Beach Profiling

Grade Level: 11-12

Teaching Methods: Analysis, Calculation, Data Collection. Discussion, Graphing/ Mapping, Observation, Small Group

Time:
- Preparation Time: 45 minutes
- Activity Time: 3 hours

Materials:

Activity I
- Pictures or profiles of the beach used in the activity that show change.

Per Group
- Two transit rods
- Light rope or heavy twine—a length that reaches from the base of the dunes to the water's edge.
- One stake wire flag
- *Beach Profiling Data* worksheet

Per Student
- *Graphing The Profile Sample* handout
- Graph paper
- Pencil
- Clipboard
- Ruler

Activity II

Per Group
- *Coastal Engineering* worksheet—Part I and Part II
- Clipboard
- Pencil
- Wave maker—3"x5" piece of plastic or thin plywood
- Wave box—see attached directions

Park Location:
- Activity I—a beach with a profile that changes or has changed historically.
- Activity II—a beach with several different types of coastal engineering strategies present—particularly hard structures.

Pre/Post Lessons:
- Pre-visit: A Model Beach
- Post-visit:

Summary:
Students measure the profile of a beach, examine a variety of coastal engineering strategies, and use models to observe the effects of various strategies.

Objectives:
- Students will measure the profile of a beach at Presque Isle.
- Students will construct a graph of the beach profile.
- Students will identify at least one physical force that can affect a beach profile.
- Students will name at least two coastal engineering strategies and list at least one advantage or disadvantage associated with a particular strategy.

PA Environment & Ecology Standards:
4.1.12. Watersheds and Wetlands

E. Evaluate the trade-offs, costs and benefits of conserving watersheds and wetlands.

4.6.12. Ecosystems and their Interactions

B. Analyze the impact of cycles on the ecosystem.

C. Analyze how human action and natural changes affect the balance within an ecosystem.

4.8.12. Humans and the Environment

A. Explain how technology has influenced the sustainability of natural resources over time.

PA Science & Technology Standards:
3.1.12. Unifying Themes

B. Apply concepts of models as a method to predict and understand science and technology.

3.2.12. Inquiry and Design

B. Evaluate experimental information for appropriateness and adherence to relevant science processes.

3.512. Earth Sciences

A. Analyze and evaluate earth features and processes that change the earth.

3.6.12. Technology Education

C. Analyze physical technologies of structural design, analysis and engineering, personnel relations, financial affairs, structural production, marketing, research and design to real world problems.

Other PA Standards:

- Geography
- Mathematics
- Reading, Writing, Speaking and Listening

Background:

Sandy beaches are the products of deposition, erosion, and sediment transport. Because sand is constantly moved on, off, and along the coastline, beaches are always changing. Everyday winds, waves, and currents shape and reshape coastlines by moving sand. These forces, which affect beach erosion and accretion (buildup), have been shaping Presque Isle for thousands of years.

Changing winds affect the direction, velocity, and size of waves. The stronger and longer the duration of the wind, and the farther it blows over open water, the larger and more forceful the waves. The most common winds at Presque Isle come from the west and blow over the largest span of open water. These winds create waves and currents that carry sand eastward along the park's shoreline.

When a wave reaches shallow water, the lower part of the wave is slowed by the lake floor, but the upper part continues at the same speed until it topples over. This is when it "breaks" on the beach. Breaking waves stir up sand and carry it on or off the beach. When waves break at an angle to the beach, it creates a current that runs parallel to the shoreline. Known as the longshore current, it moves sand year-round and can carry it considerable distances.

The amount of sediment carried to Presque Isle beaches by the longshore current is dependent on the amount of erosion along a 20 mile stretch of bluffs west of the park. These bluffs are generally considered the major source of beach building material for Presque Isle.

Beaches also change in the short term with the seasons. Waves in summer and winter are different in size and strength. In summer, waves tend to be low, gentle, and farther apart. These waves deposit sand on shore to form a wider beach with a flatter profile. As winter approaches, waves become choppier, more forceful, and more frequent. Beaches are often eroded to become narrow and steep. Winter storms can cause large, powerful waves that crash onto the beach and pull sand offshore.

