Bringing Wetlands to Market Part 4 Exercise 1
Coastal wetlands, development, and sea level rise: Where will the waterfront be?
Adapted from an Armada Project lesson on sea level rise

Overview
In this activity students will delineate and model the changed shoreline and the inundation of coastal wetlands and developed areas due to sea level rise at different levels. They will look for areas that could become marshes and areas where existing development would limit the formation of future wetlands.

Time Required
One 45-minute class session

Focus Questions
What causes sea level rise?
How will higher sea level affect coastal areas in normal conditions and in storm events?

Performance task
Students will use paper or online maps to outline areas that may be inundated at higher sea levels and during storm events.

Background for teaching
Sea level change has happened at various times in Earth history. It is a natural process that has gone on since there have been oceans on Earth. However, the increase in the global average temperature is now causing a rapid rise in sea levels.

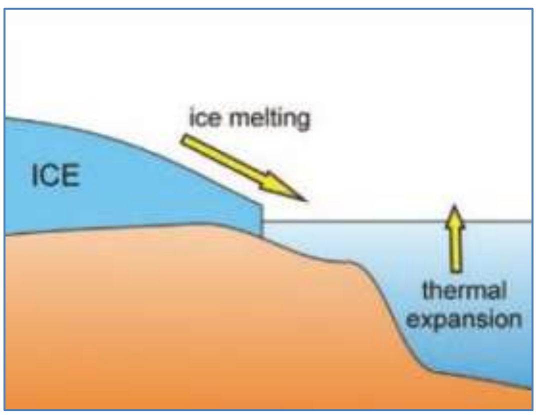


Image from ice2sea

Global warming affects the volume of the oceans and the height of the sea due to two factors: **thermal expansion**, which means that as water warms it takes up more volume than it did previously, and the **melting of land-based ice** such as glaciers and the ice caps in Greenland and Antarctica.

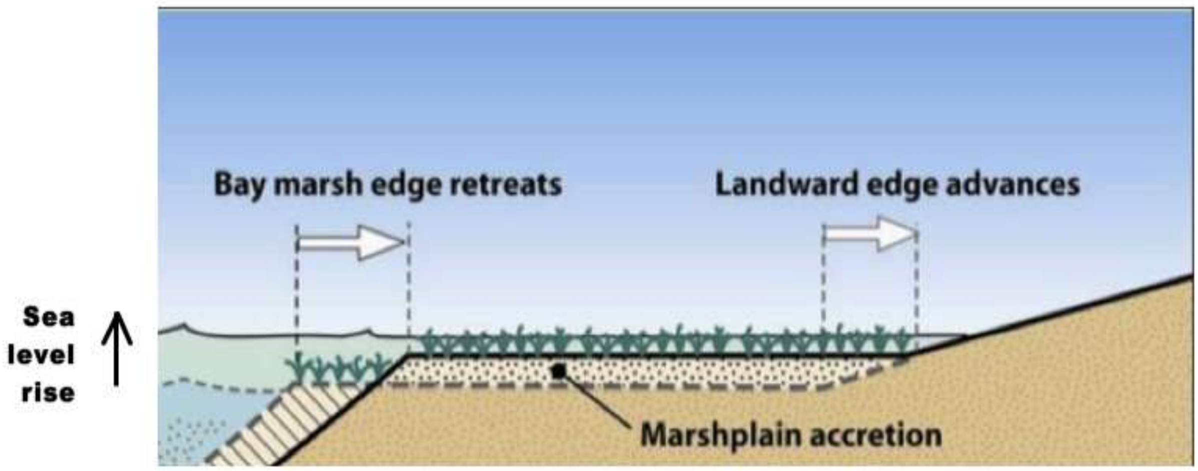
Additional diagrams and information on factors that influence sea level rise can be found at Climate Change: Global Sea Level and Sea Level Rise

Although the amount of sea level rise varies considerably from place to place due to geologic factors, research supports predictions that the oceans will rise 0.3 to 1 meter (about 1 to 3 feet) above present levels by the year 2100 (Sweet et al 2018). This means that the present levels for unusually high tides and storm surges will also be higher by that amount in 2100.

