore sand bars.

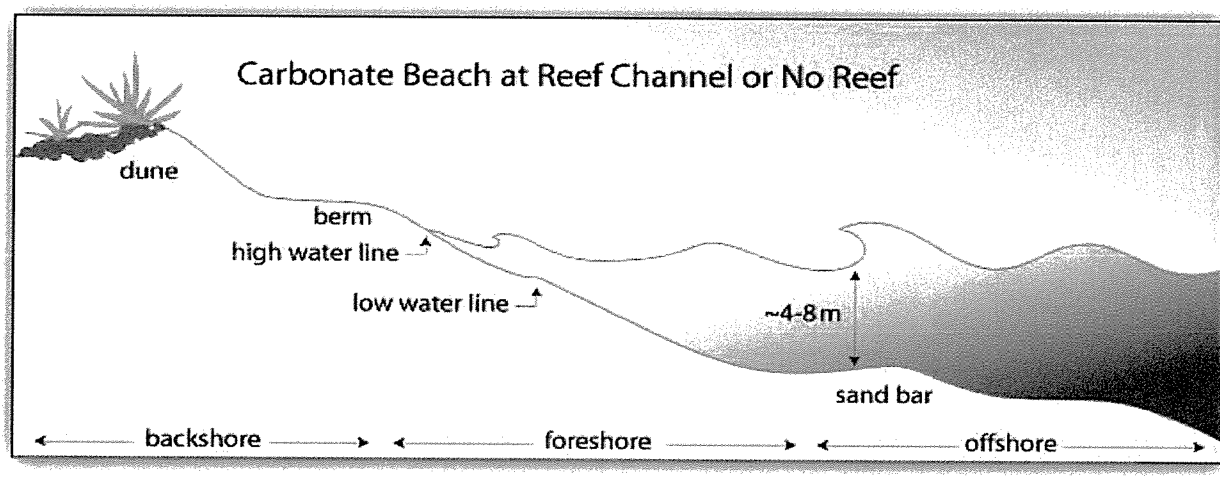


Figure a. Common features of a beach system in Hawaii with no offshore reef. (*Image: University of Hawaii SOEST*)

Many Hawaiian beaches have fringing reefs located close to shore in shallow water (Figure b). The reefs, which can extend from tens to thousands of feet offshore, are usually transected by channels that cut through the reef. The channels are often partially filled with sand and may connect the beach to offshore sand fields.

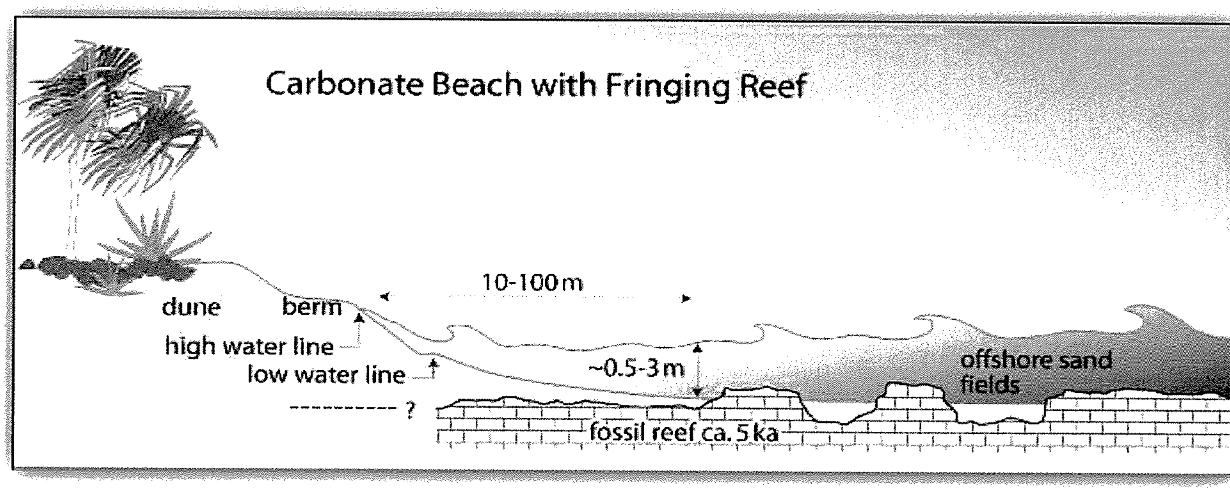


Figure b. Common features of a beach system in Hawaii with a fringing reef. (*Image: University of Hawaii SOEST*)

