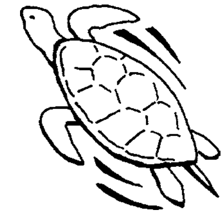


Activity #3

Causes and Consequences of Coastal Erosion

● ● ● In Advance *Student Reading and Questions*

- As homework, assign the Student Pages "Beaches on a Budget: Why Do Beaches Come and Go?" (pp. 42-45) and "Beaches on a Budget: Questions About the Reading" (pp. 46-48).

● ● ● Class Period One *Coastal Erosion Projections*

Materials & Setup

For each lab group of three to four students

- "Baldwin and Kanahā Beach Aerial Photo" acetates (master, pp. 40-41)
- Baldwin and Kanahā "Beach Study Maps and Graphs" (legal-size masters included with this curriculum). Each lab group should have the information that corresponds to its assigned beach.
- Two copies of the Student Page "Coastal Erosion Projections" (pp. 49-51)
- Overhead projector
- One sheet of legal-size or larger paper
- Colored pens or pencils
- Masking tape

For each student

- Student Page "Beaches on a Budget: Why Do Beaches Come and Go?" (pp. 42-45)
- Student Page "Beaches on a Budget: Questions About the Reading" (pp. 46-48)
- Student Page "Beach Management Alternatives" (pp. 52-53)

Instructions

1) Review student questions and responses to the homework, especially question #7 in which they explained the impact of shoreline armoring and longshore currents on beach erosion and accretion. This question is designed, in part, to help students understand how longshore currents transport and deposit sediment along coastlines, and how disrupting this current can lead to changes in the normal patterns of beach erosion and accretion.

2) Divide the class into lab teams of three to four students. Give each team a copy of the Beach Study Map and Graph for *either* Kanahā or Baldwin beach.

3) Explain that the black-and-white photos and maps are excerpts from a study published in 1991. The study looked at coastal erosion by comparing aerial photos taken in 1950, 1964, 1975, 1987,

and 1988. At each of several transects, the authors calculated the rate of coastal erosion during intervals between photos. They looked at the changing location of the coastal vegetation line to track erosion and accretion. The results are presented in the graphs that accompany each map.

4) Project the "Baldwin Beach Aerial Photo" and "Kanahā Beach Aerial Photo" acetate onto the groups' legal-sized or larger papers taped to the wall. Have each group trace its assigned beach from this image, including the water line and the vegetation line, along with any shoreline armoring that appears on the map and important reference points such as roads or large, recognizable facilities. Students can use the line-drawn maps from the 1991 study as a guide for which features could be useful to include on their tracing. When they have finished tracing the color image, they should add and number the transect lines from the corresponding "Beach Study Map and Graph."

5) Have students complete the steps and answer the questions on the Student Page "Coastal Erosion Projections."

6) After lab groups finish their work, have a class discussion to compare results and talk about how these kinds of projections can contribute to coastal management decisions.

7) Assign the Student Page "Beach Management Alternatives" as homework.

Journal Ideas

- How should projections for future shoreline erosion affect people's decisions about where and how to build houses, hotels, condominiums, roads, and other structures?
- How far into the future do you think people should look when weighing the benefits and drawbacks of shoreline armoring such as seawalls and groins?

Assessment Tools

- Student Page "Beaches On a Budget: Questions About the Reading" (teacher version, pp. 35-37)
- Traced paper maps (evaluate for neatness and accuracy)
- Student Page "Coastal Erosion Projections" (teacher version, pp. 38-39)
- Short paper describing how Baldwin or Kanahā beaches should be managed
- Participation in group work and class discussion
- Journal entries

Teacher Version

Beaches on a Budget: Questions About the Reading

1) What is an active beach?

The part of the beach where sediment transport occurs

2) What is the opposite of shoreline erosion?

Accretion

3) Explain the term "littoral budget," using at least two examples of sources and sinks.

A littoral budget is the amount and movement of sediments to and from the shoreline—between different parts of the active beach, onto the beach from elsewhere, and away from the beach to another location offshore or down-current.

Sources include

- skeletal material from coral reef ecosystems,
- offshore deposits of sand that may be transported onshore by waves and currents,
- other beaches from which longshore currents and wind can transport sediments,
- erosion of headlands and coastal uplands,
- materials from new volcanic eruptions and lava flows, and
- sediments carried from inland by streams and rivers.

