Project Resilience Teacher Guide

> Project Resilience is a 20-day high school curriculum that helps students examine the environmental challenges facing communities along the Gulf of Mexico and learn about resilience planning using a resilience planning toolkit.

UCAR CENTER FOR SCIENCE EDUCATION

SOUTH LOUISIANA WETLANDS Discovery Center

Project Resilience Teacher Guide

Introduction and Overview of Project Resilience

With the Project Resilience curriculum, high school students examine the environmental challenges facing communities along the Gulf of Mexico and learn about resilience planning using a resilience planning toolkit. Project Resilience leads students through the development of a School Resilience Plan which contains student-designed projects to address one or more environmental challenges affecting their school campus. An extension of the curriculum is to implement one of the student projects from the School Resilience Plan.

Project Resilience was developed by the UCAR Center for Science Education (UCAR SciEd) and the South Louisiana Wetlands Discovery Center (SLWDC). This project was supported by the Gulf Research Program of the National Academies of Sciences, Engineering, and Medicine under Grant Agreement number 2000009811. Read about the Project Resilience pilot project (scied.ucar.edu/project-resilience/pilot-project), implemented in Terrebonne Parish, Louisiana, during the 2019-2020 school year.

The curriculum spans about 20 days of class time, divided into seven lessons, with an optional student project extension (Lesson 8). Lessons 1-4 of the curriculum focus on learning about the environmental challenges and scientific processes in the Mississippi River delta. Students gain an understanding of what the Mississippi River delta is and how it forms, why deltaic formation is important for coastal communities in the Gulf region (including the importance of wetlands and estuaries), and why the deltaic coast is vulnerable. Lessons 5-7 of the curriculum focus on resilience planning and adaptation strategies using a resilience toolkit. As a case study, students explore current and future projects planned for Terrebonne Parish, Louisiana, including criteria for choosing and evaluating factors that put communities at risk, and the scope of different types of projects.

If possible, a half-day field trip is highly recommended. Allowing students to see examples of land loss and current resilience projects in their own and nearby communities is an opportunity to ground their learning with important connections to the real world. The Project Resilience field trip example (linked in the Curriculum Outline below) is provided as a reference should you decide to create a field trip experience for your students.

Lesson 7 helps students to recognize how these larger environmental problems are impacting their own school and culminates in students creating a school resilience plan. The resilience plan is a collection of suggested projects that students feel are necessary to address environmental problems at their school campus. As an optional extension, Lesson 8 guides students to work with school officials and community members to select one project from the resilience plan to implement at their school (exact time for project implementation will vary and is not included in the 20-day curriculum schedule).

Curriculum Layout

The Project Resilience curriculum is organized into seven required lessons, with the optional additions of a field trip and/or eighth lesson. Most of the lessons extend over multiple class periods and are divided into “parts” (Part 1, Part 2, etc.) designed to fit within one 50-minute class period. Journal prompts from the lessons should be assigned at the end of each part and are intended to be completed as homework outside of class time. The target delivery time for lessons 1-7 of the curriculum is 20 days of class time.

You may find that your students require more than 50 minutes to complete part of a lesson if the learning tasks are particularly engaging, if your students require additional direct instruction or background around a new or challenging concept, or if you choose to facilitate any of the extension activities included at the end of the lessons.

The field trip and eighth lesson (project implementation) are optional extensions. Some guidance for these extensions is provided, but extra planning and scheduling for the field trip and projects, as well as securing funding to implement student projects at your school, is outside of the scope of the curriculum.

Within each lesson, you’ll find a list of materials, guidance about preparation for instruction, learning goals, and background information with links to additional resources. Directions for instruction and links to the Project Resilience slide deck, student sheets, maps, charts, readings, etc. are also found within each lesson write-up. In addition, many lessons also include extensions, which are optional instructional activities or suggestions for diving deeper into the content.

Curriculum Outline

Lesson 1: Changing Louisiana	50 minutes
Lesson 2: The Mississippi River Delta and Estuaries	Part 1: The Mississippi River Delta (50 min) Part 2: A Focus on Estuaries (50 min) Part 3: A Valuable Environment (50 min) Part 4: Sinking Land in the Bayou Region (50 min)
Lesson 3: Case Studies of Coastal Change	Part 1: Rising Sea Level (50 min) Part 2: A Tale of Two Hurricanes (50 min) Part 3: Ecosystem Changes (50 minutes)
Lesson 4: Turning Problems into Solutions	Part 1: Make a Claim (50 min) Part 2: Designing Solutions (50 minutes)
Lesson 5: Risk and Vulnerability	50 minutes
Lesson 6: Addressing Coastal Land Loss	Part 1: Multiple Lines of Defense (50 min) Part 2: Adapting for the Future (50 min) Part 3: Reducing the Risks (50 min) Part 4: Analyzing Adaptation Plans (50 min)
Field Trip: Finding Resilience in Your Community	OPTIONAL: Approximately 3 hours* *suggested to go on the field trip before Lesson 7
Lesson 7: Resilience in Action	Part 1: Breaking Down Resilience Toolkits (50 min) Part 2: Walking Through the Resilience Toolkit and Introducing the Culminating Task (50 min) Part 3: Brainstorming Possible Adaptation Projects (50 min) Part 4: Project Design (50 min) Part 5: Present and Revise (50 min)
Lesson 8: Making Your School Resilient & Project Implementation	OPTIONAL: 12 weeks* *exact time will vary depending on the project

Standards

The Project Resilience curriculum aligns with both the Louisiana Student Standards for Science and the Next Generation Science Standards (NGSS). Within each lesson, the Performance Expectations and any additional NGSS dimensions (Science & Engineering Practices, Disciplinary Core Ideas, and/or Crosscutting Concepts) addressed within the lesson are listed. However, the NGSS dimensions are not bundled within the Performance Expectations. Because most lessons have multiple parts, each calling upon unique science content and skills, there are sometimes multiple Performance Expectations listed for a single lesson. Please note that the lesson does not necessarily provide for mastery of each aspect of the Performance Expectations as outlined in the Louisiana framework. Bold type indicates the parts of the performance expectation that are most directly addressed within each lesson. The additional dimensions are included to draw attention to NGSS elements beyond those included with the Performance Expectations that students will engage in within the lesson. The table below lists the Performance Expectations most addressed in each lesson.

Louisiana Student Standards for Science - Performance Expectations

Lesson 1
- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, the occurrence of natural hazards, and changes in climate have influenced human activity.

Lesson 2
- HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, the occurrence of natural hazards, and changes in climate have influenced human activity.
- HS.EVS1-1: Analyze and interpret data to identify the factors that affect sustainable development and natural resource management in Louisiana.
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.
- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Lesson 3
- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, the occurrence of natural hazards, and changes in climate have influenced human activity.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impact of human activities with natural systems.

Lesson 4
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Lesson 5
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.

Lesson 6
- HS-EVS1-2: Obtain, evaluate and communicate the effectiveness of management or conservation practices for one of Louisiana's natural resources with respect to common considerations such as social, economic, technological, and influencing political factors over the past 50 years.
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.

Lesson 7
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.

Lesson 8
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Instructional Routines

Project Resilience includes opportunities for students to engage in hands-on activities, with a focus on modeling and student inquiry methods. Students will explore and analyze graphs, maps, and charts throughout the lessons. There are also many opportunities for students to practice the NGSS Science and Engineering Principles (SEPs), including: questioning, modeling, collaborating, discussing, and revising ideas. Ensure that students are familiar with norms for respectful and productive discussion prior to beginning *Project Resilience*. *Project Resilience* uses a driving question board to help motivate further investigation and journaling as a means of reflection, both of which are described in more detail below.

The Driving Question Board

Throughout the *Project Resilience* curriculum, students articulate questions to define what they need to learn about the environmental challenges facing coastal communities and how communities are demonstrating resilience. They document their questions on a Driving Question Board (DQB), a tool used to generate, keep track of, and revisit student questions related to phenomena that students are exploring. The DQB is a visual representation of the questions generated by the class and is displayed in the classroom during the unit. A DQB can be constructed with sticky notes or sentence strips, written on whiteboards, or made with shared software applications. Read about using Driving Question Boards as an instructional strategy for collaboration (phenomscience.weebly.com/blog/drivingquestionboards).

The Driving Question Board is introduced at the beginning of the unit and then periodically revisited as students reach milestones within the curriculum. Plan to spend 5-10 minutes each time you revisit the DQB. It serves as a record of students' curiosities about phenomena and a way of documenting the progress that they make in understanding the phenomena being studied. It is important that students understand there will be more questions on the DQB than can be answered during the unit.

To prepare a paper version of the Driving Question Board:

- Write the driving question on a sheet of poster board or chart paper.
- Make a space in the classroom for the Driving Question Board that is easily accessible to students.
- Provide sticky notes and markers that students will use to document their questions.

Journaling

The journal prompts provide students an avenue to process the weight of topics presented within the lessons on their own. Journal assignments are intended to be assigned at the end of each day's activities and completed outside of class. The time needed for a thoughtful response is not included within the planned 50 minute class period. If you do not typically assign homework to your students, consider journals as an optional extension activity.

Share with students your expectations for journal writing. Do you expect formal, polished writing, or is informal writing acceptable? How long should the average journal response be? Will students turn in their journal writing each day, or will they keep all their journal entries together until the end of the unit? Consider sharing an example of a journal response that you feel is a good model for students to follow. A journal scoring rubric is provided (see additonal resources at the end of this Teacher Guide), please use this as a template and adapt it to meet your needs. Journal prompts are listed in a single document in the resource guide at the end of this document.

For students living in coastal communities, learning about these environmental challenges will likely hit close to home. We encourage you to incorporate journaling into your *Project Resilience* curriculum so that students will have an outlet for their thoughts and feelings.

Integrating Project Resilience with your Environmental Science Curriculum

The *Project Resilience* curriculum can be considered as a case study, encompassing many topics included within your regular environmental science curriculum. Consider where *Project Resilience* might replace or enhance lessons in your regular sequence, or use the examples within the curriculum as a springboard to launch into a more in-depth study of topics. Take liberty to adapt, supplement, and skim as needed to best fit the learning needs of your students. It is always encouraged to integrate examples with local relevance when possible, especially in the context of learning about resilience in your own community.

Assessing Student Learning
Within the structure of *Project Resilience,* students are best assessed through their ability to apply learnings to real-world situations and design solutions. Though traditional summative assessments are not included, there are multiple opportunities for formative assessment, including: student activity sheets, journal responses*, exit tickets, discussions* (Note: it will be important to establish a culture of productive talk in your classroom to facilitate effective discussions.), group CER presentations* (at the end of Lesson 4), and project presentations for the School Resilience Plan* (at the end of Lesson 7). **Rubric templates are provided in the additional resource section at the end of the Teacher guide.*

If there are summative assessments (unit tests or practice questions from the AP Environmental Science exam) that you already use with your students, pull test items from these sources that match the Project Resilience learning objectives to use as an assessment.

Student Projects
The Lesson 8 extension of *Project Resilience* is the implementation of a student-designed resilience project on the school campus. Successful project implementation will depend on your ability to secure funding, allocate sufficient time, and cultivate support from your school administration and community members who can advise students as they create the project plan.

Note: If you plan to implement a resilience project at your school campus, it is strongly recommended that you secure funding prior to beginning the Project Resilience curriculum. Sources of project funding may be: project sponsors, student fundraisers, school budgets, or grants. You will also need to work with your school administration to get their support for project implementation.

The School Resilience Plan that students will create in Lesson 7 provides a bank of projects to choose from for implementation. It is suggested that students present their project ideas from the School Resilience Plan to a panel of stakeholders (school administration, school facilities manager, community members who work in engineering, or other relevant professions) who can help select which project to move forwards with. They might be able to help students estimate the cost of the project, for example. Other things to consider might include: permitting, if special equipment will be needed, the amount of time it will take to implement the project, the cost of labor, etc.

Once a project, or projects, have been decided upon, Lesson 8 leads students through creating a detailed proposal/project plan, which includes creating a materials list, budget, and steps to implement the project. *The Campus Resilience Project: Detailed Plan* document will help guide students through creating their proposals, but students will most certainly need support from outside resources as well. There is also *Resilience Project Planning: A Guide for Teachers* at the end of this Teacher Guide.

Extending Project Resilience Beyond the Classroom
A goal of the *Project Resilience* curriculum is to empower students to be involved in making their communities more resilient. Research has shown that student engagement around topics presented at school can help engage family members as well. Encouraging students to share what they are learning through the *Project Resilience* curriculum with their families and with members of the community could inspire others to work towards resilience. Look for opportunities for students to use what they are creating in the curriculum within larger community efforts. For example, students could share their ideas for a school resilience plan with the school board or city council. Or they could submit articles to the school or local paper. They could even start a campaign to increase awareness in the community about resilience. Engaging the adults of tomorrow in civic duty helps to strengthen communities and acknowledges the important contributions that youth can make.

Supplies You Will Need
Below is an overview of the supplies that you will need to implement the Project Resilience Curriculum in your classroom. A detailed supply list that includes quantities is provided within the instructions for each part.

TECHNOLOGY

- Digital Projector
- Computers or tablets for teacher & student use, with online access
- Camera/video recorder (phone or tablet is fine)
- Project Resilience Slide Deck projected for the class
- Video clips streamed online and projected for the class

SUPPLIES FOR DISCUSSIONS, DRIVING QUESTION BOARD, & STUDENT GROUP WORK

- **C**hart paper/Bulletin board paper
- Sticky notes
- Colored dot stickers
- Composition book or notebook
- Markers

HANDOUTS
- Student Sheets, Maps, Graphs, Data, Rubrics, and Readings for each Lesson
- Journal prompts

HANDS-ON ACTIVITY AND DEMONSTRATION SUPPLIES
- Paint trays with a hole drilled into the bottom (plastic tray recommended)
- Modeling clay or play dough
- Clay tool, dowel, or pencil for carving into the clay
- Indoor/outdoor carpeting strips
- Kitchen sponges
- Food coloring
- Water jugs with adjustable water flow spout
- Sand
- Soil
- Plastic bins or buckets to catch water
- Spray bottle
- Graduated cylinders (100mL or larger)
- Liquid measuring cup (large)
- Timer or stop-watch
- Meter stick
- Tape
- Clear tennis ball container

Project Resilience Teacher Guide

Lesson 1 > Changing Louisiana

The first lesson of the Project Resilience curriculum introduces students to the anchoring phenomenon: that coastal Louisiana is changing, and people in the region are vulnerable for many reasons. Students analyze local news stories using a cooperative learning strategy to learn how coastal change is affecting people in these communities, and create a driving question board to discover what questions students have about this topic.

Time Required

- Teacher Preparation Time: 20 minutes to gather supplies, review materials
- Class Time: 50 minutes for activities and discussion

Learning Goals

- Students will understand the scope of environmental challenges facing coastal Louisiana.
- Students will discover questions they have about the effects of a changing coastal environment.

Lesson Format

- Structured information gathering and sharing
- Group activity constructing a driving question board

Science Standards

Louisiana Student Standards for Science:

- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Materials

- Project Resilience Slide Deck (slides 1-7)
- Projector & Computer
- Louisiana Coastal Stories - Jigsaw Student Note-Taking Sheet (PDF)
- Audio recordings of Louisiana coastal stories (from New Orleans Public Radio):
  - Sinking Louisiana: Studying Subsidence
  - Coastal News Roundup: Marshes Sinking Faster than Previously Thought
  - Coastal News Roundup: An Update On Isle de Jean Charles
  - Coastal News Roundup: New Reports Say State Should Fill in Oil and Gas Channels
  - Why do we measure wetlands loss in football fields?
  - Mississippi River Flooding is Decimating Coastal Fisheries
- Transcripts of Louisana coastal stories (text only):
  - Sinking Louisiana: Studying Subsidence (PDF)
  - Coastal News Roundup: Marshes Sinking Faster Than Previously Thought (PDF)
  - Coastal News Roundup: An Update on Isle de Jean Charles (PDF)
  - Coastal News Roundup: New Report Says State Should Fill in Oil and Gas Canals (PDF)
  - Why Do We Measure Wetlands Loss in Football Fields (PDF)
  - Mississippi River Flooding is Decimating Coastal Fisheries (PDF)
- Six computers or tablets for student group work
- Chart paper
- Sticky notes
- Pens/markers

Preparation

- Print copies of the Louisiana Coastal Stories - Jigsaw Student Note-Taking Sheet, one per student.
- Bookmark the Louisiana coastal stories (links above) on computers or tablets.
- Note: the transcripts of the coastal stories are provided in case playing the audio recordings is not possible, or if students would benefit from reading along while listening to the audio.
- Read about facilitating the Jigsaw cooperative learning technique, if needed.
- Read about creating a class Driving Question Board (DQB), if needed.

Directions

Introduce the anchoring phenomenon: Coastal Louisiana is changing, and people in the region are vulnerable for many reasons. (10 min)

1. Project image of Fort Proctor (slide 3). Ask students:
    - What do you see? What do you notice? What does this make you think of? Ask if anyone has ever been to Fort Proctor?
2. Orient students to the location of Fort Proctor (Fort Proctor map is also part of slide 3). Share background information (built in the 1850s and engulfed by Lake Borgne in the 1960s) as time and student interest dictates.
3. Project the map of Last Island in 1853 and 1978 (slide 4). Ask students:
    - What do you see? What do you notice? What does this make you think of? Ask if anyone has ever been to Lost Island?
4. Help students orient to the map by identifying locations in Terrebonne Parish. Point out the location of Last Island ("Isle Dernieres") on both maps. Provide background about Last Island as time and student interest dictates, sharing that the 1856 hurricane resulted in extensive land loss. Optional: show the image of Last Island during the hurricane (provided in the Lesson 1 Resources folder).
5. Share with students that Louisiana is considered to be in a "Coastal Crisis" and that every 100 minutes a football field of land disappears into the Gulf of Mexico.
6. Transition the discussion to the range of environmental challenges faced in this area, in addition to land loss. Articulate the driving question (slide 5):
    - How is our changing coast affecting the people who live here?

Broaden to profile other examples of how coastal change is affecting people. (25 min)

Jigsaw activity:

1. Arrange students into groups of six for the Jigsaw cooperative learning activity; these will be referred to as "home groups" during the jigsaw activity. Tell students that each person in their group will listen to a different news story about an environmental problem facing coastal Louisiana, and then take turns teaching the other members of their group about their story.
2. Pass out a copy of the Louisiana Coastal Stories- Jigsaw Student Note-Taking Sheet to each student. Assign one student in each of the "home groups" to each of the coastal stories (there are six different stories, please adjust assignments as needed for your class size) and have them record the title of their assigned story on their note-taking sheet.
3. Students break into "expert groups" to listen to and discuss their assigned stories. E.g., All students who were assigned "Sinking Louisiana: Studying Subsidence" will be in one expert group, all students who were assigned "Why do we measure wetland loss in football fields?" will be in another expert group, and so on. When students return to their "home groups," each of them will have learned about a different story and be in charge of teaching their home group members what they have learned.
4. Give each expert group a laptop or tablet and the link to their story so that they can listen to it together. Point out to students that the transcript for their story is also on the webpage with the recording, in case they would like to follow along or have difficulties playing the recording. Note: The story transcripts can also be printed from the links in the Materials list above.
5. Instruct students to take notes on the Louisiana Coastal Stories- Jigsaw Student Note-Taking Sheet as they listen to their story. Project the jigsaw instructions and prompts (slide 6). As they discuss in their expert groups, prompt students to think about:
    - defining the problem
    - the causes of the problem
    - who is affected by the problem
    - how our community might be affected by this problem
6. After 10 minutes, have students return to their home groups to share what they have learned. "Experts" take turns briefly sharing with their home group. Encourage students to discuss connections between various problems, and to write down any questions that come up for them on page 2 of the Jigsaw student note-taking sheet.

Directions continued

Create a Driving Question Board to capture questions students have about Louisiana's coastal crisis. (10 min)

1. Pass out sticky notes to each student. Ask them to generate questions, on their own, that they have about the problems facing the coast based on the coastal stories they have learned about today, or based on previous knowledge/experiences. Tell students to write each of their questions on a separate sticky note.
2. Have students come together to share the questions they have generated on a Driving Question Board (DQB) for the class. Use a large piece of chart paper, or a bulletin board, and write the unit driving question at the top: *How is our changing coast affecting the people who live here?*
    - Display the Driving Question Board in a public place that the students will have access to throughout the unit. You could also consider creating a digital Driving Question Board, as long as students will easily be able to view and modify it throughout the unit.
3. Consider having everyone stand and gather around the DQB, bringing their sticky notes with them. Have students take turns reading their questions aloud and then post their sticky notes on the DQB. You will likely notice patterns or commonalities emerge among questions as they are shared. Call attention to this and move the sticky notes around to sort them into groups. You might consider asking if anyone else has a similar or related question to one that has already been posted to aid in the sorting process.
4. Use the DQB as a way to motivate students to learn more about our topic (coastal change and resilience). Find a way to connect a question or group of questions on the DQB to the topic of the next lesson (deltaic formation). If there are questions about land loss, or why the land is sinking, focus student attention here. For example: "To learn about why land is being lost, we must first learn about how it formed...this is the focus of our next lesson!"
5. Tell students that we will return to the DQB throughout the unit, and give students permission to add new questions as they think of them

Introduce Resilience Journaling (5 min)

1. Explain that students will complete a reflective journaling assignment as a wrap up to each activity in the unit. There is a prompt provided for each day that correlates with the lesson. Students should complete journaling assignments throughout the unit to record their thinking and process their responses to the challenging and complex topics explored in the curriculum. Read about journaling in Project Resilience and access the complete list of all 18 journal prompts.