The amounts and fluxes of sediment in a beach are collectively known as the littoral sediment budget. Healthy beaches are in a state of **dynamic equilibrium**, where the net influx of sediment—or sources, approximately equals or exceeds the net loss of sediment—or sinks. Sources of beach sediment include skeletal material from coral reef ecosystems, onshore transport of sand from deposits in the form of sand fields or sand channel deposits, **longshore transport**, headland erosion, volcanic glass, river input, and erosion (scarping) of the coastal upland. Sediment sinks include loss to deep water, harbors, and channels, offshore transport, longshore transport, impoundment by engineering structures, and **storm surge overwash**. When there is an imbalance between sources and sinks, the beach will either erode or accrete.

Beaches are fed by sand that comes from several sources. Waves can bring sand to a beach from the surf zone as well as from neighboring beaches. Sand can also come from landward sources when sandy land erodes. In Hawaii many of the lands located behind beaches are low sandy coastal plains bordered by fields of sandy dunes created by onshore winds and fossil beach ridges deposited by higher sea level ca. 1500 - 3000 years ago (Harney and Fletcher, 2003; Calhoun et al., 2002; Harney et al., 2000).

When a beach erodes it is experiencing a loss of sand, a deficiency in its sand "budget." To correct this deficiency new sources of sand are needed. When erosion happens, the beach initially narrows. Waves then have access across the narrow beach to the sandy dunes. These dunes yield sand to the waves, which in turn nourish the beach. It is appropriate to think of the beach like you think of your personal banking. The beach is analogous to a checking account that has frequent withdrawals and deposits by low and moderate energy waves. When large waves hit, the beach erodes and needs to draw from its savings account of sand: the dunes. Human management of sand sources means that dunes, neighboring beaches, and offshore sources are important to the beach, and must be managed with this in mind.

Scientists have radiocarbon dated Hawaii beach sands and found that they are thousands of years old (Harney et al., 2001). Dated sand from offshore tends to be younger, while sands from dunes tend to be similar in age to beach sand. The explanation for this is that chronically eroding beaches are likely using the dunes as an important source of sand. In a sense, eroding beaches are relying on eroding dunes for their sand. If you imagine a landward migrating beach that uses dunes as its primary source of sand, it is not hard to see that the beach can stay wide and healthy as long as dunes are plentiful. Unfortunately, along many developed shores we have lowered the natural dunes and often removed them entirely in order to gain a view of the ocean or put in landscaping. This is unfortunate in that the savings account of sand for eroding beaches has been removed, and this is likely to cause them to narrow and often disappear entirely. On shores where the land behind a beach is clay or rock, the primary source of sand must be from neighboring beaches or offshore sources and eroding dunes play a less important role.

Coastal processes such as erosion and accretion are site-specific, season-specific, and interannual. Different beaches have different geomorphic characteristics and are subject to different oceanographic conditions. Beach processes can vary dramatically from one end of a particular beach to the other. Site-specific factors such as extent and health of coral reefs, alterations to dune systems, sediment runoff from upland areas, and other human activities also affect coastal processes. Wave and current patterns change dramatically from season to season, and from **swell** to swell. Because of these variations, each segment of each beach will have its own history of erosion and accretion trends.

Sand Dunes

Coastal dunes are mounds or ridges of unconsolidated sand contiguous and parallel to the beach (Figure c). Coastal dunes can be created by wind picking up sand grains off the beach and blowing them landward where they accumulate and are trapped by vegetation or other obstacles, or by storm waves pushing sand up the beach, or by a combination of both processes. Although some dunes are bare, most are vegetated with coastal plants, which help stabilize the dune. Vegetation

Figure c. Coastal dune at Spreckelsville, Maui. *(Photo: Zoe Norcross-Nu'u)*

traps wind-blown sand and then grows up through the new sand accumulation. This process is repeated to build larger dunes. The root system of native plants slows coastal erosion during high-wave events and helps trap wave- and wind-deposited sand during post-event recovery. Many dunes are host to burial sites and are legitimate environmental systems that support specific ecosystems. Because of their cultural and environmental sensitivity, many dunes are worthy of protection.

