

8th Grade Social Studies

6th grade - Goal 4, Objective 4.01

7th grade - Goal 6, Objective 6.03

8th grade - Goal 5, Objective 5.03, 5.05

Waves, Surf, Currents, and Sand:
The Equilibrium Defining Barrier Islands

National Park Service
Cape Lookout National Seashore
Harkers Island, North Carolina



This set of curriculum materials is part of a series of guides developed by staff at Cape Lookout National Seashore and designed to connect classrooms with the seashore.

These materials are based on the 2004 North Carolina Standard Course of Study. Descriptions of the education goals and objectives that can be completed using these materials are included for educators in other locations.

The pre-visit and post-visit activities were created to be used in conjunction with a class visit to the park or a Ranger visit to the classroom. Contact the park for more information on scheduling a Ranger program, at the park or in the classroom.



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Waves, Surf, Currents, and Sand

Overview

Description:

The learner will be able to:

- Using Cape Lookout National Seashore as an example, describe the impact of water and wind and their roles in the balance/equilibrium between the sea and shore.
- Understand how waves and currents impact the distribution of sand forming and eroding beaches.
- Understand and describe the major ways humans disrupt the natural equilibrium between the sea and shore.
- Decide if human actions are beneficial or detrimental to this balance.

Group Size: 5-25

Time: 45-50 minutes per class visit for on- and pre-site visit activities

On-site activity covers a two (2) day session

Location: Classroom

Pre-Site Visit Activities: TEACHER COMPLETED

Knowledge Assessment (in post-site materials)

The Perfect Storm

- Give each student a copy of “The Perfect Storm” Handout to read while others finish the Assessment
- Those who do not get a chance in class should finish reading this handout at home

Wind, Waves, Currents, and Beaches Activity

- Split the class into groups of two
- Give each student copies of “Wind, Waves, Currents, and Beaches Activity” and “The Smart Student’s Guide”
- Working together, the students should discuss the questions on the activity sheet and write down possible answers (some questions may have more than one answer)
- If time allows, lead a class discussion on the questions and their answers. If there is no time, have the students turn in their team work.

On-Site Visit Activities: RANGER COMPLETED

Day 1

Presentation of Economic Cost of Storms on NC's Developed and Undeveloped Barrier Islands

Discussion on the Power of Wind, Waves, and Surf

Day 2

Discussion of Beach Erosion and Deposition

Black and Tan Sands Activity

Post-Site Visit Activities: TEACHER COMPLETED

Knowledge Assessment

Ribbon of Sand: Cape Lookout National Seashore

- Have students complete the "Viewer's Guide" as they watch this 26-minute park film

Discussion Points

- Some people have mentioned "restoring" the islands of the Outer Banks. What do you think "restoring" these islands means?
 - How could they be restored?
- Should the islands of the Outer Banks be restored?
- What problems might restoring them cause?
 - How would people be impacted?
 - How would the islands be impacted?
 - How would the wildlife be impacted?
- What problems might NOT restoring them cause?
 - How would people be impacted?
 - How would the islands be impacted?
 - How would the wildlife be impacted?

Waves, Surf, Currents, and Sand

Goals and Objectives

Sixth Grade

NCSCOS Goal 4: The learner will investigate the cycling of matter.

Objective 4.01: Describe the flow of energy and matter in natural systems: Energy flows through ecosystems in one direction, from the sun through producers to consumers to decomposers; Matter is transferred from one organism to another and between organisms and their environments; Water, nitrogen, carbon dioxide, and oxygen are substances cycled between the living and non-living environments.

Seventh Grade

NCSCOS Goal 6: The learner will conduct investigations, use models, simulations, and appropriate technologies and information systems to build an understanding of motion and forces.

Objective 6.03: Evaluate motion in terms of Newton's Laws: The force of friction retards motion; For every action there is an equal and opposite reaction; The greater the force, the greater the change in motion; An object's motion is the result of the combined effect of all forces acting on the object: A moving object that is not subjected to a force will continue to move at a constant speed in a straight line and An object at rest will remain at rest.

Eighth Grade

NCSCOS Goal 5: The learner will conduct investigations and utilize appropriate technologies and information systems to build an understanding of evidence of evolution in organisms and landforms.

Objective 5.03: Examine evidence that the geologic evolution has had significant global impact including: Distribution of living things; Major geological events; Mechanical and chemical weathering.

Objective 5.05: Use maps, ground truthing and remote sensing to make predictions regarding: Changes over time; Land use; Urban sprawl; Resource management.

