The purpose of this lab is to familiarize you with the wave conditions and the kinds of shoreline features that exist, particularly along the coast southern California, and the forces and conditions that produce them. You will also consider how humans use these features.

Activity #1: Wave Refraction & Longshore Transport of Sand by Waves

Examine the pictures labeled “Wave Refraction and Longshore Transport of Sand 1.” As you can see in the pictures labeled “Goleta Point, Santa Barbara” and “Point Reyes National Seashore,” waves tend to match the shape of the shoreline as they come into a beach. Since the winds that create the waves do not match the shape of the shoreline, the waves themselves must change direction (‘refract’) as they approach the shoreline.

1. Look at the wave crest highlighted in light blue.
   Which part of the wave crest is moving slower, the wave crest at A or the wave crest at B? ________________________
   Why is the wave crest moving slower at this location?

Since the other part of the wave crest is moving faster, it covers a greater distance which bends the wave crest towards the shoreline. This has happened to the left of the dot labeled A where the wave crest is parallel to the shoreline.

Examine the pictures labeled “Wave Refraction and Longshore Transport of Sand 2.”

2. Which part of the wave crest is moving slower in the Marin County photograph, A, B, or C? ________________________

Since the wave crest is moving faster at the other 2 locations, this causes the wave crest to bend towards and wrap around the headland.

3. Which part of the wave crest is moving faster in the Torrey Pines State Beach photograph, A, B, or C? ________________________

Since the wave crest is moving faster at this location, it gets ahead of the other 2 parts of the wave crest, making a U-shape which matches the shoreline at the opening of the lagoon. The dredging equipment is used to remove sand from the mouth of the lagoon, keeping it from being blocked by sand pushed down the shoreline by the waves.
Notice that the waves begin breaking before completely refracting in the upper photograph of “Wave Refraction and Longshore Transport of Sand 1.” The breaking waves push sand and water up the slope of the beach at an angle, and then gravity then pulls them down the slope back into the ocean. The result is that the sand has moved along the shoreline (longshore transport) in a “zig-zag” motion due to the waves.

4. What is the direction of longshore transport in the upper photograph, to the north or to the south? ________________________

What is the direction of longshore transport in the lower photograph (#1), to the north or to the south? ________________________

5. What is the typical direction of longshore transport on most days and at most places along the coast of California? ________________________

6. Using the photographs labeled #1, #2, and #3, sketch the following into all 3 maps (bird’s-eye-view pictures) below:

   • wave crests in blue (sketch both the breaking & non-breaking parts of the wave crests) (white foam trails behind waves after a breaking crest goes by)

   • mark locations A, B, & C along one wave crest in #2 and #3, and put your own dots A and B into #1. Write “faster” or “slower” next to each dot in maps #1, #2, and #3.

   • use green arrows to indicate the direction that the waves are moving in

   • use small red arrows for the direction of the longshore transport along the shoreline (show the direction of longshore transport, not the zig-zag motion of the sand)
Activity #2: Estuaries and Wetlands

Estuaries are places where land partially surrounds ocean water. This can happen in a variety of ways. When sea level is lower, rivers or glaciers can erode a valley near the shoreline, and when sea level rises again, the valley is flooded. A coastal valley may also form if land sinks during an earthquake. In other cases, water is cut off from the ocean because of land rising during an earthquake, sand piling up along the shoreline, or a growing coral reef.

7. Examine the 4 estuaries shown in the picture “Types of Estuaries.”
   What do think the origin of each one is?
   
<table>
<thead>
<tr>
<th>Estuary</th>
<th>Possible Origins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chesapeake Bay:</td>
<td>Glacial Valley</td>
</tr>
<tr>
<td></td>
<td>River Valley</td>
</tr>
<tr>
<td>Pamlico Sound:</td>
<td>Earthquake</td>
</tr>
<tr>
<td>Puget Sound:</td>
<td>Sand Piling Up</td>
</tr>
<tr>
<td>San Francisco Bay:</td>
<td></td>
</tr>
</tbody>
</table>

8. a) Where is there more ocean life, in the estuary (and the nearby wetland) or along the coast outside the estuary that is exposed to the ocean? ________________
   
   b) What substance is more abundant in this place (your answer to question 8a above) and leads to the larger amount of life? ________________
   
   c) Why is the substance more abundant in one place than in the other place? For example, why is it more abundant in the estuary than along the open coast?
   
   d) Explain why both algae and animals are attracted because of the substance.
   
   e) What other benefits do animals get from living in this place? As part of your answer, describe how or why it is a good place for these activities or provides these benefits.