In 2003, the Maui County Code was amended to better protect coastal dunes. The updated ordinance specifies that any grading of the primary frontal dune – the first dune encountered mauka of the beach – is prohibited. The amendments also require a dune delineation as a submittal for a grading permit for coastal properties, prohibit the grading of any dunes located in the shoreline setback area, and specify that any fill used in the setback area must be beach quality sand.

Dunes are dynamic features; they frequently erode during periods of high waves and accrete during normal wave conditions, but are sometimes built up or shifted landward by storm wave activity. Dunes act as buffers for high surf events, absorbing the energy of the incoming waves and protecting inland structures from flooding and wave damage. During a storm or a large swell, waves may attack and erode the dune (See Figure 13, p.?). This process, known as **scarping**, releases sand that was stored in the dune to the active beach. The influx of sand is often carried offshore to build sand bars, which help attenuate incoming wave energy. Erosion of pristine coastal dunes does not release silt to the near-shore area, degrade water quality, or harm the coral reef ecosystem since these dunes are composed of clean sand. When storm waves subside, normal waves dismantle the offshore bars and rebuild the beach. Although some sand may be permanently removed from the beach system (transported to deep water by sand channels), eventually much of this beach sand is reincorporated into the dune.

Coral Reef Ecosystems

Coral reefs are also important components of the beach system. Reefs are natural breakwaters; they absorb much of the incoming wave energy and help protect the shoreline from wave attack. Without the wave buffering and sand production that coral reefs provide, rates of coastal erosion and beach loss would be significantly higher.

Furthermore, coral reefs provide habitat for a rich diversity of marine life (Figure d). Many reef organisms build their skeletons and shells out of calcium carbonate. When these organisms die, their skeletal remains are transported to the beach or are cemented into the framework of the reef. Most of the light-colored sand on beaches is derived from coral reefs and reef-dwelling marine organisms.

Figure d. Healthy coral reef system at Honolua bay, Maui. (Photo: Donna Brown)

Coral reefs are sensitive environments that require pristine coastal water quality. Corals are very efficient marine organisms that thrive in nutrient-poor environments. This is because coral polyps contain **zooxanthellae**—unicellular, symbiotic algae that produce food for their hosts through photosynthesis. Photosynthesis requires sunlight, and the depth and intensity of sunlight penetration is reduced by suspended sediment, such as mud or silt. Silt can also settle out on corals and interfere with feeding and recolonization.

Corals can survive occasional short-term **siltation** events. When stressed they produce mucus, which helps them shed the fine-grained sediments that have settled upon them. However, repeated or chronic silt plumes or a single large event will kill coral. Nutrient loading is also harmful to coral reefs. Excess nutrient levels in coastal waters can lead to algal blooms, which compete with coral colonies for space and light and disrupt the coral reef ecosystem.

Coastal Erosion, Beach Loss, and Coral Reef Degradation

Historical shoreline change studies conducted by Makai Ocean Engineering, Inc. and Sea Engineering, Inc. (MAKAI OCEAN ENGINEERING, INC. AND SEA ENGINEERING, INC., 1991), and by the University of Hawaii Coastal Geology Group (FLETCHER ET AL., 2003), reveal that Maui's sandy shorelines are eroding at an average rate of approximately 1 foot per year. Further, the University of Hawaii study found that over 8 km of Maui's beaches have been lost and another 19% of beaches have experienced significant narrowing over the period of 1949/1950 to 1997/2002.

Based on field and photographic observations, nearly all of this beach degradation is in front of or adjacent to shoreline armoring such as seawalls and revetments (Figure e). Typically, these armoring structures are erected when coastal erosion threatens oceanfront development. Armoring the shoreline usually halts coastal erosion and protects property and structures, but on sandy shorelines undergoing long-term retreat, it often leads to beach loss

Figure e. A seawall (foreground) and revetment (background), built to protect private residences, have led to complete beach loss on this Kihei, Maui shoreline. (*Photo: Zoe Norcross-Nu'u*)

(FLETCHER, ET AL., 1997). The impact that armoring has on the adjoining beach creates a conflict between the rights of coastal property owners to protect their land and the rights of the public to access the beach and ocean.