The Perfect Storm

Also known as the Halloween Storm of the Century

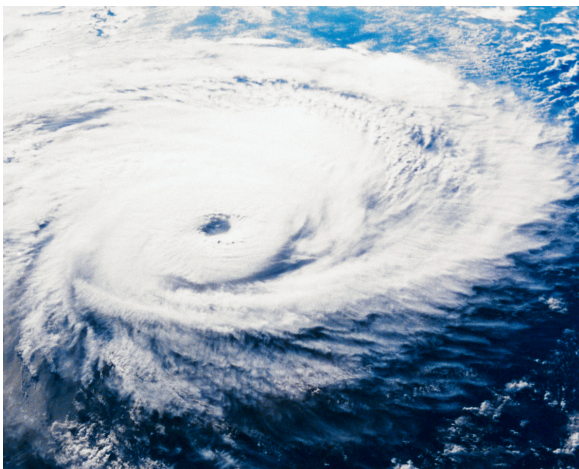
In October, most of the United States moves towards the cold winter months as the country slowly cools down from the summer heat. Ocean water always takes longer to cool off than the landmasses of North America. This is because the oceans have a high **heat capacity**. Heat capacity is how long it takes something to heat up and then to cool down. The oceans' waters take a long time to heat up, but once they do, they also take a long time to cool down.

It's this ability to hold or store heat that often results in large storms, like Atlantic hurricanes, in the cool months of September- November. Air takes on the same temperature as the land or water that's underneath it. When cooler air from the cooler land meets the warmer air from the warmer ocean it can also create a large storm called a Nor'easter.



That's what happened 19 years ago in 1991. **The Perfect Storm** was a rare monster of a storm with an unnamed hurricane in the center of it. A storm like this is estimated to occur only once every 50 to 100 years. Bob Case, a NOAA meteorologist with the National Weather Service gave the storm its nickname--The Perfect Storm--when he saw the meteorological events (two already large storms on a collision course) that were leading up to a colossal storm. The Perfect Storm began on **October 28, 1991** and became world famous when Sebastian Junger wrote about the sinking of the Andrea Gail, a sword-fishing boat, in the novel *The Perfect Storm*.

Forecasters had a rough time forecasting this Halloween storm. A high pressure system, a low pressure system, and the remains of Hurricane Grace all collided to create the most terrifying storm of the 20th century. When the systems collided they exploded into a colossal storm forming a huge white whirlpool **2,000 miles wide** that reached from Jamaica to the coast of Labrador in northern Canada. Winds blasted over the Atlantic Ocean at **more than 100 mph**. Ocean waves peaked at 100 feet, the height of 10-story buildings. Waves 30 feet high battered the New England coast, destroying 200 homes. Nine people died, including the six-man crew of the swordfish boat the Andrea Gail. It is said the worst of the storm stayed offshore.



Because The Perfect Storm occurred outside the usual boundaries of tropical hurricanes, she technically was an **extratropical cyclone**. She was extratropical because she occurred outside the area where hurricanes originate and cyclone because that is another name for a hurricane. She was also called the Unnamed Hurricane of 1991 and the No-Name Hurricane of 1991. If she had been named, she would have been Hurricane Henri. She was the last great storm of the 1991 hurricane season.

The name Perfect Storm has become a popular term to use when describing separate events *of any kind* that come together to create a really big and bad event.

Wind, Waves, Currents, and Beaches

Pre-Site Visit Activity

Description:

Students will examine the interconnected processes which shape and change barrier islands and apply that information to various scenarios to better understand how these processes interact.

Materials:

The Smart Student's Guide

Changes to Barrier Islands Handout

Directions:

1. Divide into groups of two.
2. Read "The Smart Student's Guide to Wind, Waves, Currents, and Beaches."
3. Examine your "Changes to Barrier Islands" handout
4. Pick one person in your group to be the Recorder. As you discuss the questions below, the Recorder will write down your group's answers.
5. If time allows, you will discuss the questions and your answers with the class.

Questions:

- When hurricanes strike the North Carolina coast, what role do the barrier islands play in decreasing the damage from hurricane storm surge?
- If you were making sand castles on the beach and were very proud of your work which type of wave would you rather be hit by? Why?
- You are one of the crew on a sailboat, *Maya*, and you are sailing 150 miles offshore to the east of Cape Hatteras. You've just gotten a weather report of a large storm with 50 mph winds heading in your direction.
 - What size waves can you expect? Why?
- I am a small, lightweight rock. It rained really hard last night and I got washed into the Upper Booboo Creek. The Upper Booboo is a creek in the White Oak River Basin.
 - Name one place you think I might end up some day and why.
 - How long will it take me to get there?
- I just found out about a great deal on some waterfront property. It is on a barrier island, has a beautiful view of the Atlantic Ocean, and sits right on top of a nice dune. The best part of all though is, if I buy it, I'll be about 70 feet from the beach!
 - Do you think I should buy it? Why or why not?

The Smart Student's Guide

to Wind, Waves, Currents, and Beaches

Waves are made by the wind blowing across the water. The height of a wave depends on three things:

1. **Wind speed** – how fast the wind blows
2. **Duration** – how long the wind blows in a single direction
3. **Fetch** – the distance the wind blows in a single direction

SO: The greater the wind speed, the larger the wave. The longer the duration, the larger the wave. The longer the fetch, the larger the wave.