Note: Journals are intended to be completed out of class. The time needed for a thoughtful response is not included within the planned 50 minute class period. If you do not typically assign homework to your students, consider journals as an optional activity.

2. Assign today's journal prompt. Read journal prompt #1 together and clarify expectations for journal responses. Consider sharing the Journal Scoring Rubric with students if you will be scoring journal responses.

Journal Prompt #1: Think about the environmental challenges facing coastal Louisiana that were presented today. Choose one of these issues and zoom in to focus on one small part of the problem that is important to you. Describe that one small part as if it was the only problem. Why is it important to you? What questions do you have about it? Now zoom out and consider the small part in the context of a bigger problem. How do your feelings about the problem change when you consider it on a larger scale?

Background Information

Fort Proctor

- Fort Proctor is a ruined 19th-century fort in St. Bernard Parish, Louisiana, USA. The fort is on the shore of Lake Borgne just north of the mouth of Bayou Yscloskey. The fort was intended to be part of the fortifications protecting water routes towards New Orleans. Due to delays caused by hurricane damage, and then the outbreak of the American Civil War, the fort was never garrisoned. By the end of the Civil War, improvements in artillery had made the design of the fort obsolete.
- The construction of the Mississippi River-Gulf Outlet Canal in the 1960s cut off all land access to the fort site. Now surrounded by water about one foot deep, the fort can only be seen in the distance from Shell Beach, Louisiana. Before Hurricane Katrina, there remained one small piece of dry land inside of the fort
- In 1978, Fort Proctor was listed on the National Register of Historic Places.

Last Island

Last Island (also known as Isle Dernière), off the Louisiana coast, was a long barrier island off the west side of Terrebonne Bay and a vacation destination with a large resort. The force of an 1856 hurricane broke it into many smaller islands, which today are collectively called the Isles Dernieres. Flooded by storm surge during the hurricane, much of the land and wetlands became eroded during the storm. Today, the Isles Dernieres islands that remain include much less land and wetland areas. Isles Dernieres Barrier Islands Refuge legally protects many of these islands.

About the environmental challenges profiled in the Louisiana coastal stories that students read in this lesson:

- Hydrologic Modification: Hydrologic modification is considered a "linchpin" problem of the basins, and indicates that all other issues revolve around it, and are often affected by it. When we build levees, dredge canals, or cut through natural ridges, the natural flow of water is changed. In some cases, such changes accelerate erosion. Other times it can result in changed salinity of water bodies. As a result, a freshwater marsh can transition to a more "salt-tolerant" type. In more extreme cases, marshland can be converted to open water.

- Sediment Reduction and Subsidence: Historically, the Mississippi River provided the sediment that Louisiana marshes need to survive. Now, however, levees confine the sediment to the river, bypassing the marshes, and ultimately deposit it on the continental shelf in the Gulf. Our coastal marshland continuously undergoes a natural process called "subsidence," which results in the land slowly sinking. In the past, the rate of sediment building equaled or surpassed the rate of sinking, and the marsh remained at sea level.

- Habitat loss: The rate of habitat conversion and land loss in the coastal areas of the Barataria and Terrebonne basins is alarmingly high. According to a 2010 USGS study about land area change in coastal Louisiana, the Barataria Terrebonne Estuary System (BTES) has lost a total of 865.57 square miles since 1935.

- Global Sea Level Rise Due to Climate Change: Global (or eustatic) sea level rise is one of the most well-known consequences of climate change. There are two ways that higher temperatures cause higher sea levels: (1) melting ice sheets and glaciers and (2) thermal expansion of seawater. Since 1900, sea level has risen between 1 and 2 millimeters per year (10-20 cm or 3.9-7.9 inches per century) on average.

- Changes in Living Resources: Living Resources, the animals that live in the estuary, are dependent on these diverse habitats. Approximately 735 species of birds, frogs, shellfish, reptiles, amphibians, and mammals spend all or part of their life cycle in the estuary. Several of the species are categorized either as threatened or endangered. Many factors contribute to declines in animal populations that live in the shallow ocean, in the wetlands, and on land.

Background Information (continued)

About the environmental challenges profiled in the Louisiana coastal stories that students read in this lesson (continued):

- Changes to water quality:
  - Eutrophication: When too many nutrients, such as phosphorus and nitrogen, are in the water, a condition known as eutrophication occurs. The process begins with the accelerated growth of algae. As algae and plant matter decay, oxygen in the water is depleted, killing fish and shellfish.
  - Pathogens: Pathogens are disease-producing organisms, such as bacteria and viruses. The sources of these organisms are human waste, pasture runoff from animal waste, and waste products of marsh animals, such as nutria and birds. Bacteria commonly found in sewage pollution can be of serious concern as it causes infection, rashes, and other serious diseases. Vibrio bacteria can cause both foodborne and wound-related illnesses.
  - Toxic Substances: Water, animal tissue, and sediment testing have identified a variety of toxic substances in the basins. Some are known cancer-causing agents, while others affect reproduction. Toxic concentration is magnified when some animals consume contaminated food. Human consumption of highly contaminated seafood also poses health risks. Toxins found throughout the system come from point sources, such as industry, and non-point sources, such as urban runoff.

Note: The news stories that students explore as a part of this activity are not intended to give a comprehensive overview of all environmental problems facing the Gulf Coast. Future lessons in Project Resilience will allow students to dive in-depth into a variety of resilience challenges, including, but are not limited to, those explored in this lesson. The objective is for students to end this lesson with an understanding that our coastal environment is changing and how this affects humans.

Other resources

Our Coastal Crisis (http://mississippiriverdelta.org/our-coastal-crisis/)

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Lesson 2 > The Mississippi River Delta and Estuaries

Students use a simple stream table to learn how the Mississippi River delta formed and use Google Earth to explore the Barataria-Terrebonne estuarine system in Louisiana. Next, students learn about the vital role estuaries play in coastal environments, build a model to represent the estuary services provided by these unique areas, and explore how hydrologic modification has upset the natural cycle of delta formation along the Louisiana coast. Students explore how slowing the rate of sediment deposition combined with land subsidence causes land loss in the delta region. Lesson 2 is divided into four parts, each intended for about a day of instruction time.

Lesson 2: Part 1: The Mississippi River Delta - Students discover the importance of the Mississippi River watershed and create a river delta using a stream table. Students make connections between delta formation and the land that they live on as part of a coastal community.
Lesson 2: Part 2: A Focus on Estuaries - Students learn what an estuary is. They create a model to explore the important ecosystem services provided by an estuary. Students create an articulate metaphor to explain their model.
Lesson 2: Part 3: A Vulnerable Environment - Students use Google Earth Pro to identify estuary landforms near their communities. Students will understand how hydrologic modification of the Mississippi River has impacted the natural cycle of sediment deposition in the delta and use a model to replicate changes to river characteristics as a result of artificial levees.
Lesson 2: Part 4: Sinking Land in the Bayou - Students will analyze map data to understand that land and marshes are being lost in the Bayou region and use a model to understand how land and marsh disappear when less sediment is deposited and the land is sinking. Students will learn that the loss of wetlands habitat affects species.

Time Required

- Teacher Preparation Time: 30 minutes to gather supplies prior to each day
- Part 1: 50 minutes
- Part 2: 50 minutes
- Part 3: 50 minutes
- Part 4: 50 minutes

Learning Goals

- Students learn the definition of a watershed, which watershed(s) their community is a part of, how it formed, and how it has changed over time, both naturally and from human modifications. *(Part 1)*
- Students discover the importance of the Mississippi River watershed and create a model of the river delta using a stream table. *(Part 1)*
- Students make connections between delta formation and the land that they live on as part of a coastal community. *(Part 1)*
- Students learn what an estuary is. *(Part 2)*
- Students create a model to explore the important ecosystem services provided by an estuary. *(Part 2)*
- Students create an articulate metaphor to explain their model. *(Part 2)*
- Students learn about estuary landforms near their communities. *(Part 3)*
- Students will understand how hydrologic modification of the Mississippi River has impacted the natural cycle of sediment deposition in the delta and create a model to show how river characteristics change as a result of artificial levees. *(Part 3)*
- Students will analyze map data to understand that land and marshes are being lost in the Bayou Region and use a model to understand how land and marsh disappear when less sediment is deposited and the land is sinking. *(Part 4)*
- Students will learn that the loss of wetlands habitat affects species. *(Part 4)*

Lesson Format

- hands-on modeling activity *(Part 1, 2, 3)*
- class discussion *(Part 1, 2, 3)*
- map reading *(Part 3, 4)*
- demonstration *(Part 4)*
- data analysis *(Part 4)*
- claims, evidence, reasoning assignment *(Part 4)*

Science Standards

Louisiana Student Standards for Science:

- HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. *(Part 1, 2, 3)*
- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. *(Part 4)*
- HS.EVS1-1: Analyze and interpret data to identify the factors that affect sustainable development and natural resource management in Louisiana. *(Part 2, 3)*
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues. *(Part 3, 4)*
- HS-LS2-6: Evaluate the claims, evidence and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *(Part 2, 3, 4)*

Additional NGSS Dimensions:

- Science and Engineering Practices: Designing and Using Models
- Disciplinary Core Ideas: ESS2.A: Earth Materials and Systems and ESS3.C: Human Impacts on Earth System

Materials

- The stream table investigations in Lesson 2: Parts 1-3 require additional materials, listed below and also within the lesson plans for each part.
    - Paint tray or large baking/roasting pan with a hole at one end for water drainage (one per group)
    - Large water container with spigot (one per group)
    - Access to a sink or water source
    - Bucket or tub to collect water drainage
    - Books, box, or extra tubs to prop up water jug
    - Graduated cylinders (100mL or larger) or liquid cup measurers
    - Spray bottles
    - Sand (4-5 cups per stream table, for Part 1)
    - Modeling clay (about 5 lbs of clay for every 3 groups, for Parts 2-3)
    - Soil (optional, could use sand from Part 1)
    - Clay tools, pencil, chopstick, or paintbrush to create features in the clay
    - Indoor/outdoor carpeting (strips approximately 3” wide that fit in the paint tray)
    - Kitchen sponges
    - Food coloring
    - Scissors
    - Timer

Part 1: The Mississippi River Delta

Materials

- Project Resilience Slide Deck (slides 8-11)
- Projector & Computer
- How a Delta Forms- Student Experiment Sheet (PDF)
- Paint tray or large baking/roasting pan with a hole at one end for water drainage (one per group)
- Large water container with a spigot (one per group)
- Access to a sink or water source
- Bucket or tub to collect water drainage
- Books, box, or extra tubs to prop up the water containers
- Graduated cylinders (100mL or larger) or liquid cup measurers
- Spray bottles
- Sand (4-5 cups per stream table)
- Timer

Preparation

- Drill a drainage hole into the bottom of each paint tray (stream table).
- Set up the stream table stations for each group, including filling water containers and adding sand to the stream tables (sand and water will likely end up on the tabletops and floors during this activity).
- Assign students to stream table groups.
- Print copies of the How a Delta Forms- Student Experiment Sheet (one per group)

Note: Only sand will be used in the paint trays during Part 1.

Directions

Introduce the Mississippi River Watershed (5 min)

1. Introduce students to the importance of the Mississippi River while showing the Rivers of the Mississippi Watershed visualization (slide 9)
    - Ask students to make observations about the watershed video: What do you notice? What do you think a watershed is? Why is this important for where we live in coastal Louisiana?
    - Define a watershed, also called a drainage basin or catchment, as the entire area (including tributary rivers) that drain into a single river. The Mississippi River watershed covers 41% of the lower 48 states.
2. Share some facts about the Mississippi River:
    - It is the second longest river in North America (the Mississippi-Missouri-Jefferson river system is considered the longest continuous river in North America).
    - It is the largest drainage basin in the United States.
    - The coastal land many people live on wouldn't be here if it weren't for the river.
    - Pose the question: *How might the Mississippi River and its watershed have created the land we live on today?* Have students brainstorm ideas in pairs, then share out some ideas with the whole class.

Model How a Delta Forms (25 min)

1. Introduce that coastal Louisiana residents live on land formed from sediment transported by the river and deposited where the river meets the ocean--the delta!
    - *Note: areas on the west side of the delta are now estuarine, which students will explore in Part 2.*
2. Show the set-up of the stream table and explain that we will use this as a model for how a delta forms.
    - Point out that we will be creating a very simple model, while the actual delta system is much more complex (influenced by tides along the coast, not just water flowing out of the river, for example).
3. Ask students to brainstorm different variables they could test that might affect how the delta forms (the volume of water, speed of the water, angle of incline, diverting water, etc.). Record a list of variables on the board.
4. Break students into small groups (four or five students, depending on class size and materials available), and pass out a copy of the How a Delta Forms- Student Experiment Sheet to each group.
5. Assign each group to test out a different variable from the list on the board.
6. First, each group will need to plan how they will conduct their experiment and what observations they will record.
    - Remind students that if they are experimenting with volume and velocity, they will need to measure the amount of water that passes through the stream table and the amount of time the water takes to flow.

Model How a Delta Forms (continued)

7. Then, instruct them to follow the instructions on the experiment sheet to set up the stream table to create a delta.
    - For Trial 1, groups should flow water through the stream table for at least five minutes, recording observations each minute.
    - For Trial 2, groups should flow water through the stream table with different conditions to test their variable (changing the amount of water that they allow to flow through, or changing the amount of time, etc.).

Note: students may enjoy recording a time-lapse video of their stream table experiment, or taking photos.

8. Circulate among the groups while they are experimenting with the stream tables, focusing attention on the delta and changes to the river channel. Pose questions such as:
    - What do you see happening? How is the river changing?
9. Compare experiments. Have each group share to debrief the stream table experiments. Make connections between these variables and things in the real word (flooding, building levees, etc.). Use the following prompts to guide your discussion:
    - Did anyone see the beginning of "birdfoot" like features in their stream tables?
    - What happens to delta formation when the water velocity changes? How might this happen in real life?
    - Where does the sediment that forms the Mississippi River delta come from?
    - How well do our models represent the real delta? What are the limitations of our model?

Stream Table Investigation: Forming a river delta

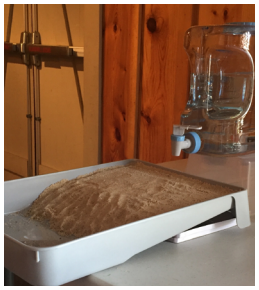


Photo 1: Suggested set up for the stream table investigation. Access to a sink or source of water will allow students to refill their water containers as needed. Students can change the angle of incline, the rate of flow of water into the stream table, the volume of water they allow to flow through the stream table, etc.

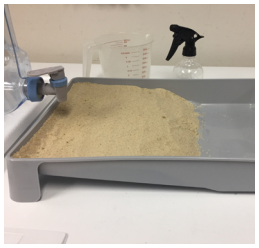


Photo 2: Press about 1 inch of sand into the upper half of the stream table, leaving space for the delta to form in the bottom half of the tray. The 4.5 cup/36 oz measuring cup is a good estimate of the amount of sand needed per sand table. Wet the sand with the spray bottle before beginning the flow of water. Note the drainage hole at the bottom, which you will need to drill out prior to facilitating the lesson.

Photo 3: As the delta forms, look for features such as a "birdsfoot" delta and braided streams.

Photo 4: Measuring the volume of water that flows through the stream table and recording the amount of time it took to flow through can provide water velocity data.

Facilitation Tips:

- Fill the top half of the tray with sand, leave the rest of the tray empty. The drainage hole should be at the bottom of the tray.
- Prop the top of the tray up with a book/blocks/etc., so that the tray sits at an incline.
- Wet the sand before you add the river.
- Position the water container above the sand at the top of the tray. This will represent the headwaters.
- Allow water to flow onto the sand as a slow but steady stream. If you are using a spigot, you can easily control how much water flows into the stream table.
- Begin recording the time when you start the flow of water if you will be making velocity calculations. Calculate water volume by measuring the amount of drainage water with a graduated cylinder (velocity=volume/time).
- Observe the stream tables for at least 5minutes, or until delta features are visible.

Wrap up- Connecting Our Models to the Mississippi River Delta (10 min)

1. Show the *Restoring America's Deltas* video segment about Delta Formation, from start to 4:46min (the video link is below, and also in slide 10). As students watch the video, have them write down any connections they notice between their stream tables and the video.
2. After watching the video, hold a short discussion. Show the image of the delta lobes (slide 11) as students discuss. This image shows how the location of the Mississippi River delta has changed over time. Use the following prompts
    - *How does what the video showed compare to what we saw with our stream tables today?*
    - *How has the Mississippi River delta changed over time?*
    - *How is the history of delta formation important for coastal Louisiana?*

Restoring America's Deltas (video)
https://www.youtube.com/watch?v=wWRGvGv1vps

Facilitation Tips:
The following time designations will help you navigate to appropriate sections of the video. While not all sections are specified in the curriculum, you may decide to include them as extension activities.

- 0:00-4:46 Delta Formation (aligns with Lesson 2: Part 1)
- 4:46-10:22 Diversity in Marshes (aligns with Lesson 2: Part 2)
- 10:28-15:00 Mississippi River Economy and Ecosystem Services (aligns with Lesson 2: Part 2)
- 15:12-19:20 History of Hydrologic Modification (aligns with Lesson 2: Part 3)
- 19:23-24:19 Solutions: Sediment Diversion and Re-forming the Delta (aligns with Lesson 2: Part 4)

Clean Up (10 min)

- Use the remaining class time to have students clean up the classroom.

Assign Journal Prompt #2.

- Prompt 2: In today's lesson, you learned about how important the river was in the formation of the land you live on. Think about a natural area or specific place in coastal Louisiana that is special to you. Describe the place and share what you like about it. From your understanding of how the Mississippi River Delta has changed over time, explain how this area might have formed.

Background Information

The Mississippi River Delta Basin

Excerpt below is from The Louisiana Coastal Wetlands Planning Protection and Restoration Act Program (https://lacoast.gov/new/About/Basin_data/mr/)

> "The Mississippi River has had a profound effect on the landforms of coastal Louisiana. The entire area is the product of sediment deposition following the latest rise in sea level about 5,000 years ago. Each Mississippi River deltaic cycle was initiated by a gradual capture of the Mississippi River by a distributary, which offered a shorter route to the Gulf of Mexico. After the abandonment of an older delta lobe, which would cut off the primary supply of fresh water and sediment, an area would undergo compaction, subsidence, and erosion. The old delta lobe would begin to retreat as the gulf advanced, forming lakes, bays, and sounds. Concurrently, a new delta lobe would begin its advance gulfward. Over the past 5,000 years, this deltaic process has caused the coastline of south Louisiana to advance gulfward from 15 to 50 miles, forming the present-day coastal plain.
>
> "For the last 1,200 years, sediment deposition has occurred primarily at the mouth of the Mississippi River's Plaquemines-Balize delta, in the area defined as the Mississippi River Delta Basin. This delta is located on the edge of the continental shelf of the Gulf of Mexico. Its bird's foot configuration is characteristic of alluvial deposition in deep water. In this configuration, large volumes of sediment are required to create land area. Consequently, land is being lost in this delta more rapidly than it is being created.
>
> "The Mississippi River Delta Basin comprises approximately 521,000 acres of land and shallow estuarine water in the active Mississippi River delta. Approximately 83 percent of this area, or 420,000 acres, is open water. The 101,100 acres of land in the basin is characterized by low relief, with the most prominent features being natural channel banks and dredged material disposal areas along the Mississippi River, its passes, and human-made channels. Coastal marshes make up approximately 61,650 acres or about 61 percent of the total land area in the Mississippi River Delta Basin. Eighty-one percent of this marsh is fresh, 17 percent is intermediate, and 2 percent is brackish-saline.
>
> "The Mississippi River discharges the headwater flows from about 41 percent of the contiguous 48 states. On a long-term daily basis, discharges in the Mississippi River average 470,000 cubic feet per second (cfs). A peak discharge of approximately 1,250,000 cfs occurs on the average of once every 16 years downstream of New Orleans."

Mississippi River Delta Basin formation and land loss:

> "Between 1974 and 1990, the land loss rate in the Mississippi River Delta Basin averaged 1,072 acres per year, or 1.69 percent of existing land area (Dunbar, Britsch, and Kemp 1992). Between the mid-1950s and 1974, the estimated land loss rate for the basin was 2,890 acres per year. This loss is the result of compaction, subsidence, hurricanes, tidal erosion, sea level rise, and human activities. The loss has been aggravated by the maintenance of navigation channels and the construction of canals for mineral exploration. The total land area lost in this basin over the last 60 years has been approximately 113,300 acres.