Sediment sinks include:

- loss of sediments to deep water;
- harbors and channels, which trap sand moving along or across the near-shore area;
- transport of sediments offshore or along the shoreline to other beaches by currents and waves;
- impoundment (trapping) behind seawalls, revetments, and other structures;
- over-wash by high storm waves and surges; and
- wind loss inland due to strong onshore winds.

4) Describe the cycle of sand dune building, scarping, and rebuilding that happens during and after large storms.

High waves during storms and large swells erode the beach. And they erode the dune, too. This process, known as scarping, releases sand that was stored in the dune to the active beach. The influx of sand from the dune is often carried offshore where it accumulates into sandbars. These sandbars intercept large waves before they reach shore, lessening their impact on the coastline.

When the high-wave event subsides and normal wave patterns return, the waves dismantle the offshore sandbars and rebuild the beach. Although some sand may have been permanently washed away from the beach system into deep water by the storm, eventually the beach and the dunes regenerate to their prestorm profile. Most of the sand transported offshore during storms and stormy seasons eventually is reincorporated into the dune.

5) Name two reasons why coral reefs are important to healthy beaches.

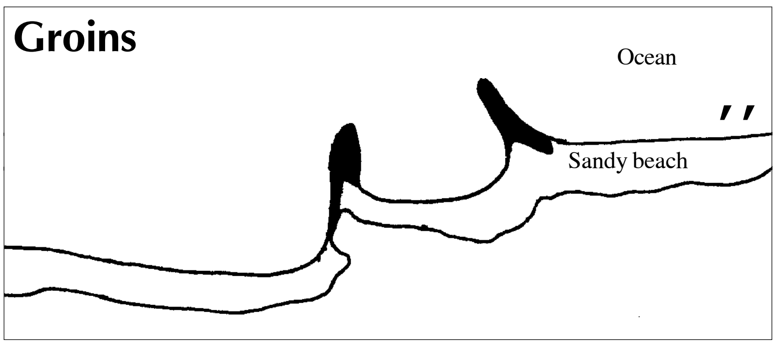
- They act as natural breakwaters, absorbing wave energy and helping protect the shoreline from wave erosion.
- They are important sources of sand production.

6) Describe two human activities that aggravate coastal erosion and reduce the amount of sand available to the beach.

Activities include
- Shoreline armoring,
- Sand mining,
- Grading dunes, and
- Maintaining and expanding harbors and navigational channels.

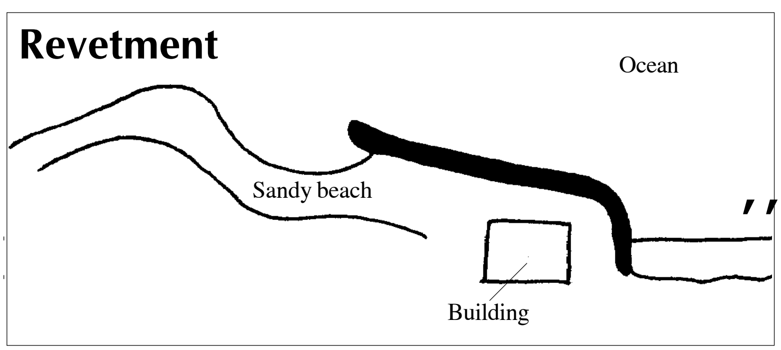
See Student Page “Beaches on a Budget” (p. 44) for descriptions of each activity.

7) True to their name, “longshore” currents run along or parallel to the shore. These currents are important mechanisms for transporting sediment within the beach system. Sediment transported along shore feeds beaches along the entire coastline. Shoreline armoring interferes with longshore sediment transport. The diagrams below illustrate two different types of shoreline armoring that have been in place for several years. For each diagram:
   a) Draw in the direction of the longshore current, and
   b) Explain how the pattern of beach erosion and/or accretion is related to the armoring structure and the longshore current.



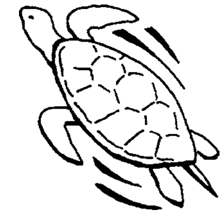
Longshore current

The groins have trapped sand behind them, causing accretion on the up-current side while robbing down-current beaches of their normal source of sediment transported by longshore currents.