9. Where is the water more turbid (muddy or murky instead of clear and blue), in the estuary or in the nearby coastal ocean? (Look at the picture showing the east coast of the United States.)  ________________
   
   Why is the water more turbid in this place?
Wetlands are often found along the edges of estuaries (as you saw in the picture of the Eel River). There are two kinds of coastal wetlands: salt marshes and mangrove forests. The plants that live in wetlands have special adaptations that allow them survive in salty water. Examine the picture “Which is a salt marsh? Which is a mangrove forest?”

10. (a) What does a wetland look like to you? In other words, describe a wetland.

(b) Which picture shows a salt marsh and which picture shows a mangrove forest?
   Picture A: __________________________   Picture B: __________________________

11. Write either “E” for “estuary” or “W” for “wetland” at the end of each arrow in the bird’s-eye-view picture below.

   ![Bird's-eye-view picture of a delta with arrows indicating the direction of water flow]

**Activity #3: Rivers and Deltas**

Examine the picture “Rivers and Deltas.” How do rivers affect the nearby ocean?

12. Do rivers make the coastal ocean more or less turbid (murkier)? ________________

   How? Why? ____________________________________________________________________

A delta develops when sediments pile up at the end of a river. The sediments can block the river, causing it to split into smaller rivers called “distributaries.” (You can clearly see this in the Mahakam Delta.) The distributaries spread out, each finding their own way through the sediments and down into the sea, sometimes giving the delta a triangular-shape. (The Greek letter “delta” has the shape of a triangle.) If enough sediment blocks the river, the river can actually shift its course.

13. What famous river feeds the delta in Egypt? ________________

When you think of Egypt, you probably think of pyramids and a barren place covered by sand, but the delta is a green place with lush vegetation. The great ancient civilizations (e.g., Egypt, Mesopotamia, China, India) started in deltas because of the rich farmland.
Examine the picture “Major River and Delta of the United States.”

**Hint:** The delta is named after the river that feeds it.

14. What famous delta of the United States is shown in the picture? __________________________

15. Many people still live in deltas, but unlike ancient peoples, we have the technology to keep the delta from changing. For example, we dredge the river and distributaries (removing sediments from the bottom) and build levees (big piles of sediment). Why do we carry out these activities? What is the purpose or goal?

Dredging the River: _____________________________________________________

Building Levees: _______________________________________________________

16. Building levees can harm the nearby wetlands. How?

Natural deltas are places where land is growing along a shoreline. New Orleans is built on a delta, but it is slowing sinking: new mud is no longer being added and the weight of the buildings is slowly squeezing out the water beneath it and compressing the mud. New Orleans is now about 8 feet below sea level, on average. The levees are the only thing keeping the Mississippi river and the ocean out.

**Activity #4: Barrier Islands, Bars, Spits, and Tombolos**

Examine the pictures labeled “Barrier Islands 1” and “Barrier Islands 2.”

17. Do barrier islands appear to be made out of solid rock or sand? __________________________

18. In the map view (bird’s-eye view) below, label the locations of (1) the ocean, (2) the lagoon (estuary), (3) the sand beach, and (4) the wetland.

**Hint:**
Levees control the river and its distributaries. What do they keep neighboring wetlands from getting?
19. Examines the pictures labeled “Barrier Island Locations.” Which of the maps show barrier islands along the coast? Use the maps to identify where barrier islands are common along the coast of United States.

Using a red pencil, circle the places on the map on the right where barrier islands appear to be present.

Where would you be likely to find barrier islands in the U.S., along the east coast, the southern coast, and/or the west coast?

Examine pictures labeled “Spits, Barrier Bars, and Tombolos.”

20. Examine the picture of Rodeo Lagoon, and not the “barrier bar” across it.

The sketches below show how a “barrier bar” can develop.

Describe how a barrier bar forms across the mouth of a bay or cove.

(A) ______________________ push sand (B) ______________________ if they arrive at a steep angle to the coast. When the sand reaches the end of the barrier bar, it sinks down. As more and more sand piles up at the end of the bar, the bar gets (C) ______________________.