Breaking waves will give you one of 3 types of surf. The area the surf is in is called the surf zone. The type of surf that forms is due to the slope of the seafloor underneath it:

1. **Spilling** breakers – the seafloor slope is low
2. **Plunging** breakers – the seafloor slope is steep
3. **Surging** breakers – the seafloor slope is VERY steep

A spilling breaker, like the one shown below, releases its energy slowly and the top (crest) of the wave slowly spills down the front (face) of the wave.

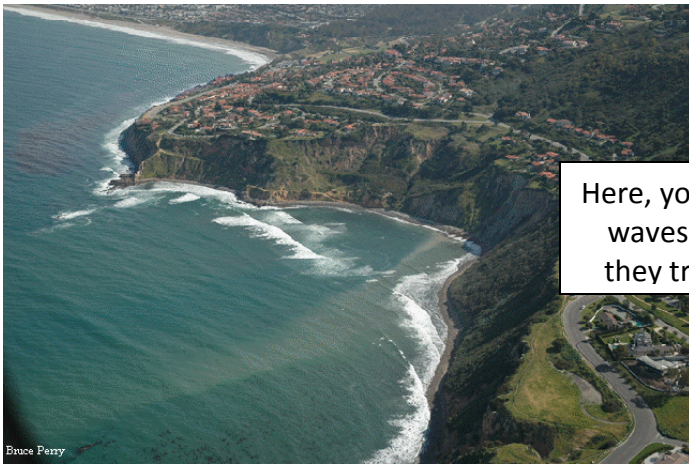
A plunging breaker (shown below) releases its energy fast and the top of the wave outruns the bottom of the wave and plunges over.



A surging breaker, like the one to the right, releases all its energy at once.



Not all waves travel in a straight line. Waves can *bend* and that can cause a wave to change direction. When waves bend we call it **refraction**.



Here, you can see the waves bending as they travel inland.



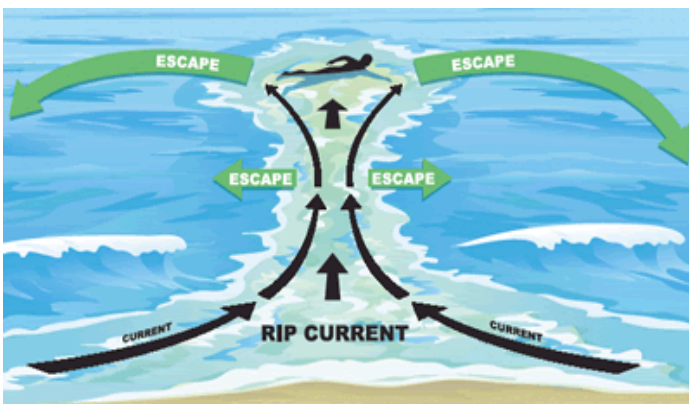
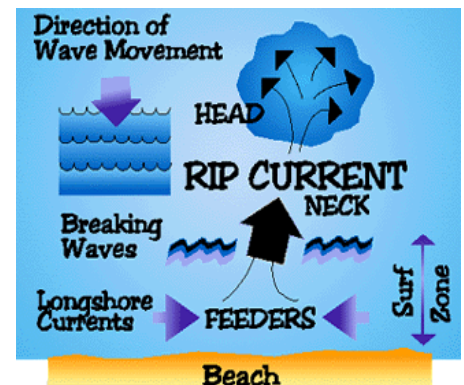
Waves bend when:

- Different parts of the same wave travel at different speeds
 - The leading edge of the wave hits the shallow water first and slows down or **drags**, but if the rest of the wave is in deeper water it will travel faster.
- They approach a curved shoreline
 - Waves come in parallel to a shoreline even if they have to bend to do it.

So, waves will bend around a headland, or anything else that sticks out into the ocean if it is large enough.

Longshore currents are created on beaches when the water flows parallel to the shore in the surf zone. This water comes from a breaking wave. The water from a breaking wave has a very hard time returning directly to the ocean through the surf zone so it runs parallel to the shoreline.