The wave climate at Presque Isle also has a seasonal aspect and is described as a storm wave environment. Long periods of calm are interrupted by short-lived, high energy storms. Calm conditions with wave heights less than .15 meters (six inches) occur 75% of the time along the shoreline. The summer months are dominated by low, gentle waves. High intensity storms occur in the fall (October and November) before the lake freezes and in the spring (March through May) after the lake ice begins to break up. During these storms high waves can quickly carry large amounts of sand away from the beach. This sand is not lost, but is stored in a system of submerged bars and troughs that lie 150 to 600 feet offshore. Some material is carried into deep water where waves can no longer reach it, but much of the sand moves parallel to shore and is eventually carried shoreward by smaller waves during the summer. In winter, when they are covered by ice, the beaches are safe from erosion.

Presque Isle continually moves and changes, because sand is eroded from some locations and deposited in others. These changes are best understood by dividing the peninsula into three parts: the Neck, the Lighthouse Beaches, and Gull Point. The northwest facing beaches (from Beach 1 to near the lighthouse) in the Neck are most exposed to approaching waves and erosion. Waves move sand away from the beaches and carry it northeastward along the shore. Between 1828 and 1923 storm waves cut completely through this area of the peninsula at least four times. One opening grew to be a mile wide and remained open for 30 years.

In the Lighthouse Beach area (from the lighthouse to Beach 10) east of the Neck, the peninsula widens abruptly. The waves approach the beach at a gentle angle and much of the sediment eroded from the neck is carried through this area. The easternmost portion of Presque Isle, known as Gull Point, is the only area that is growing, because much of the eroded sand returns to the beach here.

Beach erosion and accretion are natural processes, but human activities can alter them. People build engineering structures, such as groins or seawalls, with the goal of stabilizing beach areas or protecting coastal structures. However, while these engineering structures may protect one area, they may also cause erosion in another.

From the early 1800's to present, a variety of coastal engineering strategies have been implemented along Presque Isle to control erosion and protect the Port of Erie.

Groins

Groins are piles of rock or other material that are built perpendicular to the shoreline and usually extend to the end of the surf zone. They create or widen beaches by capturing sand that is carried by the longshore current. When the current hits the side of the groin, the sand particles drop out and build up on the updrift side of the structure. While groins do successfully build beaches, they also frequently cause erosion on the downdrift side. At Presque Isle there are 11 groins between Beach 1 and Beach 6, and a number of others east of the lighthouse. The groins at Presque Isle have been built of wood, metal sheet piling, rock, concrete, and combinations of these materials.

Seawalls

A seawall is a structure, often made of concrete, which is built on a beach parallel to the shoreline. Seawalls are a common way to protect critical areas or structures from storm waves. Seawalls can protect what is behind (landward of) them, but do not protect the beach in front of them. A seawall can be observed at the Perry Monument area of the park.

Revetment or rip-rap

A revetment is a structure consisting of large rocks or other materials stacked in front of an eroding cliff, dune, or structure to protect it from wave attack. Like seawalls, revetments do not benefit the beach in front of them. Revetments have been used to help stabilize the Lighthouse Beaches at Presque Isle.

Breakwaters

Detached breakwaters slow erosion by sheltering the shore from the full energy of the waves. Breakwaters partially block the waves causing them to lose energy, which allows some sand to settle out and accumulate behind them. They generally interrupt sand transport less than groins, but can also have side effects on the downdrift areas. The 58 segmented breakwaters at Presque Isle are expected to reduce erosion along the shoreline and the amount of sand needed for beach nourishment. They were designed to allow enough sand to move through the system so that the growth of the peninsula at Gull Point would continue, although at a slower rate than in previous years.