Longshore current

The beach area just down-current from the revetment is heavily eroded because the revetment cut off a continuing source of sediment for the longshore current to pick up and deposit there.



Teacher Version

Coastal Erosion Projections

Use your traced paper image of your beach and the space provided on this page to project changes in the coastline over time.

BEACH NAME: ____________________________________

1) The 1991 study graphs changes in the vegetation line between 1950 and 1988. For each transect on your beach segment, calculate an average annual rate of change, and record your calculations and answers below:

Transect #	Annual rate of change (+ or -)
Kanahā 5	-1.5 ft/year
6	-4.74
7	-4.08
8	3.53
9 (not on aerial photo)	5
Baldwin 17	.47 ft/year
18	-1.1
19	-2.89
20	-.39

2) You are going to be mapping projected shoreline changes based on the annual rate of change you calculated above. You will do this using the 1997 aerial photo (your traced paper image of it) as a baseline. Before you start mapping, you need to do some more calculations. Using the annual rate of change for each transect line, calculate the total erosion or accretion likely to occur by 2027 and 2057. Calculate these changes using 1997 as your starting date.

Transect #	Change (+ or -) by 2027	Change (+ or -) by 2057
Kanahā 5	-43.5 ft	-87 ft
6	-142.2	-284.4
7	-122.4	-144.8
8	105.9	211.8
9 (not on photo	.13	.26
Baldwin 17	14.1 ft	28.2 ft
18	-33	-66
19	-86.7	-173.4
20	-11.7	-23.4

3) Now mark the 2027 and 2057 vegetation lines on each of the transects on your traced paper map. (Extrapolate the scale on your traced paper map using the “Beach Study Map and Graph.”)

   Use these points and any clues you can glean from the existing shoreline features to draw an anticipated vegetation line for 2027 and 2057. (Using different-colored pens or pencils for each line helps make the map clearer.)

   With a dashed line, indicate where you think the water line will be in 2027 and 2057.

   Label your map clearly.

4) Looking at your traced paper map, as well as the photos, maps, and information from the 1991 study, describe any patterns of erosion and accretion that you see. What might explain these patterns?

   Well-reasoned responses are acceptable. The primary patterns are associated with shoreline armoring (e.g., accretion up-current and erosion down-current, or even complete erosion of the beach behind the groin).

5) In 1992, researchers estimated that 62 percent of the Maui shoreline is eroding at a rate of 1.25 feet per year. How do the erosion/accretion rates you calculated compare with that average?

   The average rate of erosion taken across all nine transects is 1.16 feet per year, slightly less than the Maui average. However, in certain places, particularly at Kanahā beach, the rates of erosion are much higher than this average, and in other places the shoreline is accreting.

6) Use your projections to identify areas where you think development should be restricted because of the potential for shoreline erosion, and areas that you think would be appropriate for development. Explain your reasoning for these areas here.

   Well-reasoned responses are acceptable

Baldwin Beach Aerial Photo

Photo: Air Survey Hawai'i

Kanahā Beach Aerial Photo

Photo: Air Survey Hawai'i

Beaches On a Budget: Why Do Beaches Come and Go?

Adapted from the Hawai'i Seagrant website, Beach Plan for Maui*, "Coastal Ecosystems" and "Coastal Erosion, Beach Loss, and Coral Reef Degradation," accessed May 25, 2000 at <www.soest.hawaii.edu/SEAGRANT/bmpm/coastal_ecosystems.html> and <www.soest.hawaii.edu/SEAGRANT/bmpm/coastal_erosion.html>.*

Long stretches of sand usually come to mind when we hear the word "beach." But a beach is actually an accumulation of any sediment along a coastline. A sediment is any material that is deposited by waves. Usually that is sand or gravel, but there are mud beaches and beaches made up of much larger rock fragments, too. The make-up of a beach depends on the type of sediment available and on the ability of the waves, tides, and currents to move it.

Beaches are naturally dynamic, changing from wave to wave, season to season, and year to year. That is because wind, waves, and currents move the sediments around. The part of the beach where sediment transport occurs is called the "active beach." As the figure below shows, the active beach is divided into three parts: the backshore, foreshore, and offshore. Behind the active beach is the coastal upland. This upland might be a dune, a cliff, a constructed seawall, a soil embankment, or another geological formation that provides a landward barrier for the beach.