Part 1 Extensions:

1. To extend learnings about how the delta formed, read How the Delta Formed and then answer the questions:
   - How has the Mississippi River changed over time?
   - What is the historical significance of the delta for New Orleans?
   - What challenges to the natural cycles is the delta experiencing today?
2. Examine and discuss the image of the delta lobes on the How the Delta Formed page:
   - Point out time (the lobes represent the location of the delta from the distant past).
     - Why are the lobes significant? Where might you expect the next lobe to form if the natural cycles were allowed to progress?
   - Point out that this no longer happens because the river is modified so that the channel does not change location.
     - What are the pros/cons of this hydrologic modification?
3. To learn more about the structure of a river delta, read and discuss the Anatomy of a Delta page on the Coastal Crisis website.
   - Return to the stream tables and look for the features described in the Anatomy of a Delta as students allow water to run through their model. Label these features on the stream table, or sketch them on paper.

Other resources

Our Coastal Crisis (http://mississippiriverdelta.org/our-coastal-crisis/)

Part 2: A Focus on Estuaries

Materials

- Project Resilience Slide Deck (slides 12-18)
- Projector & Computer
- Estuary Model Metaphor- Student Sheet (PDF)
- Paint tray or large baking/roasting pan with a hole at one end for water drainage (one per group)
- Large water container with a spigot (one per group)
- Access to a sink or water source
- Bucket or tub to collect water drainage
- Books, box, or extra tubs to prop up the water containers
- Graduated cylinders (100mL or larger) or liquid cup measurers
- Spray bottles
- Modeling clay (about 5 lbs of clay for every three groups, for Parts 2-3)
- Soil (optional, could use sand from Part 1
- Clay tools, pencil, chopstick, or paintbrush to create features in the clay
- Indoor/outdoor carpeting (strips approximately 3" wide that fit in the paint tray)
- Kitchen sponges
- Food coloring
- Scissors
- Timer

Preparation

- Print copies of the Estuary Model Metaphor Student Sheet (one per group)
- Prepare the classroom for the stream table/modeling activity.
- Organize the wetlands model building materials on a table and assign students to model building groups.
- View the Estuaries: Nature's Water Filters animation in advance to ensure it works with your technology set up.

Note: Students will use clay in the paint trays during Part 2.

Directions

Introduction to the local estuary (10 minutes)

1. Transition from the day before. Tell students today we will build upon our understanding of how the river creates land, but now we will focus on the unique types of land that form where rivers join the ocean.
2. Introduce the definition of an estuary (slide 13):
   "Estuaries are bodies of water and their surrounding coastal habitats, typically found where rivers meet the sea. Estuaries harbor unique plant and animal life because their waters are brackish -- a mixture of fresh water draining from the land and salty seawater." (NOAA)
3. Show students an example of what an estuary looks like (slide 14). The example in the slide deck shows the area where the Mississippi River meets the Gulf of Mexico in southern Louisiana.
4. Introduce the term **wetlands**, which describes ecosystems with unique types of vegetation adapted to live in water (often with changing water and salinity levels). Wetlands are a feature of estuaries that often develop along the coastline, forming a transition zone between land and sea.
   - Point out the wetlands areas in the estuary image from the previous step (in slides).
5. Tell students that the land they live on is part of an estuary called the Barataria-Terrebonne National Estuary System (BTNES). Show them the map of the area included within their coastal estuary (slide 15).
   - The northern border of the estuary begins near the city of Morganza, LA (not shown on the map, but this might serve as a reference location for Louisiana residents). From there, the estuary includes all of the land between the Atchafalaya and Mississippi Rivers as they flow down to the Gulf of Mexico.

Building an estuary (30 minutes)

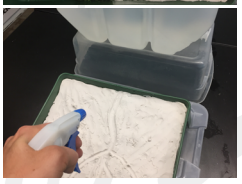
1. Transition to the stream tables. Tell students their objective is to learn why estuaries are important.
2. Break students into small groups (four or five students, depending on class size and materials available) and give each group a stream table tray and a large amount of modeling clay.
3. Tell them that their task is to build a model of an estuary, adding wetlands to the coast of their stream tables, and then use the materials provided to model how the presence or absence of an estuary affects the land, water, and the plants and animals that live there.

Building an estuary (continued)

4. Guide students as they add clay to the stream table to build the land and the river.
    - To begin, spread a layer of modeling clay in half of the tray to represent land. Leave the other half empty to represent a body of water. Be sure to leave the end with the drainage hole uncovered (this will be the "ocean" side of the tray)
    - Shape the clay so that it gradually slopes down to the water. Smooth the clay along the sides of the tray to seal the edges.
    - Use clay tools, a pencil, the opposite end of a paintbrush, etc. to form a meandering river with tributaries in the clay that lead to the body of water. Note: Natural levees will often form when the river is carved in the model. If so, have students smooth them down so that it will be easier to model flooding with their model.
    - The land should also slope towards the river so that when water is added, some of it will run into the river channel.
    - Projecting a map image of the Mississippi River might also be helpful for students to visualize the pattern.
5. Orient students to the materials they can use to model different conditions. All materials should be laid out on a table or counter for students to access. They will decide as a group which materials to use to create various conditions with their model. Students will need to brainstorm ideas and try them out. *Note: students may enjoy recording a time-lapse video of their model, or taking photos.*
6. Students will build a model that answers these questions (slide 16):
    - How does the presence/absence of wetlands affect the amount of water that flows out into the ocean?
    - How does the presence/absence of wetlands affect the amount of sediment that flows out into the ocean?
    - How do rainfall events of differing intensity affect the environment (average rainfall, heavy rainfall, flooding) with and without wetlands?
    - How does the presence/absence of wetlands affect the number of pollutants that flow out into the ocean?
7. Review the facilitation tips listed in the Inquiry Activity: Modeling an Estuary in the box below as needed to provide guidance during the modeling activity.
8. Pass out a copy of the Estuary Model Metaphor Student Sheet to each group. Explain that they will use this table to write statements to explain how their model represents the real world. The first line on the table is filled in as an example.
    - As students complete their modeling and metaphor tables, encourage them to visit other groups to compare and explain their models to each other.
    - *Note: Models will be used again in the Modeling Hydrologic Modification lesson, do not discard them!*

Inquiry Activity: Modeling an Estuary




Facilitation Tips:

- Groups should all start with the same basic setup, as shown in the picture on the right. Prop the top of the tray up to increase the slope. *Note: Use the same basic setup from the How a Delta Forms activity (Lesson 2: Part 2), only this time use clay instead of sand.*
- Students can create the main channel of the river and some tributaries by carving out clay with a clay tool or the end of a paintbrush/pencil. Point out that they should be careful not to create natural levees as they carve the river because this will prevent water and sediment from entering the river channel. To avoid this, press down on the clay so that the river banks are level with the ground.
- Ask students to brainstorm how they will add water to their system before they get started. How will they represent a typical rainfall vs. a heavy rainfall vs. a flood? How will they determine if adding wetlands to their model has an impact on the amount of water that flows into the ocean?
- Students may want to write out a brief outline of steps as they plan to create different situations.
- Point out that they will likely be taking their "wetlands" in and out of the model. They want their carpet/sponge to fit snugly against the clay "coastline" without any gaps, as shown, but they should be able to remove it as needed. Note: the "wetlands" should not extend all the way to the end of the tray. Be sure students leave open space for their "ocean" to form, as shown in the photo on the right, so that they can observe the water being filtered by the estuary.
- When adding water to their system, students will want to consider how to model different amounts of rainfall. Using a spray bottle could replicate rain (either normal rain or heavy rain, depending on how quickly you spray the water). Pouring water with a cup or opening the spigot as much as possible could replicate a severe weather event. Students should test their model to see if the rainwater will run into their river. If not, sculpt the clay so that it slopes towards the river.
- When adding sediment (soil/sand) to the model, tell students to avoid putting it directly into the river channel (since sediment washes into the river from the land), as shown in the picture. Once the "rain" or "flooding" is added to the model, sediment should wash into the river and down towards the estuary, just as it would in nature.
- Groups can rinse their model between setups if they desire. The clay and features will remain intact.
- The food coloring is suggested as a way to simulate pollutants in the water. Students can decide whether to add the food coloring directly to the river or add it through the spray bottle, or both! Encourage experimentation.

Wrap-up: Discussing the importance of estuaries (10 min)

1. Debrief the estuary models as a whole class.
    - What happened to the sediment when there wasn't an estuary present?
    - What happened during heavy rain or flood?
    - What did your model show about how pollutants move through the system?
2. Show the animation Estuaries: Nature's Water Filters (slide 17). Note: Click through the animation until you reach the "Play the Pollution Game" segment.
    - The functions of an estuary are referred to as "ecosystem services," filtering the water from pollutants and excess nutrients, holding on to sediment, and slowing the flow of water.
    - Ask students to relate their models to the function of estuaries shown in the animation.
    - Point out that as it rains, many nutrients are carried into the river and end up in the estuaries as well, not just sediment and pollutants. The nutrient-rich marshes and soils that form in estuaries are a habitat for many species of plants and animals.
3. To close the day, discuss the estuary that your students live in. In this case, it is the Barataria-Terrebonne Estuarine Basin (slide 18).
    - How is the estuary you live in important to you as an individual? How is it important to the community?
    - What evidence is there of ecosystem services provided by the Barataria-Terrebonne Estuary?
    - What examples of changes to the estuary/wetlands are you aware of? How does this impact our community? (The land along the road headed to Grand Isle is an example of fragmented marshlands. Grand Terre Island is also an example of marshland loss.)
    - Consider creating a class list of their ideas and posting it for later reference.

Assign journal prompt #3

- Prompt #3: Think about the ecosystem services that an estuary provides to the environment and describe how the environment you live in could change if the estuary were no longer there. Come up with your own metaphor for what an estuary is like and describe it.

Background Information

The Barataria-Terrebonne Estuarine System

Excerpt from The Barataria Terrebonne National Estuary (supportbtnep.org/btnep-and-the-estuary/the-barataria-terrebonne-national-estuary/)

"The Barataria-Terrebonne Estuary System (BTES) is a biologically rich and productive ecosystem encompassing 4.1 million acres of upland forests, swamps, marshes, bayous, bays, and barrier islands, bound on the west by the Atchafalaya River and on the east by the Mississippi River in south Louisiana. Sixteen parishes fall within its boundaries. Those parishes include Ascension, Assumption, Iberville, Jefferson, Lafourche, Plaquemines, Pointe Coupee, St. Charles, St. James, St. John the Baptist, St. Mary, Terrebonne, West Baton Rouge and only small portions of Iberia, St. Martin, and Orleans.

"The BTES produces a half-billion pounds of fish and oysters annually and supplies 10-15% of our nation's oil production. Its expansive marshes provide habitat for previously endangered species such as the brown pelican and the bald eagle, as well as other waterfowl and migratory birds. Recreational opportunities for residents and visitors from around the world abound. The health of the estuary and the quality of its bayous, bays, fish, and wildlife are critical to our regional economy and the sustenance of our nationally-unique culture.

"The most important factor contributing to land loss in the BTES is subsidence, a complex process in which marsh sediments compact and sink under their own weight. Historically, the annual floods over the banks of the Mississippi River provided fresh water and sediment to BTES marshes, which kept them above water. Levees were constructed to protect communities across the nation from these floods, but they also prevent water and sediment from reaching the BTES marshes.

"Subsidence drowns coastal marshes, causing chemical changes in wetland soils, which eventually kill marsh vegetation. Without plant roots to hold it together, the marsh soil breaks up and is carried away by wave action. The end result is the marsh converted to open water. This additional volume of water causes an increase in the tidal prism, forcing passes to enlarge and reducing the lengths of barrier islands, which protects interior marshes from wave action and hurricanes. Barrier islands are also subsiding, and due to both these stressors, they ultimately disappear without new sediment inputs.

"Other human-caused and natural factors can influence land loss rates in the BTES. For example, canals and raised roadbeds, breached natural ridges, and other hydrologic modifications can interrupt tidal exchange and allow salt water intrusion."

Background Information (continued)

What is an estuary?

Excerpt from NOAA's Estuaries website (https://oceanservice.noaa.gov/education/tutorial_estuaries/welcome.html)

"An estuary is a partially enclosed body of water, and its surrounding coastal habitats, where salt water from the ocean mixes with fresh water from rivers or streams. In fresh water, the concentration of salts, or salinity, is nearly zero. The salinity of water in the ocean averages about 35 parts per thousand (ppt). The mixture of seawater and fresh water in estuaries is called brackish water, and its salinity can range from 0.5 to 35 ppt. The salinity of estuarine water varies from estuary to estuary and can change from one day to the next, depending on the tides, weather, or other factors (Levinton, 1995).

"While strongly affected by tides and tidal cycles, many estuaries are protected from the full force of ocean waves, winds, and storms by reefs, barrier islands, or fingers of land, mud, or sand that surround them. The characteristics of each estuary depend upon the local climate, freshwater input, tidal patterns, and currents. Truly, no two estuaries are the same. Yet, they are typically classified based on two characteristics: their geology and how saltwater and freshwater mix in them.

"However, not all estuaries contain brackish waters. There are a small number of ecosystems classified as freshwater estuaries. These estuaries occur where massive freshwater systems, such as the Great Lakes in the United States, are diluted by river or stream waters draining from adjacent lands."

Video: What's An Estuary? Now you Know (https://www.youtube.com/watch?v=XLumSN4G5P4&feature=youtu.be)

Why are estuaries important?

Information below from NOAA's Why Are Estuaries Important? (https://oceanservice.noaa.gov/education/tutorial_estuaries/est03_ecosystem.html)

Estuaries are important natural places. They provide goods and services that are economically and ecologically indispensable. Often called nurseries of the sea (USEPA, 1993), estuaries provide vital nesting and feeding habitats for many aquatic plants and animals. Most fish and shellfish eaten in the United States, including salmon, herring, and oysters, complete at least part of their life cycles in estuaries. Estuaries also help to maintain healthy ocean environments. They filter out sediments and pollutants from rivers and streams before they flow into the oceans, providing cleaner waters for marine life. Estuaries and their surrounding wetlands are also buffer zones. They stabilize shorelines and protect coastal areas, inland habitats, and human communities from floods and storm surge from hurricanes. When flooding does occur, estuaries often act like huge sponges, soaking up the excess water. Estuarine habitats also protect streams, river channels, and coastal shores from excessive erosion caused by wind, water, and ice.

Threats to estuaries

Excerpt below from NOAA's Human Disturbances to Estuaries (https://oceanservice.noaa.gov/education/tutorial_estuaries/est09_humandis.html)

"Because they are transitional areas between the land and the sea, and between freshwater and saltwater environments, estuaries can be seriously impacted by any number of human, or anthropogenic, activities.

"The greatest threat to estuaries worldwide is, by far, their large-scale conversion by draining, filling, damming, or dredging. These activities result in the immediate destruction and loss of estuarine habitats. Until the last few decades, many estuary habitats in North America were drained and converted into agricultural areas; others were filled to create shipping ports and expand urban areas. In the United States, 38 percent of the wetlands associated with coastal areas have been lost to these types of activities (Good et al., 1998). In some areas, estuarine habitat loss is as high as 60 percent.

"Of the remaining estuaries around the world, many are seriously degraded by pollution. People have historically viewed estuaries and waterways as places to discard the unwanted by-products of civilization. Pollution is probably the most important threat to water quality in estuaries. Poor water quality affects most estuarine organisms, including commercially important fish and shellfish. The pollutants that have the greatest impact on the health of estuaries include toxic substances like chemicals and heavy metals, nutrient pollution (or eutrophication), and pathogens such as bacteria or viruses.

"Another, less widely discussed human-caused disturbance is the introduction of non-native or invasive species into estuarine environments."

Background Information (continued)

Monitoring estuaries

Excerpt from from NOAA's Monitoring Estuaries (https://oceanservice.noaa.gov/education/tutorial_estuaries/est10_monitor.html)

> "The National Estuarine Research Reserve System (NERRS) is a partnership program between NOAA and U.S. coastal states that protects more than one million acres of estuarine land and water. The health of every reserve is continuously monitored by the NERRS System-wide Monitoring Program or SWMP (pronounced "swamp"). SWMP measures changes in estuarine waters to record how human activities and natural events, including weather, affect coastal habitats."

Part 2 Extensions

1. Use the NOAA Why are Estuaries Important? Ecosystem Services website (https://oceanservice.noaa.gov/education/tutorial_estuaries/est03_ecosystem.html) as a resource for understanding the role of estuaries. Assign students to read the page, and then discuss the following prompts with a partnerWhat happened to the sediment when there wasn't an estuary present?
    - What ecosystem services are estuaries providing?
    - How are estuaries like a sponge?
    - Where do the pollutants that estuaries filter come from?
    - What role do estuaries play in a flood?
2. In a whole class discussion, ensure that students understand what is meant by "ecosystem services" and can explain the two ecosystem services described in the reading: water filtration and habitat protection. Brainstorm if there are other "services" estuaries provide.
3. Have students view the next segment of the Restoring America's Deltas video (https://www.youtube.com/watch?v=wWRGvGv-1vps) about diversity in marshes (time signature 4:46-10:22).
    - Discuss connections between the video and the estuary modeling activity they completed in class.
    - Ask students to share any questions that they now have after watching the video. Post questions on a Driving Question Board for the class.

Part 3: A Vulnerable Environment

Materials

- Project Resilience Slide Deck (slides 19-28)
- Projector & Computer
- Student computers/tablets with Google Earth Pro installed. Note: Chromebooks will need to run the online version of Google Earth instead of downloading Google Earth Pro
- Paint tray or large baking/roasting pan with a hole at one end for water drainage (one per group)
- Large water container with a spigot (one per group)
- Access to a sink or water source
- Bucket or tub to collect water drainage
- Books, box, or extra tubs to prop up the water containers
- Graduated cylinders (100mL or larger) or liquid cup measurers
- Spray bottles
- Modeling clay (about 5 lbs of clay for every three groups, for Parts 2-3)
- Soil (optional, could use sand from Part 1
- Clay tools, pencil, chopstick, or paintbrush to create features in the clay
- Scissors
- Timer

Preparation

- Prepare the classroom for the stream table/modeling activity.
- Download the free Google Earth Pro to classroom computers. Orient yourself with the software so you can help students navigate during the lesson.

Note: Students will use the same models (with clay) from Part 2 during Part 3.

Directions

Exploring Estuaries using Google Earth Pro (20 min)

Note: To save time, install Google Earth Pro on computers in advance.

1. Transition from the day before. Now that we are aware of how the delta and wetlands form, let's take a look at our local area and identify some of the unique estuary features near us.
2. Assign students to work on computers, using Google Earth Pro to view the Barataria-Terrebonne estuary and explore estuary features near them.
    - Orient students to Google Earth Pro, using the tips in the box below.
    - Once students are familiar with Google Earth Pro, begin exploring estuaries.

Exploring Estuaries Using Google Earth Pro

Facilitation Tips:

View the NOAA Estuary Education Google Earth Tutorial.

Note: Google Earth Pro is not compatible with Chromebooks. For Chromebook, use the online Google Earth version instead.

1. Download Google Earth Pro and launch the program.
2. Type the location you are interested in into the search field in the upper left hand of the screen. To practice navigating, have your students find their school with Google Earth Pro.
3. Hover over the navigation tools along the right side of the screen and then practice selecting them to zoom in/out, to rotate your view (drag the "N" around the circle), or to move locations on the map. You can also double click on the map to zoom in, and click and drag your cursor on the map to move locations.
4. There are many options for layers, displayed in the box at the bottom left. Many layers will already be enabled so students can explore which they would like to view. Roads and Terrain are good ones to add in, and under "Ocean" you can select to show Dead Zones, which will be a nice prelude to upcoming lessons (they will display as fish skeletons in locations where hypoxic zones have been reported).

Exploring Estuaries using Google Earth Pro (continued)

3. Once students are comfortable navigating with Google Earth Pro, introduce the following estuary landforms and features using the Estuary Landforms and Features- a Google Earth Scavenger Hunt (slides 20-24). Use Google Earth Pro to find these features in your local area:
    - Inlets, bays, and sounds
        - Find places where freshwater mixes with saltwater to create brackish water.
        - Ask students to think about where the water would be more or less salty, and how this might influence the plants and animals that live there.
        - A good example is the Mississippi River Gulf Outlet and the surrounding areas (Fort Proctor, from Lesson 1, can be seen from there too!).
    - Salt marsh or tidal flats
        - Salt marshes have a high influx of nutrients from rivers and streams and often circulation of water through tidal flows
        - Search for "Marsh Island" as an example.
        - These areas might be difficult to pinpoint. Please suggest a known marsh area that students should navigate to and examine.
    - Mangroves
        - Mangroves forests consist of salt tolerant trees that can handle fluctuating water levels.
        - Mangroves are found in St. Bernard Parish (though they aren't distinguishable from marshland in Google Earth).
    - Barrier Islands
        - Barrier islands are bars of sand that are parallel to the mainland.
        - Locate examples of barrier Islands, such as Whiskey Island.
    - Additional features to explore with Google Earth Pro (as time permits):
        - To make a connection to deltaic formation (Part 1), type "Mississippi River delta" into the search field and zoom out to see the birdfoot delta features more clearly.
4. Take a closer look at human-made channels and canals, which stand out from natural features due to their straight/uniform shapes.
    - Search for "Houma Navigational Canal" and zoom in to view.
    - Ask students to think about how these channels & canals are impacting the wetlands.
    - Use this as a transition to the next activity, modeling hydrologic modification.

