Laboratory Exercise #5 – Shoreline Processes

Section A – Shoreline Processes: Overview of Waves

The ocean's surface is influenced by three types of motion (waves, tides and surface currents). Shorelines dominated by wave action comprise approximately 80% of the coastlines on earth and will be the focus of today's laboratory exercise. Tidal action is dominant in 17% of the earth's shorelines with surface ocean currents (such as the Gulf Stream) dominating only 3% of shorelines.

The anatomy of a wave includes the **crest** or highest point on a wave and the **trough**, which is the lowest point on a wave (Figure 1). The vertical distance between the crest and trough is referred to as the **wave height**. Additional important concepts include the **wavelength**, which is the distance between two successive crests. The **wave base** is the water depth below which no energy is felt by the passage of a wave. Note that the orbitals reflecting the movement below a wave are circular. Also, these orbitals become progressively smaller with greater depths until they disappear. The depth at which the orbitals disappear and where the water is no longer being moved by the wave is the wave base. There is a simple mathematical relationship that defines wave base.

Wave base = 1 / 2 of wavelength

For example, a typical fair weather wave has a wavelength of 60 feet. This wave will have a wave base of 30 feet. The shape of the orbitals below the wave in Figure 1 is circular. This type of wave is a **wave of oscillation** and occurs offshore. Waves of oscillation occur in water with depths greater than the wave base of the wave.

What happens when the wave begins to touch the seafloor as it approaches the shoreline? First, friction begins to slow the wave and decrease wave velocity (Figure 1). As the wave velocity decreases the wavelength becomes shorter and the wave height becomes greater. Additionally, the orbitals below the wave become distorted and orbitals closest to the surface are displaced closer to the shoreline than slower orbitals that are touching the sea floor. Shallow water waves that interact with the shoreline are referred to as **waves of translation**.

Ultimately, the wave can be built only so high and then the wave will disintegrate, which is referred to as **wave breaking** (or **breakers**). Wave breaking occurs when water depth becomes 1 / 20 of an open ocean wavelength. For example, again a typical fair weather wave that has a wavelength of 60 feet will have breaking waves in 3 feet of water. Obviously, waves break immediately offshore. The water that runs up onto the beach from the surf zone where all the waves are breaking is referred to **swash** and the return flow of water to the ocean is **backswash**.

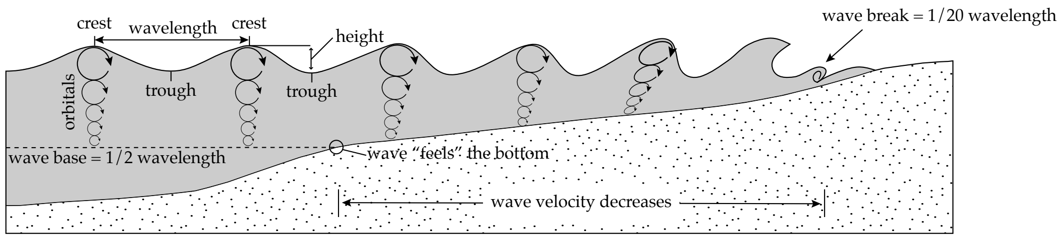


Figure 1. Waves of oscillation and translation with standard wave terminology.

Most shorelines have irregularities. Headlands are regions that project into the ocean and bays are indentions in the shoreline (Figure 2). Common sense would dictate that headlands receive more of a pounding from the ocean therefore more erosion occurs along headland than in bays. Additionally, bays would seem to be ideal zones of deposition compared with headlands. These interpretations, albeit simplistic, are nonetheless accurate. However, a deeper understanding of these processes is possible by studying the behavior of waves as they approach the shoreline. Realize that the contours of the sea floor (called bathymetry) generally mimic the shape of the shoreline. Additionally the bathymetry of the seafloor has a profound affect on the movement of the wave as it approaches the shoreline. As the wave encounters shallower water the wave will be bent towards progressively shallower areas (**wave refraction**). The net result of wave refraction is to bend waves into areas of shallower water such as those immediately offshore of a headland. Due to wave refraction the headland receives the bulk of wave energy along an irregular shoreline and therefore will be a zone of intense erosion. Conversely, most of the wave energy will be deflected away from the bay and therefore this will be a zone where deposition, and not erosion, dominates.

Questions:

1. Where do waves of oscillation and translation occur in relation to the shoreline? Label their locations on Figure 1.

2. Compare the differences in wave height, wavelength, and wave velocity between a wave of translation and a wave of oscillation.