A rise of 1 meter would have a dramatic effect on our coastlines. Seventy per cent of the world's population lives within 100 miles of the coast. If the height of the ocean increases 1 meter, many coastal areas, including many cities, will be vulnerable to erosion, flooding, and storm surge. A serious impact of sea level rise would be the inundation and loss of coastal wetlands. Scientists estimate that two-thirds of the coastal wetlands in the United States are vulnerable and may be lost if the sea level rises 1 meter (Spencer et al 2016).

Coastal wetlands are a very important sink, or storage pool, for atmospheric carbon. The amount of plant biomass that is produced naturally on an acre of salt marsh is greater than that produced on fertilized farmland, and wetland soils can hold on to carbon for hundreds to thousands of years. Coastal wetlands are also important as a home for fish, birds, shrimp, crabs, and many other types of animals, a place they can reproduce, a source of food, and a resting place on migration. According to NOAA's [National Ocean Service](#) , about two-thirds of the species of food fish harvested from the Atlantic and Pacific Oceans and most of the shellfish must live in salt marshes or estuaries for part of their life cycles.

Salt marshes can increase their elevations to keep up with natural sea level rise through accretion, or accumulation, of sediments if the rate of sea level rise is slow enough. In order to keep pace with sea level rise, coastal marshes must have an adequate sediment supply and be protected from severe wave erosion. Salt marshes naturally migrate toward upland areas as they build up with sea level rise (see diagram below), and one of the most serious problems for sustaining coastal marsh systems is that development along the coast often prevents natural marsh evolution.



Through natural processes, a coastal marsh will gain elevation and retreat landward as sea level rises. Rapid sea level rise or coastal development blocking landward retreat will impair this process. Modified from a diagram by Jeremy Lowe

The distance that rising sea levels bring seawater onto land is dependent on many factors, including the shape of the land, amount of erosion, local ocean currents, and tides. Loss of wetlands due to sea level rise is most severe in areas with small elevation gradients, where the coastal land slopes gradually. For example, coastlines with a gradient of 20 to 1 will lose 20 meters (65.6 feet) of horizontal land or wetland for every 1 meter that the sea level rises. Salt marshes will be especially affected because of their gentle gradients – many have much lower gradients than 20 to 1 or are nearly level.

In addition to rapid sea level rise, coastal wetlands are vulnerable to additional pressures from climate change. The increased energy in the water cycle due to warming temperatures can cause intense precipitation to fall in severe events (USGCRP 2014). Intense storms can cause erosion and major damage to wetlands and other coastal ecosystems, as well as to roads, buildings, and utility structures along the coast.

We can help slow the rate of warming by reducing the use of fossil fuels by industry, in our communities, and as individuals, and by increasing the uptake of CO_2 by protecting and restoring wetlands and forests. Cooler average temperatures will reduce both thermal expansion of the ocean and land ice melting, and will allow coastal wetlands more time to assimilate sediments, sequester carbon, and increase their elevation to keep pace with sea level rise.

References

Schuerch, Mark & Spencer, Tom & Temmerman, Stijn & Kirwan, Matthew & Wolff, Claudia & Lincke, Daniel & Mcowen, Chris & Pickering, Mark & Reef, Ruth & Vafeidis, Athanasios & Hinkel, Jochen & J. Nicholls, Robert & Brown, Sally. (2018). Future response of global coastal wetlands to sea-level rise. Nature. 561.

Spencer, Thomas & Schuerch, Mark & J. Nicholls, Robert & Hinkel, Jochen & Lincke, Daniel & Vafeidis, Athanasios & Reef, Ruth & McFadden, Loraine & Brown, Sally. (2016). Global coastal wetland change under sea-level rise and related stresses: The DIVA Wetland Change Model. Global and Planetary Change. 139. 10.1016/j.gloplacha.2015.12.018.

Sweet, W.V., R. Horton, R.E. Kopp, A.N. LeGrande, and A. Romanou, 2017: Sea level rise. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 333-363, doi: 10.7930/J0VM49F2.

U.S. Global Change Research Program, 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., 19-67. doi:10.7930/J0KW5CXT.

Investigating coastal impacts of sea level rise

Materials

*Print copies of topographic maps with contour lines for two coastal areas with different slopes; you may choose to use the maps provided with this lesson. Maps are available at this link: USGS topographic maps of the local area
or visit your local conservation commission, town GIS department, or fishing and hunting supply store to find topographic maps.

