Lab Section #6
Waves, land and sea interactions, sediments, and coastal processes

Learning Objectives:
• To understand the processes that transport sediments from the continents to the oceans and along the coasts
• Understand how the sediments record the Earth’s History
• Understand ocean waves, their origin, and propagation
• Understand how waves affect the beach

This lab meets at the entry to the Goleta Pier

Preparation and materials checklist
___ Read sediments and waves and beaches chapters in course textbook
___ Read this chapter (Waves, land and sea interactions, sediments, and coastal processes)
___ Complete "Reading Outline" in this write-up
___ Homework #6 worked and entered into computer
___ Finalize the Climate/atmosphere paper, which is due next week

Lab Activities Schedule:
• Meet at Goleta pier for waves and beach observations (100 min)
  Weather observation
  Seawall
  Waves activity
  Measure longshore current
  Beach observation and interpretation
  Cliff erosion
  Campus Point

This lab requires a walk along the beach, of approximately 1.5 miles. If you have a physical disability that will make this impossible for you, please inform your TA in advance (please give him/her a week to make arrangements).

Introduction
The surface of the Earth is constantly changing. Continental mountains are “wearing down” and other portions of continents are being created or uplifted by volcanoes, rising buoyant material from below the crust, by compression which thickens and raises the crust (e.g. India - Eurasia collision), or by the addition of new material to the continents as sediments are scraped off the top of subducting slabs. The exposed rocks that form the mountains are broken down into smaller particles by weathering processes (water and air are two examples). The relentless march of sediments to the sea results in the temporary nature of water storage dams, which will eventually fill with sediments and become useless as reservoirs.

Sediments are Earth materials that are deposited in particulate, unconsolidated form. Sand and mud are examples. The grains of sand, and mud particles form a loose aggregate rather than a solid chunk (e.g. a rock). The most abundant sediments come from the weathering and chemical breakdown of continental rocks. Buried with the sediments are skeletons of the animals that lived
during that time. When the sediments are undisturbed by geologic forces, the oldest are at the bottom of the sediment "column" and the youngest are at the top. This sediment "column" provides a remarkable record of the Earth's history. It records not only the rock type, but the environment within which the sediment was deposited (sea, land, lake, etc.) and some of the rock's history, depending on its shape (angular, rounded, etc). Because certain kinds of animals and plants only lived during certain time periods, the types of fossils found in the sediments allows us to determine an approximate date at which they were deposited. The chemical composition of some of the skeletons can also tell geochemists about the chemical environment, often including the temperature (paleotemperature) of the ancient Earth.

Transport by water is one of the most common mechanisms for the transport of terrigenous sediments. When there is a large rainstorm, the ocean water turns brown with the sediments transported from the coastal mountains by the runoff. Dams that store water are slowly filled with sediments that are transported to it by the streams that fill the lake behind it, decreasing their capacity. Our beaches are made up of sediments transported from the hills by the streams and rivers that drain into the ocean, and are deposited onto the beaches by the longshore currents.

When sediment travels a long distance, larger particles (which settle out quicker) are left behind, which means that deposits further from the source will consist of smaller grains. Also, grains that travel a long distance will become progressively rounder as the sharp edges get knocked off by bumping against other grains. Figure 1 shows how the angularity of sediments is described.

Because larger particles sink faster, one commonly finds larger particles at the bottom of a depositional sequence and finer particles at the top. This could happen, for example, if a large rainstorm or landslide initiated a flow of sediments into a body of water. Large sediments

![Figure 1](https://example.com/fig1.png)

Figure 1. Silhouette comparison diagram for sand grain roundness (from “Practical Sedimentology”, by D.W. Lewis, pg. 64, published by Hutchinson Ross Co., 1984).

would fall out first, then smaller ones would settle later. This “sorting” of sediments by size is commonly used to identify sediments that were transported by water, and to identify the top of the sediments in regions where the sediment record might have been rotated or inverted by geologic processes.
Figure 3. Comparison diagrams for visual estimation of sorting. (from “Practical Sedimentology” by D.W. Lewis, pg. 63, Published by Hutchinson Ross Co, 1984).

**Rates of deposit**

The rate of deposition depends on how much sediment material is delivered to a region. Rock erosion rates depend strongly on rainfall and the chemistry of the rainwater. Biogenic sedimentation rates will depend on the amount of biological activity. Sedimentary deposits may happen in sudden episodes, such as when a large volcano erupts. Ash from Mt. Pinatubo circled the Earth for several years after its eruption. Worldwide deposits have been associated with the hypothesized meteor impact that caused the extinction of the dinosaurs.