In the summer of 2003, an intern was hired by the Maui Planning Department to conduct a shoreline hardening inventory for the island of Maui. Of approximately 56 miles of shoreline surveyed with a Trimble GPS GeoExplorer III, 15.6 miles were found to be hardened. There were 371 structures, 66% of which are likely to be having a negative impact on coastal processes or public access.

Coastal and Beach Erosion

Sea-level rise, wave and current impacts, and human activities lead to the sediment deficiencies that drive coastal and **beach erosion** (Figure f). The longer-term effects of sea-level rise and human activities are often more difficult to detect than the dramatic erosional impacts of seasonal high surf events. Upon closer observation, however, signs of long-term erosion may be seen. Examples of such signs exist in the form of fallen or leaning trees, scarps at the seaward edge of vegetation, makeshift erosion control measures such as discarded vegetation or old military pillboxes that were once located up on the dune and are now partially submerged as the sand has retreated.

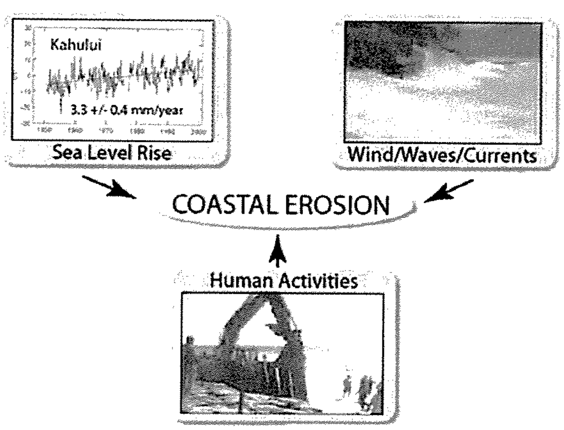


Figure f. Sand deficiencies that lead to erosion result from both natural and human-induced causes. (*Image: Zoe Norcross-Nu'u*)

An important distinction exists between coastal erosion and beach erosion. While coastal erosion describes a retreat of the shoreline position, frequently the beach width is preserved as the entire shoreline shifts landward. Sediment stored in upland deposits is released to supply the beach with sand as the shoreline retreats. In contrast, beach erosion describes a condition in which a sandy beach experiences narrowing and loss of sand due to an absence of sediment supply, resulting from either impoundment of the supply by a structure, or simply from the lack of a marine or upland sand supply. The next paragraphs look more closely at the factors leading to erosion.

1) Sea-Level Rise

Shoreline position may change due to global sea-level rise (erosion), sediment deficiency (erosion), sediment excess (accretion), or a combination. Global sea-level rise, currently averaging 3.3 +/-0.4 mm/year (1993-2006; Rahmstorf, et al., 2007), causes a **littoral system** with a balanced or deficient sediment budget to shift landward by eroding the upland area—usually a coastal dune or the coastal plain. This natural process, known as coastal erosion, has occurred for millennia as sea level has risen over 110 meters since the last ice age (Figure g). The retreat of the shoreline—and associated loss of coastal lands—is the natural response of the beach to rising sea levels (TAIT AND GRIGGS, 1990) and has been the underlying premise of coastal engineering theory for over 40 years (e.g. "The Bruun Rule", BRUUN, 1962). Shorelines with an excess sediment budget may continue to accrete or may shift to erosional behavior depending on the relative balance of sediment influx and sea-level rise. The average rate of erosion for Maui's sandy beaches has been 1 foot per year over the last century (FLETCHER ET AL., 2003).

The influx of sediment released to the active beach by erosion of coastal uplands, helps maintain beach width. Erosion of coastal uplands consisting of clay banks or terraces, however, contributes very little material to beaches, as the fine clay particles become suspended in the ocean, creating reddish or brown **sediment plumes**.