Clear plastic sheets to overlay on maps
Fine tip markers, erasable or permanent

*If you prefer, students can use interactive online maps to investigate sea level rise. Interactive maps for modeling sea level rise can be found at the NOAA Coastal Services Center Sea level rise viewer

Procedure

1. Review with students the concept of sea level rise based on the background in this lesson or other resources of your choice. Confirm that they understand that the main causes of sea level rise are thermal expansion and melting of land based ice.

2. Give each group of students a local or regional topographic map, if your community is coastal, or a map of the terrain around Waquoit Bay NERR if your community is inland. You may wish to use the maps provided in student resources below. Have students find the scale and the contour line elevation interval, which is generally 10 ft for USGS 7.5 minute series maps.

If you are using an on-line sea level rise viewer , ask students to set the initial sea level rise to zero, and find the scale indicator in the image.

3. Have students choose a section of the map that encompasses a coastal area with relatively level ground. It will be most interesting to have an area with natural (marsh, beach, rocky shoreline) as well as man-made (houses, businesses, jetties, piers) features.

4. Ask students to examine their maps to determine the current shoreline, represented by the mean high water line. Provide them with a clear overlay (such as a transparency sheet for an overhead projector). Ask them to trace a length of the current coastline with a fine tip marker.

5. Download and print graphs from NOAA Sea Levels Online (or use the example included with student resources below) or have students go to the site to find the rate of sea level rise for the location they are studying. While visiting the website, ask them to compare the rate of sea level rise for the nearest coastal area and one in a different part of the country.

6. Have students examine the impacts of more than one predicted value for sea level rise over the next century. Begin with the prediction of a 1 meter increase in sea level (or use 3 feet, if that is more practical for your students). They will have to use the contour lines as guides to estimate where they should mark the new shoreline due to this sea level rise. They should assume that the slope of the land between contour lines is uniform. Have students mark the shoreline at the new sea level, using a different color marker.

7. Have students repeat the exercise showing the impact of a 2 meter, and then a 5 meter (approximately 6 foot and 15 foot) increase in sea level to model the effects of storm events with storm surge.

8. Within groups, students should discuss the implications of the shoreline change for each scenario and record their comments in a document or on poster paper. Ask students to write brief notes on the effect of sea level rise on habitats and human structures on the map and have them propose actions that could help solve or remediate the problem for each impact of sea level rise. Some questions for discussion could include:

a. What natural and man-made features are affected?

b. How much land has been lost? Choose a location to assess and measure the change in area as accurately as possible.

c. Have buildings, houses, or structures such as roads or power plants been inundated?

d. Have coastal salt marshes or other natural areas been inundated? What animals and plants might have been affected?

e. What will the economic costs be due to this coastal change?