Although different rock types weather at different rates, an approximate world average rate of sediment deposit into the deep ocean is 5 to 10 meters/million years. This means that, averaged over the entire Earth, five to ten meters of all of the continents is transported into the oceans every million years.

**Beaches and Sediments**

The sand you observed on the beach comes from eroded sediments that are transported by the rivers that drain into the ocean. However, sand appears on beaches that are far from the river mouth. The transport mechanism is called “Longshore Drift.”

**Longshore Currents:**

Longshore currents are one of the mechanisms that transport sediment along shorelines and cause some of the changes we see in the sediment distribution at the beach. They travel parallel to the shoreline between the breaker zone and the shore. Along the coast of California, the net direction of longshore transport is to the south. Conditions may vary locally and temporally.

Longshore currents are formed and maintained when the incoming waves approach the shore at an oblique angle. The breakers’ energy has components both perpendicular and parallel to the shoreline (see Figure 4). Longshore currents are formed by the wave energy component that travels parallel to the shoreline which causes part of the water mass to be transported along the shoreline. If the breakers are approaching perpendicular to the shoreline, longshore currents will not form because there is no horizontal component of wave energy parallel to the shoreline.

Sand is transported along the beach by longshore currents. Figure 5 shows how the sand piles up behind obstructions in the longshore current. The Santa Barbara Harbor is an example of how an obstruction (the harbor) has required the harbor to be dredged constantly, to remove sand that would normally be carried down the beach.
Figure 4: Waves that approach the beach at an angle generate a longshore current. The figure shows that waves that approach from the right generate a longshore current that runs to the left. This is because there is a component of the wave velocity in the leftward direction.

Figure 5. Sand builds up in front of obstructions that interrupt the “downstream” flow of sand in the direction of the longshore current. Can you find an instance of where this happens on your local beach?

Changes in the Beach
You may have noticed during walks on the beach that the amount of sand and the shape of the beach change as the seasons do. The sand appears to disappear in the winter, sometimes leaving the beach rocky, and reappears during the summer. You may have also noticed that the width of beaches varies depending on their location.

Much of the action at the beach takes place underwater, to a depth of about ten meters. Daily, the waves move the sand up and down the beach. Seasonally, the sand is moved onshore and offshore. The wide California beaches that most of us think about occur during the summer. The ideal summer beach has a gradual smooth slope (Figure 6). The portion of the beach, which is fairly flat and mostly dry, is called the berm. At high tide, material may be deposited on it. During the storms of late fall the summer slope (berm) is eroded and sand is transported offshore, forming a longshore bar. The winter beach has a higher and narrower berm. The reason for this difference is the wave action. The large waves of winter erode the berm; the small waves of summer rebuild the
berm. Basically, the sand does not disappear during the winter, but is stored offshore in the longshore bar. Figure 6 shows the major features of the beach profile.

As described in the pre-lab, you are going to measure the "profile" of the beach at a carefully marked place. The shape and features of the beach change with the seasons markedly as the sand is moved onshore and offshore by the changing wave energy. Scientists would normally do their beach profile measurements during the lowest daytime tide of a tidal cycle, or about every two weeks. Your lab will probably not occur during a low enough tide for you to be able to see all the features shown in Figure 6. Because of this, we will be primarily concerned with the **backshore**. If you are lucky, and your lab occurs during a very-low tide, then you will be able to see the **low tide terrace**, and perhaps the **longshore bar**. If your lab occurs during the spring, you may see two berms, winter and summer, as the summer berm forms, and migrates oceanward.

![Figure 6](image_url)

**Figure 6.** Important features of a beach profile.

![Figure 7](image_url)

**Figure 7.** Variations in the beach profile during the seasons. Winter storm waves take sand out to form longshore bars. Small summer waves move the sand onshore and create a wide berm and flatter offshore topography (after Bascom, W., Waves and Beaches, Anchor Press, New York, p 251).
Views of UCSB Beach at three different times of year. The upper left is during the fall, when the sand is high. The upper right is after the first winter storm, and the figure to the left is in January. During this quarter, and while you are at UCSB, be sure to notice the effect of storms on our beach.

