Geol 110L Shoreline Stability Investigation

Overview

Description

70% of Virginia's population lives in a coastal area (VA DCR, 2021). The coastal area is vital for the economy of our state, provides critical habitat, is a valuable recreational resource, and protects the mainland from inundation by rising sea level and erosion caused by waves. This area is at risk due to increasing development pressure, flooding due to sea level rise, and erosion by storm waves. In fact, VA has the second highest rate of sea level rise in the United States. The first being Louisiana.

In this activity, students will evaluate the stability of multiple coastal sites. The framework for the evaluation will be based on the USGS Coastal Vulnerability Index. The criteria include- sea level rise, wave height, and topography (morphology, elevation, and slope). Sites will be selected from the Virginia shoreline. Students will use simple physical models and authentic data to evaluate three sites- Virginia Beach, Cedar Island, and Savage Neck. A 4th example, Assateague National Seashore, is also included for instructors to use for exam questions. The data is provided as an ArcGIS Experience. This allows for easy access to the data from a website, no GIS skills are necessary.

Based on the initial investigation, students will create a hypothesis about which site is the most vulnerable to erosion and inundation. They will then test their hypothesis by calculating the rate of erosion at each of the 3 sites. If the rate of erosion is highest at the site they hypothesized was most at risk, then the hypothesis is correct. If not, the students must learn why their hypothesis was incorrect.

Virginia Department of Conservation and Recreation (DCR). (2021). *Virginia Coastal Resilience Master Plan*. https://www.dcr.virginia.gov/crmp/document/virginiacoastalresiliencemasterplan-print.pdf

Learning Objectives

1. Use models and evaluation framework to help us understand natural phenomena and make predictions
2. Create a hypothesis and test it with data
3. Use spatial and numerical data to analyze and interpret natural phenomena.
4. Demonstrate critical thinking skills (written or oral) by using geologic data to draw conclusions based on evidence.
5. Recognize climate related hazards in the regional community.

Outline

1. Introductory Lecture (15 min)
    a. Key Points
        i. Why is coastal erosion a problem?
2. Investigation of sea level rise, grain size, and waves with physical models (25 min). Students complete page 1 of the student handout.

3. Data collection demo for VA Beach: VA Beach is used as an example for how to collect data. (15 min). The instructor demonstrates how to collect and record data using Virginia Beach as an example.
4. Independent work (15 min)
    a. Students will complete data collection for one of 2 sites- Savage Neck or Cedar Island
5. Collaborative work (30 min)
    a. Students will pair up with a student who collected data for the alternative site and share data.
    b. Once students collect data for all 3 sites, they create a hypothesis identifying the site most at risk. Then they use the orthophoto to calculate the rate of erosion at each site.
6. Assessment (10 min)
    a. The class will review the answers together. Students are given a red pen to correct their own mistakes. This approach is used because the exam is next week and the students need to understand their mistakes to succeed on the exam. There is not time to collect the assignment, have the instructor grade the assignment, and then turn them back the following week.

Data and Background

a. Data Sources
    i. Waves: National Data Buoy Center
    ii. Sea level Rise: NOAA
    iii. Topography (slope and max elevation)
    Elevation/Bathymetric Data from Open Topo
    NOAA Coastal Lidar Data. 2017 USACE NCMP Topobathy Lidar: East Coast (NY, NJ, DE, MD, VA, NC, SC, GA). Distributed by OpenTopography. https://portal.opentopography.org/noaaDataset?noaaID=6329. Accessed 2025-09-30
    iv. Orthophotos: Virginia Geographic Information Network (VGIN)
    v. Online Map: https://experience.arcgis.com/experience/8a56c883113d4c15be67d10d13c70c15
b. Background Resources:
    i. National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast (https://pubs.usgs.gov/of/1999/of99-593/pages/toc.html)
    ii. Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/ui/info/item/CDKmLpj)

Student Handout

Student Name:______________________________ Independent Site: ______________________________

Partner's Name:______________________________ Partners Site: ______________________________

Part 1: Physical Investigation

Station 1: Waves

Create a hypothesis that predicts how waves will impact erosion.