A: longshore transport, rain, tides, waves, winds
B: down the coast, into the lagoon
C: longer, shorter

21. Sometimes sand piles up between an island or sea stack and the shore, and connects the island to the land (this is called a “tombolo”). Why does the sand pile up between the island and the shore?
Activity #5: Sea Cliffs, Wave-Cut Terraces, and Marine Terraces

Examine the pictures labeled “Sea Cliffs.”

22. Does it look like the bottoms of the cliffs are being eroded by waves at the time the photographs of Torrey Pines, Point Reyes, and Solana Beach were taken? _______________________

   When will the bottom be eroded?
   (Hint: Happens twice each day.) __________________________________________

23. What kind of rock are the cliffs made out of, igneous rock or sedimentary rock? ________________________

   How can you tell from the pictures? __________________________________________

24. Sedimentary rock can form at the bottom of valleys on land or at the bottom of the ocean. The solid rock of the coastal cliffs in the photographs formed from sediments that piled up on the bottom of the ocean, not valleys on land. What evidence could we look for in the cliffs which would help confirm or refute this claim?

Examine pictures labeled “Wave-Cut and Marine Terraces.” Pay particular attention to the pictures of “Pismo Beach” and the coast “South of Point Arena.”

The bottom of the cliff is a wave-cut terrace (also know as a wave-cut platform or bench), and top of the cliff is a marine terrace. When waves erode a shoreline, they push back the cliffs, leaving a broad, flat area (the wave-cut terrace) behind. If sea-level falls (e.g., during an ice age) or an earthquake lifts the land, then the flat area is no longer underwater of the ocean and we call it a marine terrace. (Palos Verdes is famous for its marine terraces.)

25. Sketch a profile (side-view) of a wave-cut terrace and at least two marine terraces into the space below. Include the ocean’s surface in your sketch. Label the wave-cut terrace, the marine terraces, the cliffs, the ocean, and the land.

   Make one picture showing how the features are related to one another.
Activity #6: Headlands, Coves, Sea Stacks, and Sea Arches

Examine the pictures labeled “Headlands, Coves, Sea Stacks, and Sea Arches.”
They show a rocky, erosional shoreline with several features:

<table>
<thead>
<tr>
<th>Headlands or Peninsulas</th>
<th>where land extends out into the ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coves or Bays</td>
<td>where the ocean pushes into the land</td>
</tr>
<tr>
<td>Sea Stacks</td>
<td>rocks poking above the surface of the ocean, small islands</td>
</tr>
</tbody>
</table>

26. Sketch a map view (bird’s-eye-view) of a cove, a headland, and a sea-stack.
Label all three features, the ocean, and the land.

27. Which rock erodes easily and which rock is wave resistant?
   Headland: __________________________
   Cliffs of the Cove: __________________________
   Sea Stack: __________________________
Write “wave resistant” in green at appropriate places in your sketch above.
Write “erodes easily” in red at appropriate places in your sketch above.
Shorelines Lab (6B) Review: Hints & Advice

Activity #1

There are two common misconceptions when answering question 1. Sometimes students will say “part X arrived at the shoreline first, because it is moving faster.” This answer is simply wrong. In deep water, all parts of a wave are moving at the same speed and since most waves approach the shore at an angle, one part of the wave naturally reaches the shoreline first – because of the direction it comes from, not its speed. In shallow water, the speed of waves is determined by the depth of the water. When answering question 1, you need to say more than simply “part X of the wave moves slower, because the water is shallow” or “because the water is deep.” In addition, explain why the wave moves slower under these conditions.

The green arrows and red arrows should go in different directions. The green arrows show the direction of the waves. The red arrows show the direction of LST (the sand) along the coast. Therefore, the red arrows should always be parallel to the coast. (As stated in the instructions, do NOT show “zig zag” motion.)

Do not forget to label the wave crests in all 3 pictures with location markers A, B, and C, and to write “faster” and “slower” next to appropriate locations.

Activity #2

The purpose of question 7 is to get you to look at estuaries and to be able to recognize them in maps. Do NOT waste a lot of time debating the answers to this question; instead, ask questions if you are uncertain. Hint: (1) The easiest origin to match is for the estuary created by an earthquake (the land went down). Which location is known for earthquakes? (2) Next, which estuary is in a place where it looks like glaciers could come down from nearby mountains? (3) & (4) That will leave you with two more estuaries. One location should look like valleys that have been flood, while the other location is surrounded by long, thin piles of sand (light-colored lines) that separate it from the ocean. These long, thin piles of sand are “barrier islands.”