Recent evidence has shown that sea-level rise has accelerated over the last decade (CHURCH AND WHITE, 2006). Further, rates of sea-level rise are

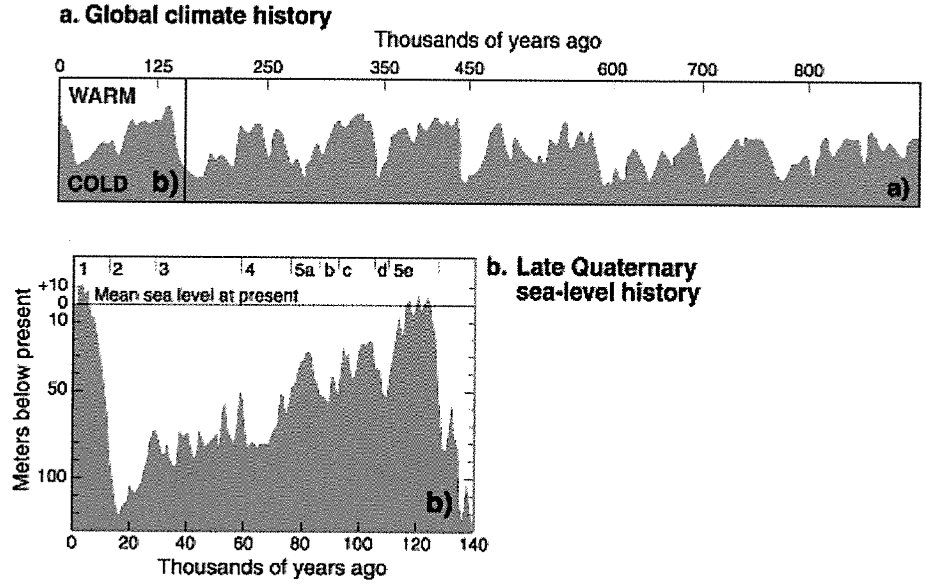


Figure g. Fluctuations of global climate history and sea level history through time. The rise and fall of sea level over the last 140,000 years roughly corresponds with the rise and fall of global temperature. (*Image: University of Hawaii SOEST*)

projected to accelerate over the next century, with up to one meter or more of sea-level rise expected in the next century (Rahmstorf, 2006; Overpeck et al., 2006). The Intergovernmental Panel on Climate Change (IPCC, 2007) projects sea level rise of 0.18 to .059 m by the end of the century, but their analysis does not include the behavior of major ice sheets which by melting may increase these levels. Evaluation of IPCC modeling by Rahmstorf et al (2007) reveals that since 1990 the observed sea level has been rising faster than the rise projected by models. The implications of such a dramatic increase in sea level are widespread, including inundation of low-lying areas, increased vulnerability to storm damage, aquifer contamination by saltwater intrusion, damage to public infrastructure and utilities, the formation of new wetlands, and growth in areas of poor drainage. On coasts with beaches the first evidence of accelerating sea-level rise that we are likely to see is an increase in shoreline retreat and coastal erosion; indeed, severe and worsening erosion problems are already affecting all of Maui's coasts. On coasts that have been heavily developed and urbanized, the first indication of sea-level rise is likely to be expansion of rain-flooded areas because of high water tables and poor drainage (Figure h).

2) Wind, waves and currents

While sea-level rise often contributes to long-term or **chronic erosion**, seasonal variations in wind, wave and current patterns lead to short-term or **seasonal erosion**. As the name implies, this erosion is part of an annual, seasonal cycle that is usually followed by partial to complete recovery of the beach, or accretion, under the opposite seasonal conditions. Typically, seasonal conditions on Maui include swells out of the north in the winter; swells out of the south during the summer; trade winds out of the east and northeast all year but stronger and more consistent during the summer; and, occasionally, strong rain-bearing winds called Kona Storms out of the south in the winter (Figure i). Seasonal erosion and accretion can take place gradually over a period of months, or rapidly over a period of days, depending on the strength, direction and duration of the event (Figure j). Seasonal erosion often recovers during fair-weather or off-season waves. However, superimposed on long-term sea-level rise, erosion caused by seasonal high swell may experience a reduced ability to fully recover and the shoreline may establish a new, landward position that is in equilibrium with higher sea level.