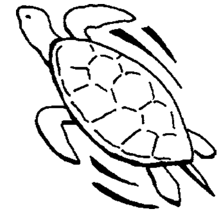
Beaches on a Budget

Each beach has a "littoral budget." "Littoral" refers to the shoreline. The "budget" is the amount and movement of sediments between different parts of the active beach, onto the beach from elsewhere, and away from the beach to another location offshore or down-current. Healthy beaches have balanced budgets—the net influx of sediment equals the net loss of sediment. It's like earning and spending the same amount of money in a month.

Where do the sediments come from and where do they go? Coastal geologists refer to "sources" and "sinks" of beach sediment. Sources include:

- Skeletal material from coral reef ecosystems,
- Offshore deposits of sand that may be transported onshore by waves and currents,
- Other beaches from which wind or currents that run along the shoreline can transport sediments,
- Erosion of coastal uplands and points of land that jut out into the ocean,

Photo: Ann Fielding



- Materials from new volcanic eruptions and lava flows, and
- Sediments carried from inland by streams and rivers.

Sediment sinks include:

- Loss of sediments to deep water,
- Harbors and channels, which trap sand moving along or across the near-shore area,
- Transport of sediments offshore by currents and waves to underwater "sand banks" from which beaches can be replenished seasonally or after large storms,
- Transport of sediments along the shoreline to other beaches by currents and waves,
- "Impoundment" (trapping) behind seawalls, revetments, and other structures,
- Over-wash by high storm waves and surges, which flush sand inland where it cannot be redeposited onto the beach, and
- Wind loss inland due to strong onshore winds.

When there is an imbalance between sources and sinks, the beach will either erode or "accrete" (build up).

The Beach System

Many of the sandy beaches on Maui are part of a beach system that includes dunes and coral reefs, as well as the beach itself. Each element of the whole system is important in the natural cycle of beach erosion and accretion.

Beaches naturally erode and accrete in cycles that correspond with seasonal weather changes and episodic storm events. During a storm, or through the course of a high-wave season, nearly all of the sand may seem to disappear from a beach, and the dune may be almost entirely washed away.

But after a couple of weeks or a few months of calmer weather, the beach and dunes rebuild. On undeveloped beaches, this cycle usually results in the complete rebuilding of the beach and dune profile to what it was like before the storm event or high-wave season began.

Sand Dunes

Along the coast, just as inland, dunes are accumulations of windblown sand. Some coastal dunes are unvegetated, but most are covered with coastal plants. The thick root systems of most native plants help hold the sand in place, slowing the rate at which the dune erodes during high winds and waves. Plants such as *naupaka* and beach morning glory also help dunes rebuild by trapping windblown sand and growing up through the new layers of sand to build larger and wider dunes.

Like beaches, dunes are dynamic. They erode during times of high waves and accrete during normal wave conditions. Dunes are like sand savings accounts for beaches. High waves during storms and large swells erode the beach. They erode the dunes, too. This process, known as "scarping," releases sand that was stored in the dunes to the active beach. The influx of sand from the dunes is often carried offshore where it accumulates into sandbars. These sandbars intercept large waves before they reach shore, lessening their impact on the coastline.

When the high-wave event subsides and normal wave patterns return, the waves dismantle the offshore sandbars and rebuild the beach. Sand blown inland from the beach can then rebuild the dunes. Although some sand may have been permanently washed away from the beach system into deep water by the storm, eventually the beach and the dunes regenerate to their prestorm profile. Most of the sand transported offshore during storms and stormy seasons is eventually reincorporated into the dune.

Coral Reefs

Coral reefs act as natural breakwaters in the beach system. They absorb much of the incoming wave energy and help protect the shoreline from wave erosion. Coral reefs and the invertebrates and algae they support are also important sources of sand production for beaches as the skeletons and other hard structures they produce are eroded by waves and animal activity. Most of the light-colored sand on beaches comes from coral reef ecosystems. Because coral reefs buffer waves and produce sand, they slow the rate of coastal erosion and beach loss.