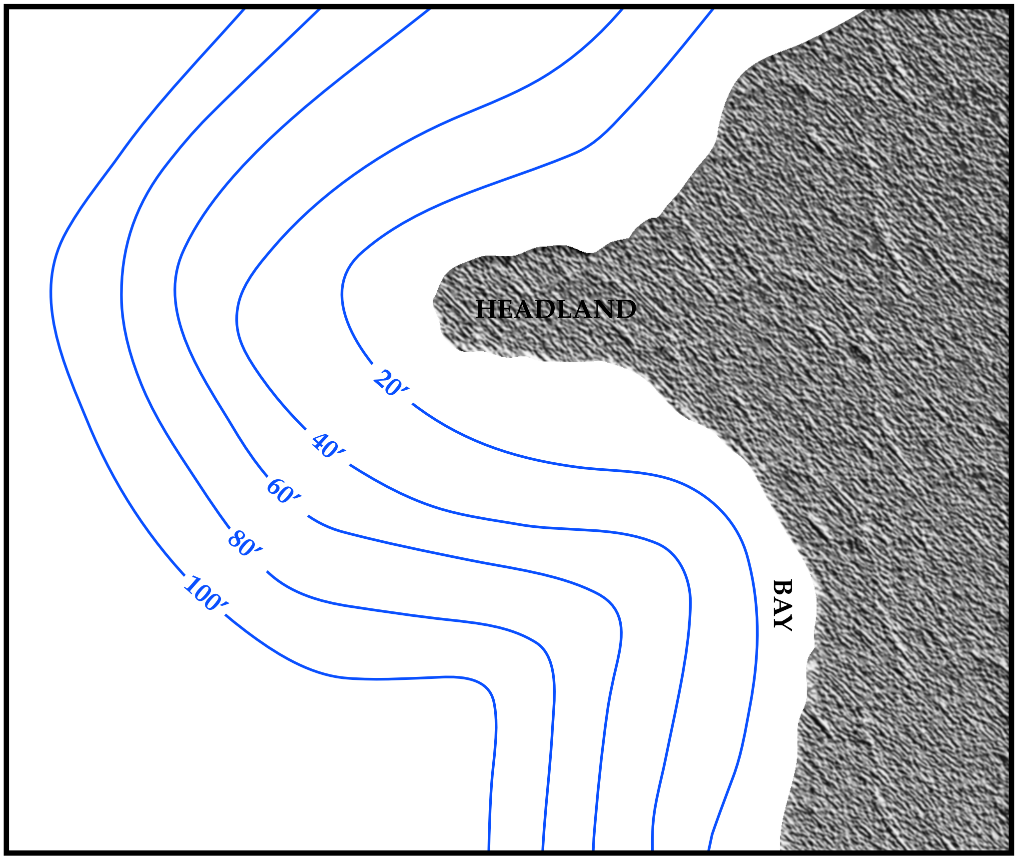


Figure 2. Seafloor bathymetry and shoreline map showing positions of a headland and bay.

3. Contrast water movement within a wave of translation and a wave of oscillation. Draw how the shapes of the orbitals are different for these two wave types.

4. How do you determine the water depths for wave base and wave break for a given wave? (Write the equations to calculate wave base and wave break.)

5. On Figure 2 indicate the water depth of wave base and the water depth of breaking waves for a wave with a wavelength of 100 feet.