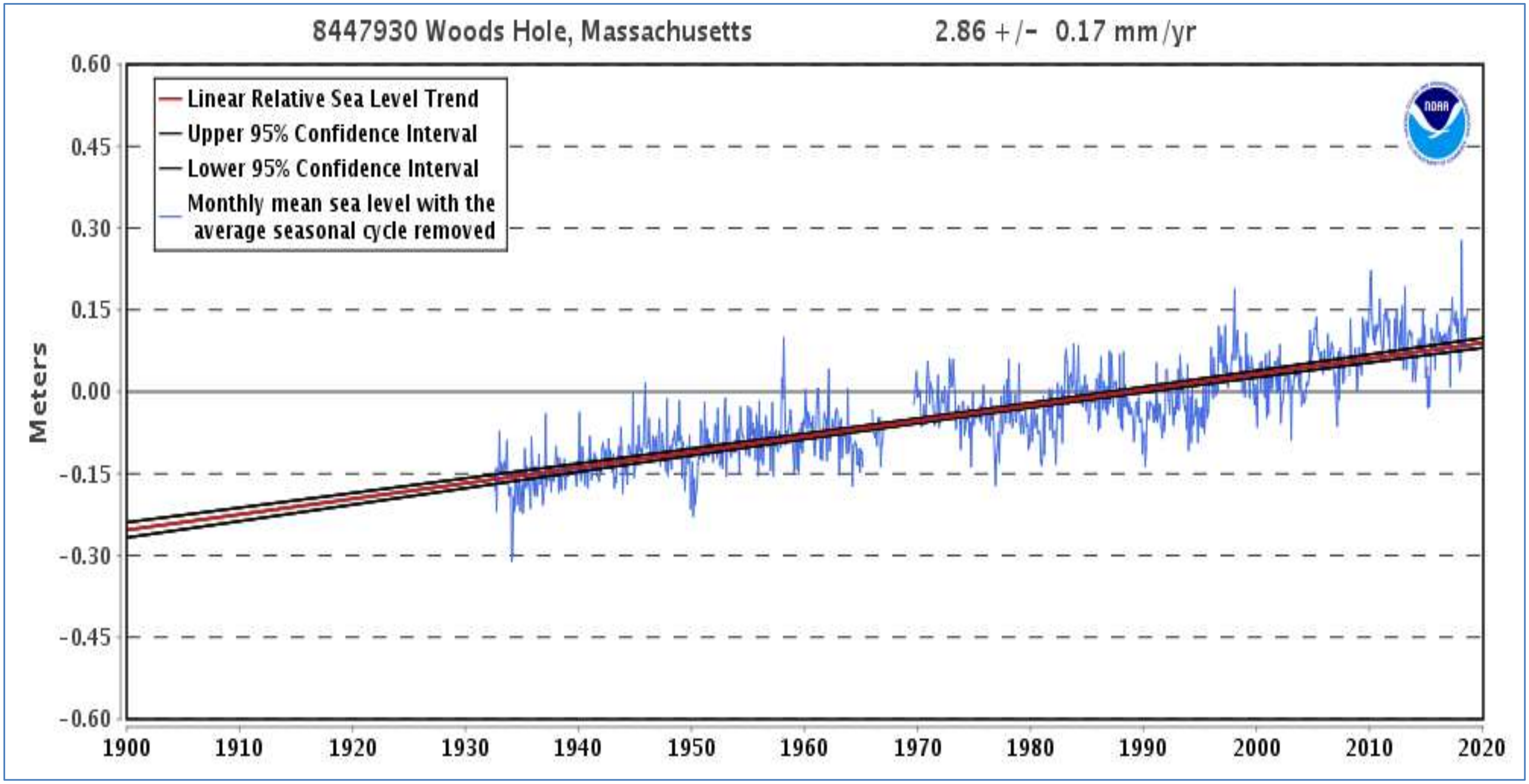
f. Find a salt marsh. Is there an adjacent place where the salt marsh could become established at a higher elevation than its present location?

6. Discuss the results as a class. Have students make maps or electronic displays of their findings.

Extensions

1. For a lesson where students compare the rate sea level rise for locations around the coasts of the US, see Activity 3 of the Estuaries 101 curriculum for middle school, "Water going up, water going down." The lesson also has an extension, an interactive introduction to how climate change impacts estuaries, accessible at this link.