Questions 8 and 9 are “compare-and-contrast” questions. In your answers, you need to discuss the differences between estuaries and the nearby coastal ocean. If your answers are statements that are true about both places, then you have failed to distinguish between them and have not fully addressed the questions.

Note: Some estuaries have rivers that empty into them, but many do NOT have rivers flowing into them.

The substance referred to in question 8 is NOT “phytoplankton.” Instead, phytoplankton are found in the estuary because of the substance that you are asked to identify. You will explain why phytoplankton need the substance in your answer to question 8d.

The substance is found BOTH along the coast and in estuaries. When answering question 8c, explain how or why MORE of the substance is found in the estuary than along the open coast. Note: If you claim that the substance gets “trapped” in estuaries, you need to explain how or why it is “trapped.” For example, how does the substance enter the estuaries? Why is it hard for the substance to leave estuaries?

When answering question 8d, make sure that you discuss why BOTH algae AND animals want to live in the estuaries. The question states that your reasoning must be related to the substance that is more abundant in estuaries. Do NOT give other reasons animals want to live in the estuary; you will be asked to discuss these reasons in your answer to question 8e.

When answering question 8e, make sure that you explain HOW or WHY an estuary is a good place for these activities or provides these benefits.

(Continued on the Next Page)
Note that “calm water” is not necessarily good for ocean life. Earlier we learned that many plankton like or even need waves to stay afloat, because their heavy shells make them more dense than water if the water gets too fresh or warm. Many animals rely on waves and currents to bring their food (plankton) to them, and algae rely on waves and currents to bring nutrients to them – or to bring them to nutrients. Many animals and algae live in estuaries in spite of – not because of – less water motion.

There are a few possible good answers to question 9. I am often told “The water in estuaries is murky (not clear), because there is a lot of mud in the water.” I will accept this answer only if you also explain why (1) mud is more abundant in the estuary than elsewhere along the coast, and (2) why the mud does not sink to the bottom. (In other words, what keeps it stirred up and in the water instead of on the bottom?) If “mud in the water” is the best answer, the water color should be brown, but this is often not the case. Aside from bluish or brownish, what color is the water in estuaries? What does this color indicate is in the water and makes it murky in many estuaries?

**Activity #3**

Nutrients do NOT discolor the water.

Although sediments dredged from the river are used to build levees, the purpose of dredging the river is NOT primarily to build the levees. What kinds of human activities are easier or safer if a river is deep instead of shallow?

**Activity #4**

If you look carefully at the pictures of barrier islands, you will notice that one side of the island has a sandy beach and the other side of the island has a wetland (if the island has not been “developed” by humans). One side of the island faces the ocean, and the other faces the lagoon (estuary). The small gap between the islands in the map is NOT the lagoon (estuary); it is called an “inlet.”

Some of the locations in the “Barrier Island Locations” question (question 19) do NOT have barrier islands. You must look at the maps to see whether or not barrier islands are present. Then, based on your work, you must identify the coasts of the United States where barrier islands are commonly found. Notice that oceanographers discuss 3 different coasts (east, SOUTHERN, and west), not 2. **Hint:** Barrier islands are common along 2 of the 3 coasts of the United States.

**Remember:** LST does not “push” sediments down the coast; instead, LST IS the sand moving down the coast.

Answers like “because the sand is trapped between the island and the shore” are not satisfactory answers to question 21. Yes, the sand is piling up in this location because it is “trapped.” However, you are being asked to explain HOW or WHY the sand is “trapped” in this location.

**Activities #5 and #6**

Answers to question 23 like “because of the color” are not specific enough. What is it about the color (or other things that you see in the pictures) that allows you to identify the kind of rock?

The answer “because of the layers” is not a satisfactory answer to question 24. Sediments that pile up at the bottom of the ocean and in valleys BOTH form layers, so this answer does not distinguish between the two possibilities.

Draw only ONE picture as your answer to question 25, and draw only ONE picture as your answer to question 26. In both cases, make sure that you label ALL of the assigned features CLEARLY. I recommend that you use arrows to point at the locations that you are trying to label. If a label is ambiguous, it will be marked “wrong.”