Figure h. Floodwater drainage problems such as that shown here on South Kihei road will occur with greater frequency as sea level and the water table rise. (*Photo: Zoe Norcross-Nu'u*)

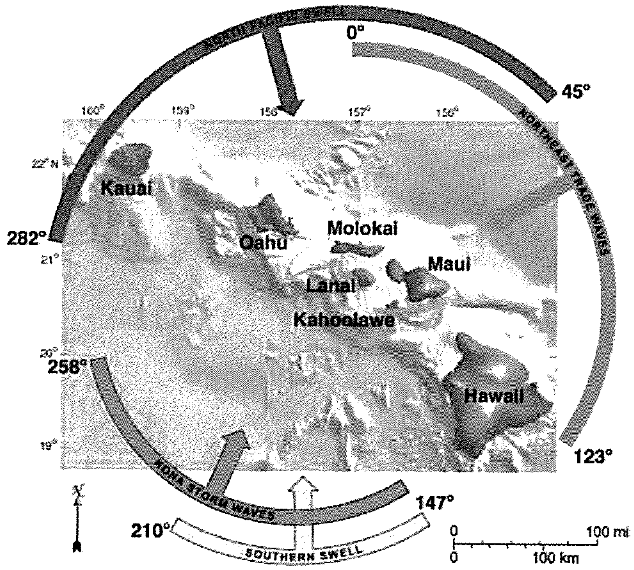


Figure i. Prevailing wave directions for the Hawaiian Islands. (*Image: University of Hawaii SOEST*)

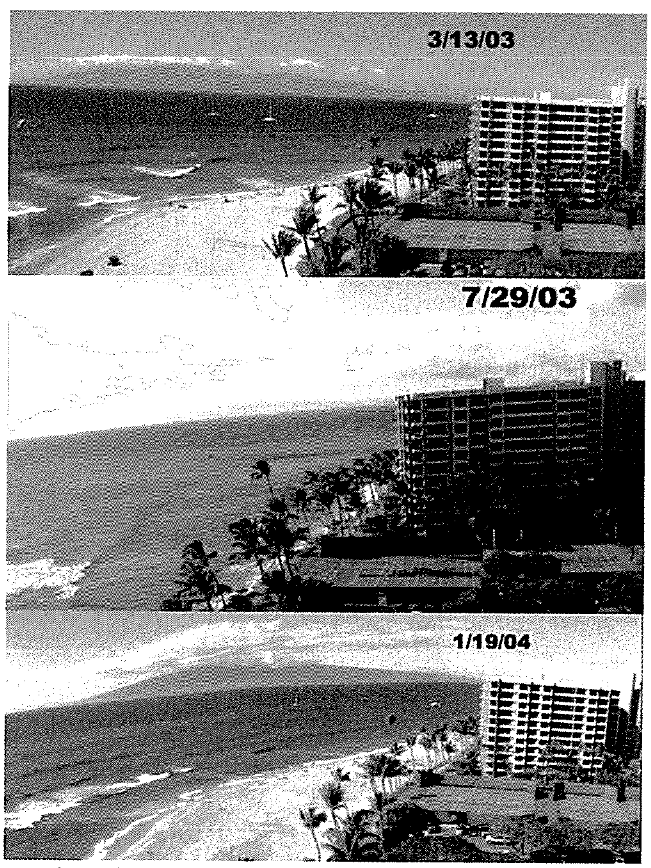


Figure j. Seasonal beach erosion and recovery at Kaanapali, Maui. (*Photos: Robb Cole*)

3) Human activities

Certain human activities create sediment deficiencies and aggravate coastal erosion. These include sand mining, dune alteration (e.g., dune grading or damage from foot or vehicular traffic), and sand impoundment. Sand impoundment results when shoreline structures such as seawalls, revetments, and groins, trap sand that would otherwise have been released to the beach by erosion or wave action. Other human activities such as construction of harbors and navigational channels, and actions leading to the degradation of coral reefs, can also contribute to sediment deficiencies.

3a) Sand mining

Sand mining on the beach removes sediment from the littoral system leading to beach narrowing and **deflation**. Until the early 1970's, large volumes of sand were mined from beaches around Maui to provide cement aggregate for construction and lime for sugar cane processing. Mining of sand from the beach was prohibited in 1986, but it is likely that impacts from historic mining operations continue to aggravate beach loss in formerly mined areas.