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**Waves at Campus Point, UCSB**

Waves are generated by storms at sea. They propagate over vast distances. Sometimes waves from storms halfway around the world delight California surfing enthusiasts. Waves also have a large effect on the shape of the coastline. Wave action is a powerful force for coastal erosion. During large storms, the low atmospheric pressures raise higher than normal tides and large waves cause damage to the many homes where courageous folks build their houses on the beaches or bluffs.
overlooking beaches. You can observe this in Southern California during storms, when movie stars living on the beach in Malibu are sand-bagging their homes in a sometimes futile attempt to keep them from being undermined and collapsing into the storm surf. During World War II, considerable research was put into the prediction of wave action at beaches. Invasions were conducted through the surf, and it was vital to be able to predict the surf so that hazardous conditions could be avoided. In more modern times, satellites can easily locate storms and wave action can be accurately predicted.

**Describing a wave:**
A wave propagates at some velocity. It also has a height, period, and wavelength. In many ways, the water wave is analogous to the light wave, the radio wave, and the seismic wave. The most important parameters describing a wave are the **wave period**, **speed**, and **wavelength**.

The **wave period**, \( T \), is the amount of time (in seconds) between the passage of two successive waves past a stationary point. The **wave velocity**, \( V \), is the speed at which an individual wave travels. The **wavelength**, \( \lambda \), is the horizontal distance between a point on one wave to the same point on the next wave, e.g. crest-to-crest or trough-to-trough.

![Diagram of a wave](image)

Figure 1. Parts of a wave. The wave height is indicated later as the symbol \( H \).

These are related to each other through a series of simple equations. Normally expressed as:

\[
\lambda = VT
\]

where: \( \lambda \) = wavelength, usually measured in meters
\( V \) = wave speed, usually measured in meters/sec
\( T \) = wave period, usually measured in sec.

Notice that the form of the “wave equation” is similar the \( x = vt \) equation that describes the motion of any moving object. The “\( x \)” is a distance, which corresponds to “\( \lambda \)” the distance between wave peaks. \( V \) is a speed, which is the same speed, and \( t \) is time, which corresponds to “\( T \)” the period of the wave in seconds. Use units to help you remember this equation.

**Example:**
What is the wave period of a wave traveling at a speed of 3 m/sec with a wavelength of 15 m?
Solution:
Step 1) $l = 15\text{m} \quad V = 3 \text{m/sec} \quad T = \text{the unknown}$
Isolate the unknown. (To do this divide both sides of the equation by $V$)
$T = \left(\frac{l}{V}\right)$
Step 2) Check the units. No conversions are necessary.
Step 3) Substitute values with correct units into the original equation and solve.
$T = \frac{15\text{ m}}{3\text{ m/sec}} = 5 \text{ sec}$

If the wave speed is expressed in meters/second, and the wave period is in seconds, then the wavelength is expressed in meters. Occasionally, you might see the wave frequency, $f$, which is $1/T$. The equation is expressed as

$$\text{Wavelength} = \frac{(\text{Wave Speed})}{(\text{Frequency})}$$

The wave equation can be arranged in the following forms:

$$\Box = V \cdot T \quad \Box = \frac{L}{V} \quad V = \frac{\Box}{T}$$

There is an important distinction between velocity and speed, when you are doing physics. Velocity implies both speed and direction. For this class, it will make no difference. The two will be used interchangeably here. But, if you see the symbol $C$, that is speed, which you can use interchangeably with $V$.

**Velocity of wave propagation:**
When you are at the beach, you notice that the waves travel from one place to another. This travel can be described by a speed and a direction. The speed of a wave is determined by a number of physical parameters. There are two situations that allow us to write a simple formula for the wave speed. This is in deep water, where the water depth ($D$) is greater than $\frac{l}{2}$ ($D > \frac{l}{2}$), and in shallow water, where $D$ is less than $\frac{l}{20}$. We can write this as $D < \frac{l}{20}$. There is a range of depths where the velocity is neither greater than $\frac{l}{2}$ nor less than $\frac{l}{20}$. There is no simple formula for velocity in this depth region. The velocity is somewhere between that computed by the two formulae. The reason that the velocity is different in shallower water is because the circular water motion that extends to about $\frac{l}{2}$ beneath the wave is interfered with by the sea bottom. This motion is forced to be flat, since the bottom does not to move. This effect acts to slow the speed of the wave.

In order to keep the velocity formulae as simple as possible, we are relaxing the requirements on units. Be very careful to use meters and seconds in the wave speed formulae. For other formulae, continue to use units.

**Deep water wave speed:**
When the water is deeper than $1/2$ the wavelength, ($D > \frac{l}{2}$ or $\frac{D}{l} > \frac{1}{2}$) so that the motion of the water beneath the surface is not affected by the bottom, the waves are called deep-water waves.