Beach nourishment

Beach nourishment is the process of moving sand from offshore or inland sources and depositing it onto the beach. This practice has been used at Presque Isle since the 1950's. This method combats erosion by replacing eroded material and supplying new sand to the longshore transport system, allowing the growth of beaches downdrift. The success of nourishment depends on the best combination of grain size and quantities of sand to match wave conditions. A balance is reached between having some sand stay on the beaches and allowing enough to be carried along shore to maintain active beaches downdrift. Nourishment must be repeated regularly and is expensive.

Dune stabilization

A dune is a hill or ridge of sand built up by the wind. Plants, such as grasses, that become established on the dune trap sand grains and stabilize shifting sands. As more sand is trapped, the dunes are built up and form a barrier to erosion from waves and high water. The lake shore dunes on the north side of the Presque Isle peninsula are built and stabilized primarily by beach grass and switchgrass.

Getting Ready:

Activity I

- Purchase or make the transit rods—see attached directions. If using purchased rods that do not have a sighting hole, drill a hole (1/2 " diameter) through the center of each pole at the zero mark. It is not necessary, but makes sighting the horizon easier.
- Copy the *Beach Profiling Data* worksheet—one per group.
- Copy the *Graphing the Profile Sample* handout—one per student.
- Select a beach area to profile. It should be a beach that shows change with the seasons or has shown change historically. Ideally, students should be able to compare their profile to other profiles or historic photographs of the same beach in different seasons.
- Select a profile location on the beach for each group. You will need one location for every 4-6 students. At each location, place a flag at the starting point—the base of the dunes. Each site should have a reference point, such as a tree, building, etc. Mark the reference point on the flag, so students can locate the object and you can locate the site again for future groups to profile.
- Set up one additional profile location. Use this site to demonstrate the profiling procedure.

Activity II

- Select a beach area that contains several examples of coastal engineering strategies—particularly hard structures such as breakwaters, groins, and revetments.
- Assemble the wave box equipment—see attached directions. The sand can be added to the box in advance, if desired. Add the water just before the activity or have the students add it.
- Place the wave boxes in a fairly level location not too far from the source of water you will use. Lake water or tap water can be used.
- Copy Part I and Part II of the *Coastal Engineering* worksheet—one per group.

Activity:

Activity I – Beach Profiling

1. Ask the students what they know about how beaches are formed. Where does the sand on beaches come from? Do beaches look the same year round? What might cause them to change appearance in different seasons?
2. Tell the students that they will be gathering data that will allow them to make a beach profile. A beach profile will provide them with a side view of the shoreline.

3. Take the students to the demonstration profiling area and review the procedure for collecting and recording beach profiling data. Select different students to help demonstrate each step of the profiling procedure.

- Explain that each profile location has a reference point. The reference point is a permanent object that makes it easier to locate the profile area at various times of the year. Tell the students that the reference points have been pre-selected and marked on flags. Have a student look at the flag and find the reference point, such as a tree, rock, building, etc.
- Give two students the rope. Have them lay the rope on the beach to make a straight line from the flag to the water's edge. Have the students leave the rope in place and return to the group. Explain that measurements will be taken at two meter intervals along this line.
- Select two students and give each a transit rod. Have one student stand at the flag and hold the first transit vertically on the rope. This is the starting point. Have another student place the second transit two meters (one transit rod length) ahead of the first moving toward the water. The measurements on the second transit should be facing the person at the dunes. Make sure that the transits are kept vertical and the rope is perpendicular to the transits.
- Tell the students that they will use the horizon (the point where the sky meets the water) as a constant to line up a reading on the transit. Have another student stand at the first transit and sight through the hole to the second transit. Have them read the value on the second transit at the point where the horizon meets the transit. If they cannot see the numbers due to distance, the person on the second transit can be guided to move their finger up or down until they point to the mark on the transit. (see picture on page 7.)
- Show the students the *Beach Profiling Data* worksheet and have a student record the plus or minus reading on the data sheet in the space labeled "Site 1." Have them record 2 meters in the *Cumulative Distance* column.
- For the second measurement, have the student who is holding the first transit move it two meters ahead of the second transit. Explain that they should keep the second transit in place as it will now serve the same role as the first transit. Have a student take a reading from the transit and record it on the data sheet under "Site 2."