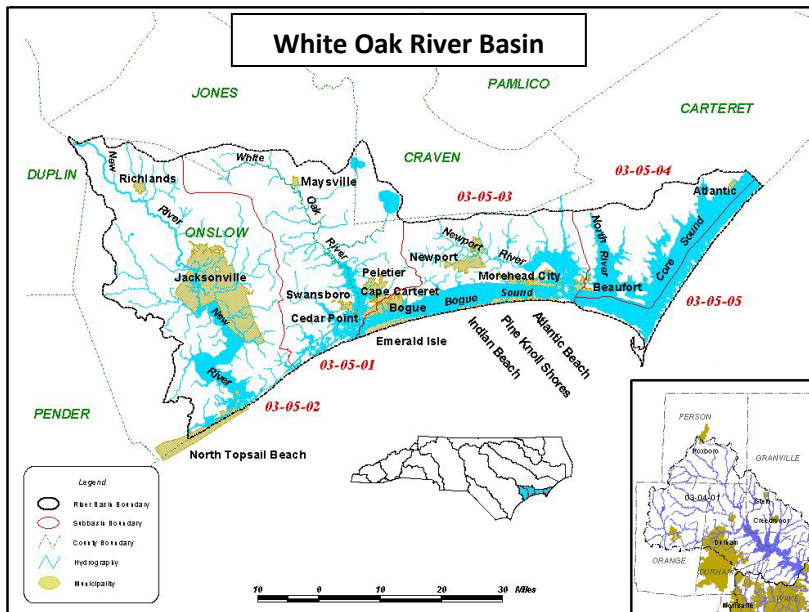
As the waves get bigger the flow of the water along the shoreline gets stronger. It will keep flowing parallel to the shore until it gets strong enough to return to the ocean through the surf zone. Once it finds a place to return, this **offshore current** is usually in a confined space with lots of water moving quickly in a narrow area. Now it has become a **rip current**.



Rip currents can easily carry a person offshore. Never try to fight your way back to shore through the rip current. Swim parallel to the shoreline until you cannot feel the water pulling you out to sea, then turn and swim into the beach.

Did You Know? There is no such thing as a rip tide. This is an incorrect term for a rip current.

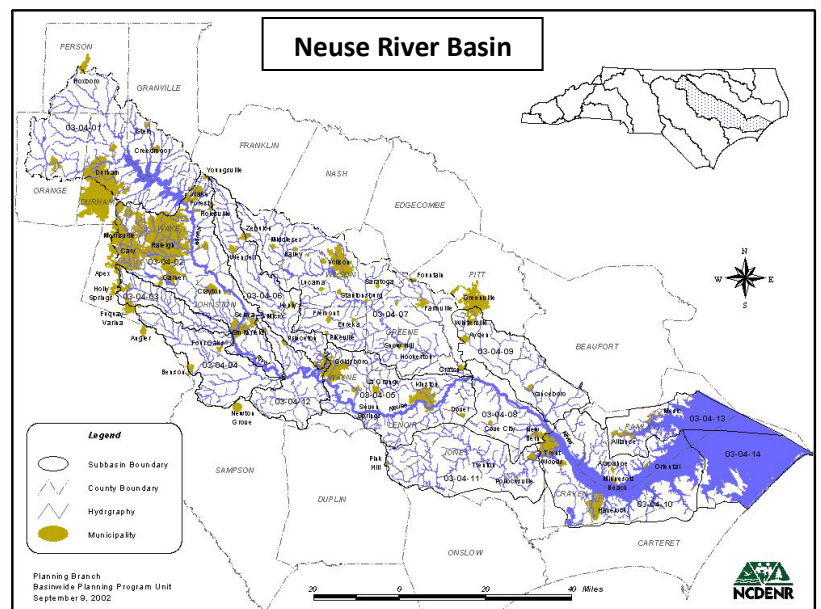
Beaches and water are inseparable. Water in the form of waves and currents shape and reshape our barrier islands. Of course, there wouldn't be barrier islands to reshape if it were not for sand.



Water in the ocean (in the form of waves and currents) moves sand from place to place.

Surface runoff is responsible for much of this sand. These maps show the White Oak River and the Neuse River Basins. A **river's basin** is the land area that contributes water to that river and includes all the water from streams, creeks, and other rivers that drain from the lands they run through.

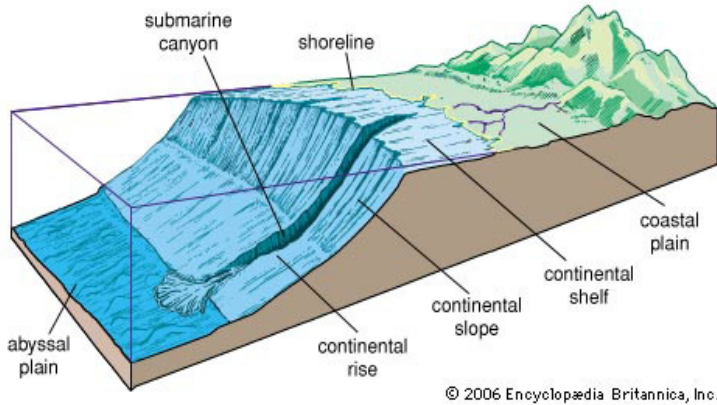
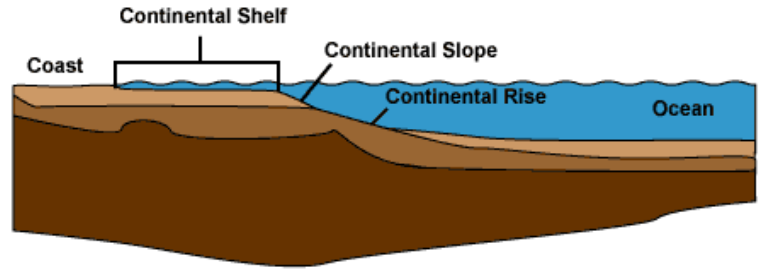
Along the way, soil, small pebbles, rocks and sand gets picked up by surface runoff and carried into the streams, creeks, etc. Then it's transported to the larger river. The larger river carries the lighter soils, sand and rocks to the river's **ocean outlet**. Even the rocks can become sand as they tumble along breaking up into smaller pieces in a river's flow.