Design an experiment to test your hypothesis. Sketch the experiment below.

Did your experiment support your initial hypothesis?

Explain the results.

Station 2: Coastal Geology

Create a hypothesis that predicts how beach morphology will impact erosion.

Design an experiment to test your hypothesis. Sketch the experiment below.

Did your experiment support your initial hypothesis?

Explain the results.

Station 3: Slope and Sea Level Rise

Create a hypothesis that predicts how coastal slope and SLR will impact erosion.

Design an experiment to test your hypothesis. Sketch the experiment below.

Did your experiment support your initial hypothesis?

Explain the results.

Part 2: Field Investigation

Use the online data site to complete the table on the following page. Use the link below to the right to access the data. You should use a large screen to interact with the data site.

(https://experience.arcgis.com/experience/8a56c883113d4c15be67d10d13c70c15)

Table 1: Shoreline Evaluation Criteria						
Variable	*High Stability*	*Stable*	*Slightly at Risk*	*Vulnerable*	*High Risk*	*Notes*
Geomorphology	Rocky Beaches, High Bedrock Cliffs	Medium Cliffs	Low Cliffs or Cobble Beaches	Estuary or Protected Beaches	Barrier Beaches, Sand Beaches, Salt Marsh, or Mud Flats	Classify the site visually.
Offshore Slope	>0.04	0.03-0.04	0.02-0.03	0.01-0.02	<0.01	The slope from the waterline seaward 300 meters. Use the topographic profile to calculate this parameter.
Maximum beach Elevation (meters)	>7	5-7	3-5	1-3	<1	Use the topographic profile to measure this parameter.
Relative Sea Level Rise (mm/yr)	<2	2.0-3.0	3.0-4.0	4.0-5.0	>5.0	SLR data has been calculated by NOAA.
Significant Wave Height (m)	<0.55	0.55-0.85	0.85-1.00	1.00-1.25	>1.25	Wave height is measured by the National Data Buoy Center.

Complete the table below.

Table 2: Shoreline Data						
	Class Example: Virginia Beach		*Your Site: Cedar Island or Savage Neck Circle the location*		*Partner Site: Cedar Island or Savage Neck Circle the location*	
Variable	*Description or Value*	*Vulnerability*	*Description or Value*	*Vulnerability*	*Description or Value*	*Vulnerability*
Geomorphology						
Offshore Slope						
Maximum beach Elevation (meters)						
Relative Sea Level Rise (mm/yr)						
Significant Wave Height (m)						

Review the data you have collected and recorded in table 2. Create a hypothesis that predicts which of these locations is the most vulnerable to future shoreline erosion. Explain which of the variables cause the beach to be more vulnerable than the other sites.

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Part 3: Validation

You will now return to the data to test your hypothesis. The data sets provided include orthophotos from 2002 and 2021. The change in shoreline location between the 2 photos can be measured and then the erosion rate can be calculated. The erosion rate is the distance divided by the time.

$$\text{Shoreline Change Rate} = \frac{\text{change in shoreline location (meters)}}{\text{Time (years)}}$$

The change in location should be measured in meters. The time in this example will always be 19 years (2021-2002=19 years). On the photo, the shoreline is identified as the wet/dry line, not the waterline. The wet/dry line is used rather than the waterline because the waterline will fluctuate each time a wave breaks on the shore. Erosion should be noted with a negative rate while accretion (beach growth) should be recorded as a positive rate. Calculate the rate of shoreline change and record it in the table below. For partial credit, show your work.

Table 3: Shoreline Change

	Virginia Beach	*Cedar Island*	*Savage Neck*
Shoreline Change (m/yr)			

Review your hypothesis and the rate of shoreline change. Is the erosion rate the highest at the site you predicted to be the least stable?

Yes No

In the future sea level rise is expected to accelerate because of warming temperatures and ice melting. Which type of beach do you expect to be most impacted by accelerating sea level rise? You should discuss the impact of specific variables in your response. Is there a correlation between potential inundation caused by sea level rise and proximity to an offshore subduction zone?