Explain that to complete the profiles, they will repeat this process, leapfrogging over the transit for each successive measurement until they reach the water's edge.

- Have a student record the *Cumulative Distance* for Site 2. Make sure they understand that additional entries for distance are added to the previous reading (i.e. cumulative).
- Explain how to record the *Cumulative Change In Elevation*.

4. Divide the students into groups of 4-6 students. Give each group two transit rods, a rope, a *Beach Profiling Data* worksheet, a pencil, and a clipboard. Point out the flags that mark the different profile areas and assign one to each group. Tell them that when they get to their area they should complete the general information on the worksheet, make a straight line with their rope from the flag to the water's edge, and begin to take their measurements. Explain that as they take each measurement they should also record any other observations about the immediate area, such as whether the sand is coarse or fine or whether there are any plants present.

5. Give the students an allotted amount of time and send them to their areas to begin their profile.

6. Once the students have finished, gather all of them together. Explain that they will create a graph of their data. Give each student a piece of graph paper, a clipboard, a pencil, a ruler, and the *Graphing The Profile Sample* handout. Make sure the students understand that the sample graph is not based on real data and is only an example of how to set up the graph. Have them set up their graph in a similar fashion. Tell them to make sure the unit of elevation on their graph matches the units on the transit rod. Once the graph is set up, they should plot the *Cumulative Change In Elevation* data on the graph.

7. Once they have finished their graphs, review their profiles. Note any differences between the profiles and what they might indicate. Ask the students how much the elevation changed from the beach to the water's edge.

8. Explain that beach profiles are often taken regularly at the same spot, but at different times of the year. Ask the students what information this type of monitoring would provide. *(it can show how a beach changes over time; if it is building up or eroding; what times of year it is most vulnerable to erosion)* What physical forces might cause the profile to change? *(wind, waves, currents)* What part of the profile would be most affected? Which areas are the most stable? How could they tell? *(students should use the observations they made during the profile—such as evidence of plants, steepness of the beach; condition of the sand, or signs of erosion)*

9. Ask the students to explain how they think their beach profile might change throughout the year and why. In what seasons would you expect more erosion? Why? Explain the seasonal storm environment at Presque Isle and how it affects the beaches. If possible, have the students compare their profiles to other profiles or photographs of the same area at different times of the year. Ask them in which season they think the profile or photograph was taken.

Activity II – Coastal Engineering

1. Take the students closer to the water. Ask them to observe the waves moving toward the shoreline. Ask them to describe what they see. How are the waves hitting the beach? Have them take a closer look at the waves. Ask the students in what direction sand would be moved along the shoreline. Explain the longshore current and how waves move along the shoreline.

2. Explain that beach erosion and accretion (buildup) are natural processes, but that human activities can alter them. Briefly explain some of the history of beach erosion at Presque Isle. Explain that many different coastal engineering strategies have been used at Presque Isle to prevent beach erosion. List the different types of strategies mentioned in the background information. Describe what they are, but not how they function. For example, groins are piles of rock or other material that are built perpendicular to the shoreline and usually extend to the end of the surf zone. If they are visible at the activity site, point them out. If not, show the students pictures of the different strategies.

3. Tell the students they will be focusing on built structures. Assign each group a particular engineering structure that can be seen at the site—a groin, revetment, seawall, or breakwater. If necessary, assign the same structure to more than one group. Give each group a copy of the *Coastal Engineering* worksheet. Tell the students they should complete Part I of the worksheet. Explain that the students must describe the structure and what they think it is designed to do. Then they should list what they think are its advantages and disadvantages. Tell them they must be able to explain their reasoning.