The speed of a deep-water wave is $C = \sqrt{\frac{g l}{2}}$, where $g$ = the acceleration of gravity, which is 9.81 meters/sec$^2$, or more simply, $C = 1.25 \sqrt{\Box(m)}$. $C$ has units of m/sec. The speed depends only on the wavelength, $\Box$. The simplified formula is valid for $\Box$ in meters.
A wave in 100 m of water has a wavelength of 25 m. What is its speed?

First, check that it is a deep-water wave. \( \frac{D}{\lambda} = \frac{100}{25} = 4 \), and 4 is greater than 1/2 so it is a deep-water wave. We use the deep-water velocity formula:

\[
C = 1.25 \sqrt{\frac{25}{25}} = 1.25 \cdot 5 \text{ m/sec} = 6.25 \text{ m/sec}.
\]

The wavelength of a deep-water wave varies depending on its period, according to: \( \lambda = 1.56T^2 \), so if you know the wave period, it is easy to calculate its wavelength. This relationship is important for this lab because it is easy to measure the wave period with a wristwatch, but is more difficult to go out into the water to get an accurate measurement of its wavelength.

**Shallow water wave speed:**
When the wave travels to a shallower depth where the depth \( D < \frac{\lambda}{20} \) (or \( \frac{D}{\lambda} < 120 \)), it becomes what we call a "shallow water wave". A shallow water wave travels at a speed given by

\[
C = 3.1 \sqrt{\text{depth}(m)}.
\]

Again, \( C \) has units of m/sec. The speed depends only on the depth of the water.

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**Example:**
A shallow water wave is traveling in a depth of 4 m. What is its speed?

\[
C = 3.1 \sqrt{4} = 3.1 \cdot 2 = 6.2 \frac{\text{m}}{\text{sec}}
\]

---

**Example:**
A wave is propagating in water with a depth of 200 m. Its period is 14 sec. What is its velocity?
First, you must determine whether it is a deep water, or a shallow water wave. To determine this, the wavelength is needed. We will use the formula for period of a deep-water wave. If the wavelength shows that it is a deep-water wave, then we are home free. Let’s try it.

\[ \ell = 1.56 T^2 = 1.56(14)^2 = 305 \text{m} \]

Since \( D > \frac{305}{2} = 152 \text{m} \), the wave is a deep-water wave. We use the deep-water wave formula to find \( C \).

\[ C = 1.25 \sqrt{305} = 21.8 \frac{m}{\text{sec}} \]

If the depth would have been a shallower (say 100 m), we could have tested it for a shallow water wave by the following method:

We know, for any water wave, \( C = \sqrt{\ell T} \) (from above), and that for a shallow water wave, \( C = 3.1 \sqrt{D} \), so we can say \( 3.1 \sqrt{D} = \sqrt{\ell T} \) by just setting the two formulae equal to each other. We know \( T=14 \text{ sec} \), so let’s see if the answer makes sense if we use shallow water wave formulae.

\[ 3.1 \sqrt{100} = \sqrt{\ell} \]

\[ 31 \times 14 = \ell \]

So \( \ell = 434 \text{ m} \). Since the depth is 100m then \( D/\ell = 100/434 = 0.23 \). The wave is not a deep-water wave, but not a shallow water wave either, since that requires \( D/\ell < 20 \). This means that the speed calculated by the above formula is not correct either. This kind of internal consistency check is the way you figure out whether a wave is deep water, or shallow water. If you notice that the shallow water speed equation gives a higher velocity than the deep water speed equation (21.8 m/sec vs. 31 m/sec), you can see that something’s wrong, since shallow water must act to slow the wave down.

**Conditions that change the wave’s direction:**

As the wave moves from deep into shallow water, all of its parameters except its wave period (\( T \)) change. The wavelength (\( \ell \)) and speed (\( C \)) decrease, while the wave height (\( H \)), and wave steepness (\( H/\ell \)) increase. When it hits obstacles such as rocks, or encounters a shallower bottom, it reacts in several possible ways described as **reflection**, **refraction**, and **diffraction**. During the lab at Campus point, conditions permitting, you will observe all three conditions.
Figure 2. The bending of waves around Rincon Point is an example of refraction. (after Bascom, W. Waves and Beaches. Anchor Press, New York, p. 102. Photo by Steve Bissell/Surfing Magazine).

Figure 3: Wave refraction attacking a headland (after Bascom, W. Waves and Beaches. Anchor Press, New York, p. 79).