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Sketch a beach that is highly vulnerable to erosion and flooding and another that is more stable. Annotate both sketches to highlight the differences.

Unstable Beach	Stable Beach

Guide For Physical Investigation

Station: Waves (Figure 2)	Station: Grain Size (Figure 3)	Station: Slope and Sea Level Rise (Figure 1)
Setup Materials: Materials: Sand (Aquarium gravel works well because there is no cohesion and it dries quickly.) Large, long plastic container. We used an underbed storage container. Plexiglass to separate the large and small waves. Beach slope made from concrete 2 Wooden Paddles to create waves. One has screen in the center, and one is solid. The solid paddle will create larger waves. Video of the Model: https://jmu.instructuremedia.com/embed/dadd9219-9942-4174-b648-2cd260d8f560	**Setup** Materials: Materials: aquarium gravel in 2 sizes. Our sediment was gravel and coarse sand. Plastic tray 2 2x4 blocks- one to prop up the tray and one to create waves. Model of the Model: https://jmu.instructuremedia.com/embed/8d03de5a-0dc8-4d15-9df1-6852564895f4	**Setup** Materials: Two small plastic tubs Beach face with 2 different slopes Beakers for water Action: Fill both tubs with water. This is the initial sea level. Mark the shoreline on the tub with a dry erase marker. Add an equal amount of water to both tubs. Mark the new shoreline. Students can measure the erosion in each tub. The flatter slope will have more erosion.

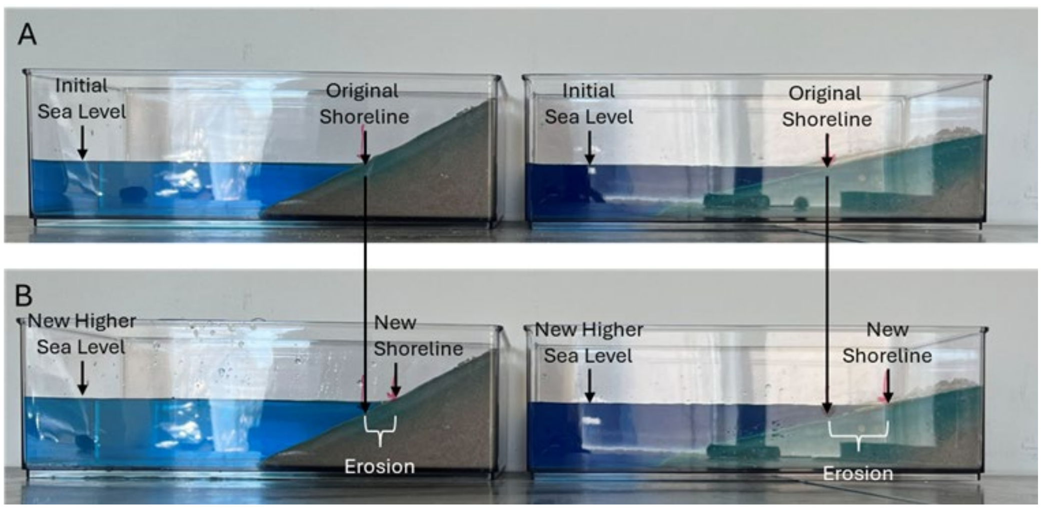

Figure 1. Sea level rise station. This photo shows an example of the physical model to examine the relationship between sea level rise and coastal slope. A is the initial condition and B is after sea level rise. In the model, sea level has been increased 1 cm on both the steep (left) and flatter beach (right). The resulting erosion, indicated in white, is greater on the flatter beach. Students learn that steeper beaches are less vulnerable to erosion caused by sea level rise.

Figure 2. This is the physical model to demonstrate the effect of small vs large waves. The tank is separated with a Plexiglas sheet in the center. The sediment is uniform in size on both sides of the model. The waves are created with two paddles- one is solid and the other has screen in the center. The paddle with screen will make smaller waves. The sediment with larger waves will mobilize first.