Hydrologic Modification (5 minutes)

1. Show the schematic of the lower Mississippi River (slide 25), which shows the location of levees along the Mississippi River. Point out the river (blue line) and the levees (red lines).
2. Read aloud the quote about artificial levees:

    "Because of flood protection measures demanded by the public and then instituted by Congress following the Great Flood of 1927, in conjunction with those of private landowners and the State of Louisiana prior to the flood, artificial levees now line much of the Mississippi River."-BTNEP
3. Ask students to share their experiences with levees: *How have levees impacted your community (positively/negatively)?*
4. Show the image of Lake Pontchartrain from March 2018 (slide 26). Ask students to share observations of the image:
    - *What do you see? What do you notice?*
5. Explain that the spillway was opened to prevent flooding of New Orleans, diverting fresh water and sediment into the brackish waters of the lake. The spillway has been opened several times since its construction in 1931, including from Feb-July, 2019, when the spillway was opened for the most consecutive days in its history.
6. Tell students that these are examples of hydrologic modification, which refers to changing the natural flow of a river. These changes protect communities, but that there are unintended consequences as well.
    - Ask students to consider: *What could be the impacts of all that water entering Lake Pontchartrain?*
    - Sediment that should be helping to create land at the delta is going into the lake instead.
    - Nutrients entering the lake are causing an overgrowth of algae, which can be toxic and also leads to **hypoxia** (waters depleted of oxygen, such that aquatic life cannot be supported).

Modeling land loss due to hydrologic modification (20 minutes)

1. Transition to levee modeling activity. Students should return to their model and group from the previous day. If the clay has started to dry and pull away from the sides of the tray, add more clay to seal it. For this modeling activity, remove the wetlands from the model (carpeting/sponge). *Note: students may enjoy recording a time-lapse video of their stream table experiment, or taking photos.*

Modeling land loss due to hydrologic modification (continued)

2. Pose the question (slide 27): How does hydrologic modification of the river influence the natural cycle of wetland formation in the delta?
3. Tell students that their task is to build a model that shows:
    - Why flooding is important to the delta. (Where does the sediment end up?)
    - What changes occur due to the presence of levees. (What is different? Compare the amount of sediment carried by the river before and after the levees are built.)
4. Have students add soil/sand to their model as they did before, sprinkling it over the land. This time it is ok if the soil gets into the river channel.
5. Create a flood, by spraying lots of water from the spray bottles or pouring water over the land at the top of their model. Students should notice that the soil is carried down the river and spreads out across the land.
    - Where does the sediment end up? What happens when river sediment is spread over the land?
    - Reference the video about delta formation from Lesson 2: Part 1 to remind students how seasonal flooding is important in the formation of land at the delta.
6. Next, have students use clay to create levees along the entire river. Create rainfall and/or flooding and observe what happens this time.
    - *Are there any differences? Where does the sediment end up this time? Compare the amount of sediment carried by the river before and after the levees are built.*
    - Remind students of what changes they saw when the velocity of the water changed in Lesson 2: Part 1. Point out that the levees cause the water to move faster because the channel is narrower, and the water can't spread out.
7. Hold a short discussion to debrief the modeling activity's key Ideas:
    - Flooding and spreading of sediment across the floodplain are unable to happen due to levees.
    - Less sediment enters the river due to levees.
    - Sediment that does enter the river doesn't end up where it is supposed to (sediment diversion).
    - Limitations of the model

Wrap Up (5 min)

- **Exit Ticket:** Show the image of sediment wasted (slide 28) and have students write down their answer to the following question as an exit ticket assessment to wrap up the day: How are changes to the Mississippi River causing land loss in coastal Louisiana?

Assign Journal Prompt #4

- **Prompt #4:** Hydrologic modification is an issue that can be represented as a tug of war. Draw a line across your paper to represent a rope for our 'hydro' tug of war scenario. Give a name to each end of the rope that reflects two opposing viewpoints that might be taken in this issue, such as "Hydrologic modification is good because…" on one end, and "Hydrologic modification is bad because…" on the other end. On one side, what are the "tugs" or reasons that support it? You might not personally agree with the tugs, but you can still identify them. On the other side, what are the "tugs" that support it? Write the "tugs" along the rope and consider how the reasons compare with one another. Stronger reasons should be closer to the ends, while reasons that may not be clearly on one side or the other can be closer to the middle.

Background Information

Hydrologic Modification

Excerpt below from BTNEP: Hydrologic Modification (btnep.org/estuary-issues/hydrologic-modification/)

"Because of flood protection measures demanded by the public and then instituted by Congress following the Great Flood of 1927, in conjunction with those of private landowners and the State of Louisiana prior to the flood, artificial levees now line much of the Mississippi River."

"The levees coincidentally prevent sediment and water from being dispersed into the surrounding wetlands through periodic flooding and levee breaks. Concrete mattresses placed along the channel bank have prevented the natural tendency of the river to change course. In fact, the length of the river has been shortened by approximately 150 miles by cutoffs in the central portion of the lower Mississippi River. Both the shortening of the river and the placement of concrete mats on the banks have reduced the river area exposed to erosion. In the past, soil from the river's edge was the primary source of sediment that fed the marshes."

Background Information (continued)

"Canals for navigation and oil and gas exploration and production are another type of hydrologic modification. When canals are constructed, the excavated material is placed alongside the canal, creating spoil banks. The impact of this type of activity can be threefold. First, the canal itself creates paths of ingress for waters of higher salinity, forcing animals to either adapt or relocate. Native plants have little choice but to adapt to their new environment or die. Second, erosion can occur along the canal banks with the passing of each vessel, converting more land to open water. Third, the dredged material alters the natural flow of water across the estuary landscape, sometimes creating lakes and, in other cases, depriving large areas of water, nutrients, and sediments."

"Impacts of canals are not, however, all necessarily negative. Canal banks do provide some diversity of habitat, especially in coastal areas. Canals provide significant recreational opportunities and aquatic production potential as well."

Opening the Bonnet Carre Spillway in March 2018 caused algae blooms in Lake Pontchartrain
Excerpt below from NASA Earth Observatory Coloring Lake Pontchartrain (earthobservatory.nasa.gov/images/91977/coloring-lake-pontchartrain)

"Blooms of phytoplankton appeared in Lake Pontchartrain several times in March 2018. The Operational Land Imager (OLI) on Landsat 8 acquired this image of a colorful bloom on March 3, 2018."

"Lake Pontchartrain and other nearby lakes and inlets compose a huge estuary east of the Mississippi Delta; collectively, they drain an area spanning 12,000 square kilometers (4,600 square miles). Unusually warm temperatures in February and March helped spur the early spring bloom shown above, even before nutrients from the Upper Mississippi could pour into the region."

"Blooms become more likely when excess river nutrients reach the lake through the Bonnet Carré Spillway. During flood season, the spillway is occasionally opened to divert excess water from the Mississippi River and relieve pressure on levees near New Orleans."

"On March 8, the U.S. Army Corps of Engineers started to open the spillway in response to flooding along the Ohio and Mississippi Rivers. The pulse of sediment-laden water is visible on March 14. Such inputs of nutrients—often fertilizer from the Mississippi watershed—can set the stage for large blooms of algae and cyanobacteria—single-celled organisms that can contaminate drinking water and pose a risk to human and animal health. Satellite imagery can help identify the occurrence of a phytoplankton bloom, but direct sampling is required to discern the species."

"The extra nutrients from the Mississippi helped trigger another bloom around March 25. However, cloud cover impeded satellite views on most days."

"By early April 2018, the blooms appeared less vibrant. John Lopez of the Lake Pontchartrain Basin Foundation reported that wind on the lake helped to break up the second bloom and suppress its growth. But nutrients from the river can persist in the lake for months, making it possible for more blooms to develop later this year."

Mississippi River Delta basin formation and land loss
Excerpt below from The Mississippi River Delta Basin (lacoast.gov/new/About/Basin_data/mr/)

"Between 1974 and 1990, the land loss rate in the Mississippi River Delta Basin averaged 1,072 acres per year, or 1.69 percent of existing land area (Dunbar, Britsch, and Kemp 1992). Between the mid-1950s and 1974, the estimated land loss rate for the basin was 2,890 acres per year. This loss is the result of compaction, subsidence, hurricanes, tidal erosion, sea level rise, and human activities. The loss has been aggravated by the maintenance of navigation channels and the construction of canals for mineral exploration. The total land area lost in this basin over the last 60 years has been approximately 113,300 acres."

Part 4: Sinking Land in the Bayou

Materials

- Project Resilience Slide Deck (slides 29-34)
- Projector & Computer
- Brown Shrimp CER- Student Sheet (PDF)
- Large graduated cylinder or clear tennis ball container
- Two colors of sediment (sand and dirt, for example)
- A meter stick

Preparation

- Print copies of the Brown Shrimp CER- Student Sheet for each student.
- View the video of the sedimentation and subsidence demo to help you prepare to lead this with students. Test out the demo before trying it with students.
- If you are using a clear tennis ball container for the demo, use a permanent marker to label centimeters on the side. If you are using a graduated cylinder, estimate what volume is about a centimeter.

Directions

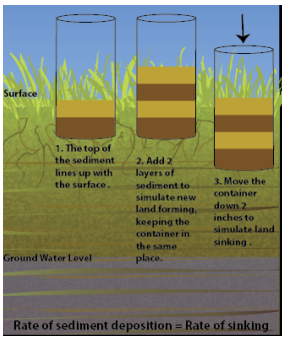
Analyze maps of land loss (10 minutes)

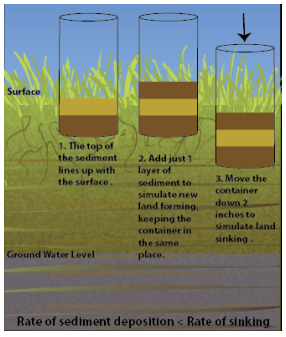
1. Project the 2011 map of the Louisiana coast (slide 30).
2. Orient students to the map.
    - To help students understand where they are in relation to the 2011 map, project a map of this area using Google Maps.
    - Terrebonne Bay is on the left side of the 2011 map. The towns Montegut and Bourg are in the upper left. The larger town in the upper right is Galliano.
    - Orient students to the map's colors: Ask what they think blue represents (water), darker gray (low land or marsh), and lighter gray (higher land). Point out that there are also small amounts of green (and the key at the bottom indicates that this is new land).
3. Next, show the 1932 map of the Louisiana coast (slide 31).
    - Tell students that this map is of the same area as the previous map.
    - Ask students to share what they notice about this 1932 map as compared to the 2011 map.
4. Finally, show both maps side by side (slide 32). Hold a class discussion, comparing the two maps and focus on how the coast changed between 1932 and 2011. Use the following prompts during your discussion:
    - What is different about the region in 2011 compared to 1932?
        - There are more channels through the wetlands, some of the lakes are now open to the ocean, and there is less low-lying land, which is mostly wetland.
    - What is the same about the region in both maps?
        - The natural bayous are still in the same places, the town of Galliano is in the same place, the barrier islands are still there, etc.
    - What type of environment appears to be the most vulnerable?
        - The most low-lying land, such as wetlands.

Other reasons for land loss: Subsidence demonstration (15 minutes)

1. Remind students of our explorations about sediment wasting from the previous day, which is one cause of land loss. Introduce the idea that there is more than one reason for land loss.
2. Show the 4 minute Sinking Mississippi Delta video to introduce subsidence (slide 33).
    - Have students record observations/interesting ideas and questions in 2 column notes as they watch the video: "What do I notice" in one column, and "What do I wonder?" in the other.
3. After watching the video, ensure that there is a common understanding of subsidence (the sinking of land as sediment deposited from the river compacts and sinks down-- this is a natural process!).
4. Delta sediment demonstration:
    a. Draw a cross-section of a wetland on the board with Spartina grasses at the top, sediment and organics in the middle, and a waterline below, but near, the top of the sediment.
    b. Tell students that this demonstration will simulate how sediment deposition and subsidence happen at the same time in coastal Louisiana. Gather three student helpers.
        - One will hold the container, one will hold the meter stick, one will pour the sand and soil (or you may want to do this yourself).

Other reasons for land loss: Subsidence demonstration (continued)





c. Hold the container so that the bottom of the container lines up with the top of the wetland sediment layer. Hold the meter stick alongside the container.
d. Tell students that we will first observe what happens when the rate of sediment deposited and the rate of sinking are the same. Demonstrate sediment layers deposited in a container that's sinking slowly. (see the diagram at the right)
   - For the first year: add two centimeters of sediment to the container (deposition) and then lower the container by two centimeters (subsidence).
   - Repeat with the other color of sediment for the next year (adding 2 cm of soil to the container, lowering the container 2 cm).
   - Alternate the colors of sediment to simulate several years.
   - Have students note that the level of the top of the wetlands stays the same.
e. Ask students to predict what will happen if the amount of sediment deposited each year decreases (the land gets lower).
f. Test it out: decrease the amount of sediment added for each year, but continue lowering the container by 2 cm. (see the diagram at the right)
   - Add one cm of sediment (deposition) to the container and lower it by two cm (subsidence).
   - Repeat with the other color of sediment for the next year.
   - Alternate the colors of sediment to simulate several years.
   - Have students note that the top of the sediment is getting lower over time.
g. Figure out how many years it would take to be underwater, given the location of the waterline on the board.
h. Ask students to predict what would happen if more sediment was deposited. Students should understand that the land would build higher if the amount of sediment deposited is more than the amount the land is sinking (if time allows, simulate this with students).

5. Remind students about their delta/estuary models and the impact of artificial levees on the sediment supply and velocity (from Lesson 2: Part 3) to help them understand why there would be less sediment in the Mississippi delta now than in the past.
   - *Note: there are other factors that contribute to wetlands loss. On a local scale, cutting channels through the wetlands for boats or oil and gas infrastructure causes erosion of the sediments. On a large scale, global sea level rise contributes to wetlands loss, which is covered during the next lesson.*

The impact of lost wetlands on brown shrimp (15 minutes)

Note: This activity could be started in class and completed as homework.

1. Ask students: How do you think wildlife is affected by wetlands loss? Discuss.
2. Present students with the following claim (slide 34): *Fewer wetlands in Louisiana means less brown shrimp.*
3. Pass out copies of the Brown Shrimp CER- Student Sheet. Instruct students to use the information on the student sheet, as well as from their own experiences, as evidence to support the claim. They should also explain their reasoning.
   - *Note: Students may also wish to explain other factors besides wetlands loss that are making shrimp populations vulnerable, such as pollution.*
4. Share out some examples of evidence and reasoning once students have had some time to fill out the activity sheet.
   - Students should notice that brown shrimp depend on estuaries and marsh wetlands for part of their life cycle.
   - Students should notice that Louisiana is experiencing extensive wetlands loss as compared to the other Gulf coastal states (Note: this is because Louisiana is at the center of the Mississippi River drainage basin).
   - Students should notice that Louisiana is a major source of brown shrimp in the Gulf.
   - By piecing this evidence together, students should make connections between the loss of Louisiana wetlands and the risk to brown shrimp populations.
   - Though it is not addressed in this activity, students may also note the potential impact on shrimp fisheries, which are an important part of Louisiana's economy and culture. This will be covered more extensively in Lesson 3: Part 3.

Transition

- Transition to the next lesson: Tell the students that there is another part of the story. The next lesson will explore how sea level rise caused by climate change is also causing land and marsh to become submerged.

Revisit Driving Question Board (continued)

- Have students revisit the class Driving Question Board (DQB) that they created in Lesson 1. You might consider doing this in small groups and then share out as a whole class. Ask the following questions:
  - *Are there any questions that we can now answer?*
  - *Do we want to re-arrange any of the questions? Are there any connections between topics that we should show on the DQB?*
  - *Would anyone like to add any additional questions?*

Assign Journal Prompt #5

- **Prompt #5:** In today's lesson about land loss, you were asked to consider a claim about how brown shrimp and other wildlife might be affected. Write a headline, similar to what you would see in a newspaper, that describes how you feel or what you think about this. A headline should be brief but also contain carefully selected words that serve to summarize the main idea. Explain your headline.

Background Information

About Subsidence

Subsidence is sinking land. Land can sink for many reasons - both natural and human-caused. It can sink slowly over thousands of years. Or it can sink more quickly over tens of years.

Several types of natural processes cause slow subsidence over a long time. Land can sink when there is a large weight on it. For example, Antarctica has been pushed downward by the weight of all the ice that is above it. Subsidence can also happen naturally due to plate tectonics where land is stretched apart, forming faults, and when rocks deep underground cool, become more dense, and sink. Subsidence can also happen near the ground surface as sediment compacts or dissolves in the case of limestone.

Subsidence can also be caused by humans, particularly when we remove materials that were once underground. Where groundwater or oil and gas is extracted from below the surface, the land surface can sink. Mining can also cause the land surface to sink.

In coastal Louisiana, subsidence is occurring for several reasons that are both natural and human-caused.

- Sediment compaction
- Oil and gas extraction
- Groundwater extraction
- Plate tectonics (probably - this is an area of active research)

The opposite of subsidence, uplift, happens when land rises higher over time, which can happen because of plate tectonics movements, such as where cliffs meet the sea on the west coast of North America. It can also happen when land that had been under large amounts of glacial ice bounces back once the ice melts and the weight is removed. This is happening to land in Northern Canada that used to be under an ice sheet during the last Ice Age, about 20,000 years ago.

Learn more:

- NOAA: What is subsidence (https://oceanservice.noaa.gov/facts/subsidence.html)

Part 2 Extensions

Use the list of **Endangered Animals and Plants of Louisiana**, which is Section 1-Activity 4-page 8 of the Educator's Guide to the Barataria-Terrebonne Estuary, to see the number of species that depend on the wetlands.

- Have students make a claim about the impact on a specific species if their wetland habitat deteriorates.
- Have students research a species from the list to find evidence to support their claim.

Project Resilience Teacher Guide

Lesson 3 > Case Studies of Coastal Change

Students investigate three case studies of environmental change, including how the combined effects of sea level rise and sinking land are projected to impact the Louisiana coast this century, how hurricanes affect the coast, and how fisheries are impacted due to environmental change. Lesson 3 is divided into three parts, each intended for about a day of instruction time.

Lesson 3: Part 1: Sea Level Rise - Students will use an online interactive tool to discover how global sea level rise is affecting locations in Terrebonne Parish, LA, depending on elevation.
Lesson 3: Part 2: A Tale of Two Hurricanes - Students will explore hurricane data to learn that different hurricanes cause different types of damage in coastal communities where they make landfall.
Lesson 3: Part 3: Changing Ecosystems - Students will discover that the life cycle of the brown shrimp depends on multiple environments, each with unique water characteristics. They will use data to make connections between changing wetlands ecosystems and declining Brown Shrimp populations.

Time Required

- Teacher Preparation Time: approximately 50 min
- Part 1: 50 minutes
- Part 2: 50 minutes
- Part 3: 50 minutes

Learning Goals

- Students will discover how global sea level rise is affecting locations in Terrebonne Parish, LA, depending on elevation. *(Part 1)*
- Students will explore hurricane data to learn that different hurricanes cause different types of damage in coastal communities where they make landfall. *(Part 2)*
- Students will discover that the life cycle of the brown shrimp depends on multiple environments, each with unique water characteristics. *(Part 3)*
- Students will use data to make connections between changing wetlands ecosystems and declining brown shrimp populations. *(Part 3)*

Lesson Format

- Use of computer visualization and video *(Part 1)*
- Analysis of data, maps, and images *(Part 2, 3)*
- Class discussions *(Part 1, 2, 3)*

Science Standards

Louisiana Student Standards for Science:

- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, the occurrence of natural hazards, and changes in climate have influenced human activity. *(Part 1, 2, 3)*
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impact of human activities with natural systems.
- *(Part 1, 3)*

Additional Dimensions:

- Science and Engineering Practices: Analyzing and Interpreting Data *(Part 1, 2, 3)*
- Engineering connection: Influence of Science, Engineering, and Technology on Society and the Natural World *(Part 1, 2)*

Part 1: Sea Level Rise

Materials

- Project Resilience Slide Deck (slides 36-39)
- Projector & Computer
- Computers with Internet access & video streaming capability
- Sea Level Rise Student Sheet (PDF)
- NOAA Digital Coast Sea Level Rise Viewer (https://coast.noaa.gov/slr/)

Preparation

- Preview the video and the NOAA Digital Coast Sea Level Rise Viewer.
- Print copies of the Sea Level Rise Student Sheet for each pair of students.

Directions

Navigate from the previous activity:

- Remind students what they learned about subsidence and sediment deposition in the previous lesson. Explain that while the land in the Bayou is sinking lower, there is another cause of land loss: the level of the ocean is rising higher. This combination leads to even more land loss in our region.