3b) Dune alteration

Dune grading entails bulldozing the upper portion of the dune to flatten it, often in order to allow an unobstructed view of the ocean or as part of building construction. This practice sharply reduces the dune's natural capacity to buffer coastal erosion and other coastal hazards. Furthermore, if the dune area is covered with soil fill, subsequent coastal erosion will release silt and other fine-grained sediments to the ocean, which degrade water quality. The Maui County Code was updated in 2003 to prohibit grading of any frontal dune or any dune in the shoreline area. In addition, the code now prohibits the use of soil as fill in the shoreline setback area.

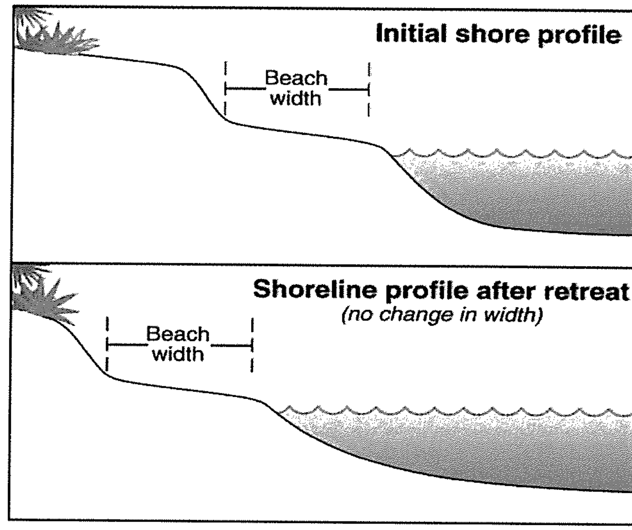
Unrestricted foot traffic or vehicular traffic on dunes destroys and prevents vegetation from growing. Without the sand-trapping protection offered by groundcover, dunes often undergo deflation as the wind carries the bare sand further inland and out of the active beach system. Where beach access paths or drainage outlets are aligned parallel to the prevailing wind direction, **blowouts** often occur as a result of the funneling effect of wind through openings in the vegetation (Figure k). These areas often experience heavy sand loss mauka of the dune system.

Figure k. Dune blowout at Spreckelsville, Maui. (*Photo: Zoe Norcross-Nu'u*)

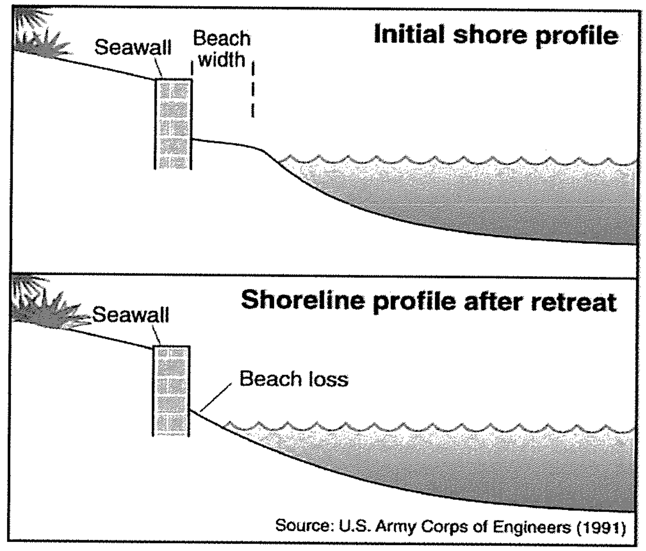
3c) Sand Impoundment

While not all shoreline structures lead to erosion, armoring on sandy shorelines undergoing long-term retreat with structures such as revetments and seawalls halts coastal erosion, but refocuses the erosion onto the beach in front of the structure (TAIT AND GRIGGS, 1990; FLETCHER ET AL., 1997). Sand that is trapped behind a structure is unable to be released to feed the beach, and the beach is deprived of its main source of sediment (Figure l). This leads to beach narrowing - a decrease in the usable beach width - and beach loss, the volumetric loss of sand from the active beach such that it is submerged at high tide. Coastal armoring often aggravates erosion along **downdrift** properties by decreasing the supply of sediment to downdrift areas.

Groins are linear rocky structures built perpendicular to the shoreline, which trap sand moving along the shoreline (Figure m). While they may be successful in building up sand on the up-drift side of the structures, the down-drift side of a groin often ends up experiencing erosion as the longshore sediment supply has been cut off by the groin.