**Reflection** occurs when a wave encounters a steep obstacle such as a large rock (larger than the wavelength of the wave), or a sea wall. When this happens, most of the energy of a wave bounces
back, or is reflected. If the water is deep, the wave does not break, but just changes direction. You can observe this when looking over a steep cliff facing the open ocean. When a wave strikes a sea wall, much of the energy is also reflected back to sea. This can also be observed by walking out on the Santa Barbara Harbor jetty. Since the water depth is shallow where the waves strike it, there is a good deal of turbulence, which can lead to erosion of the sand beneath it.

**Diffraction** occurs when a wave energy spreads out, through an opening such as a harbor mouth. As the wave moves through the opening, it is confined. When it has passed through the opening it is no longer confined, and, it begins to spread out. This process is called diffraction.

**Refraction** is a change in direction of a wave because of a change in propagation speed. This occurs because the wave slows down as it moves into shallow water. Since one portion of the wave is moving at one speed, and another is moving at a different speed, the wave crest appears to bend. Figure 2 shows waves bending around Rincon Point due to refraction. One consequence of refraction is the straightening of beaches. A resistant portion of the coast will erode more slowly than surrounding rocks and will project into the sea as a point. The wave energy will be concentrated on it by refraction, tending to increase its erosion rate. There are many examples of this along the California coastline. When a beach is flanked by rocky points, wave energy is concentrated on the points, allowing sand to build up on the beach area between them.

**Breaking Waves**
As a wave travels into shallow water, it slows down and increases in height. A wave breaks when it gets high enough so that the top portion is unstable and spills over on itself. In the open ocean a wave will break when $H/\lambda$ is about 1/7. So, a wave with a wavelength of 7 m will break when its height is 1 m or greater. In shallow water, waves are observed to break when the water depth is one to two times the wave height. This depth depends mostly on the steepness of the bottom. For the purposes of this lab, assume that the waves break at a depth of 1.25H. Surfers know that the largest waves break further from shore, where the water is deeper. Being "caught inside" may mean a tumble from a large wave.

The depth where a wave breaks depends on the shape of the bottom. You might have observed that when the beach is steep, there may be a large "shorebreak." This is where the wave breaks very close to shore and when the waves are large, this can be dangerous to swimmers. At "The Wedge" at the Newport Beach jetty, it is common for a 15-foot wave to break in a few feet of water. There are quite a number of paraplegic body-surfers who have found that "The Wedge" can be a very unforgiving place to play in the surf.

A wave model for Southern California surf. This shows the direction and height of waves hitting beaches in Southern California.
**Surfing on the World-Wide Web:**
California surf information is available on the worldwide web. Figure 4b shows the wave heights offshore from Southern California. The circular plot shows the location of storms at sea. Lighter colors indicate stronger storms. Notice that the waves are coming almost due south. The Channel Islands shield the waves, creating shadow zones. Notice how south swells, usually prevalent in the Fall due to tropical storms west of Central America and Mexico, shadowed Santa Barbara.

You can get to the above screens, which are updated daily, at:
http://facs.scripps.edu/surf/weather.shtml

You have to poke around the site a bit. Click on “Wave Models”
Homework #6:

Notice: Your group online presentation is due at the start of this lab section. The instructions for this presentation are at the Assignments section of this lab manual at the start.

1) Select the number corresponding to the berm in picture of Arroyo Burro below.

![Figure 6. View of Arroyo Burro beach looking west. This picture was taken in February of 2000.](image)

2) The beach changes during the year. This problem, and the next one show Arroyo Burro Beach in the winter and in the late summer. Select the season that each of the photos was most likely taken.

![Photo for Problem 2. Was it most likely take in the winter or summer?](image)
3) Below is another season showing the same beach. Was it most likely taken in the winter or summer?

4) What is the most important difference between the state of the beach shown in the two previous photos, in terms of beach processes?

5) In the summer:
   - the berm is expected to be (large/small)
   - the longshore bar is expected to be (moving onshore/offshore)
   - because wave conditions are (large/small)

6) In the winter:
   - the berm is expected to be (large/small)
   - the longshore bar is expected to be (moving onshore/offshore)
   - because wave conditions are (large/small)

The Wave Speed equations and breaking conditions:

Define the following:

9) C=

10) \[ =

11) T=

12) H=
Consider an ocean wave. Answer the following questions about it. Note that it is possible that there is not a simple formula, under certain conditions.

It is a deep-water wave when:
16) \( \frac{D}{\lambda} = \) \\
17) Then the Speed (m/sec) = \\
18) and it breaks when:

It is a shallow water wave when:
19) \( \frac{D}{\lambda} = \) \\
20) Then the Speed (m/sec) = \\
21) and it breaks when:

Using the formulas that you used in the previous questions, calculate \( \frac{D}{\lambda} \) the Speed in m/sec, and whether it is breaking or non-breaking.