Explain how climate warming causes sea level rise. (20 min)

1. Watch from minute 7:43 to 18:36 of the Sea Level Rise video from the NOAA National Ocean Service (slide 37). There are pauses for discussion embedded within the video. If you would like students to discuss, pause the video whenever you see "Pause for Discussion" on the screen. Or, you may wish to provide students with the following guiding questions to consider as they watch the video.
    - How much of the sea level has risen in the past century? *(Over the past century, there has been an average rise of 1.5 mm/yr, but the rate of the rising is increasing. It was 1.1 mm/yr early in the century and 2.79 mm/yr rise recently.)*
    - How do we know? (measurements from tide gauges and satellites)
    - What are the two reasons for the increase in global sea level? *(melting of glaciers and other ice on land, and thermal expansion of seawater)*
    - How do increases in air temperature *(global warming) cause sea level to rise? (the ocean is absorbing most of the extra heat, expanding water, and is causing ice on land to melt and add water to the ocean)*
    - Why is the air temperature warming? *(because there is extra CO2 in the atmosphere from fossil fuel emissions)*
2. Ask students what the two reasons for sea level rise are that they learned about in the video: (1) seawater expands with heat, and (2) water is added to the ocean as land-ice melts.
3. Ask students why these two processes are happening now. *(Because of climate warming.)*
4. Show students that thermal expansion impacts the total volume of water in the ocean and also has a regional impact. Show students the NASA images of sea level (slide 38) as measured by satellites and point out the location of the Gulf of Mexico.
    - Areas where water is warm, experience higher sea level than areas with cold water. The water is warmed in the Gulf, causing a slightly higher sea level than areas with cooler water.

Investigate maps that show the impacts of sea level rise. (20 min)

1. Tell students that over this century, sea level will rise an average of 1.7-4.0 feet (0.5-1.2 m) worldwide. There are also a variety of unknowns, such as whether large parts of ice sheets will slip into the ocean and how ocean currents will change due to warmer temperatures. In the Gulf, that number will be higher due to the combined effect of less sediment coming in, subsidence, and sea level rise caused by climate warming.
2. In this activity, students will explore what the impact of higher seas and lower land will be in Terrebonne Parish.
3. Break students into pairs and pass out copies of the Sea Level Rise Viewer Student Sheet to each pair of students.
4. Assign each pair of students to a computer and have them open the Sea Level Rise Viewer. Tell students that the Sea Level Rise Viewer is a model. Models are used in Earth and environmental science to simulate real conditions so that we can predict how environments will be affected when there is a change
5. Guide students as they use the Sea Level Rise Viewer Student Sheet to answer questions and explore using the Sea Level Rise Viewer. (https://coast.noaa.gov/slr/)
    - Students will first become familiar with the NOAA Digital Coast Sea Level Rise Viewer.
        - On the left side is a water level indicator. The blue circle indicates the water level compared to today. (MHHW means "Mean Higher High Water," which is the average height of the highest tide recorded each day during the recording period).

  - Listed to the left of the water level indicator are the special map features.
  - At the top is a field where you can enter an address or town/city. Only coastal locations within the continental United States are included.
  - In the top right are options for the map and a key to the colors. Zoom in and out with the buttons in the lower right.
- Students will enter "Terrebonne Parish, LA" into the search and then zoom into the map a bit.
- Students should change the units on the water level indicator to metric (the switch is at the bottom of the indicator).
- Give students the information that the water level in coastal Louisiana is rising at an average rate of 12.8 mm/yr.
- Students will calculate how much sea level rise they'd expect by 2060 and 2100. Remind students that they will need to convert the units to meters by dividing by 1000.
  - For 2060, students should find a little over half a meter of sea level rise (if they do the assignment in 2019).
  - For 2100, students should discover about one meter of sea level rise.
  - Use a meter stick to help students visualize the water depths predicted for 2060 and 2100.
- Students will move the water level indicator in the Sea Level Rise Viewer to visualize what areas of Terrebonne Parish are most vulnerable to sea level rise. Encourage students to use the zoom tool to find places familiar to them and see if they are vulnerable to sea level rise.

Discussion: Sensemaking (10 min)

1. Ask students to share what they discovered about the most vulnerable places and those that are safer from flooding. Share some examples and how much the water is expected to rise in those areas. Again, use a meter stick to help students visualize the water depths predicted by the Sea Level Rise Viewer.
2. Discuss the Sea Level Rise Viewer as a model. How does it accurately simulate real conditions? How is it simplified? Students may mention the following:
   - The model includes information about the elevation of the land surface, which is what allows it to identify what areas might flood in the future.
   - The model does not include predictions of areas where sediments may accumulate in the future, or how floodgates and human-built levees could change the outcome.
3. Ask students to share their ideas about why the amount of sea level rise is still uncertain.
   - Share that this is because there are some unknowns. For example, we don't know when and how the Antarctic and Greenland ice sheets will break apart and end up in the ocean. Because the climate is warming, ice is melting. That's certain. But, how quickly the ice sheets, which flow like molasses, move towards the ocean is difficult to predict and is one reason why there is a large range in sea level estimates.
4. Show students the A Changing Landscape image (slide 39), which shows projected land loss in Louisiana over the next 50 years if no action is taken. Explain that Louisiana has created a Master Plan to address land loss and other environmental challenges.
   - Alternatively, project the Master Plan Data Viewer, http://cims.coastal.louisiana.gov/masterplan/, (optional) for the class and navigate the data viewer to compare predicted land change under different environmental scenarios, with and without planned projects to slow land loss.

Assign Journal Prompt #6

- **Prompt #6**: Reflect on today's lesson about sinking land and sea level rise. How do you think you and your family will respond to the changes brought about as a result of sea level rise? Do you think your life will be affected a lot, a little, or not at all? What feelings come up for you when you think about the future with respect to sea level rise?

Background Information

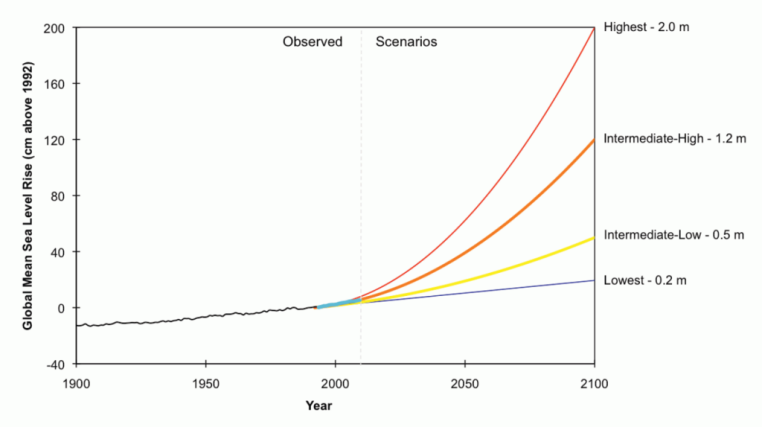
Sea Level Rise

Since 1900, sea level has risen between 1 and 2 millimeters per year (10-20 cm per century) on average, which is ten times faster than sea level rise over the previous 3,000 years. Looking into the future, models project the rate of sea level rise will increase, although the amount it will rise largely depends on the amount of warming.

Scientists use averages from a large number of tide gauges worldwide to estimate the global average sea level. Since 1992, global sea level has also been observed using satellite data too, with more accurate results than tide gauges (according to the Intergovernmental Panel on Climate Change AR4 report, archive.ipcc.ch/publications_and_data/ar4/wg1/en/faq-5-1.html). Satellite measurements show a rate of sea level rise of 3 mm per year, far more than the tide gauges. Some scientists suspect that the satellite is incorrectly calibrated. Others suspect that the difference may be because the satellite measurements cover much of the globe while tide gauges are near coastlines.

Background Information (continued)

The graph to the right shows the global mean sea level rise estimates due to melting ice and thermal expansion for four scenarios (according to Parris et al., 2012). Notice that there is a wide range in the scenarios, in part because there are unknowns about how much we will decrease greenhouse gas emissions in the future, and in part because of the possibility of the Antarctic and Greenland ice sliding into the ocean. Notice also that the rate of sea level rise is likely to be non-linear, with an increasing rate of sea level rise over time. In this lesson, students look at sea level projections for two timeframes (2060 and 2100) to focus on the most vulnerable areas of the coast. You may wish to extend student learning on this topic by having students analyze and interpret the graph above.



How climate change causes sea level rise
There are two ways that a hotter climate leads to sea level rise: (1) as temperatures warm, ice that is on land melts and the water is added to the ocean, and (2) as the water in the ocean warms, it expands. Both are described below in more detail.

Melting Ice
There are between 24 and 30 million cubic km of ice on land. About 90% of this ice is in Antarctica. Most of the remaining ice is in Greenland, and a tiny fraction is locked up in mountain glaciers elsewhere. As global temperatures rise, some of this ice is melting, and the meltwater flows into the ocean, gradually raising sea level. Melting has outpaced snowfall, and the most substantial loss of ice has been on mountain glaciers in the mid-latitudes and tropics and on the Greenland ice sheet.

Additionally, warmer temperatures can cause ice in glaciers and ice sheets to flow faster towards the oceans. In Antarctica, ice is now flowing towards the ocean at a faster rate than in the past. Complete melting of glaciers and ice sheets would raise sea levels worldwide, almost 70 meters (230 feet) above current levels. Of this rise, 7.2 meters would be from the Greenland ice sheet, and 61.1 meters would be from the Antarctic ice sheet. Melting glaciers would add another half of a meter.

For some perspective on all this melting ice, consider this: sea level has risen about 120 meters since the last glacial maximum (approximately 20,000 years ago) when ice covered large parts of the Northern Hemisphere and wooly mammoths roamed the Earth.

Note that melting sea ice, which is ice formed from sea water, does not affect the sea level since the ice is already in the water.

Thermal Expansion of Seawater
Water expands as it gets warmer, and it is warmed as the climate warms. The amount the water warms is very small, but since there is so much water in the ocean, it expands a lot. Scientists estimate that nearly half of sea level rise is due to thermal expansion of sea water.

For example, suppose 1 liter of water, initially at 20° C, was heated to 21° C. It would expand by 0.021% (see the table of volume and temperature). It would increase in volume by 0.21 milliliters. This tiny increase seems trivial, but the ocean contains about 1,400,000,000 cubic kilometers of water. Even a tiny fractional increase adds up to a very large increase in volume, and hence substantial sea level rise.

The different layers of the ocean (surface layers and deep ocean) are not heated equally. Also, the volumes of the various layers are not the same, nor are their initial temperatures, which affects the rate at which they expand.

- The surface layer of the ocean contains roughly 50,000,000 km3 of water and has temperatures ranging from freezing near the poles to around 30° C in the tropics.
- The mid-ocean, where the thermocline produces the transition from a warm surface to cold deep water, holds about 460,000,000 km3 of water and spans a wide range of temperatures.
- The deep ocean holds the most water, some 890,000,000 km3, but because of its relatively cool temperatures of 4° C or less, it is also less prone to expansion as its temperature rises slightly.

Learn more about the NOAA Digital Coast Sea Level Rise Viewer (https://coast.noaa.gov/digitalcoast/tools/slr.html).

Part 1 Extensions:

- Explore the LA-SAFE plan, with and without projects more closely. Ask students to choose one aspect to compare under the different scenarios (medium, low, high) and give a 2-minute presentation about it to their classmates.
- Have each student choose one adult with which to have a conversation about the LA- SAFE Master Plan.
    - Tell students to ask the following questions to their adult:
        - How do they feel about the plan-- do they think it is adequate to provide resilience to your community.
        - Do they see any drawbacks or unintended consequences?
        - If they are unaware of the Master Plan, tell them about it and then ask them to share their first impressions of the plan.
        - Have students write about their conversation. Tell them to describe how they felt about the person's perspective with regards to the Master Plan.

Part 2: A Tale of Two Hurricanes

Materials

- Project Resilience Slide Deck (slides 40-43)
- Projector & Computer
- A Tale of Two Hurricanes: CER Student Sheet (PDF)
- Lesson 3: Hurricane Data (PDF)

Preparation

- Familiarize yourself with Hurricane Michael and Hurricane Florence, and Lesson 3: Hurricane Data.
- Print or make electronic copies of the Hurricane Data available for student use. **Note: Students will need to view the Lesson 3: Hurricane Data in color to be able to accurately interpret the maps and images. If you are unable to print color copies, consider having students use digital versions or projecting the data. Depending on class size, you may wish to print one copy of the Hurricane Data set to spread out at stations around the classroom that students visit during the data exploration activity.*
- Print copies of the A Tale of Two Hurricanes: CER Student Sheet.

Directions

What types of hazards can a hurricane cause? (15 min)

1. Open class by connecting with a local example of a hurricane.
    - Remind students of a hurricane or tropical storm that affected your location and what sorts of damage occurred.
    - Split students into pairs and have them take turns sharing a story about a hurricane they have experienced.
    - Call out any common themes that emerge from these discussions.
2. Have students navigate to and read through the overview of Hurricane Hazards from NOAA (nhc.noaa.gov/prepare/hazards.php) on the National Hurricane Preparedness website.
    - Ask them to focus on the types of hazards that a hurricane can cause. They might choose to make a list of these hazards.
    - The following hazards are discussed in the article. Note that the first three listed are the most common hurricane hazards, which will be the focus of this lesson.
        - Storm surge
        - Rain and inland flooding
        - Winds
        - Tornadoes
        - Rip currents
3. Tell students that not all hurricanes are the same - some cause one type of hazard, some cause many different types of hazards. The hazards are related to a hurricane's characteristics (slide 41), such as:
    - Winds: Some have high winds, and others have lower winds. Wind speed defines the Saffir-Simpson Category of a hurricane.
    - Size: Some are geographically large, and others are smaller. Size controls the area impacted by strong winds. Size (in combination with how fast the storm is moving inland) also controls how long the damaging winds blow for and how long it rains.
    - Speed: Some hurricanes travel fast, and others move slowly.

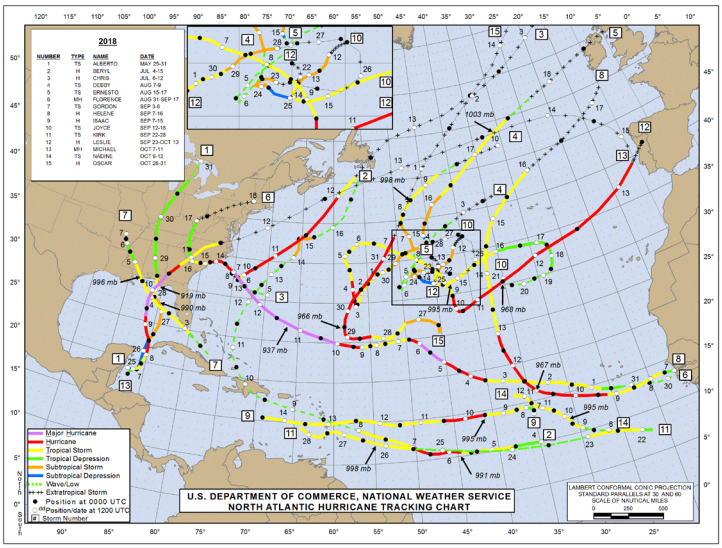
Introduce data exploration. (10 min)

1. Tell students that they are going to compare the impact of two hurricanes that hit the U.S. coast in 2018: Hurricane Florence and Hurricane Michael.
2. Show students the 2018 hurricane tracking chart (slide 42). A small version is on the next page, and a larger pdf version is online (scied.ucar.edu/sites/default/files/images/activity/lesson_3_hurricane_tracking_chart_.pdf), should you want it. Point out that there were many more storms in 2018. We will just be comparing the two that caused the most damage in the U.S. that year.
    - While looking at the hurricane tracking map, point out that there is a white circle along each storm's track that indicates noon. This means the distance between two white circles along a path is how far a storm moved in 24 hours.
        - Ask: What do you notice when you compare the paths of Michael and Florence?
        - Students should notice that the white circles are closer together on the Florence path, indicating that it was moving more slowly.

Introduce data exploration. (continued)

- Florence: Traveled more slowly in the Atlantic and made landfall in North Carolina on September 14, 2018. The maximum sustained winds were approximately 90 mph (Category 1) when it made landfall.

- Michael: Traveled quickly through the north-eastern Gulf of Mexico and made landfall in the Florida panhandle on the afternoon of October 10, 2018. The maximum sustained winds were 160 mph (Category 5) when it made landfall.



Student data analysis (20 min)

1. Pass out copies of the Tale of Two Hurricanes: CER Student Sheet.
2. Direct students to use the Lesson 3: Hurricane Data about the impacts of Hurricane Florence and Hurricane Michael to answer the question: *Which hurricane caused the most damage, Hurricane Florence or Hurricane Michael?* (slide 43)
    - Students can work in pairs or visit stations on their own to explore the hurricane data.
    - Students will make a claim, cite evidence from the data about the storms, and then explain their reasoning using the Tale of Two Hurricanes: CER Student Sheet.

Note: Students will need to view the Lesson 3: Hurricane Data in color to be able to accurately interpret the maps and images.

Note: Satellite images of both hurricane locations are included within the Lesson 3: Hurricane Data (see PDF). It may also be helpful if each student uses a map of the area as they explore the data to become familiar with the location of flooding, high storm surge, etc.

Revisit Driving Question Board (10 min)

- Have students revisit the class Driving Question Board (DQB) that they created in Lesson 1. Ask the following questions:
    - *Are there any questions that we can now answer?*
    - *Do we want to re-arrange any of the questions? Are there any connections between topics that we should show on the DQB?*
    - *Would anyone like to add any additional questions?*

Assign Journal Prompt #7

- **Prompt #7:** What is the tale of a hurricane that has affected your family or community? If you have not experienced a hurricane yourself, ask a family member or friend who has to tell you about it. Describe what you or they remember the most, and how things were different in the months and years after the storm. Imagine what it might be like to experience hurricanes in coastal Louisiana 20-30 years from now. How and why might things be different?

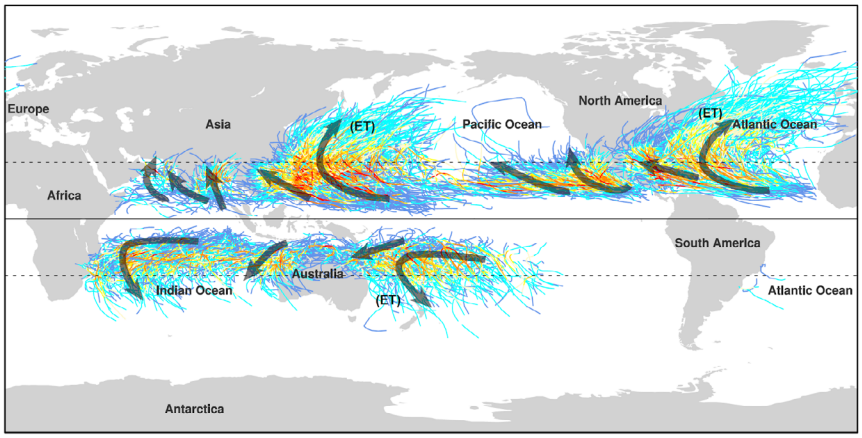
Background Information

Hurricanes, known more generally as tropical cyclones (TCs), are weather systems that form in the tropics (typically 30° North and South of the equator) and generate severe winds (i.e., 63 km/h, which is 39 mph) that rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Tropical cyclones with sustained winds exceeding 119 km/h (74 mph) are known as hurricanes over the North Atlantic, Central Pacific, and East Pacific and are called typhoons over the western North Pacific. Over the Indian Ocean and the South Pacific, TCs are called cyclones. TCs mainly occur during the summer season (which is at opposite times of the year in the Northern and Southern Hemispheres).

Where they form and travel

Similar to a stick floating down a stream, the route, or track, of a TC is largely controlled by the prevailing winds, which, at tropical latitudes (30°), typically flow from East to West and are called Trade Winds. At higher latitudes, prevailing winds flow from West to East.

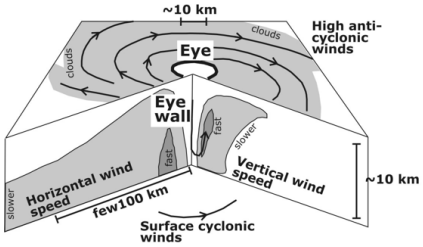
Background Information (continued)



The world map above shows the tracks of tropical cyclones (TCs) between 1980 and 2013 colored by Saffir-Simpson category. Arrows indicate general TC tracks, and '(ET)' indicates where TCs can transition to become extratropical storms (i.e., outside the tropics). TCs are most prevalent from June to November in the Northern Hemisphere peaking in mid-September, and from November to April in the Southern Hemisphere peaking in mid-February. Notice that TCs occur only rarely over the South Atlantic and the eastern South Pacific.

Anatomy of a Tropical Cyclone

Mature TCs are approximately symmetrical around a central eye. The eye is a calm area surrounded by a wall of strong winds and rain known as the eyewall.