6. On Figure 2 indicate on the shoreline where deposition (D) and erosion (E) will most likely dominate.

7. On Figure 2 indicate where most of the wave energy will be concentrated by drawing arrows.

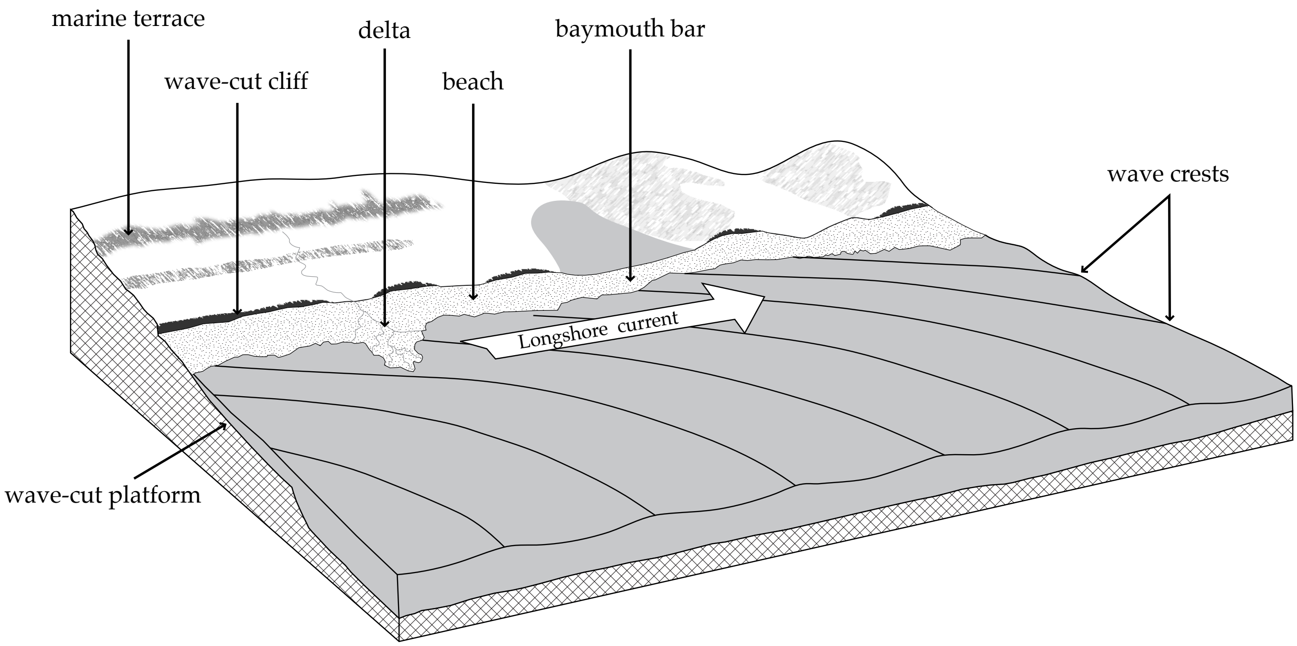
8. Where would a house immediately next to the shoreline most likely fall into the sea; next to a bay or on the headland? Explain in detail.

Section B – Wave Alteration of Passive Margin Shorelines

In the continental United States there are two fundamental types of shorelines. Tectonically passive margins that have low relief and consist of smooth sandy beaches, which are present on the Atlantic and Gulf coasts. Tectonically active margins with localized uplift associated with earthquake-prone areas, such as the Pacific coast, where the coastline has a predominately rocky character.

In passive margin settings the typical shoreline has a sandy character with special features formed by wave refraction. Remember the tendency of wave refraction is to bend the waves so that they become parallel to the orientation of the shoreline. However, wave refraction is almost never perfect and waves will commonly strike the shoreline at a slight angle (Figure 3) setting up a **longshore current** that has an overall movement that parallels the shoreline. In reality the movement of sediment along a beach has more of a zig-zag pattern, which can be referred to as **beach drift**. From this discussion you should realize that the sand on a beach is always moving.

Longshore current is responsible for the development of several landscape features most notably a **spit** (Figure 3) A spit is a hook-shaped extension of land the built out into the quiet waters of a bay. Note that the hook always indicates the direction in which the longshore current is flowing towards, which in the case of spit on Figure 3 is toward the east. Another feature is when a bay gets completed closed by sediment forming a **baymouth bar**. Finally, a long, linear island that separates the mainland from the ocean is referred to as a **barrier island**. Note that spits and baymouth bars can occur on the shoreline associated with a barrier island.