4. Place the groups so they have a good view of their structure and can work without overhearing other groups.

5. Take the students to the wave boxes. Determine if they did the pre-visit activity, A Model Beach, before their trip. If so, ask them what they observed about wave action on beaches. Explain that the wave box they will use today is a

model of a beach along the lake side of Presque Isle. Point out east and west as marked on the box. Ask the students from what direction the waves would approach the beach. Use a wave maker to create gentle waves moving in a west to east direction. Ask the students to describe how the coastline changed.

6. Explain that each group will add their engineering strategy to a wave box and test the results.

7. Assign each group a wave box and show the students the various materials for creating the engineering structures. Tell them that the placement of their model structures must be similar to the actual structures they observed. Review Part II of the worksheet. Tell the students that they must predict the results before using the wave box. Once they have completed the test, they should record the actual results.

8. Give the groups time to use the wave box and complete their worksheets.

9. Bring all of the students together and have each group describe their structure and present their findings. If more than one group had the same structure, did they get the same results? Discuss how the coastline changed and whether the results were what they expected. Did they observe any of the advantages or disadvantages they thought the structure might have? If necessary, provide further explanation of the strategy. Continue in this manner with another group until all of the strategies have been demonstrated.

10. As a group discuss which strategies had the greatest benefit to the model beach. Which might benefit the model beach and also cause the least amount of problems for other areas? Briefly discuss the function of other strategies that were not tested in the wave box. Considering all of the available options, including those not tested in the model, what combination might work best? Ask the students why they think there are so many different coastal engineering strategies at Presque Isle.

Evaluation:

- Students produce an accurate profile of the beach by graphing data they collected.
- Students discuss physical factors that may change beach profiles and explain their reasoning.
- Students use a model to demonstrate a coastal engineering strategy. Students draw conclusions between model results and inferences they made about the advantages and disadvantages of the strategy.

Extensions:

- Have the students determine which combination of strategies would provide the best protection from erosion with the least effect on beaches downdrift by testing them in the wave box.
- Take the students to another area to observe additional coastal engineering structures.

References:

- Burkhart, Dr. Patrick, Slippery Rock University, *Shifting Sands* and personal contact, 2004.
- Davenport, Julia, California Coastal Commission, *Waves, Wetlands, and Watersheds*, 2003.
- Pennsylvania Department of Conservation and Natural Resources, Bureau of State Parks, *Resource Management Plan Presque Isle State Park*, 1998.
- Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey and Bureau of State Parks, *Pennsylvania Trail of Geology, Presque Isle State Park*, 1991.
- http://mciunix.mciu.k12.pa.us/~seastar, Rumpp, Phyllis & Rumpp, George, *Seastar*, Measuring Beach Profiles, 1999.
- www.njmsc.org, *The Education Program at the New Jersey Marine Sciences Consortium,* Beach Profiling.

Developed By:

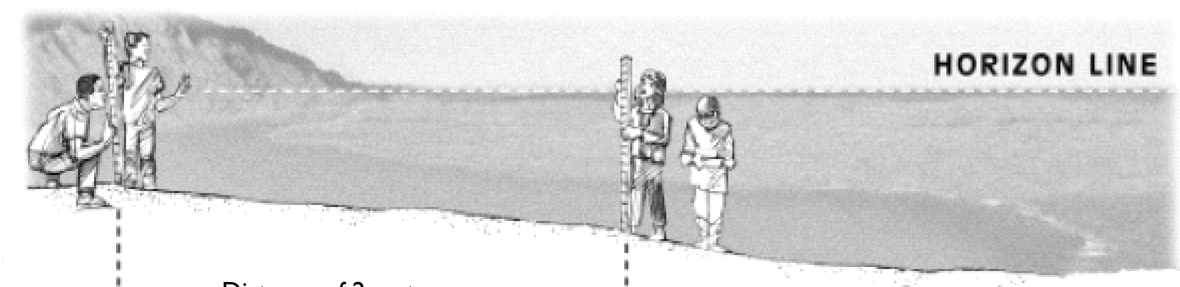
- E-Concepts LLC, Albert, JoAnn and Davis, JoAnn, 2005.