Here you can see where the White Oak River, Neuse River and other rivers drain their basins into the Albemarle, Pamlico, Core and Bogue Sounds. The **estuaries** are where the rivers meet the sounds. Sounds are shallow water areas largely due to the **deposition** of sand, silt and clay from the rivers. When the river meets the sound its speed slows and it doesn't have the force to carry the sand and soil anymore. It drops it into the sounds. The lighter colored areas in the satellite image to the left are areas of shallow water. You can see the sand below the surface.

Once the sand makes it into the sound it gets moved by tides, currents, and waves. If you don't think it can move all that much, just consider where it started from. The sand on our beaches started out thousands of years ago as rocks in the Appalachian Mountains of North Carolina. It has traveled hundreds of miles to get to the estuaries.

There is another sand deposit offshore beyond the estuaries and the barrier islands themselves that contribute to the formation of the islands. Our continental shelf is a large, long sand deposit that gradually slopes into the deeper waters of the ocean.

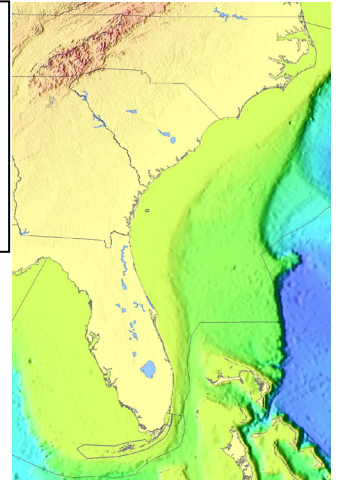


Sea levels have fluctuated throughout time. When glaciers covered most of the earth, sea levels were lower because more of earth's water was tied up in ice. As the ice melted, the glaciers retreated and sea levels rose. There was more land on NC's coast when sea levels were lower because the shoreline was farther out. When levels are higher, there is less land as water levels rise and move inland. There are **ancient sand deposits** that were carried inland by prehistoric river systems to their estuaries and seas.

This is where the sand comes from to build the barrier islands and beaches and this is where the sand goes when the islands and beaches are destroyed! These are the processes of **deposition** and **erosion**. The water in the form of waves either deposits more sand or erodes what is already there, building or destroying our beaches.

If one beachfront is destroyed by erosion, another beachfront is formed farther inland from the destroyed beachfront. When waves **overwash** a low-lying barrier island, they carry sand from the ocean side. Then, as they cross the island, they slow down and finally they drop the sand on the sound side. Eventually the whole island moves closer to the mainland.

YELLOWISH GREEN is the continental shelf,
DARKER GREEN is the slope and rise,
BLUE is the abyssal plain.



Equilibriums exist in nature. Sometimes human interests compete with these natural processes.