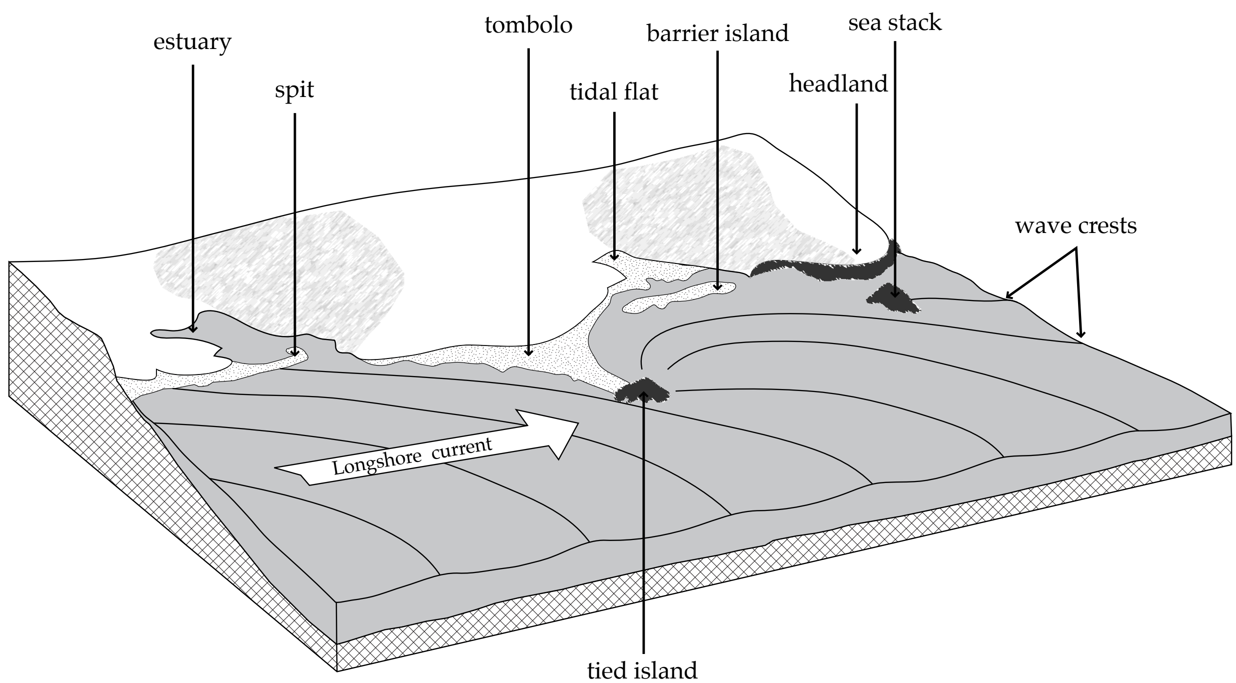


Figure 3. Diagrams illustrating common coastal features.

Question:

9. Are beach drift and longshore currents the same? Explain in detail.

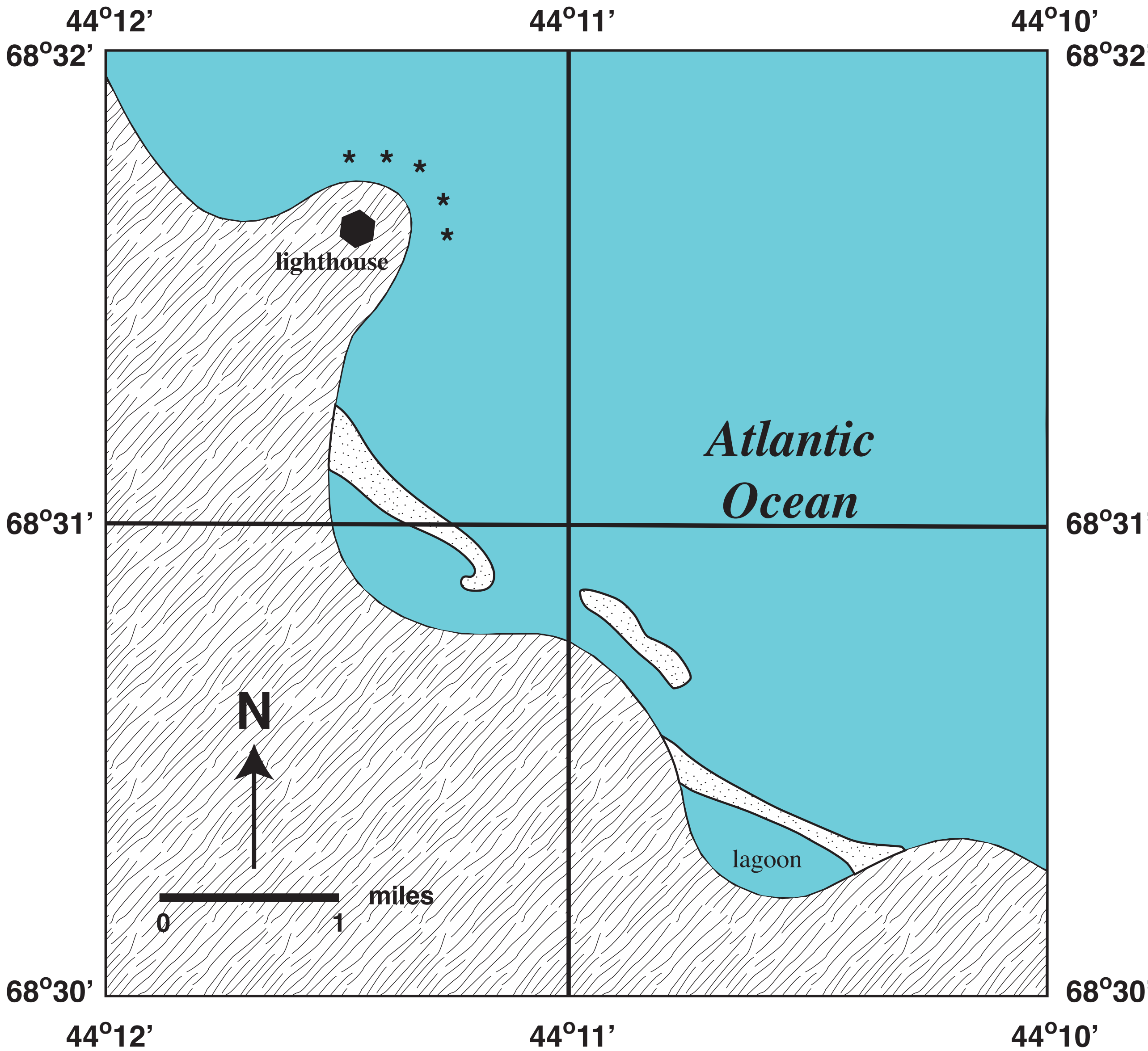


Figure 4. Map of a shoreline showing erosional and depositional features

Section C – Wave Alteration of Active Margin Shorelines

The Pacific coast is dominated by rocky shorelines that have distinctive landscape features. The headlands in this region are commonly pounded by wave action forming **wave-cut cliffs**. As these cliffs are eroded by wave action a flat level surface develops that is referred to as a **wave-cut platform** (Figure 3). Additional features develop during the erosion of the headland. A **sea arch** is formed when material from the bottom the headland is removed forming a hole or arch in the rock. A **sea stack** is a column of rock that is an erosional remnant of a largely eroded headland (Figure 3). Figure 4 (on page 8) shows features associated with both passive and active margin shorelines.

Questions:

10. Determine the type of shoreline feature, from Figure 3, present near the following coordinates on **Figure 4.**

Coordinates	**Feature**
68º 31' 45" N, 44º 11' 20" W	______________________
68º 30' 52" N, 44º 11' 10" W	______________________
68º 30' 45" N, 44º 10' 52" W	______________________
68º 30' 20" N, 44º 10' 30" W	______________________

11. Indicate the direction of the longshore current near the spit by drawing an arrow on Figure 4.

12. Wave refraction will cause waves to bend toward features that project outward. On Figure 4, indicate where this process is most concentrated by drawing arrows that converge on the headland.

13. Determine whether deposition or erosion will dominate at the following locations on Figure 4

Coordinates	**Deposition or Erosion**
68º 31' 40" N, 44º 11' 20" W	______________________
68º 30' 45" N, 44º 10' 50" W	______________________

Section D – Modification of Wave Dominated Shorelines

In wave dominated shorelines structures can be built that can alter the balance of erosion versus deposition along a segment of the coast. **Groins** are wall built from the shoreline offshore and are designed to trap sand on the side facing the longshore current (Figure 5). However, on the opposite side of the groin the sediment transport from the longshore current is blocked so resulting in significant beach erosion. Another structure is a **jetty** that protected an inlet from depositing sediment from longshore current. In affect a jetty prevents the formation of a baymouth bar (Figure 5). A **breakwater** is a wall parallel to the shoreline that is built offshore and is designed to block wave action and thus results in deposition along the protected beach (Figure 5).