Interfering with Nature

Coastal erosion is at least partly a natural process. One contributing factor is the rising sea level. Since the last ice age, the sea level has risen nearly 110 meters (361 feet), and as it rises, the whole littoral (shoreline) system moves further inland. Coastal uplands are eroded, and the influx of sediment released to the active beach helps maintain the beach width. We can expect that coastal erosion will continue as sea level rise is currently averaging 2.5 centimeters (about one inch) per decade on Maui.

But sea level rise is only one cause of changing coastlines, and not the most visible and dramatic cause. In many cases, coastal erosion has been aggravated by human activities that reduce the amount of sand available to the beach. Sand mining, dune destruction, and harbor and channel construction, for example, have led to increased rates of coastal erosion on some beaches.

Sand Mining

Taking sand from the beach system leads to beach narrowing and a decrease in sand volume. Until the early 1970s, large volumes of sand were mined from beaches around Maui to provide cement aggregate for construction and lime for sugar cane processing. In fact, on Baldwin Beach, a large structure that once protected the lime kiln from the encroaching sea is now well out in the water because of subsequent coastal erosion.

Dune Destruction

During building construction, dunes are often bulldozed to flatten their tops, allowing better views of the ocean or to make way for construction. Changing the shape of the dunes changes how they respond to storm waves and reduces their ability to serve as a natural buffer. Further, if the dune is then covered with soil for landscaping, future storms will erode the fine sediments of the soil, carrying silt into the ocean.

Dunes are also damaged by people walking or driving over them. This destroys dune vegetation, which is critical to holding the sand in place. A dune with damaged or reduced vegetation cover is more susceptible to erosion and less able to rebuild.

Harbor Construction

Maintaining and expanding harbors and navigational channels change natural patterns of sediment transport. Sand transported by near-shore waves and currents is deposited into these artificial depressions and removed from the littoral system. Also, constructing harbors and channels can entail dredging parts of coral reefs, allowing larger waves to reach the shoreline and accelerate coastal erosion.

Protecting Property

Waves and currents naturally transport sediments along shorelines, within the active beach zone, and sometimes offshore. Episodic and seasonal erosion is a fact of life along the coastlines—and so is the landward migration of the shoreline. But that reality does not always fit well with people's ideas about property. When people build in coastal areas, they want their homes, hotels, roads, and other structures to be standing on solid ground in ten, 50, or 150 years. And we want our beach parks to stay beach parks!

"Shoreline armoring" is a common approach to slowing coastal erosion, stabilizing coastlines, and protecting beachfront property. Armoring structures include "seawalls," "revetments," and "groins" (see the figure on this page for an explanation). These structures usually halt coastal erosion in the immediate area, but they can lead to unintended consequences. On shorelines that have been retreating over time anyway, they often lead to beach loss. You'll see this effect in action during your next class as you map changes in two Maui beaches over time.

Types of Shoreline Armoring

Photo: Dolan Eversole

Seawall

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

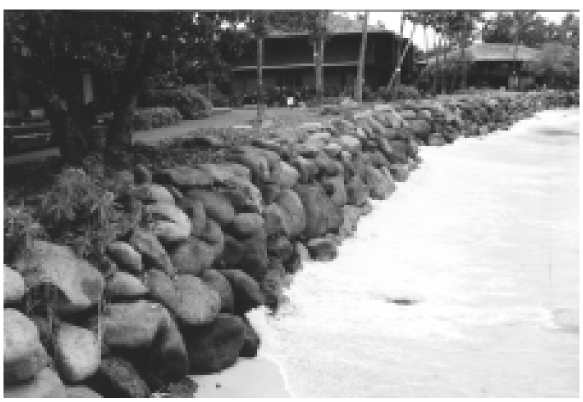


Photo: Dolan Eversole

Revetment

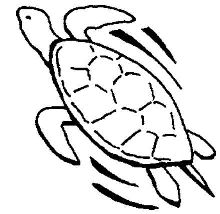
A sloping type of shoreline armoring often constructed from large, interlocking boulders

Revetments tend to have a rougher (less reflective) surface than seawalls.

Photo: Kim Martz and Forest Starr

Groin

A structure resembling a wall, constructed perpendicular to the shoreline and extending into the ocean from the beach



Beaches On a Budget: Questions About the Reading

1) What is an active beach?

2) What is the opposite of shoreline erosion?