Poorly constructed riprap



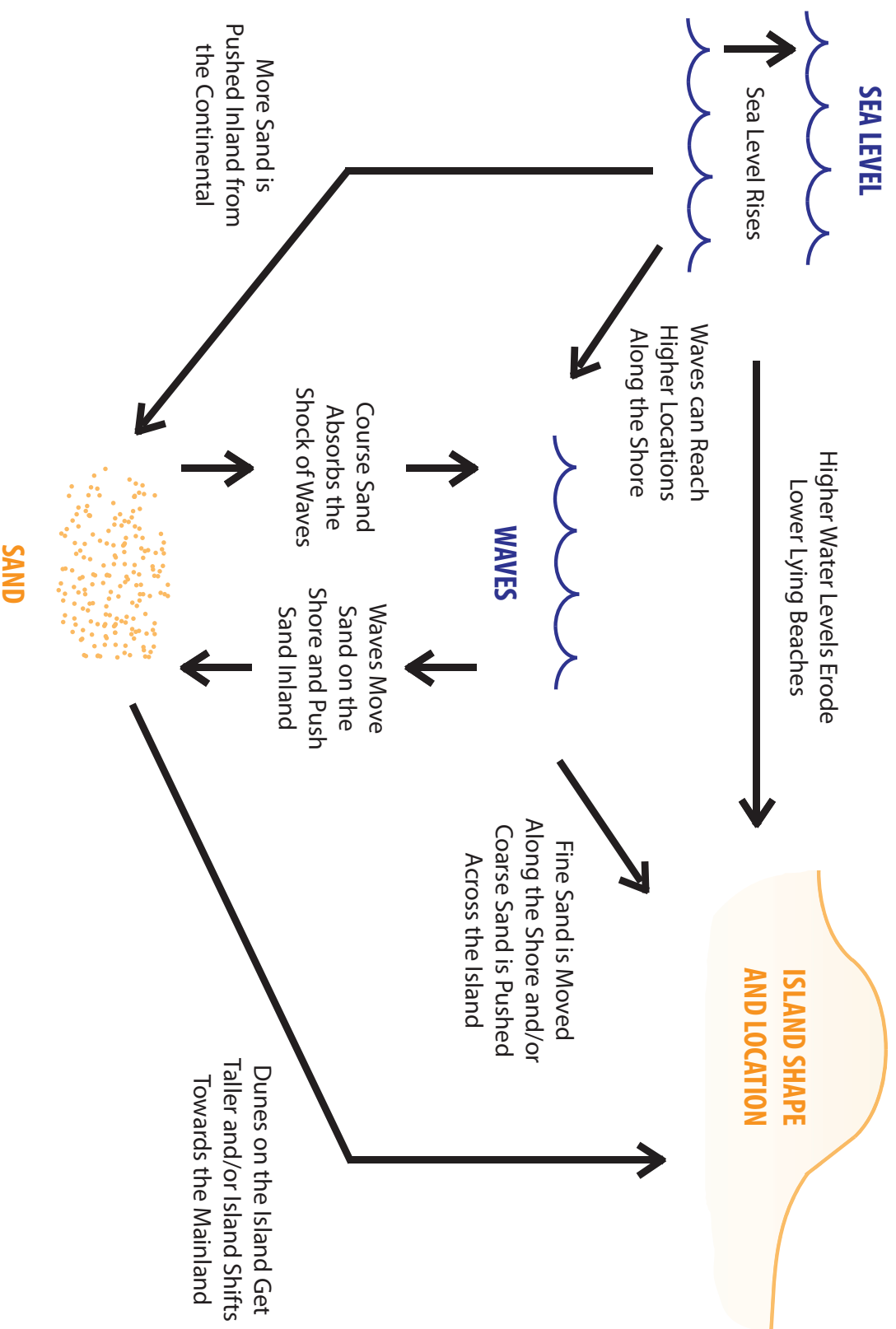
Rock jetty



Two groins



Changes to Barrier Island Shape and Location

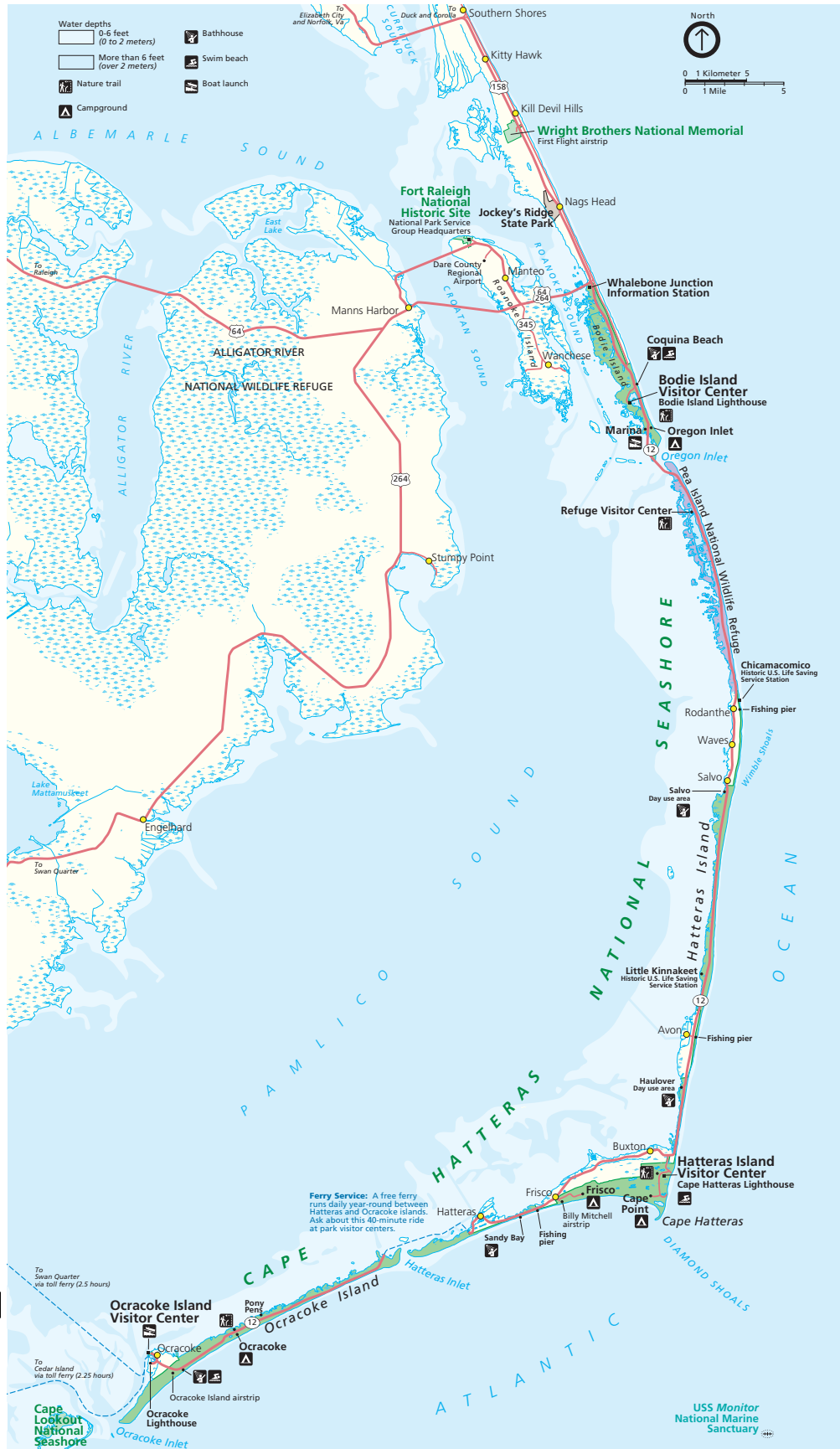


Cape Lookout National Seashore



Cape Lookout National Seashore

Cape Hatteras National Seashore



Cape Hatteras National Seashore

The Sands of Cape Lookout

On North Carolina's beaches most of the sand is made up of the minerals quartz and feldspar. These grains of sand come from igneous and metamorphic rocks from the Piedmont of North Carolina. They are hundreds of millions of years old. Quartz is the most common mineral and feldspar is the second most common mineral making up our sand.



These photos of quartz (above), feldspar (right), and mica (below right) are courtesy of the US Geological Survey.

Feldspar is actually **less than 10%** of the sand on the beaches of Cape Lookout. Quartz is about **80-90%**. The reason quartz makes up so much of our sand is because it is hard and very strong. It can survive transport down the rivers to the coast and can survive being thrown around by the wave action of the ocean. Additionally, it is very chemically stable so it doesn't react with other minerals or the chemicals in the ocean that could break it down.

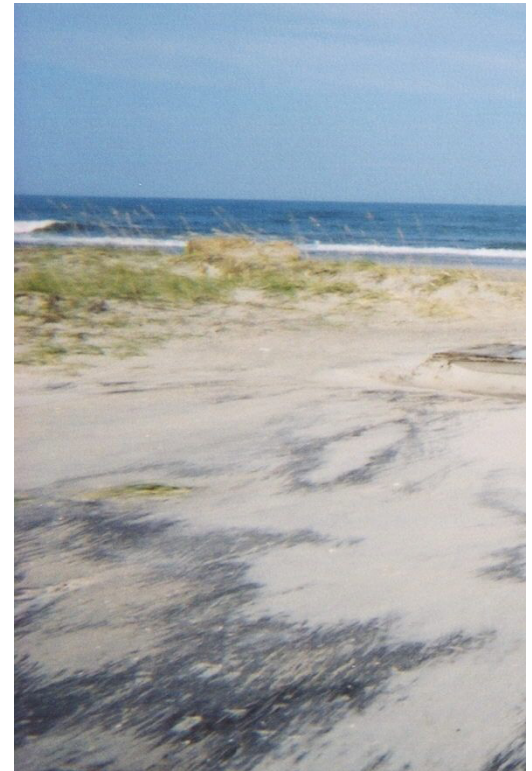
There are other minerals in our beach sand besides quartz and feldspar. Mica can be visible in the sand as shiny flakes that reflect the light. While easy to see, it only makes up about 1% of the sand. A common misconception is that lots of our beach sand comes from broken up seashells. While pieces of broken or even whole shells make the beaches interesting, shells don't comprise much of the sand.



It is the quartz and feldspar that gives our sand its color. The **tan color of the sand** is from the quartz and feldspar being stained by "rust." Once out of the water and exposed to oxygen, small amounts of iron oxides in the sand rust giving the sand its tan color. If the quartz and feldspar wasn't stained by rust it would be gray.

The next time you are out at Cape Lookout National Seashore look at the color of the sand. The "new" sand used to replenish the sound-side beach by the lighthouse is gray, while the "older" sand on the Atlantic-side is a tan color. The "new" sand was dredged up from Barden Inlet and hasn't had time to get rust-stained.

If you walk the beaches of Cape Lookout, you might see a **black patch** or line running through the sand. Many people think these black patches are from an oil spill or from decayed plant matter that got trapped in the soil. Neither is true.



These photos of black and tan sands were taken just after Hurricane Isabel hit the park in September of 2003.