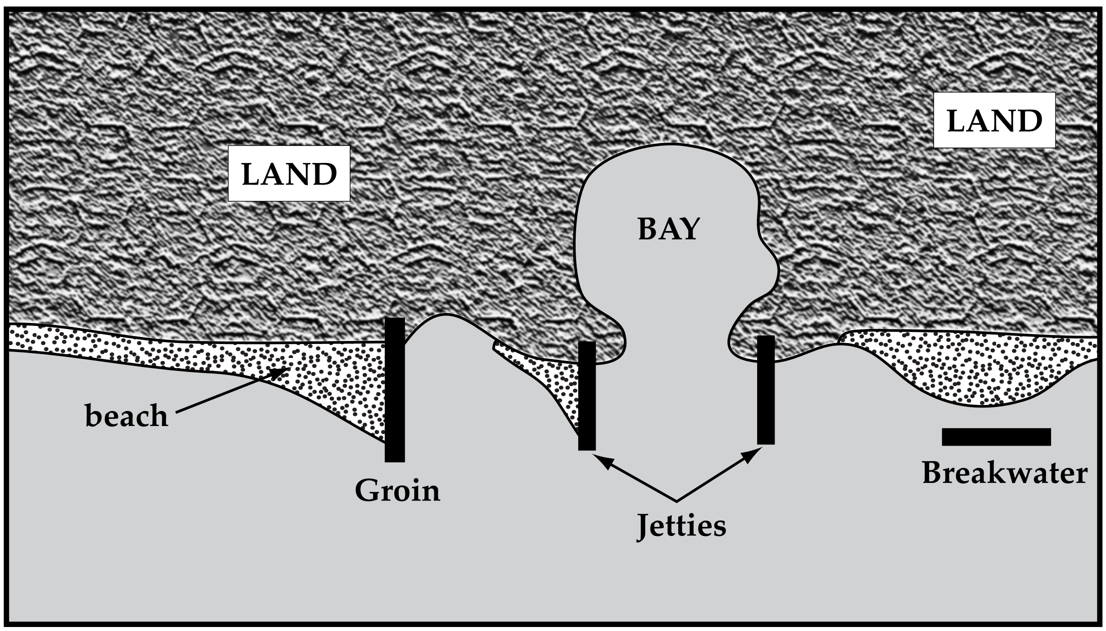


Figure 5. Diagram illustrating groin, jetty, and breakwater.

<u>Question:</u>

14. Examine Figure 5 and Figure 6 (top map) and describe the difference between a groin and breakwater? Your answer should include the orientation relative to the shoreline for both of these features.