3) Explain the term "littoral budget," using at least two examples of sources and sinks.

4) Describe the cycle of sand dune building, scarping, and rebuilding that happens during and after large storms.

5) Name two reasons why coral reefs are important to healthy beaches.

-
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6) Describe two human activities that aggravate coastal erosion and reduces the amount of sand available to the beach.

7) True to their name, "longshore" currents run along or parallel to the shore. These currents are important mechanisms for transporting sediment within the beach system. Sediment transported along shore feeds beaches along the entire coastline. Shoreline armoring interferes with longshore sediment transport. The diagrams below illustrate two different types of shoreline armoring that have been in place for several years. For each diagram:
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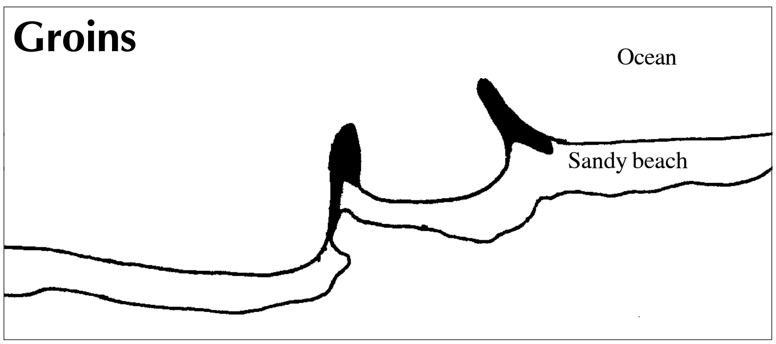
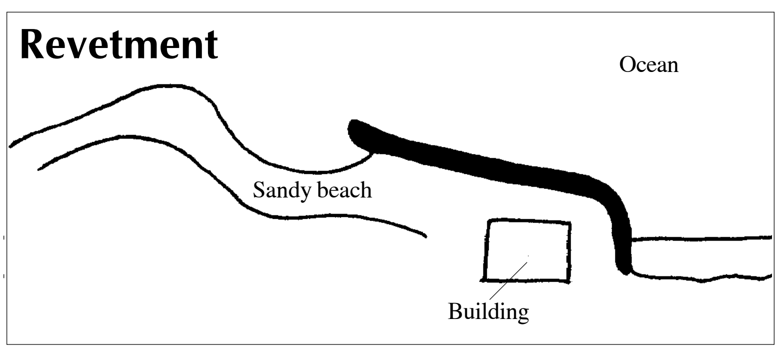
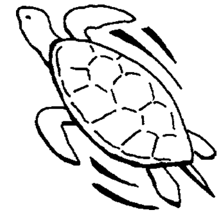






Coastal Erosion Projections

Use your traced paper image of your beach and the space provided on this page to project changes in the coastline over time.

BEACH NAME: ____________________________________

1) The 1991 study graphs changes in the vegetation line between 1950 and 1988. For each transect on your beach segment, calculate an average annual rate of change, and record your calculations and answers below:

   Transect #   Annual rate of change (+ or -)

2) You are going to be mapping projected shoreline changes based on the annual rate of change you calculated above. You will do this using the 1997 aerial photo (your traced paper image of it) as a baseline. Before you start mapping, you need to do some more calculations. Using the annual rate of change for each transect line, calculate the total erosion or accretion likely to occur by 2027 and 2057. Calculate these changes using 1997 as your starting date.

   Transect #   Change (+ or -) by 2027   Change (+ or -) by 2057

3) Now mark the 2027 and 2057 vegetation lines on each of the transects on your traced paper map. (Extrapolate the scale on your traced paper map using the "Beach Study Map and Graph.")

   Use these points and any clues you can glean from the existing shoreline features to draw an anticipated vegetation line for 2027 and 2057. (Using different-colored pens or pencils for each line helps make the map clearer.)

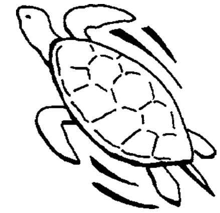
   With a dashed line, indicate where you think the water line will be in 2027 and 2057.

   Label your map clearly.

4) Looking at your traced paper map, as well as the photos, maps, and information from the 1991 study, describe any patterns of erosion and accretion that you see. What might explain these patterns?