Figure 3. This is the physical model to demonstrate the effect of grain size on shoreline stability. The model is a plastic tray propped up on one end with a 2x4 to create a slope. There are 2 sediment sizes used. The sediment closer to the camera is finer than the sediment on the far side. Both sediments were aquarium gravel purchased at a pet store. The store sold the gravel in 2 sizes. Waves are created in the deep end with a block of wood.

Review Sheet For Exam

Shoreline Stability Review Sheet

Use the online data site to complete the table below for Assateague. Compare this site to the 3 you studied in class. Use this data to answer the questions

Use the link below to access the data. You should use a large screen to interact with the data site. (https://experience.arcgis.com/experience/8a56c883113d4c15be67d10d13c70c15)

	Assateague	
Variable	*Value*	*Vulnerability*
Geomorphology		
Offshore Slope (%)		
Maximum beach Elevation (meters)		
Relative Sea Level Rise (mm/yr)		
Shoreline Change (m/yr)		
Significant Wave Height (m)		

1. Compare Assateague to Cedar Island. The erosion rate at Cedar Island is greater than Assateague. Example why this might be.

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2. All the sites you have looked at (Cedar, Assateague, Savage and VA Beach) are along the coast of Virginis and therefore have many similarities. Which site is least like the others? Why do you think that is?

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3. Which parameters make Assateague most vulnerable to erosion?

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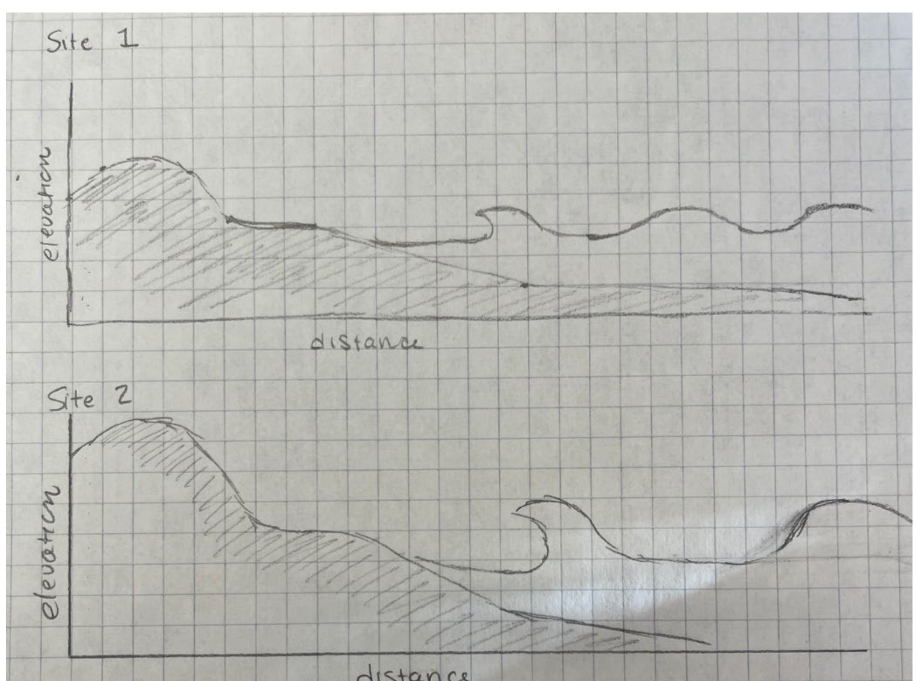
Examine the sketch to the right. Annotate the drawings to describe features that make the site more resilient or vulnerable to shoreline erosion.



Example Exam Questions

1. Calculate the rate of shoreline erosion.
2. Give the students 2 hypothetical sites to compare. Sketches and data will be provided. Answers will be multiple choice, possible multiple answers.
3. Essay: Evaluate the two sites provided. Which site is more vulnerable to erosion? Justify your conclusion with the data provided. Your explanation must include the parameters you believe make the site more vulnerable and an explanation for why the parameter increases vulnerability.