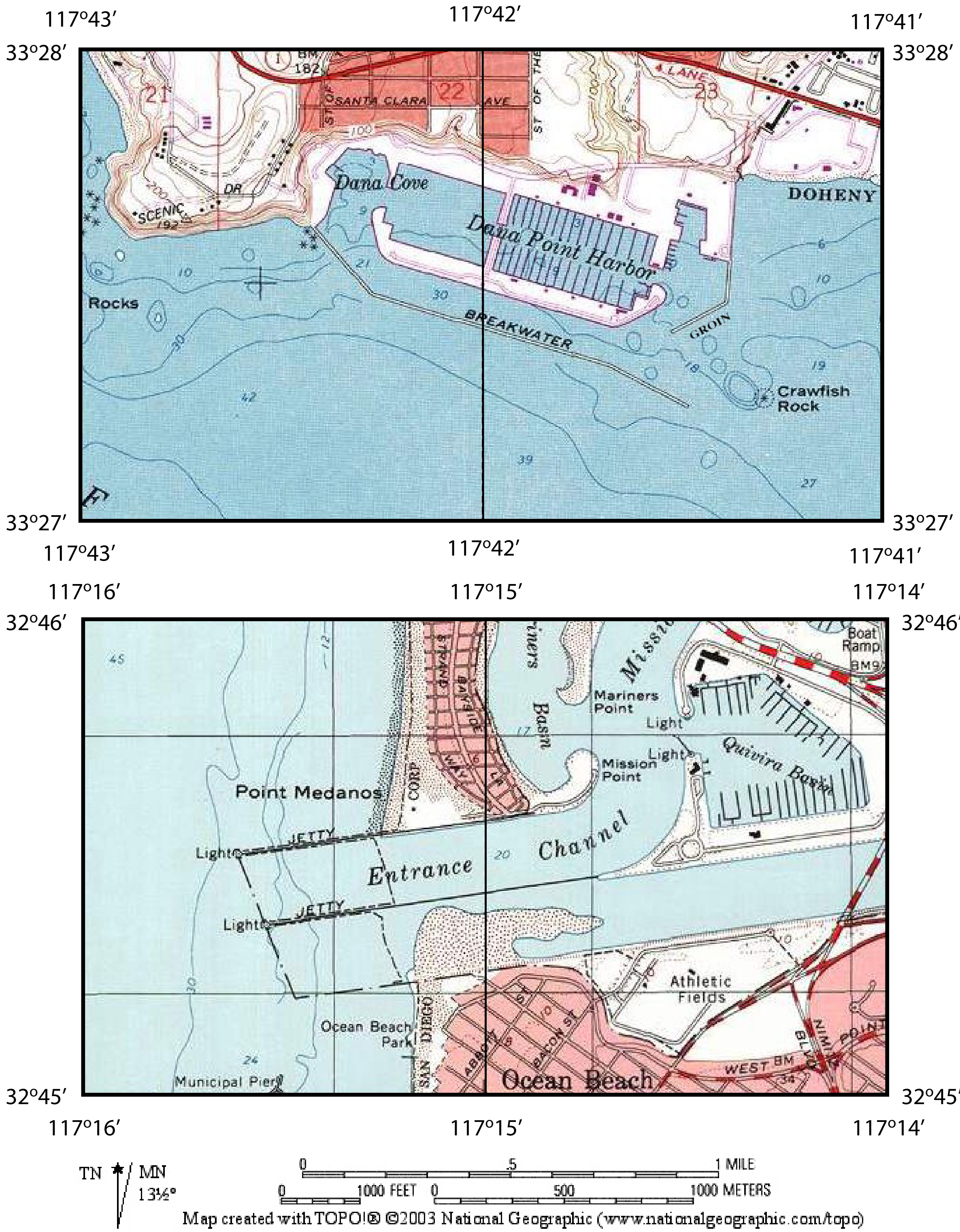


Figure 6. Maps of sandy shorelines with constructed features.

Questions:

15. Determine whether deposition or erosion will dominates at the following locations on **Figure 6 (bottom map)**.

Coordinates	**Deposition or Erosion**
32° 45' 30" N, 117° 15' W	______________________
32° 45' 45" N, 117° 15' 15" W	______________________
32° 45' 30" N, 117° 15' W	_____________________

16. Do groins protect the entire shoreline from beach erosion associated with storms? Explain in detail.

17. Explain the difference between a jetty and a groin.

Section E – Shoreline Processes: Overview of Tides

Tides result from the uneven gravitational attraction on the world's oceans from the moon and to a lesser extent the sun. There are two separate time scales over which tides operate (daily tides and monthly tides). **Daily tides** operate on a 24 hour and 52 minute cycle resulting from the changing position of the moon relative to different locations on the earth (Figure 7). Depending on your exact location you will experience either one or two **high tides** per day when the moon is directly overhead of your position on earth. The second high tide occurs when the moon is lined up with your position but is on the opposite side of the planet. **Low tides** occur when the moon is located at 90° relative to your position on earth. The vertical difference in elevation between high and low tide is referred to as the **tidal range** (Figure 8).

Monthly tides operate on a 29 day cycle resulting from the relative alignment of the sun, earth, and moon. Twice a lunar month, during the new and full moon (Figure 9), the sun, earth, and moon are alignment. During these days the gravitational attraction causing tides is maximized resulting in a **spring tide** in which the tidal range is greatest. During two other days in the lunar month the moon is orientated perpendicular relative to the earth and sun (1st and 3rd quarter moon). During these days the gravitational attraction causing tides is minimized resulting in a **neap tide** in which the tidal range is least.

Finally, in coastal regions dominated by tides unique landscape features are developed. Commonly, inland from the beach is a **tidal flat** that fills with water during high tide and is drain during low tide (Figure 3). Tidal flats common look like a mini-river system with a **tidal inlet** that allows water that branches into small "tributary" tidal channels the transfer water within the tidal flat.