25) For a wave with \( \lambda = 30 \text{ m}, H = 5 \text{ m}, D = 20 \text{ m} \):
   \( \frac{D}{\lambda} = \) \\
   Speed= \\
   Breaking or non-breaking?

26) For a wave with \( \lambda = 30 \text{ m}, H = 2 \text{ m}, D = 1 \text{ m} \):
   \( \frac{D}{\lambda} = \) \\
   Speed= \\
   Breaking or non-breaking?

27) For a wave with \( \lambda = 4 \text{ m}, H = 1 \text{ m}, D = 5 \text{ m} \):
   \( \frac{D}{\lambda} = \) \\
   Speed= \\
   Breaking or non-breaking?

28) From the previous six problems, what happens to a wave when it moves into shallow water?

29) Surfers! A storm 4,000 miles away generates waves of wavelength of 400 m. How many days will it take those waves to reach us?
30) A tsunami (a shallow water wave) occurs offshore from Alaska at 12:00 PM (noon). How many hours will it take the wave to arrive in Santa Barbara? The quake is 3,200 miles in distance from Santa Barbara. Use a reasonable average depth for the propagation path of this wave to estimate its speed.
Section #6 Activities:

The following exercises are to be completed during lab session. You will meet at Goleta Beach Pier for this lab. It will take you about 10 minutes to walk from Campus, so please allow enough time to get there. The lab will start promptly. The specific items addressed in this lab will depend on wave and weather conditions. Dress appropriately for the weather and/or bring sunscreen.

Conditions on the beach change constantly. These changes depend on the season and both the local and worldwide weather. You will be making observations that may be very different from those of your classmates in another section, or who have taken this course at another time.

It is very important to record all conditions that might affect your observations. Enter the following information:

Name: _____________________________________________
Date: ______________________________________________
Time: ______________________________________________
Location: __________________________________________
Weather (cloudy/overcast/rainy/snowing?):______________
Wind Speed:________________________________________
Wind Direction:_____________________________________

Some of the observations listed below may not be possible because of local conditions (no waves, etc.). Your TA will specify which observations are relevant for this walk.

• First, be sure that you can orient yourself on the map of Figure 7. Mark the starting point of this walk on your map.

A recent development:
A rock seawall was installed at Goleta Beach early March, 2000. The work was initiated by the county government, under emergency conditions. The bathroom was being washed out during high tides and high waves. Two photos of the seawall are shown below, with a recent letter to the editor of the Santa Barbara News Press, from a representative of the Surf-Rider Foundation. Be sure to look at the sea wall on your beach walk and discuss possibility of an occurrence of the effects predicted by the author of the letter.
Overview of Goleta Beach, with the seawall installed on the left.

Closer view of the seawall, as it was being installed.
LETTERS TO THE EDITOR

Rock sea wall at beach needs immediate review

The Santa Barbara Chapter of the Surfrider Foundation is very concerned about the rock sea wall which has been placed upon Goleta Beach County Park. This rock sea wall was placed within an emergency work permit. The emergency was a 30-foot bathroom 60 feet from the edge.

The supposed emergency has warranted a 750-foot rock sea wall, costing the county's park fund $100,000. First, the Goleta Beach County Park is fill in the tidal zone. The ocean is retrieving some of what the park has been borrowing for many years. The normal ebb and flow of a healthy beach habitat takes precedence over parking lot readjustment and loss of a few feet of fill and lawn.

The threat to the bathroom was, at best, remote but a couple loads of sand could have buffered the immediate area in front of it quite adequately. The tree directly in front of the bathroom is still standing and more could be planted to stabilize the lawn edge. That bathroom is not essential to the park and could be relocated.

The Santa Barbara County Park Department made the decision to line 750 feet of Goleta Beach County Park with boulders. This decision was done without any environmental impact review. Coastal Commission permits, or public input, and will have far-reaching impacts to the beach eco-system.

The scalping of the beach is a fact of life for beach barriers. The wave energy does not dissipate when it hits the wall, it carves and scalps the beach which results in less beach. The scalping also happens at the end of sea barriers.

There are many examples of this process. Look at what has happened to Ventura County's coast, with its many sea walls, revetments and jetties. The irony of the Goleta Beach erosion is when the west parking lot was damaged in the 1996 storm and the parks department dumped boulders onto the beach, which pushes the wave action eastward toward the lawn area.

There is a 300-foot section of beach from the end of the just-installed sea wall to the Beachside Cafe which will need armoring in the future. Then the wave energy will be conveniently diverted down coast toward More Mesa, which will start experiencing increased cliff failure and will want armoring also.