The illustration to the right shows the basic structure of a TC and the terms used for different parts of a storm. Horizontal winds spiral cyclonically inwards and are at their fastest just above the ground or ocean surface and in the eyewall where vertical winds send air high into the upper troposphere and lower stratosphere. This air that moves upward fans out anti-cyclonically at the top of the storm, which means that the winds at the top of the storm are rotating opposite to the winds at the bottom of the storm. In the Northern Hemisphere, cyclonic is anticlockwise, and anticyclonic is clockwise (note the wind directions in the diagram above). Winds rotate in the reverse pattern in TCs that occur in the Southern Hemisphere.

Typically, TCs transfer heat energy from the tropical ocean surface, where sea surface temperatures (SSTs) are more than 26° C, into the atmosphere. This process is called cyclogenesis. Several other factors must also align for a TC to form. For example:

- Warm, moist air with a tendency to rise, is essential for a TC to form. The rising air moves heat energy higher in the atmosphere and establishes the storm's structure.
- Humid conditions at mid-levels are needed to limit the number of downdrafts of dry air to the surface.
- For a TC to form, wind shear must be low. Wind shear is the difference between winds at low and high altitudes. When strong, it can tear apart a developing TC.
- Finally, a trigger is needed to start a TC. Triggers can be various types of atmospheric phenomena, including trailing cold fronts, monsoonal circulations, or pulses of energy in the atmosphere known as tropical waves.

While all tropical cyclones have similar morphology, as shown in the figure above, they vary in terms of their geographic scale, wind speeds, the amount of water vapor they carry, and the speed they move.

- Geographic scale: A small TC may have hurricane-force winds over an area about 150 km (about 90 mi) across, like Hurricane Michael in 2018, while a very large TC might have hurricane-force winds that affect the coast of several states as the storm makes landfall.
- Storm speed: TCs also vary in the speed they travel, which is called translation rate. Slow-moving TCs may stall completely while fast-moving storms, like Hurricane Michael, travel over 500 km (312 miles) in 24 hours.
- Wind speeds: Historically, wind speeds are used to categorize TCs according to the Saffir-Simpson Scale. Tropical depressions and tropical storms have weaker winds. Saffir-Simpson categories (between 1 and 5) are assigned to TCs depending on wind speed within the storm. (See the Saffir-Simpson Scale graphic below.)
- Water vapor: TCs generally carry large amounts of water vapor and clouds, but some storms carry more water than others. A TC with large amounts of water can cause intense rainfall. For example, Hurricane Harvey dropped between 30 and 60 inches of rain in the Houston, TX area in 2017.

Background Information (continued)

Flooding from Cyclones

The most dangerous storms are not necessarily the strongest at landfall. Only three of the ten deadliest tropical cyclones were "major hurricanes" (Category 3 or higher on the Saffir-Simpson Scale) when they came ashore. Six of the ten were tropical storms or Category 1 hurricanes at landfall.

Although hurricanes are categorized into the Saffir-Simpson scale according to their wind speeds, most fatalities associated with hurricanes are caused by floodwater, not wind. Flooding is caused by two factors: storm surge and rainfall.

Storm surge: One of the most dangerous hazards associated with TCs, storm surge is responsible for about half of all TC-related fatalities. Storm surge happens when the ocean spills out over the land as a TC makes landfall. The strong TC winds exert a pull on the ocean surface, which sets the surface layer of the ocean into motion. The strength of the storm surge depends on the peak hurricane winds, the area covered by strong winds, how fast the storm is moving towards land, and the shape of the coast and shallow ocean. Surge is also driven in part by the low surface pressures at the center of the storm. The surge builds up over many days tracking with the storm and spills out over the land as the storm makes landfall. Storm surge can inundate coastal locations with many feet of fast-moving water in a matter of minutes.

- *NCAR visualization of storm surge flooding: Researchers at NCAR used a three-dimensional GIS model to create this visualization, which shows how fast storm surge can flood an urban area during a hurricane. (ral.ucar.edu/pressroom/features/storm-surges-can-cause-serious-flooding-fast)*

Rainfall: The amount of rainfall depends on how much moisture a tropical cyclone is carrying and the speed at which a storm is moving. A TC that carries a lot of moisture and is slow-moving can cause a large amount of rain to fall in one location. The rain floods rivers and impervious urban areas. The amount of flooding caused by rain depends on the land topography, and whether the water can permeate into the ground.

About Hurricane Michael

Michael was the third most intense hurricane ever to make landfall in the United States. The storm's central pressure plunged to 919 hPa at landfall, which caused very high winds (sustained 1-minute average winds were 160 mph). These were the strongest U.S. landfalling winds since Hurricane Andrew in 1992.

Hurricane Michael formed within rich, moist air of the Caribbean and over unusually warm ocean water. The sea surface temperatures were 2-4°F above normal. The intensifying storm became embedded within a southerly flow between two large weather systems. Forecast models handle these large-scale weather systems very well, which led to excellent track forecasts.

Michael continued to intensify as it moved northward across the Gulf of Mexico. However, even at Category 3 intensity, Michael had not formed a complete eye-wall structure. Eventually, overnight on Oct 9th, a complete eye-wall formed, allowing the robust storm's winds to jump to Category 5 speeds. Nothing stood between the storm and the Florida coast, other than warm waters, which fueled the storm. The storm continued to intensify right up until landfall.

Michael produced devastating winds and storm surge. Damaging winds extended far inland, even bringing Category 3 winds into southwest Georgia. The storm was directly responsible for 16 deaths and about $25 billion in damage in the United States.

About Hurricane Florence

What started as a distant prospect off the African coast developed over many days to be a record-breaking U.S. event. Hurricane Florence broke rainfall records for tropical storms in North and South Carolina. Rains in South Carolina peaked at nearly two feet, while rains in North Carolina reached almost three feet.

Florence intensified rapidly offshore, supported by warm waters that extended to great depth. High winds were generally light, which allowed the storm to mature. Florence was guided around the southern side of a subtropical high-pressure system, towards the U.S. Florence then put on the brakes as it came up against a high-pressure region over the Ohio Valley. With its path blocked, it got stuck for days.

Stalling near the coast meant that half of the storm remained over the ocean and allowed the storm to pump moisture inland continuously for many hours. This dangerous scenario of a stalled coastal hurricane was eerily reminiscent of 2017's Hurricane Harvey, setting the stage for unprecedented state rainfall and a storm surge that spanned multiple tide cycles.

Background Information (continued)

References

- Sea level rise in the United States: Sweet et al. (2017) Global and regional sea level rise scenarios for the United States
  - https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf
- Hurricane Fatalities: Rappaport, E.N., 2014: Fatalities in the United States from Atlantic Tropical Cyclones: New Data and Interpretation. Bull. Amer. Meteor. Soc., 95, 341–346.
- Before and After: Coastal Change Caused by Hurricane Michael (USGS)
  - https://www.usgs.gov/news/and-after-coastal-change-caused-hurricane-michael
- Hurricane Michael's heavy rainfall measured by NASA (AAAS EurekaAlert!)
  - https://eurekalert.org/pub_releases/2018-10/nsfc-hmh101518.php
- Hurricane and Typhoon Updates: Michael 2018 (NASA Blogs)
  - https://blogs.nasa.gov/hurricanes/tag/michael-2018/

Part 3: Changing Ecosystems

Materials

- Project Resilience Slide Deck (slides 44-48)
- Projector & Computer
- Expert Group 1: Brown Shrimp Student Investigation Sheet (PDF)
- Expert Group 2: Brown Shrimp Student Investigation Sheet (PDF)
- Expert Group 3: Brown Shrimp Student Investigation Sheet (PDF)
- Expert Group 4: Brown Shrimp Student Investigation Sheet (PDF)
- Expert Group 5: Brown Shrimp Student Investigation Sheet (PDF)

Preparation

- Determine student grouping in advance (students will need to be in groups of five for the jigsaw activity).
- Print copies of the *Expert Groups 1-5: Brown Shrimp Student Investigation Sheets* (unless students can access them digitally).
- Review the background information and data within the Brown Shrimp Student Investigation Sheets.

Directions

Introduce the case study on Brown Shrimp (5 min)

1. Show quote about shrimp fisheries to illustrate how important shrimping is to the Louisiana economy (slide 45):
   "77% of the shrimp harvested in the U.S. come from the Gulf of Mexico, especially Texas and Louisiana. Total domestic shrimp harvest brings around $500 million per year to US economies." (NOAA Fisheries, July 2019)
2. Ask students if they are, or know anyone who is, associated with shrimping. Ask if anyone has ever been out shrimping before. Allow for some telling of personal stories to anchor the idea of fisheries as a part of Louisiana's culture.
3. Tell students that today's goal is to see how the challenges facing coastal Louisiana are affecting local ecosystems, and how changes to local ecosystems in turn affects us. As an example, we will consider the case of brown shrimp.
4. Introduce the investigation question for the day, perhaps write it on the board:
   How are brown shrimp impacted by the changing coastal environment? How does this affect the people of Louisiana?
5. Tell students we will be exploring two different parts of the Brown Shrimp story today: the effects of floodwater management and the effects of dead zones.
6. Show the labeled map of Lake Pontchartrain (slide 46) (pronounced Pon-cha-train). You may also use Google Earth to show the location of Lake Pontchartrain to orient students to the area if they are not familiar with where it is.
   - Tell students that Lake Pontchartrain is the largest estuary system in coastal Louisiana. Point out that Lake Pontchartrain receives freshwater from several rivers but also opens to the Gulf of Mexico, which means that it contains brackish water.
7. Show the map of Global Dead Zones (slide 47).
   - Provide a general definition of Dead Zones as an area of ocean water that is devoid of living things. The map shows the location of Dead Zones and correlations to human population density, as well as the size of the Dead Zone areas, indicated by the size of the red circle. Students will likely make connections between increased water pollution where human populations are highest, thus leading to Dead Zones. Point out that Dead Zones are a global issue, not just a problem for Louisiana.
8. Tell students that we will learn more about what dead zones are, and why Lake Pontchartrain is important, in our group investigations.

Jigsaw investigation of brown shrimp (25 minutes)

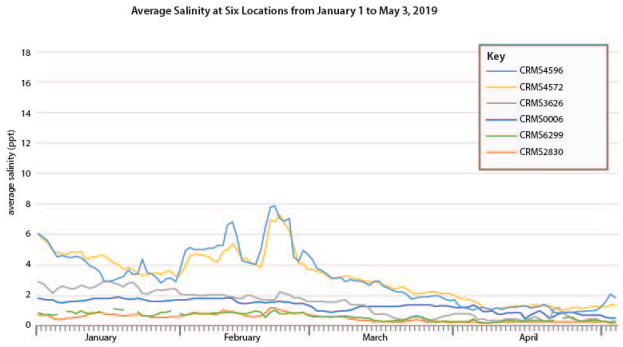
1. Split students into "home" groups, each home group should have five students (if some groups need to have more than five students, "extra" experts for Group 3 is suggested). Tell students that each member of their group will investigate a different part of the Brown Shrimp story, using the jigsaw structure (from Lesson 1). Refresh students on the jigsaw structure as needed.
   - Each person in the group will become an "expert" on their part of the story.
   - There are more channels through the wetlands, some of the lakes are now open to the ocean, and there is less low-lying land, which is mostly wetland.
2. Assign one student from each home group to join the following "expert" groups. Then have students work with their expert groups to investigate the information on their activity sheets and answer the questions.
   - Expert Group 1: Give each student a copy of the Expert Group 1 activity sheet. They will read an article about the opening of the Bonnet Carre Spillway and how this has impacted the fishing industry.
   - Expert Group 2: Give each student a copy of the Expert Group 2 activity sheet. They will use the readings to learn about the brown shrimp life cycle and habitat requirements.

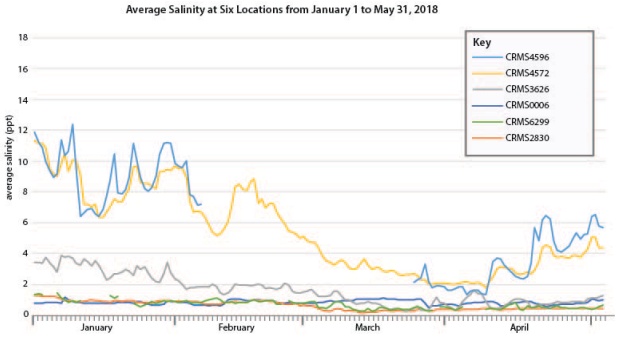
- Expert Group 3: Give each student a copy of the Expert Group 3 activity sheet. They will read about ocean salinity and interpret graphs of salinity data from Lake Pontchartrain to piece together understandings about how changing conditions in the marsh ecosystems could affect brown shrimp populations.
- Expert Group 4: Give each student a copy of the Expert Group 4 activity sheet. They will read an article about dead zones and how they impact the fishing industry.
- Expert Group 5: Give each student a copy of the Expert Group 5 activity sheet. They will use the reading and dead zones map to learn what dead zones are and where they occur in the Gulf of Mexico.

3. Have students return to their home groups to share what they have learned.
   - In home groups, students should be piecing information together to answer the investigation question for the day: *How are brown shrimp impacted by the changing coastal environment? How does this affect the people of Louisiana?*

Since the Clean Air Act was passed: Interpreting the Salinity Data

Facilitation Tips:





- Students may notice there are some disconnected trend lines in the graphs. These are the result of missing data from the monitoring sites, which could be for a variety of reasons.
- Though students are not examining an entire year of data, they should notice a natural cycle of decreasing salinity during the spring rainy season, with an increase in salinity heading into the warmer months due to increased evaporation. This natural cycle is apparent in the 2018 data, and a disruption of this cycle is observed in the 2019 data due to prolonged flooding and the opening of the Bonnet Carre Spillway.
- The sites with the highest overall salinities are located outside of the official boundaries of Lake Pontchartrain, which is to be expected. The drastic decrease in salinity of these two sites from 2018 to 2019 signals the potential impact of freshwater inundation on the ecosystem, which is supported by reports from the fishing industry about low Brown Shrimp landings for the 2019 season.

Conclusions from the Brown Shrimp Investigation: (10 min)

1. Bring the class back together for a share-out. Ask students to put together the pieces of the story that we now know. Sharings might include:
   - The fisheries were able to catch significantly less in 2019, which puts financial stress on the industry.
   - Much more water from the Mississippi is entering Lake Pontchartrain, which means that the salinity of Lake Pontchartrain decreased. There is also an increase in sediment entering the lake, along with an increase in fertilizers and pollutants.
   - Shrimp use marshlands, like Lake Pontchartrain, and the gulf waters during different parts of their life cycle.
   - Shrimp are sensitive to salinity levels; lower salinity levels in the marshlands where juvenile shrimp feed impacts the fishing industry.
   - Dead zones are caused by an increase in nitrogen from fertilizers used on farmland along the Mississippi River from Montana all the way to the Gulf of Mexico.
   - Eutrophication (which causes dead zones) intensifies in the summer due to warmer temperatures. Students might also connect that higher temperatures and lower oxygen in the water would affect salinity as well.
   - The increase in dead zone size and frequency is making it harder for the fishing industry, and their harvests have been lower in recent years.

2. Ensure that the investigation question for today has been adequately answered. Check for any remaining questions that students might have. Provide these additional clarifications, as needed:
    - Reference the explorations with Google Earth from Lesson 2, where dead zones appeared on the map as fish skeletons to help students make connections to the previous learnings.
    - Remind students that in Lesson 3 we learned that the brown shrimp catch is highest in the summer, which is when adult shrimp have moved back out into open water. This coincided with the appearance of Dead Zones.
    - Students may think that shrimp catch will decrease because the adult shrimp have died due to lack of oxygen, but while this may in part be true, mostly shrimp are simply harder for fishermen to find. Because shrimp are mobile, they are able to leave the hypoxic zones.
    - In addition, because environmental conditions are less desirable both in the marsh and in the ocean due to the extensive flooding of the Mississippi River in 2019, shrimp did not develop as quickly or grow as large, which are side effects that impact the fishing economy.
    - Share that dead zone conditions occur in Lake Pontchartrain as well (slide 48). Opening the spillway caused a toxic algae bloom from the added fertilizer pollutants, just as it does in the ocean.
3. Tell students that during the following class, we will shift our thinking towards the direction of solutions!

Revisit Driving Question Board (10 min)

- Have students revisit the class Driving Question Board (DQB) that they created in Lesson 1. This is the final time we will visit the DQB with this driving question (we will add a new driving question for the next part of the curriculum). Ask the following questions:
    - *Are there any questions that we can now answer?*
    - *Do we want to re-arrange any of the questions? Are there any connections between topics that we should show on the DQB?*
    - *Would anyone like to add any additional questions?*

Assign Journal Prompt #8

- **Prompt #8:** Step inside the perspective of someone who is connected to the challenges brought by changing ecosystems in coastal Louisiana. Imagine yourself as this person, and list your responses to the questions below from that perspective:
    - What would this person see or notice about their ecosystem?
    - What challenges might this person face?
    - What might be important to this person?
    - What might this person wonder about?

Background Information

Brown Shrimp life history

- Louisiana's shrimp industry is based around the brown shrimp and white shrimp.
- Post-larvae the shrimp move to inshore estuaries (May-November). Juveniles move to nursery areas in estuaries and migrate out as they grow larger (August – September). Adults inhabit saltier offshore waters. Juvenile shrimp prefer marsh edge habitats, flooded grasses, & aquatic vegetation in upper estuaries.
- The life expectancy of brown shrimp is about 18 months. They reach harvestable sizes in 2–3 months under favorable environmental conditions.
- Louisiana is number one in commercial shrimp landings in the United States. Shrimp have been harvested commercially since the 1800s and are the most valuable and second-largest commercial fishery in Louisiana.

Factors impacting shrimp growth

- Salinity, water temperature, and dissolved oxygen can influence function, distribution, growth, survival, and movement of shrimp.
- Hydrological conditions within nursery (particularly in spring) play a large role in dictating next season's potential harvest.
- They commonly tolerate lower salinity levels and exhibit a slower growth rate at higher salinities.
- Shrimp population size relates to river discharge and its effect on estuarine salinities.
- Extremes in salinity have been shown to reduce the growth rates of juvenile shrimp.

Factors impacting shrimp abundance

- Marsh habitat loss may affect shrimp yield because the yield of an estuary is directly related to marsh acreage.
- Low dissolved oxygen (hypoxia) areas have less shrimp. The appearance of Dead Zone corresponds with peak shrimp fishing and may impact shrimp harvests (shrimp avoid low oxygen areas).

Background Information continued

Coastwide Reference Monitoring System (CRMS)

- https://www.lacoast.gov/crms/crms_public_data/publications/CRMS_FactSheet_Web.pdf

The CRMS design includes a suite of sites encompassing a range of ecological conditions of swamp habitats and fresh, intermediate, brackish, and salt marshes. Approximately 390 sites are monitored using standardized data collection techniques and fixed sampling schedules. The CRMS sites are located within nine coastal basins and four CWPPRA regions, covering the entire Louisiana coast. Comparisons of changing conditions are not limited to project influences but are possible throughout the coastal zone because CRMS was designed as a reference network.

The reference network approach enables assessment of ecological conditions at multiple scales. Within a CRMS site, there are many CRMS stations or plots. At each site, data are collected at a broader 1 km2 and a finer 200 m2 scale (Figure 3). At the 1 km2 scale, high-resolution aerial photography is used to calculate the ratio of land to water to investigate land change trends through time. Within the 200 m2 area, data are collected in the field using standardized protocols and consistent sampling intervals. CRMS data include water level, salinity, sediment accretion, surface elevation change, composition and abundance of vegetation, the ratio of land to water, and soil characteristics. The ten vegetation stations are in a diagonal transect across the 200 m2 area. The rod surface and accretion stations are nested around a boardwalk. The hydrologic station is generally in a bayou or water body near the boardwalk.

Salinity

Excerpt below from National Ocean Service Monitering Estuaries Tutorial (oceanservice.noaa.gov/education/tutorial_estuaries/est10_monitor.html)

> "Under laboratory conditions, pure water contains only oxygen and hydrogen atoms, but in the real world, many substances are often dissolved in water, like salt. Salinity is the concentration of salt in water, usually measured in parts per thousand (ppt). The salinity of seawater in the open ocean is remarkably constant at about 35 ppt. Salinity in an estuary varies according to one's location in the estuary, the daily tides, and the volume of fresh water flowing into the estuary.
>
> "In estuaries, salinity levels are generally highest near the mouth of a river where the ocean water enters, and lowest upstream where fresh water flows in. Actual salinities vary throughout the tidal cycle, however. Salinity levels in estuaries typically decline in the spring when snowmelt and rain increase the freshwater flow from streams and groundwater. Salinity levels usually rise during the summer when higher temperatures increase levels of evaporation in the estuary.
>
> "Estuarine organisms have different tolerances and responses to salinity changes. Many bottom-dwelling animals, like oysters and crabs, can tolerate some change in salinity, but salinities outside an acceptable range will negatively affect their growth and reproduction, and ultimately, their survival.
>
> "Salinity also affects chemical conditions within the estuary, particularly levels of dissolved oxygen in the water. The amount of oxygen that can dissolve in water, or solubility, decreases as salinity increases. The solubility of oxygen in seawater is about 20 percent less than it is in fresh water at the same temperature."