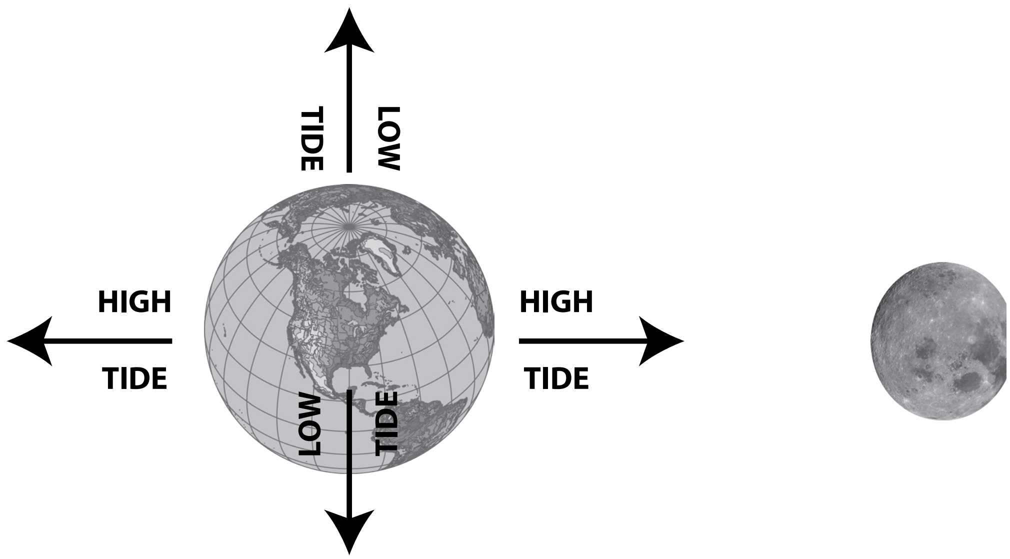


Figure 7. Diagram illustrating the position of the earth and moon associated with low and high daily tides.

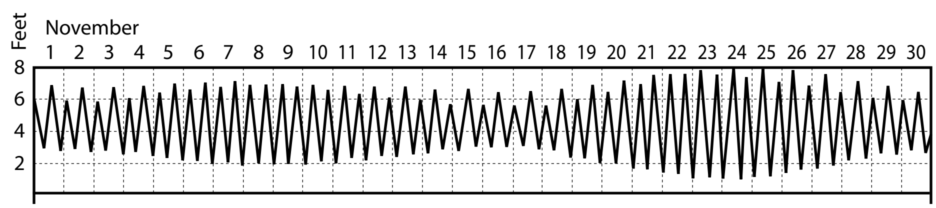


Figure 8. Typical variation in tides over a thirty-day period.

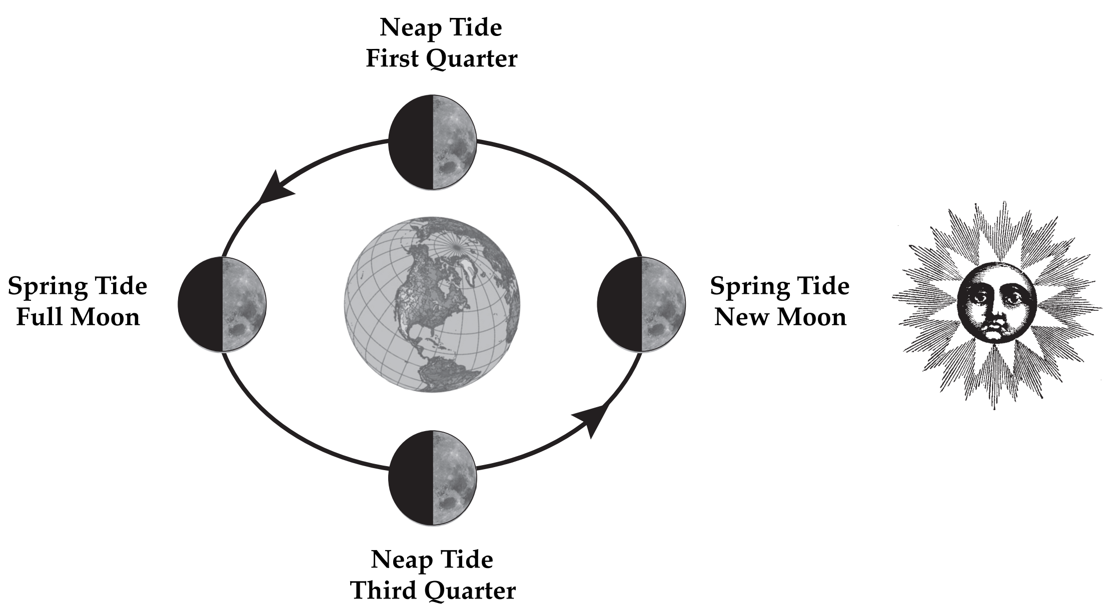


Figure 9. Diagram illustrating the position of the earth, moon, and sun associated with monthly spring and neap tides.

Questions:

18. Typically, how many high and low tides does this locality have on November 4th?

19. Is the tidal range constant throughout the month? Explain in detail.

20. What is the tidal range on Nov. 15th? (note: that this date had a 1st quarter moon).

High Tide - Low Tide = Tidal Range

_______ - ________ = __________

21. What is the tidal range on Nov. 24th?

High Tide - Low Tide = Tidal Range

_______ - ________ = __________

22. What is the lunar phase on Nov. 24th? (Hint: read question 21 again.)