How To Make Transit Rods

For two transit rods:
Equipment: One 2 in x 4 in x 8 ft board, drill with 1/2 inch bit, white paint, black paint or permanent marker

Directions:

- Cut two wooden rods to 5 cm x 5 cm x 2 meters (2 in x 2 in x 6.5 ft). The rods must be made identical to each other. A single 2 in x 4 in can be cut in half lengthwise to make two rods.
- Drill a 1/2 inch diameter hole in the center of each pole for use as a sighting device.
- Paint the poles white.
- Mark and number lines with black paint or permanent marker at 10 cm intervals. The hole is the zero point. Number intervals using positive numbers (+10, +20, etc.) from the zero point to the bottom of the pole. Number intervals above the zero point using negative numbers (-10, -20, etc.) **Note: Rods can also be marked in inches or decimeters, if preferred.



How To Make Wave Boxes

For one wave box:
Equipment for box: One large rectangular plastic container with low sides, sand, water, water containers—buckets or jugs, paper, permanent marker, tape

Equipment suggestions for coastal engineering structures:

- Groins—rulers, yardsticks, or thin wood (such as furring strips) cut to fit the size of the box.
- Revetments—limestone gravel—a size that would resemble small boulders in the model and be comparable to those used on the beach, but to scale.
- Breakwaters—small plastic boxes filled with stone, square pieces of metal or rock, anything somewhat square that will not float.
- Seawalls—piece of wood or metal that can be pushed into the sand so it stands upright like a wall.

Directions:

- Cut two strips of paper. Use the marker to label one "East" and the other "West." Tape the labels to opposite sides of the pan.
- Pour sand up to 4 inches deep in the south end of the pan. Shape the sand so it angles out somewhat—approximating the angle of Presque Isle to westerly waves.
- Add water up to 2 inches deep to the north end of the pan.
- Use a wave maker (3" x 5" piece of plastic or thin plywood) to create gentle waves coming from the west.
- If the model has been used for the initial demonstration, set the beach to its original configuration.
- Add model engineering structures in the appropriate place.
- Use the wave maker again to create gentle waves from the west.

Beach Profiling Data

Date: ________________ **Beach:** ________________ **Reference Point:** ______________________________

Directions:

1. Use the rope to make a straight line from the flag to the water's edge.
2. The starting point is the flag at the base of the dunes. Transit measurements should start at this point and follow the rope in a straight line to the water's edge.
3. Use the transit rods to measure the elevation of each site at two meter intervals (one pole length).
4. Record the measurement from the transits in the ***change of elevation*** column.
5. To determine the ***cumulative change in elevation*** add the current site reading to the previous cumulative change in elevation. For example, the cumulative elevation at the starting point is 0. If the measurement at Site 1 is -5, the cumulative elevation for Site 1 is 0 + (-5) = -5. If the measurement for Site 2 is -2, the cumulative elevation is -5 + (-2) = -7. If the measurement for Site 3 is +1, the cumulative elevation is -7 + (+1) = -6.
6. Record observations in the immediate area of each site. Examples of observations might include sand conditions (wet, dry, etc.), sand grain size (fine, coarse, rocky, etc.), or evidence of plant or animal life.