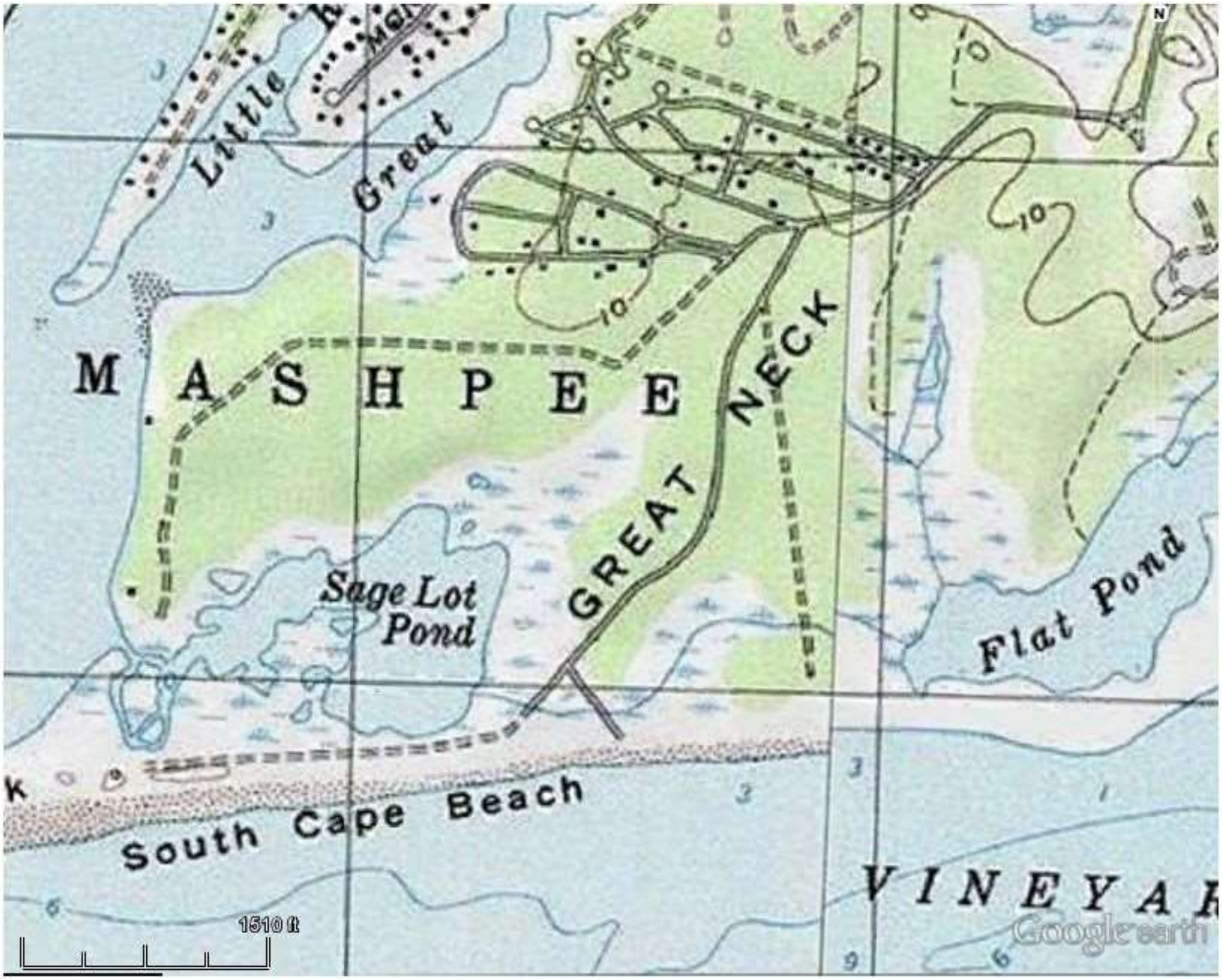
2. Students can model the impact of sea level rise on different types of shorelines with the activity "Sea level rise models," found at the end of this activity. Older students could construct models and use the models to introduce younger students to some of the basic concepts in the lesson. They could also be challenged to create scale models of actual coastlines.



Mean sea level trend for Woods Hole, MA. Average rate is 2.86 mm per year.

Data for many locations is available at https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Topographic maps for sea level rise activity