These black sand lines or patches are concentrations of heavy mineral sand grains. These black sands are mostly made up of **magnetite** and **ilmenite**. Magnetite is an iron oxide and ilmenite is a titanium oxide. Can you guess which one of these is also helping to providing the tan color to the beaches?

Black sands concentrate in a line or patch because they are heavier than the surrounding tan sands (quartz and feldspar). Because the lighter quartz and feldspar is easier to move by the blowing winds and the waves, they get blown or washed away leaving the heavier black sands behind.

The black sands make up only 1-3% of the sand on our beaches.

Did You Know?

If you take a magnet and pass it over the black sands in the park, you can sometimes pick up the magnetite.

These black sands also originate from rocks from the Piedmont of North Carolina. They also are **hundreds of millions of years old** and have traveled hundreds of miles to get to our shores.

These are the major components of our sands, but these sands also contain small portions of other heavy minerals like garnet, tourmaline, rutile, kyanite, zircon, staurolite, and epidote.

Waves, Surf, Currents, and Sand: Barrier Island Equilibrium

Circle one answer only.

Name _____ Grade _____

1. North Carolina has the longest area of natural barrier islands along the U.S. east coast.

True

False

2. Barrier islands are useful as-----

Buffers open ocean storms and the mainland

Permanent places to build houses

3. Sand begins its journey from the land to the oceans in-----

Surface runoff

Creeks and rivers

Storm winds

All of these

4. Barrier islands are constantly changing.

False

True

5. Whether waves are small or big is a result of-----

Sand, tides, and currents

The summer or winter equinox

Wind speed, duration of wind, and fetch

All of these

6. Currents and waves are the great builders and destroyers of beaches.

True

False

7. Rip currents are created when-----

Longshore currents return to the ocean

Big waves hit the beach

High tides come in

None of these

8. Sea levels rise and fall depending on how much water is-----

Used for agriculture

Tied up in ice fields and glaciers

Used in our homes

Raining from the skies

9. Sands transported to the sounds, and sands deposited offshore in ancient times now on the continental shelf both contribute to barrier island formation.

False

True

10. If barrier islands are left alone nature establishes a balance between sand deposition and erosion.

True

False

11. Sand deposition builds-----

Beaches and barrier islands

Only beaches

Only barrier islands

12. It is becoming increasingly important to restore our barrier islands to a natural state because-----

They protect the mainland

Storm damage costs are too high

We are losing barrier islands

All of these

13. Sand on coastal dunes came from the beach before moving onto the dune.

True

False

14. The Outer Banks is a good example of how land development can erode the sand on a barrier island.

True

False

15. North Carolina's barrier islands are migrating (moving) toward the mainland.

True

False

16. Plants help hold sand in place on dunes.

True

False

17. Man-made structures on beaches to hold

the sand in place, like sandbags, riprap, artificial dunes, and seawalls usually only speed up the destruction of beaches.

True

False

18. Which part of the beach operates like a “giant conveyor belt” to move sand up the beach to the dunes?

Upper shoreface

Lower shoreface

Intertidal zone

Lower continental shelf

19. Cape Lookout National Seashore is a good example of a healthy barrier island system.

True

False

20. Hurricane storm surge is-----

Decreased by barrier islands

Not affected by barrier islands

Increased by barrier islands

None of these



Additional Resources:

How to Read a North Carolina Beach by Orrin H. Pilkey et al.

University of North Carolina Press, 2006.

Information on the processes which shape beaches.

The Nature of North Carolina's Southern Coast by Dirk Frankenberg

University of North Carolina Press, 1997.

Guides to areas connected to Cape Lookout and ecological processes which affect barrier islands.

“Barrier Islands” from Florida Oceanographic Society

http://www.floridaoceanographic.org/envIRON/bar_isl.htm

“The Perfect Storm: October 1991” and “Unnamed Hurricane: 1991” by NCDA

<http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/cyclones/pfctstorm91/pfctstorm.html>

<http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/hurricanes/unnamed91/unnamed91.html>

Information on and satellite imagery of the storm of 1991.

“Canadian Tropical Cyclone Season Summary for 1991” from Environment Canada

<http://www.ec.gc.ca/ouragans-hurricanes/default.asp?lang=en&n=9D24F0EE-1>

Path of the unnamed storm (note: the path changes colors from green to blue to red to blue again).

“‘Perfect Storm’ Damage Summary” by NCDA

<http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/cyclones/pfctstorm91/pfctstdam.html>

Damage estimates by state following the Halloween storm.

“Know the Power of Nor’easters” by NOAA

http://www.noaa.gov/features/03_protecting/noreasters.html

Basic information on nor’easters and the effects they can have on coastal communities.

“Hurricane Information” from Florida Oceanographic Society

<http://www.floridaoceanographic.org/hurricanenew.html>

Explains the differences among hurricanes and provides links to several other resources.

“The Perfect Storm” by About.com

http://weather.about.com/od/winterweather/p/perfect_storm.htm

Information on this unnamed storm.