A beach undergoing net longterm retreat will maintain its natural width.



Beach loss eventually occurs in front of a seawall for a beach experiencing net longterm retreat.

Figure l: Beach response to chronic retreat on an unarmored vs. armored shoreline. (*Image: University of Hawaii SOEST*)

3d) Harbor/navigation channel construction

Harbors and navigational channels can interfere with sediment transport. Sand moved by nearshore waves and currents is deposited in these artificial depressions and is removed from the littoral system. In such instances, if the sediment that accumulates is not contaminated, it should be returned to the local littoral system when the harbor is dredged. Harbor and navigational channel construction also compromise the reef's wave buffering capacity. If a portion of the reef is dredged during harbor and channel construction, larger waves can reach the shoreline and accelerate erosion.

Figure m. Groin at Kahului, Maui. (Photo: Rick Nu'u)

3e) Reef and Water quality degradation

Several human activities degrade water quality and harm coral reef ecosystems. Since most carbonate sand – the white and tan sand found on most of Hawaii's beaches – ultimately derives from the coral reef ecosystem, poor water quality reduces the amount of sand produced by the reef and delivered to the beach. Impacts to water quality caused by human activities include: siltation, nutrient loading, and **polluted runoff** (Figure n). The erosion of dirt embankments or coastlines that have been artificially filled releases fine sediments to the nearshore waters. Furthermore, the significant increase in drainage outlets for recent developments and concrete channelization for flood protection have both had significant impacts on nearshore water quality and sediment loads.

In addition, over-fishing can deplete the reef ecosystem of certain species of fish and upset the ecological balance necessary for healthy coral reef ecosystems, and introduced species have disrupted the preexisting food web, which also disrupts the reef ecosystem. Finally, anchoring on reefs causes physical damage to coral, as does standing on or touching these sensitive ecosystems.

Managing Coastal Processes

The site-specific history of coastal processes for a particular beach segment must be assessed to help guide the most effective beach management practices. Certain management tools—beach nourishment and dune restoration, for example—can counteract coastal erosion and beach loss. Other management tools—such as requiring sufficient building setbacks and wiser construction codes—can delay or prevent the need to armor the shoreline to protect beachfront development. Hence, coastal erosion does not necessarily present a conflict between coastal property owners and the public. Erosion can be mitigated through effective beach management strategies.

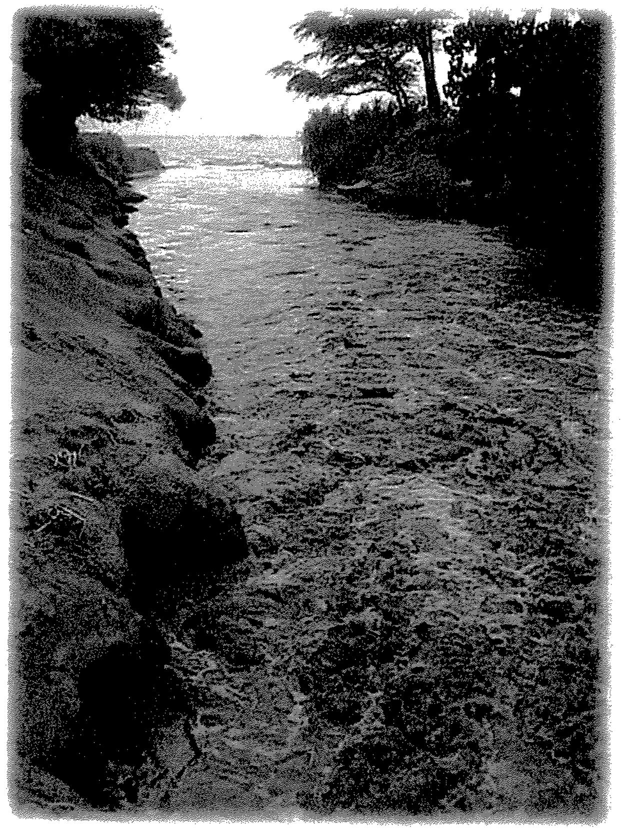


Figure n. Polluted runoff at Kihei, Maui