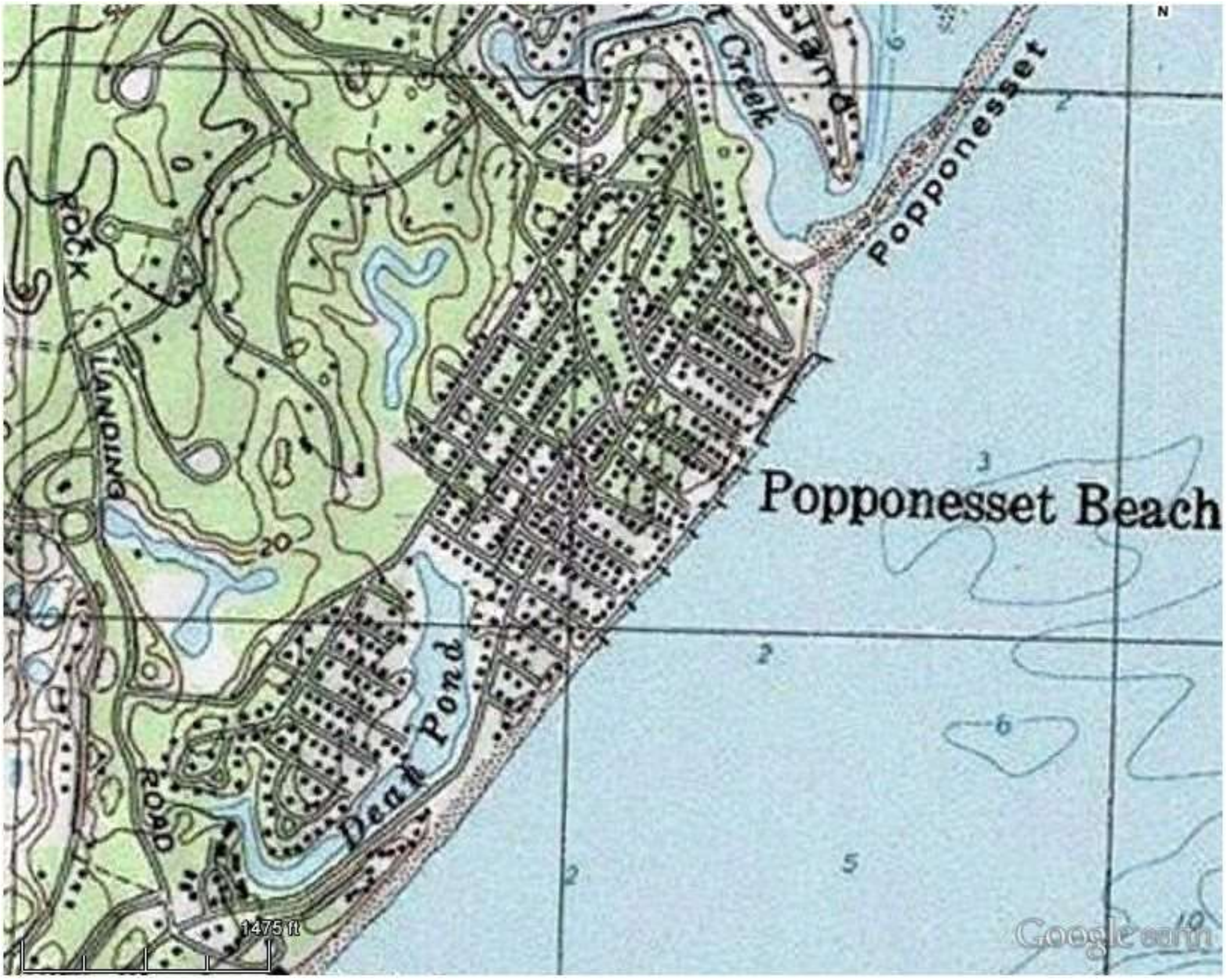


Sage Lot Pond area, Bringing Wetlands to Market project study site

Low development

Contour line 10 feet; depths in feet

Scale in feet



Popponesset Beach, near Bringing Wetlands to Market project study site

High development

Contour line 10 feet; depths in feet

Scale in feet

Extension Modeling Activity: Sea Level Rise and Coastal Wetlands

This is a simplified activity about the impacts of sea level rise on coastal wetlands. High School students can be challenged to create a scale model of an actual coastline in their area or use the simplified models to explain these concepts to younger students.

Background

Sea level change has happened at various times in Earth history. It is a natural process that has gone on since there have been oceans on Earth. However, the increase in the global average temperature is now causing a rapid rise in sea levels. Global warming affects the volume of the oceans and the height of the sea due to two factors: thermal expansion, which means that as water warms it takes up more volume than it did previously, and the melting of land-based ice such as glaciers and the ice caps in Greenland and Antarctica. Scientists predict that the oceans will rise 0.5 to 1.0 meter above present levels by the year 2100.

A rise of 1 meter would have a dramatic effect on our coastlines. Seventy per cent of the world's population lives within 100 miles of the coast. If the height of the oceans increases 1 meter, many coastal areas, including many cities, will be vulnerable to erosion, flooding, and storm surge. Scientists estimate that two-thirds of the coastal wetlands in the United States are vulnerable and may be lost if the sea level rises 1 meter.

Coastal wetlands are important as a home for fish, birds, shrimp, crabs, and many other types of animals, a place they can have their babies, a source of food, and a resting place on migration. About two-thirds of the species of food fish harvested from the Atlantic and Pacific Oceans and most of the shellfish must live in salt marshes or estuaries for part of their life cycles. The mass of plants and animals (biomass) that is produced naturally on an acre of salt marsh is greater than that produced on fertilized farmland.