Hard scalping is not the answer to beach erosion; it creates more problems.

The decision that the Santa Barbara County Parks Department made is a two-fold environmental disaster, because a neighbor somewhere in a nearby county has a very large hole in the ground where all those boulders were quarried. The fact that the boulders were imported could impact any number of beach organisms from contamination from the foreign material. The boulders are not only unattractive, they also pose an obstacle to beach access.

There are many questions and issues that need to be addressed with an environmental impact report.

Visiting the park it is painfully obvious that the decision to drop 2,000 tons of rock on the beach was made by someone who does not understand the dynamics of a shoreline. Since the lawn is more important than the beach, I propose we change the name to Goleta Lawn County Park. A review of Santa Barbara County Park policy is in order, the present park director is not qualified to have made this decision. The California Coastal Commission should have been notified and the proper permits obtained before any work was done. The arrogance of this act is very disturbing.

The Santa Barbara Chapter of Surfrider Foundation demands an immediate public hearing and removal of this environmental disaster.

Keith Zandoni
Chapter chair
Surfrider Foundation

Find the URL of the SurfRider Foundation in the class links, or do a web search.
Part I. Waves at Goleta Pier:
Select a region of the pier just beyond the surf zone where the wave crests are clearly visible but the waves are not breaking. Make the following measurements and calculations. **Show your work**, not just answers.

1) Select one piling of the pier to serve as a marker. Count the number of wave crests that pass the piling in one minute. Repeat the measurement at least three times to get a good average. The wave period is the amount of time between passing wave crests. Make a data table of your results. Calculate the wave period as follows:

\[
\frac{60 \text{ seconds}}{\text{ave. # of waves}} = \text{wave period (in seconds)}
\]

2) Select two pilings about 20 m apart. Record the time it takes for a wave crest to travel the 20 m distance. Repeat this measurement at least three times. Make a data table of your results. Now calculate the wave speed:

\[
\frac{\text{distance between pilings (m)}}{\text{average time interval (sec)}} = \text{wave speed (m/sec)}
\]

3) Calculate the wavelength from the wave period and wave speed as follows:

\[
\text{Wave speed (m/sec)} \times \text{Wave period (sec)} = \text{Wavelength (m)}
\]

4) Estimate the distance from shore the waves are breaking. Record this distance. We will use this distance in the next exercise. (Hint: If you are on the pier, pace the distance to breakers by walking along the pier).
Part II. Measuring longshore currents:
5) Move to a location on the pier just outside the surf zone. The teaching assistant will throw in a marker. Describe the movement of the marker.

6) Now throw a marker into the surf zone. Observe and describe its movement. Is there a longshore current? Why or why not?

7) If there is a longshore current, pace out 30 m along the beach parallel to the swash zone, and throw a marker into the surf zone at the up-current end of the longshore current. Record the time it takes the marker to reach the other end of the 30 m. Divide the distance by the travel time to get the speed of the longshore current in meters/sec. Show your work below.

Part III: Beaches and the Shifting Sands of Goleta (a walk down the beach)
You will notice that the beach varies in width. The longshore transport, and the locations of the beach help to determine its width. The distance from a source of sand, such as a river or stream, also helps determine its width. Without a source for sand, there would be no beach. Streams and rivers carry much of the sand for the beaches from the inland regions to the coast. The rivers get the material to make sand from the hills surrounding their drainages. If a river is dammed, or an area is paved, then the amount of sand making it into the beaches is reduced. Of course, the sediment doesn’t stop its inevitable journey to the sea. It is just temporarily delayed while it fills the depressions behind man’s obstructions and some day (speaking in geological time), will find its way into the sea.

8) What other sources of sand or materials for a beach might be available?

9) The longshore transport for the Santa Barbara coast is predominately east, how might you be able to determine the transport direction is east?
10) Which beaches would you expect to have the widest beaches:
East-facing North-facing South-facing West-facing

11) Draw the direction of longshore transport on your map.

12) At the West end of Goleta Beach, at the base of the cliffs south of the campus:
   A) How wide is the beach on the west-facing side? ________________ meters
   B) How wide the beach on the east-facing side? ________________ meters
   C) What might be causing the difference in the width of the beaches?

Campus Point is a headland, a point of rock which is eroding slower than the surrounding rock. The sand moves around the headland. Depending on the season, width of the beaches near this headland will vary.