The Gulf of Mexico Dead Zone

Excerpt below from an article by Elizabeth Carlisle in The Louisiana Environment (tulane.edu/~bfleury/envirobio/enviroweb/DeadZone.htm)

> "The Gulf of Mexico hypoxic zone is a seasonal phenomenon occurring in the northern Gulf of Mexico, from the mouth of the Mississippi River to beyond the Texas border. It is more commonly referred to as the Gulf of Mexico Dead Zone because oxygen levels within the zone are too low to support marine life. The Dead Zone was first recorded in the early 1970s. It originally occurred every two to three years, but now occurs annually. In the summer of 1999, the Dead Zone reached its peak, encompassing 7,728 square miles.
>
> "Hypoxic conditions arise when dissolved oxygen levels in the water fall below two milligrams per liter of water, too low to sustain animal life in the bottom strata of the ocean. The Dead Zone forms each spring as the Mississippi and Atchafalaya Rivers empty into the Gulf, bringing nutrient-rich waters that form a layer of fresh water above the existing salt water. It lasts until late August or September when it is broken up by hurricanes or tropical storms. The nutrients provide favorable conditions for the excessive growth of algae that utilize the water's oxygen supply for respiration and when decomposing.

Background Information continued

"The Mississippi River Basin covers forty-one percent of the continental United States, contains forty-seven percent of the nation's rural population, and fifty-two percent of U.S. farms. The waste from this entire area drains into the Gulf of Mexico through the Mississippi River. Included in this agricultural waste are phosphorus and nitrogen, the primary nutrient responsible for algal blooms in the Dead Zone. Nitrogen and phosphorus were first used in fertilizers in the United States in the 1930s. Concentrations of nitrate and phosphate in the lower Mississippi have increased proportionately to levels of fertilizer use by agriculture since the 1960s when fertilizer use increased by over two million metric tons per year. Overall, nitrogen input to the Gulf from the Mississippi River Basin has increased between two and seven times over the past century. In addition to agricultural waste, inadequately treated or untreated sewage and other urban pollution are also dumped into these waters. Nitrogen is normally a limiting factor, meaning its restricted quantities limit plant growth and reproduction. However, excessive amounts of nitrogen can lead to eutrophication, the takeover of nutrient-rich surface water by phytoplankton or other plants. If nutrient pollution is not greatly reduced, fish and shellfish may someday be permanently replaced by anaerobic bacteria."

Part 3 Extensions:

- Effects of flooding- Claim-Pass Activity: Ask students to make a claim about which piece(s) of evidence they think most support the idea that the flooding of the Mississippi River and the extended opening of the Bonnet Carre Spillway are responsible for the predicted decline in brown shrimp landings in 2019.
  - Each student writes down their claim and evidence on a piece of paper. (Note: Be sure that each student writes their name on their paper so they can get it back at the end of the activity.)
  - Have students choose a partner and take turns explaining their claim to one another.
  - Students trade papers and find a new partner, this time explaining the claim on the traded paper (instead of their claim) to their new partners.
  - If time, trade papers again and repeat.
  - Share out and record student ideas.
- Use the Interactive - Gulf Dead Zone Through the Years to see how the Dead Zone has changed over time. Students can do this independently on computers/tablets, or project it to use a whole class.
- Use the online CMRS Spatial Viewer to locate specific areas where conditions would be favorable for juvenile brown shrimp to live, or investigate other water qualities, such as temperature, depth, vegetation, etc.
  - Navigate to the CRMS Spatial Viewer.
  - Click on a yellow dot to see information about a specific site.
  - Click on the "Water" tab to see data such as salinity, water depth, and temperature. Click on the "Veg" tab to see marsh classification data.
  - Investigate several different CRMS sites to gain an understanding of how conditions vary from site to site.
- For an additional case study of freshwater diversion, refer to the Mid Barataria Sediment Diversion plan and the article about the effects of river diversions on fisheries from The Advocate to consider the benefits and challenges associated with diverting sediment into Barataria Bay.
  - Use the CRMS Spatial Viewer to locate sites that would be affected by the Mid Barataria Sediment Diversion plan.
  - What might be the impact on shrimping fisheries if the sediment diversion plan is enacted? What might be the impact on the greater community if the plan is NOT enacted?

References

Additional Articles related to the opening of the Bonnet Carre Spillway:

- Blind swarms, algae blooms in Louisiana's 'uncharted' territory: Inside true costs of Bennet Carre (https://www.nola.com/news/environment/article_5ed1a994-9c32-11e9-9695-bb42b9b7a073.html)
- Spring shrimp season late this year (https://www.theadvocate.com/baton_rouge/sports/outdoors/article_1fb48ece-6dc1-11e9-bf2a-73128bbad271.html)
- NOAA predicts below-average season for commercial harvest of brown shrimp in western Gulf of Mexico (https://www.fisheries.noaa.gov/feature-story/noaa-predicts-below-average-season-commercial-harvest-brown-shrimp-western-gulf-0)

Dead Zone resources:

- What is a dead zone? (https://oceanservice.noaa.gov/facts/deadzone.html)
- Gulf of Mexico Hypoxia (https://gulfhypoxia.net/)
- Hurricane Barry effect on Gulf of Mexico 2019 Dead Zone (https://www.noaa.gov/media-release/large-dead-zone-measured-in-gulf-of-mexico)

Project Resilience Teacher Guide

Lesson 4 > Turning Problems into Solutions

Students consider all of the environmental challenges presented in Lessons 1-3 to make connections and synthesize ideas. Students work in groups to construct a claim about which environmental problem is a priority to address in coastal Louisiana and brainstorm solutions to the problem. Students are introduced to the concepts of resilience and adaptation and the differences between these two important strategies. Lesson 4 is divided into two parts, each intended for about a day of instruction time.

Lesson 4: Part 1: Analyzing the Problems - Students analyze environmental problems facing coastal Louisiana to understand the underlying causes and connections between them and use claim, evidence, and reasoning to construct an argument about which environmental problem should be addressed first.
Lesson 4: Part 2: Designing Solutions - Students present their claims about which environmental problem is a priority to address and their ideas about solutions to the problem.

Time Required

- Teacher Preparation Time: approximately 20 min
- Part 1: 50 minutes
- Part 2: 50 minutes

Learning Goals

- Students will analyze environmental problems facing coastal Louisiana to understand the underlying causes and connections between them. *(Part 1)*
- Students will use claim, evidence, and reasoning to construct an argument about which environmental problem should be addressed first. *(Part 1)*
- Students learn about different priority problems and consider proposed solutions to these problems. *(Part 2)*
- Students are introduced to the concepts of resilience and adaptation and the differences between these two important strategies. *(Part 2)*

Lesson Format

- Group sensemaking activity
- Formulating a scientific argument using claims, evidence, and reasoning

Science Standards

Louisiana Student Standards for Science:

- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues..
- HS-ESS3-4: Evaluate or refine a technological solution that reduces the impact of human activities with natural systems.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Additional Dimensions:

- Science and Engineering Practices: Developing and Using Models, Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: ESS3-C: Human Impacts on Earth Systems
- Crosscutting Concepts: Patterns, Cause & Effect, Stability & Change

Part 1: Analyzing the Problems

Materials

- Project Resilience Slide Deck (slides 49-54)
- Projector & Computer
- Student access to internet/computers (optional)
- Turning Problems into Solutions- CER Student Sheet (PDF)
- Lesson 4:CER & Presentation Rubric (PDF)
- Chart paper
- Sticky notes
- Markers
- Colored dot stickers

Preparation

- It is suggested to let students form groups with others that have chosen the same priority problem, but if students will be more successful in assigned groups, determine them in advance.
- Print copies of the *Turning Problems into Solutions: CER Student Sheet.*

Directions

Making connections (20 min)

1. Introduce Lesson 4 by explaining the following: *Now that we have explored many of the problems facing coastal Louisiana, let's shift our focus to solutions. But in order to arrive at effective solutions, we need to make sure we understand the root of the challenges and how they can have an impact on other challenges.*
    - Remind students of the driving question we have been focusing on so far (in slide 51): How is our changing coast affecting the people who live here?
2. As a class, create a list of environmental problems/challenges facing coastal Louisiana. Draw upon issues explored during Lessons 1-3 to create the list. Post this list somewhere that will be accessible to the class.Note: students will need to refer to this list during Part 2 of the curriculum, so do not discard it!
3. The list of problems may include: subsidence, sediment loss, wetlands/estuary destruction, the decline of wetlands species, loss of fishing economy, flooding, sea level rise, hurricanes, etc.
    - Students may add issues not addressed in the Project Resilience curriculum as well (such as pollution, oil spills, etc.), allow this.
4. Write each problem on its own piece of paper and hang them on the walls around the room. A digital brainstorming platform (like Padlet) would also work well for this.
5. Have students find a partner. Give each pair a small stack of sticky notes.
6. Tell students their goal is to analyze the problems and to see if problems connect to each other.
    - Depending on your class size and the number of problems your class came up with, consider assigning each pair of students to focus on a specific problem.
7. Students should write one idea per sticky note to address the "get at the root of the problem" questions/prompts below, and then add them to the respective problems posted on the walls.
    - Read through the questions together as a group before students get started with their partners. Define primary, secondary, and linchpin problems as needed (see definitions below).
    - Make sure sticky notes are being added to each of the different problems.

Getting at the Root of the Problem Questions: (slide 52)

- How would you define the problem?
- What is/are the cause(s) of the problem?
- Are the causes of the problem anthropogenic (caused by humans), natural, or both?
- Is the problem a primary or secondary problem? Is there a linchpin problem?
    - Secondary problems are dependent upon primary problems. Without addressing the primary problem, the secondary problem cannot be solved.
    - A linchpin problem is one that all other problems stem from.
- What is the scale of the problem? (Individual, community, population/species, ecosystem, global, etc.)
- What are the resulting effects of the problem? How are people in your community affected by the problem?
    - There will likely be many, and they will likely lead to more connections.
    - A problem can be the "effect" of another problem.

Getting at the Root of the Problem Questions: (slide 52, continued)

- Does the problem connect to another problem?
  - › Add sticky notes to show connections. For example, land loss connects to diverting water from the river, sea level rise, and subsidence. Add sticky notes that say "Connects to land loss..." on each of the other problems.

Make a claim (10 min)

1. When students have finished hanging sticky notes, pose this question (slide 53):
   If you had a limited amount of resources, which problem would be the priority to address? Which problem, when fixed, would have the greatest impact?
2. Have a gallery walk. Tell students to think about the question as they read through the problem analyses. Give each student three different colored dot stickers (red, yellow, and green are suggested). Tell them to place a red dot sticker next to the problem they feel should be the #1 priority, a yellow dot sticker next to the #2 problem, and a green dot sticker next to the #3 problem.
   - As students walk around reading the analyses and ranking the problems, they should engage in conversation with each other about what they find interesting/challenging about the different problems, what they still have questions about, and which problem they chose as the priority.
3. Instruct students to look around the room to see which problems received the most votes.
   - Ask students to share their reasoning for choosing these problems as priorities over others.
   - Ask students to call out any connections between the top-ranked problems. Refer to the analysis of sticky notes for evidence.

Proposing Solutions (20 min)

1. Have students form groups with others who chose the same priority problem as them, if possible. It is ok if there are multiple groups focusing on the same problem (it is better for group sizes to be small so students will have more opportunities to engage in deep conversation).
2. Tell students that they will work with their newly formed groups to create a presentation about their priority problem, which will be shared with their classmates tomorrow.
3. Each group will make a poster on chart paper (or using a digital platform) that will include their claim, their supporting evidence, and their reasoning. Proposed solutions should also be included and should be described in as much detail as possible. Encourage creativity! Provide students with internet access if they would like to research their problem/solutions further. Pass out copies of the Turning Problems into Solutions: CER Student Sheet for groups to use as they plan what to write on their poster (optional).
4. Show the question and CER details (slide 54) while groups work:
   - Question: If you had a limited amount of resources, which problem would be the priority to address.
   - Your claim: Which problem should be the priority? Provide details about the problem.
   - Your evidence: What specific factors support your claim? Give examples when possible.
   - Your reasoning: Why does your evidence support your claim?
   - Your solution(s): Describe your ideas for a solution to this important problem. Explain how the solution will address the problem and how it would benefit the people who live in your community.

Groups will finish up their CER and solutions posters using the first 15 minutes of class tomorrow.

Assign journal prompt #9

- **Prompt #9:** Think back to when we began this unit about coastal Louisiana and reflect on how your thinking has changed. First, recall the ideas you used to have about the environmental problems facing your community. Write down what it is that you used to think, starting with the words "I used to think…" Next, think about how your ideas have changed as a result of what we have been studying. Write down a few lines to capture where you are in your thinking now, starting with the words "Now, I think…"

Background Information

Resources for using Claim-Evidence-Reasoning with students:

- Claim, Evidence, & Reasoning (CER) Writing Scientific Explanation, a presentation from Deer Valley Unified School District, Arizona (https://www.dvusd.org/cms/lib/AZ01901092/Centricity/Domain/5849/CER.pdf)
- Teaching Channel video: Claims, Evidence, Reasoning (https://www.teachingchannel.org/video/support-claims-with-evidence-getty)

Adaptation and resilience:

Given the complexities of the environmental threats facing the gulf coastal communities, both adaptation and resilience must be considered when we begin to discuss solutions. Adaptation in this context means taking action to cope with the effects of environmental change. For example, the fishing industries will likely need to alter their fishing practices to adapt to shrimp occupying different areas in the ocean. Sediment diversion projects can help re-establish land forming processes in the delta. These are both examples of adaptation, but it is important to note that not all communities can, or need to, adapt in the same manner. Resilience defines a community's ability to respond and bounce back from threats, but risk and vulnerability play a large role in determining this. Not all places/people/things are able to be resilient due to variations in their local conditions. Thus, a variety of solutions are needed and a ranging scale of implementation of these solutions.

For students to consider which problem is the most important to address, given the reality of limited resources, they will need to expand their thinking to include the unique impacts of environmental threats on a range of scales. Suggest that students consider their chosen environmental threat from the perspective of various stakeholders and begin to think about trade-offs and how multiple solutions are likely needed. The overarching challenge of living with more water is at the crux of every scenario. Creative solutions are needed not only in coastal Louisiana but in coastal communities around the world.

Examples of adaptation and resilience organizations in Louisiana:

- LA SAFE (Louisiana's Strategic Adaptations for Future Environments) was created to help Louisiana's communities and economies adapt to coastal challenges and take advantage of emerging opportunities by discussing adaptation alongside restoration. By demonstrating the power of citizen-led planning informed by science and fueled by the vision of residents, LA SAFE is developing a suite of adaptation projects that can be used as we become a stronger, safer, more resilient Louisiana.
  - https://lasafe.la.gov/
- The Water Institute of the Gulf's Resilience Lab undertakes research, outreach, capacity building, development of best practices, and knowledge exchange focusing on developing innovative solutions to the challenges confronting river and coastal communities.
  - https://thewaterinstitute.org/focus-areas/community-resilience

Other examples of adaptation & resilience:

- United Nations Climate Change Adaptation & Resilience (https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean)

Part 2: Designing Solutions

Materials

- Project Resilience Slide Deck (slides 55-57)
- Projector & Computer
- Student access to internet/computers (optional)
- Turning Problems into Solutions- CER Student Sheet (PDF)
- Lesson 4:CER & Presentation Rubric (PDF)
- Chart paper
- Markers

Preparation

- Print copies of the *Lesson 4: CER & Presentation Rubric* to use when scoring the group presentations.

Directions

Proposing solutions (15 min)

1. Hang the claim posters around the room and have a modified gallery walk. Tell each group that goal is to give and receive feedback to each other so that we can revise and strengthen our claims and proposed solutions.
    - 1-2 group members remain with their group's poster to explain and answer questions (this is the "stay" portion).
    - The other group members walk around and visit the other posters (the "stray" portion).
    - Encourage questions and answers about the CERs and the proposed solutions.
2. Use the Lesson 4: CER & Presentation Rubric to assess during the stay-stray presentations.
3. Have students return to their groups to share any new ideas and suggestions that arose during the stay-stray presentations.
4. Individually, have students revise their group's argument, based on the new ideas and suggestions from the stay-stray presentations, and on any new ideas they might have. Give each student a copy of the Turning Problems into Solutions: CER Student Sheet and have them fill in the revised argument here.
    - This should be completed as homework and can be used as an individual assessment.

Introducing Resilience Planning and Returning to our Driving Question Board (20 min)

1. Transition to this final section. Each group created a solution for just one problem, but the reality is that communities are dealing with many challenges simultaneously. Many factors determine how well a community is able to respond to these challenges.
2. Introduce the ideas of resilience and adaptation.
    - Share the definitions (slide 56):
        - Resilience is the ability to recover from or adapt to difficulty, while adaptation is an action taken to become better suited to our environment.
        - Resilience is a characteristic, while adaptation is an action taken.
        - Point out the connection between the two concepts; adapting can make a community more resilient.
3. Provide an example of community resilience and adaptation that your students will connect to. For example, Terrebonne Parish adopting a multi-year plan to respond to flooding in the community is an example of being resilient. People who live down the bayou elevating their homes because flooding is common is an example of adapting.
4. Have students come up with an example of both resilience and adaptation with a partner. It does not need to be an example related to environmental challenges. Rather, it can be any example to demonstrate that students understand the difference between the two terms. Invite students to share their examples with the class if they would like.
5. Share that complex problems almost never have simple solutions. In the case of the environmental problems affecting the Louisiana coast, communities must discover multiple ways to be resilient, and adapting is one way to become more resilient.
6. Return to the Driving Question Board. Tell students that we have wrapped up our exploration of the problems facing coastal Louisiana and that we will now spend some time learning what we can do about them. Introduce a new focus for our Driving Question Board (slide 52):
    - *How do communities become resilient to a changing environment?*
7. Write the new question on the driving question board. Just as in Lesson 1, pass out sticky notes to each student and ask them to generate questions about resilience. As an option, students can generate questions in small groups instead of individually.
8. Have students come together to share the questions they have generated. Consider having everyone stand and gather around the Driving Question Board, bringing their sticky notes with them. Have students take turns reading their questions aloud and then post their sticky notes on the Driving Question Board. Move the sticky notes around to sort them into groups.

Introducing Resilience Planning and Returning to our Driving Question Board (continued)

9. Find a way to connect the Driving Question Board to the next investigation, which focuses on risk and vulnerability. For example, if students wrote questions about figuring out what problems to address first, or how to determine which problems affect the most people, tell them that we will focus on answering these questions in Lesson 5.

Assign journal prompt #10.

- **Prompt #10:** Describe a time when you have been resilient. What skills did you need in this situation? What was the most challenging? How could the lessons you learned from your own resilience be applied to the larger idea of a resilient community? Explain your thinking.

Background Information

See background information in Lesson 4, Part 1: Analyzing the Problems

Part 2 Extensions:

Defining Resilience & Adaptation (Agree-Disagree Line):

- Show the statements and ask students to think to themselves which one they agree with more:
  - Resilience is necessary for communities to respond to environmental change
  - Adaptation is necessary for communities to respond to environmental change
- Announce that one side of the room is the "Agree with statement 1" wall while the opposite side is the "Agree with statement 2" wall.
  - Ask students to stand somewhere along an imaginary agree-disagree line between the two walls to show which statement they agree with (and by default, which statement they disagree with). The line represents a continuum, and they can stand anywhere along that continuum. If they agree equally with both statements, they can stand in the very middle, if they agree with one more than the other, they can show that as well.
  - After everyone has chosen their initial place along the line, students should turn to a neighbor and explain why they chose to stand where they did.
  - Offer that students can change where they are standing at any point if their thinking changes as a result of the discussion.
  - Choose students standing at different places to explain their thinking with the whole class. Ask students to share why they agree/disagree.
  - Ultimately it should come up that an agreed-upon definition of "resilience" and "adaptation" is needed.
  - Pose the questions: What do you think of when you hear the word "resilience"? What do you think of when you hear the word "adaptation"? Students turn and share their responses with someone they are standing near.
  - Offer one final time for students to adjust where they are standing. Provide a summary statement of how your students currently feel. (Eg. "It looks like many of us feel like both resilience and adaptation are needed, but the majority of us still feel that resilience is the only way forward.)
  - Students return to their seats. Hold a discussion to wrap up the activity.

Project Resilience Teacher Guide

Lesson 5 > Risk & Vulnerability

Students are introduced to the concepts of risk and vulnerability by considering the different factors that cause some communities to experience more land loss than others.

Lesson 5: Risk & Vulnerability - Students will understand the difference between risk and vulnerability and be able to identify and analyze the risks impacting their coastal communities.

Time Required

- Teacher Preparation Time: approximately 20 min to gather supplies and review material
- Class Time: 50 minutes for activity and discussion

Learning Goals

- Students will understand the difference between risk and vulnerability.
- Students will be able to identify and analyze the risks impacting their coastal communities.

Lesson Format

- Map reading
- Class discussion

Science Standards

Louisiana Student Standards for Science:

- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.