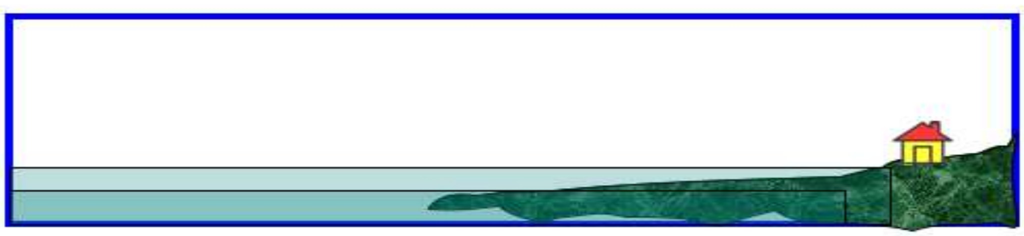
In addition to rapid sea level rise, coastal wetlands are vulnerable to other pressures from climate change. The increased energy in the water cycle due to warming temperatures can cause precipitation to fall in more severe events. Intense storms can cause erosion and damage to wetlands and other coastal ecosystems, as well as to roads, buildings, and structures along the coast.

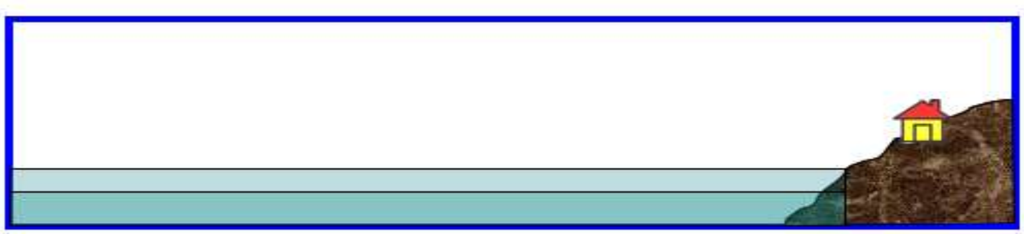
The actual distance that rising sea levels bring seawater onto land is dependent on many factors including the shape of the land, land cover, amount of erosion, and tides. Loss of wetlands due to sea level rise is most severe in areas with small elevation gradients, where the elevation of the coastal land doesn't change very much or slopes gradually. Coastlines with a gradient of 20 to 1 for example, will lose 20 meters (65.6 feet) of horizontal land or wetland for every 1 meter that the sea level rises. Salt marshes will be especially affected because of their gentle gradients – many have much lower gradients than 20 to 1 or are nearly level.

Overview
In this activity students will build a model of a coastal area such as a salt marsh and the land surrounding it. Students will use this model to see what happens to coastal landforms when the sea level rises, and how the slope of the land and the topography affect the impacts of sea level rise.

Preparation
In two clear, oblong storage containers about the size of a shoebox, use clay to construct models of a steep, rocky shore and a gradually sloping coastal wetland. Add small models of clay or tokens to represent wildlife such as nesting birds near the water line, and houses, roads, or other buildings a little further up along the shore. You can also use paint trays to reduce the amount of clay needed, as long as students can observe from above.

Find a few images of a rocky shore and a coastal wetland (see examples at end), and a map that shows different types of shorelines. The image below shows how the same amount of increase in sea level rise inundates much more land if the slope is gradual.





Points to make during activity:

1. Introduce climate change: more heat is retained in atmosphere; air and ocean temperatures are warming

2. When things warm up, they usually take up more room (volume or space): hold a thermometer in your hands or place a thermometer from a cold cup into a warm one and watch what happens to the liquid inside the tube

3. The ocean is warming, and it takes up more space → this is called sea level rise; it is due both to thermal expansion (increased volume due to heating) and added water from melting ice on land

4. There are different types of shorelines: rocky; sandy; developed; wetlands. Find locations of these on a map. What plants and animals might live there?
5. Some of these habitats are especially important. Wetlands are important as a home for fish, birds, shrimp, crabs, and many other types of animals, a place they can have their babies, a source of food, and a resting place on migration.

6. What is the effect of sea level rise on a wetland area compared to a steep, rocky shore?
    a. Measure the depth of water in the model in cm using a ruler
    b. Add 0.5 to 1 liter or 5 or 10 turkey basters full of water to each model
    c. Describe what you observe
    d. Look at the diagrams of coastal areas. What will be affected if the sea level rises to the first contour line? The second or third line?

7. Salt marshes can keep up with natural sea level rise if the rate is slow enough. We can help slow the rate of warming and protect coastal wetlands by reducing CO2 emissions

This activity was developed by Pat Harcourt, adapted from a lesson in URI's *Discovery of Estuarine Environments*.