Part IV: Cliff Erosion (walking around the point:)
The most expensive property in Southern California is just above the coastal bluffs. The view is great, usually the ocean is accessible, and the sounds of the waves breaking screen out the omnipresent city noise. The bluffs seem to last forever, unless there is an extremely wet winter. Then, a house on the bluff may find itself 40 ft or more closer to the edge, or perhaps even sliding down onto the beach. These effects are observable on the beach west of Arroyo Burro Beach, and in Isla Vista, where home owners try to get approval to put up seawalls, which ultimately cause problems at their endpoints.

13) Observe the cliffs and see if you can predict which locations will fall down soonest. Where would you build your house? Make some notations on your map.

14) A natural slope for the kind of material that makes up the sea cliffs in more gentle (about 40 degrees). Why might the sea cliff be vertical?

15) If we could protect the base of the seaciff from eroding, would this stop the top of the sea cliff from eroding?
16) A homeowner wants to place a seawall on his property. What is going to happen at the ends of the seawall? Think about headlands, wave refraction, and wave erosion.

Part V: Campus Point

17) Notice on your contour map how the coastline forms a headland at Campus Point and then curves in toward campus before straightening out again along Goleta Beach. Stand at the point and face north (you should be looking at the mountains and Storke Tower should be slightly off to your left). The coastline to your right faces which direction?

18) About how far offshore do the waves break?

a) On the east side of the point ______________

b) On the west side of the point ______________

c) Draw the approximate location of the breakers on your contour map. Why don't the waves break the same distance from shore on both sides of the point? (Hint: look at the contour map).

19) Shallow water waves break when the water depth is between one and two times their height. Estimate the height of the breakers. Don’t try to calculate it in any way. Discuss it with anybody handy and make an educated guess.

20) Use your estimate of the breaker height to calculate the depth of the water. Is the water depth shown on the map less, greater than or equal to the depth you calculated. Why or why not?
21) What other factors might effect the where and when waves break?

22) What happens to the waves as they go around the point?

23) Draw in the wave crests, in both deep and shallow water, on your Campus Point map.

24) Illustrate and label the other two types of wave behavior on your Campus Point map by drawing in the wave crests as lines. Use different colored pencils or ink to differentiate the two types and label them appropriately.
Figure 7. Map of the area of your beach walk.
Figure 8. Detail map of Campus Point
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Period of observed waves</td>
<td></td>
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<tr>
<td>2) Speed of observed waves</td>
<td></td>
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<tr>
<td>3) Wavelength of observed waves</td>
<td></td>
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<tr>
<td>4) Distance from shore waves are breaking</td>
<td></td>
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<tr>
<td>5) Movement of marker:</td>
<td></td>
</tr>
<tr>
<td>6) Was there a longshore current (yes/no)</td>
<td></td>
</tr>
<tr>
<td>7) Speed of longshore current</td>
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<tr>
<td>8) Other possible source of sand</td>
<td></td>
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<tr>
<td>9) Evidence for East longshore current</td>
<td></td>
</tr>
<tr>
<td>10) Which direction of beaches have widest beaches</td>
<td></td>
</tr>
<tr>
<td>11) This will be included on your map</td>
<td></td>
</tr>
<tr>
<td>12) Width of beaches</td>
<td></td>
</tr>
<tr>
<td>A)</td>
<td></td>
</tr>
<tr>
<td>B)</td>
<td></td>
</tr>
<tr>
<td>C)</td>
<td></td>
</tr>
<tr>
<td>13) Notate on map (ideas?):</td>
<td></td>
</tr>
<tr>
<td>14) Why is seacliff vertical?</td>
<td></td>
</tr>
<tr>
<td>15) Protection of base of seacliff stops erosion?</td>
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<tr>
<td>16) Effects of seawall</td>
<td></td>
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<tr>
<td>17) Coastline to right faces which direction?</td>
<td></td>
</tr>
<tr>
<td>18) Estimate distance offshore to breaking waves</td>
<td></td>
</tr>
<tr>
<td>A) on east side</td>
<td></td>
</tr>
<tr>
<td>B) on west side</td>
<td></td>
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<tr>
<td>C) include breakers sketch on map</td>
<td></td>
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<tr>
<td>19) Estimate height of breakers</td>
<td></td>
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<tr>
<td>20) From breaker height, estimate depth of water</td>
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<tr>
<td>21) Any other factors?</td>
<td></td>
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<tr>
<td>22) What happens when waves go around point?</td>
<td></td>
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<tr>
<td>23) Draw wave crests on map</td>
<td></td>
</tr>
<tr>
<td>24) Detail map, draw refraction, reflection, diffraction at Campus Point</td>
<td></td>
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</tbody>
</table>