5) In 1992, researchers estimated that 62 percent of the Maui shoreline is eroding at a rate of 1.25 feet per year. How do the erosion/accretion rates you calculated compare with that average?

6) Use your projections to identify areas where you think development should be restricted because of the potential for shoreline erosion, and areas that you think would be appropriate for development. Explain your reasoning for these areas here.



Beach Management Alternatives

When protecting coastal property comes at the expense of adjoining beaches, it can set up a conflict that no one really wins—not the property owners, not beach-goers, not the government agencies charged with managing coastal areas, and certainly not the natural system.

There are alternatives. Here are some management tools that are being used to make Maui beaches and coastlines healthier for everyone:

Beach Nourishment

This process is used to create a new sandy shoreline where a beach is eroding or has been lost. It is the only management tool that protects coastal development without degrading the beach.

Beach nourishment involves placing sand fill along the shoreline to widen the beach. The sand may come from inland dunes or coastal plains, or from offshore sources such as dredge spoils from harbor maintenance, and underwater sand fields and banks.

So far on Maui, only small-scale beach nourishment projects have been undertaken, funded by homeowners associations such as Sugar Cove Condominiums in Pāʻia and Kanaʻi o Nalu in Māʻalaea. The sand for these projects has come from inland sand mines that also ship sand to Oʻahu for cement manufacturing.

The potential for beach nourishment on Maui is limited by the availability of high-quality sand. Maui does not have dredging equipment or the knowledge of offshore sources to be able to tap them for nourishing beaches.

Restoring and Protecting Dunes

The first step in restoring damaged dunes is usually to erect fences that help trap windblown sand. In 1997, for example, drift fences were erected to restore Keālia Beach's sand dunes. By 1999, sand had buried the fences in spots. Volunteers, including students and adults involved in the Kīhei Canoe Club, took the next steps by helping replant native vegetation on the growing dunes. Native dune plants have dense root systems and spreading vegetation that trap even more windblown sand. They grow up through the new layers of sand to build larger and wider dunes.

Native plants and the dunes they help keep in place are sensitive to trampling. Plants can be uprooted by people walking across dunes going to and from the beach. Another approach to protecting dunes is to build moveable walkways that provide access without the danger of trampling. These walkways can easily be moved when needed.

Building Setbacks

According to the Hawaiʻi Department of Land and Natural Resources document *Coastal Erosion and Beach Loss in Hawaii* at <www.soest.hawaii.edu/SEAGRANT/CEaBLiH.html>, much of the beach loss in Hawaiʻi "could have been avoided if houses were not built so close to the water. The law presently allows homes 40 feet from the shoreline. On coasts experiencing chronic erosion this is too close and leads to hardening [building sea walls and revetments] in order to protect houses from the waves."

"Shoreline setbacks" (the required distance from a structure to the shoreline) are intended to establish a buffer zone to protect beachfront development from high waves and coastal erosion. In 1990, the Maui County Planning Department revised its rules so that some building setbacks were based on the average depth of the lot, rather than on the state's 40-foot minimum. But according to the Maui Beach Management Plan, more effective setbacks would be site-specific, based on projected shoreline erosion 30, 60, or even 90 years in the future.

Even if coastal erosion hazard maps are not used to guide government rules about building setbacks, these projections could be used to give planners and landowners information that will help them plan and design coastal developments.

Construction Guidelines

Many coastal landowners and developers are not fully aware of shoreline erosion, the potential impacts of development on the beach, and design and construction options that could minimize the threat to their property and the adjacent beach. Consulting with experts and government agencies could help them design projects with minimum impact. Since county and state goverments are aware of the problems associated with coastal development and protection measures such as seawalls and revetments, they need to advise and educate coastal landowners on environmentally compatible alternatives.

In order to choose which strategies to use and where, we need to consider the history of erosion and accretion for each specific stretch of beach. These processes can vary dramatically even from one end of a beach to the other. Knowing more about how each stretch of the coastline has changed over time will help point out areas in which different approaches are most likely to work.

Your Assignment

On a separate piece of paper, write a one- to two-page paper describing how you think either Baldwin beach or Kanahā beach should be managed to protect the beach and the shoreline property behind it. Your paper should include suggested actions and explain your reasoning. In writing your paper, consider your coastal erosion projections for different stretches of this beach.