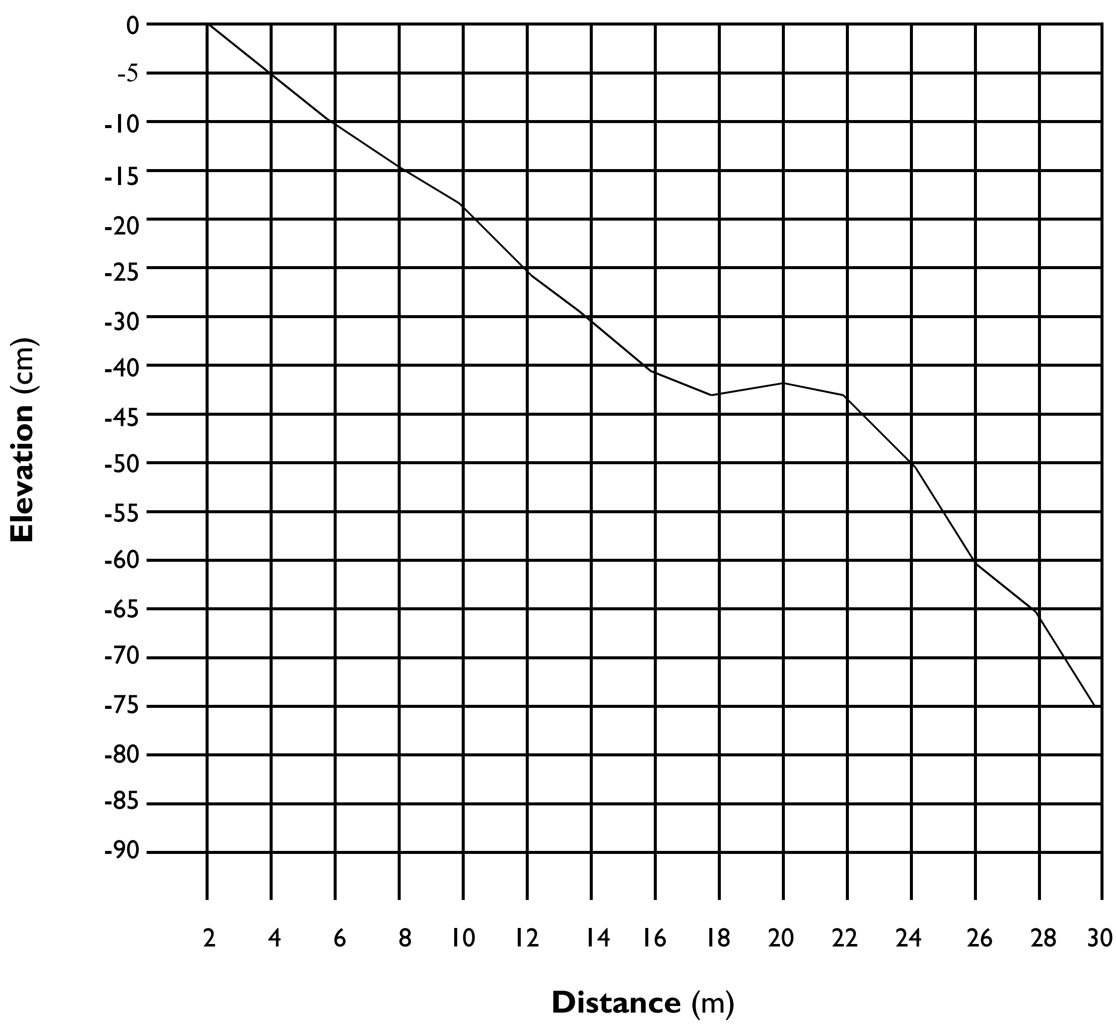
	Change Of Elevation (centimeters)	**Cumulative Change In Elevation**	**Cumulative Distance** (meters)	**Other Observations**
Starting point	0	0	0	
Site 1				
Site 2				
Site 3				
Site 4				
Site 5				
Site 6				
Site 7				
Site 8				
Site 9				
Site 10				
Site 11				
Site 12				
Site 13				
Site 14				
Site 15				

Graphing the Profile
Sample

The graph below is an example of how to set up the graph. It is not based on real data or any particular beach.

In this profile the elevation on the beach dropped 75 centimeters over a distance of 30 meters (or 2.5 feet over a distance of 32.7 yards).

Profile of Beach A



Coastal Engineering

Part I

1. **Describe the engineering strategy you are observing. What do you think it is designed to do?**

2. **List what you think are the advantages of this strategy.**

3. **List what you think are the disadvantages of this strategy.**

Coastal Engineering

Part II

1. **Based on your observations in Part I, predict what will happen to the beach when your engineering structure is in place.**

2. **After testing the structure, describe what happened. Did the results match your predictions?**