Additional Dimensions:

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: ESS3.C: Human Impacts on Earth Systems
- Crosscutting Concepts: Stability and Change

Materials

- Project Resilience Slide Deck (slides 58-63)
- Projector & Computer
- Barry Closes in Article (PDF)
- Communities at Risk Student Sheet (PDF)
- Paper
- Markers

Preparation

- It is suggested to let students form groups with others that have chosen the same priority problem, but if students will be Print out copies of the *Barry Closes In* article and Communities at Risk Student Sheet. One article and map per group.
- The *Barry Closes In* article can be replaced with an example of an event relevant to your community, or a more recent event that students will know about. Select an article that illustrates vulnerability and a community's response to an environmental threat.
- Plan student grouping arrangements. Each group will need to assign a team/table leader and a recorder. The team/table leader will help lead discussions and project design. The recorder will keep notes for the group.

Directions

Vulnerability vs. Risk (15 min)

1. Ask: What did you & your family do to prepare for a tropical storm/hurricane, like Barry?
    - If you are using a different community event, discuss how your students and their families prepared for the event. These actions may include a family emergency plan and will differ depending on the type of community event.
2. Tell students that resilience requires taking steps to be prepared for emergency events. Remind students of the definition of resilience (Slide 59), which was also discussed in Lesson 4. The actions a community will take to be resilient are different depending on their specific vulnerabilities and risks. Communities will have different vulnerabilities and risks depending on the community's makeup (location, median resident age, etc.).

Vulnerability vs. Risk (continued)

3. To highlight that vulnerabilities and risks are different for each community, have students consider how people that live in Grand Isle prepared for Tropical Storm Barry as compared to how those that live in Houma prepared. Grand Isle is outside of the Morganza to the Gulf levee system, while Houma is inside the levee system. Ask students: what would the people in these communities do to prepare for the storm?
4. Have students read through the Houma Today article Barry Closes In and highlight or circle examples of what people did to prepare for the storm. Using a different color or notation, note what the concerns or threats were.
5. Introduce the definition of vulnerability and explain that the concerns and threats highlighted in the article are vulnerabilities (Slide 60). Vulnerabilities are the characteristics of a community that increase the exposure to a threat.
6. Refer to the map (Slide 60) with Houma and Grand Isle highlighted to illustrate the locations of the two. Ask students: what vulnerabilities might Grand Isle have that Houma doesn't? (Location/proximity to the Gulf, outside vs. inside the levee, limited road access, presence of marsh in Houma but not Grand Isle, lower elevation, etc.).
    - Students should see that Grand Isle is more vulnerable when a storm approaches.
7. Introduce the idea of risk as a sum of vulnerabilities: more vulnerabilities = higher risk (Slide 61). Both Houma and Grand Isle were vulnerable to wind and water damage during Barry, but the location of Grand Isle was an additional vulnerability that caused them to have a higher risk.
8. Check that students understand the distinction between vulnerability and risk before moving on. You could have students form pairs and take turns explaining vulnerability and risk to each other. Engage in additional class discussions if needed.

Identifying Communities at Risk (25 min)

1. Break students into groups. Hand each group one copy of the Communities at Risk Student Sheet.Using the map (Slide 62), students should identify the top five communities most at risk due to Louisiana's land loss. Students should revisit the list of their environmental problems from Lesson 4 to review the causes and problems of land loss.
2. Once students identify their five communities, have them identify factors that may increase the vulnerability of each of the communities.
    - Factors could be from the community's environment or the community itself.
    - Environmental factors could include rates of subsidence or loss of wetlands.
    - Community factors may include geographic isolation, the average age of the community, or the community's economic status.
3. Have students break into pairs (with someone who was not in their group) to discuss the following for 5 minutes:
    - Make comparisons between their lists of communities.
    - What factors would cause flood risk to increase in these coastal communities?
    - Are some places more at risk than others?
4. Create an imaginary line through the classroom with "resilient" at one end of the room and "not resilient" at the other end. Students should stand at a spot on the line to represent their thinking about the following question: *Do you think the communities you chose are resilient or not resilient?*
5. Remind students of the definition of resilience (Slide 59) and that you can become more resilient by decreasing your risks. Have students turn to someone they are standing near and explain why they chose to stand in that location. Note: students do not have to stand only at "resilient" or "not resilient." Standing somewhere along the line represents a gradient.

Wrap Up and Transition (5 min)

- Introduce students to the idea of coastal protection and restoration. Tell them that once we understand the risk and vulnerabilities of an area, we are better able to become more resilient through different coastal projects. These projects are done at the local, state, and national levels. The Coastal Master Plan is at the state level (Slide 63). The next activity will include a more in-depth look at coastal protection and restoration projects.

Revisit Driving Question Board (10 min)

- Have students revisit the class Driving Question Board (DQB). You might consider doing this in small groups and then share out as a whole class. Ask the following questions:
    - › *Are there any questions that we can now answer?*
    - › *Do we want to re-arrange any of the questions?*
    - › *Are there any connections between topics that we should show on the DQB?*
    - › *Would anyone like to add any additional questions?*

Assign Journal Prompt #11.

- **Prompt #11:** Reflect on the communities from today's lesson. Many of these communities are facing increased flood risk due to Louisiana's coastal land loss crisis. What makes some Louisiana's coastal communities more or less resilient than others? Explain your thinking.

Background Information

Planning for Resilience

When communities make decisions about what actions to take to build resilience, they have to consider which areas have the most need, and which actions will have the largest impact. Resources such as time and money are often limiting factors, and local governments, and even individuals, must consider tradeoffs when deciding where to apply those resources. Determining risk and vulnerability help people plan and implement resilience efforts.

Risk: Combination of the threat, vulnerability, and consequences.
Vulnerability: The characteristics of a community that increase the exposure to a threat.

Factors that contribute to vulnerability:

- Poverty
- Geographic isolation
- Illness
- Disability
- Age

Resilience: The ability to recover from, or adapt to, difficulty.

Coastal Protection and Restoration

Local:

Information below from Terrebonne Parish Department of Coastal Restoration and Preservation (http://www.tpcg.org/index.php?f=coastal_restoration&p=index_)

- **Mission**: to provide aggressive leadership, direction, and consonance in the development and implementation of policies, plans, and programs which encourage multiple uses of the coastal zone and achieve a proper balance between development and conservation, restoration, creation, and nourishment of Coastal Resources in Terrebonne Parish for the enjoyment and long-term benefit of our residents.
- **Responsibilities and Services:**This office has a similar focus at the Parish level as the Governor's Office of Coastal Activities does at the State level. This office handles the coordination of Terrebonne Parish's interaction with the following:
  - CWPPRA
  - Louisiana Coastal Area Study
  - Louisiana Department of Natural Resources
  - Louisiana Office of Coastal Protection and Restoration

State:

Information below from CPRA & Louisiana's Coastal Master Plan (https://coastal.la.gov/)

- Following Hurricanes Katrina and Rita in 2005, the Louisiana Legislature created the CPRA and tasked it with coordinating the local, state, and federal efforts to achieve comprehensive coastal protection and restoration. To accomplish these goals, CPRA was charged with developing a master plan to guide our work toward a sustainable coast.
- Developed using the best available science and engineering, the master plan focuses our efforts and guides the actions needed to sustain our coastal ecosystem, safeguard coastal populations, and protect vital economic and cultural resources.

Extensions:

- Use Louisiana population and demographics data from the census to further explore a few of the common metrics for vulnerability. (https://data.census.gov/cedsci/all?q=Louisiana&g=0400000US22)
  - How would a community's age affect their risk? Income?

Project Resilience Teacher Guide

Lesson 6 > Addressing Coastal Land Loss

Students investigate the various projects included in Louisiana's Coastal Master Plan and the LA SAFE adaptation plans to determine the impacts of these projects on coastal communities. Lesson 6 is divided into four parts, each intended for about a day of instruction time.

Lesson 6: Part 1: Multiple Lines of Defense - Students will be able to identify CPRA projects along the coast and understand the impacts of these projects on the flood risk of coastal communities.
Lesson 6: Part 2: Adapting for the Future - Students will use the LA-SAFE Adaptation Plan to identify the difficulties associated with creating adaptation plans for Louisiana's coastal communities.
Lesson 6: Part 3: Reducing the Risks - Students will use flood risk scenarios from three Louisiana parishes to investigate types of risk reduction projects and understand how community factors impact the selection of the community's risk reduction projects.
Lesson 6: Part 4: Analyzing Adaptation Plans - Students will understand the environmental threats for Terrebonne Parish and investigate the effectiveness of the proposed LA SAFE adaptation plan.

Note: A field trip to visit local adaptation projects in your community is suggested as an extension to Lesson 6: Part 3 - Reducing the Risks. If possible, plan to take the field trip before beginning Lesson 7. An activity write up of the field trip taken during the Project Resilience pilot project is provided as an example should you decide to create a field trip for your students.

Time Required

- Teacher Preparation Time: approximately 50 min
- Part 1: 50 minutes
- Part 2: 50 minutes
- Part 3: 50 minutes
- Part 4: 50 minutes

Learning Goals

- Students will understand the difference between risk and vulnerability. *(Part 1)*
- Students will be able to identify and analyze the risks impacting their coastal communities. *(Part 1)*
- Students will gain experience evaluating the needs and values of their community as a way to create a plan for resilience. *(Part 2)*
- Students will understand why it is often difficult to create an adaptation plan for coastal communities. *(Part 2)*
- Students will explore the difference types of risk reduction projects. *(Part 3)*
- Students will understand the factors that communities must consider when selecting risk reduction projects. *(Part 3)*
- Students will evaluate proposed LA SAFE adaptation projects to determine which will have the most impact on community resilience. *(Part 4)*
- Students will learn about the environmental threats facing Terrebonne Parish, and which areas are most at risk. *(Part 4)*

Lesson Format

- Map reading
- Class discussion

Science Standards

Louisiana Student Standards for Science:

- HS-EVS1-2: Obtain, evaluate and communicate the effectiveness of management or conservation practices for one of Louisiana's natural resources with respect to common considerations such as social, economic, technological, and influencing political factors over the past 50 years.
- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.

Additional Dimensions:

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: ETS1.B: Developing Possible Solutions
- Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World

Part 1: Multiple Lines of Defense

Materials

- Project Resilience Slide Deck (slides 65-70)
- Projector & Computer
- Flood Risk and Coastal Communities Student Sheet (PDF)
- Coastal Projects in Louisiana Student Sheet (PDF)
- CPRA Terrebonne Parish Fact Sheet (PDF)
- CPRA Plaquemines Parish Fact Sheet (PDF)

Preparation

- Print out copies of the Flood Risk and Coastal Communities Student Sheet and the Coastal Projects in Louisiana Student Sheet, one copy per group.
- Gather details about any flooding events your school has experienced in the past.

Directions

Introducing Multiple Lines of Defense (15 min)

1. Begin by asking students: *How might coastal land loss affect our day to day activities?* If the students have trouble answering the question, ask the questions below. Remind students to think of how wetland loss and subsidence lead to an increase in flood risk.
    - Have they heard of any school flooding or any damage to schools from flooding events? Is there any way an increasing flood risk may affect health facilities (hospitals, doctor offices)? Could roadways be impacted by an increasing flood risk?
2. Pass out the *Flood Risk and Coastal Communities Student Sheet.* Once students have completed the student sheet, ask: *What did you find surprising about the flood risk information?* How could a community decrease their flood risk?
3. Introduce students to the concept of multiple lines of defense (Slide 66). Explain how these defenses affect the flood risk of a community.
    - Scientists and engineers work to integrate hurricane protection with coastal restoration efforts to develop defense strategies for coastal residents. Human-made barriers complement natural barriers to provide multiple lines of defense against storms.
4. Using the map of Terrebonne Parish (Slide 67), have students identify multiple lines of defense protecting their homes, both natural and human-made.
5. Ask: *What type of project or structure would form a strong defense for coastal communities?* Review the goal of the Coastal Master Plan from the end of Lesson 5. Introduce students to the plan's project list (Slide 68). Explain how these projects can form multiple lines of defense for coastal communities.

Introducing Multiple Lines of Defense (15 min)

1. Give each group a copy of the Coastal Projects in Louisiana Student Sheet. Explain that the type of coastal project constructed in an area depends on the project's location and the location's environmental threats. Using the Coastal Scenario Maps 1 & 2 and the CPRA Coast Master Plan Project Categories list, have students complete Task 1 of the student sheet.
    - The Scenario Maps are color coded to represent land loss over the next 50 years. If you are unable to print color copies for the students, the maps can be viewed on the slides.
2. Once the groups have completed Task 1, have them move to a computer and complete Task 2 using the CRMS Spatial Viewer website (lacoast.gov/crms_viewer/Map/CRMSViewer). Students will need to turn off the CRMS site layer by unchecking the CRMS box on the left and turn on the Master Plan layer.
    - If students do not have internet access, students can also use the CPRA Terrebonne Parish Fact Sheet and CPRA Plaquemines Parish Fact Sheet instead of the CRMS Spatial Viewer.
    - You might notice that the CRMS Spatial Viewer performs better on certain web browsers than others (Internet Explorer seems to load the fastest).
3. Once students have completed Task 2, ask: *Were any of your selected projects included in the parish's Master Plan list? What did you notice about the Plaquemines Parish projects? The Terrebonne Parish projects?*
    - Plaquemines Parish includes sediment diversions from the Mississippi River. Terrebonne Parish includes more marsh creation projects and structural projection projects.
4. Have students then zoom out to view the whole Louisiana coast (Slide 69). *What projects stand out to you? How will these projects protect areas of the coast from eroding further or help restore areas of the coast that have been lost? How will these projects help coastal communities adapt to rising sea levels? How do these projects form or reinforce multiple lines of defense for coastal communities?* (Slide 70)

Directions (continued)

5. Review the definition of adaptation and explain the difference between resilience and adaptation. An example of resilience is identifying possible evacuation shelters in case of severe flooding, while an example of adaptation would be raising your home after flooding. Have students return to their CPRA Project list from the Coastal Projects in Louisiana Student Sheet. Ask: *Which projects would you consider to be resilience projects? Adaptation projects? Why are both types of projects necessary for the restoration and protection of the coast?* Explain that communities will still have to adapt to a changing coastline, even with the coastal protection and restoration projects.
    - Explain to students that community adaptations can increase the resilience of the community.
    - Terrebonne Parish is still projected to lose 40% of its land in the next 50 years, even with the planned projects.

Revisit Driving Question Board (10 min)

- Have students revisit the class Driving Question Board (DQB). You might consider doing this in small groups and then share out as a whole class. Ask the following questions:
    - *Are there any questions that we can now answer?*
    - *Do we want to re-arrange any of the questions?*
    - *Are there any connections between topics that we should show on the DQB?*
    - *Would anyone like to add any additional questions?*

Assign Journal Prompt #12.

- **Prompt #12:** Think of a coastal project in or around your community. How has this project affected your community? (The Coastal Projects in Louisiana Student Sheet from today's lesson lists the different types of coastal projects.

Background Information

Adaptation: becoming more suited to your environment

CPRA Coastal Master Plan
Information below from the Coastal Protection and Restoration Authority (https://coastal.la.gov/)

- Who is CPRA?
  - The CPRA is established as the single state entity with authority to articulate a clear statement of priorities and to focus development and implementation efforts to achieve comprehensive coastal protection for Louisiana.
  - The Coastal Protection and Restoration Authority's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration Master Plan.
- History
  - Formed 2005 after the effects of Hurricanes Katrina and Rita
  - First Coastal Master Plan published in 2007
    - Updated every five years
- Coastal Master Plan
  - Developed using the best available science and engineering, the master plan focuses our efforts and guides the actions needed to sustain our coastal ecosystem, safeguard coastal populations, and protect vital economic and cultural resources.
  - Additionally, the master plan provides the context needed to evaluate other activities in the coastal zone, including transportation, navigation, and port projects; oil and gas development; groundwater management and land use planning.
- Project descriptions
  - Restoration Projects
    - Bank Stabilization: Onshore placement of earthen fill and vegetative plantings designed to reduce wave energies and maintain shorelines in open bays, lakes, and bayous.
    - Barrier Island/ Headland Restoration: Creation and restoration of dune, beach, and back-barrier marsh to restore Louisiana's offshore barrier islands and headlands.
    - Diversion: Use of channels and/or structures to divert sediment and fresh water from the Mississippi and Atchafalaya Rivers into adjacent basins.
    - Hydrologic Restoration: Project features that restore natural hydrologic patterns either by conveying fresh water to areas that have been cut off by human-made features or by preventing the intrusion of saltwater into fresh areas through human-made channels and eroded wetlands
    - Living Shoreline: Establishment of bioengineered oyster reefs to improve oyster propagation and serve as breakwaters to attenuate wave energies.
    - Marsh Creation: Creation of new wetlands in open water areas through sediment dredging and placement.
    - Ridge Restoration: Re-establishment of historic ridges in basins through dredging, sediment placement, and vegetative plantings to restore natural ridge functions.
    - Shoreline Protection: Near-shore rock breakwaters to reduce wave energies on shorelines in open bays, lakes, sounds, and bayous.
- Risk Reduction Projects
  - Structural Protection: levees, floodgates, floodwalls, and pump stations
  - Nonstructural Protection: elevation, floodproofing, voluntary, and acquisition
- Cost
  - The total cost of the plan is $50 billion.
- Terrebonne Parish projects:
  - Barrier island restoration
  - Raccoon Island
  - Whiskey Island
  - Trinity Island
  - East Timbalier Island
- Marsh creation projects
  - North Lost Lake Marsh Creation/Enhancement Project
  - Madison Bay Marsh Creation and Terracing
- Freshwater introduction

Part 2: Adapting for the Future

Materials

- Project Resilience Slide Deck (slides 71-72)
- Projector & Computer
- LA SAFE Adaptation Student Sheet (PDF)

Preparation

- Print copies of the LA SAFE Adaptation Student Sheet. One for each group.

Directions

Consider what adaptation means for coastal communities (15 min)

1. Begin by reviewing the definition of adaptation (Slide 71) from the day before and asking: *What is an example of a community adapting to changing environmental conditions?*
    - Write these adaptation examples on a whiteboard at the front of the classroom.
2. Explain how Louisiana's people have adapted to environmental conditions in the past. Have the students then come up with at least five examples of community adaptations. These examples will be needed later on in the lesson.
    - In the late 1700s, Cajuns swapped from wheat to rice due to the change in climate (see Rice Story included in background information).
    - New Orleans planters also began swapping from indigo to sugarcane crops in the late 1700s due to drought, insects, and loss of market.
3. Engage in a discussion by asking: *What environmental factors are affecting coastal communities right now? What factors will impact these communities in the future? What problems are these communities facing due to these environmental factors?*
4. Have students consider the various factors necessary to design an adaptation project. *What type of factors would you need to consider when putting together an adaptation project for a coastal community?*
    - Examples of factors: geography, economics, demographics, values
5. Ask: *Would you have any tough decisions or trade-offs when designing an adaptation project?* Explain that many adaptation strategies require tough decisions and compromise. Ask: *What type of compromises would the communities have to make?*

Explore how adaptation plans are created (35 min)

1. Divide students into groups and provide each with a copy of the LA SAFE Adaptation Student Sheet. Explain to the students that these questions are some of the first questions asked when forming an adaptation plan. Have students discuss and complete questions 1-5 on the student sheet.
    - Instead of working as a group, students could work individually to complete questions 1-5 of the *LA SAFE Adaptation Student Sheet.*
2. Once questions 1 through 3 are completed, ask the following: *Was it easy to answer these questions? Did you have to make any tough decisions? Did everyone in your group agree? Was it easy to compromise?* It is important to realize that this process can be difficult, and compromises are necessary to move forward.
3. Using question 3 from the *LA SAFE Adaptation Student Sheet*, have each student write down which issue they believe to be the most important. This can differ from the issue the group chose. After writing down their selection, students should find a partner that was not in their group. Partners will take turns explaining why they chose that specific issue as the most important for the parish. Remind students the goal of this activity is to relate to or understand other viewpoints.
4. After explaining their reasoning, students will exchange issues and find a new partner. Using their new issue, students will explain why their new issue is the most important to the parish. Students will use what they just heard from their first partner to explain their new issue. Repeat with another partner, if time allows.
5. Have students return to their original groups and complete questions 4 and 5. Each group will have to compromise and have one completed list for each question. Repeat the questions from step 4.
6. Introduce LA SAFE (Slide 72). Have you heard of LA SAFE or the adaptation strategies for Terrebonne parish?
7. Explain that the questions on their *LA SAFE Adaptation Student Sheet* were also used during LA SAFE meetings to identify important factors within the communities.

Assign Journal Prompt #13

- **Prompt #13:** To form parish adaptation plans, LA SAFE held several rounds of community meetings. The goal of these meetings was to receive input from the residents about what type of adaptation projects they wanted to see in their community. Do you think this is an effective process for developing community adaptation plans? Why or why not? What aspects of your community would you want to protect with an adaptation project?

Background Information

Adaptation: becoming more suited to your environment

Adaptation examples from the past:

- The story of rice - When Cajun peoples migrated from Nova Scotia they brought wheat with them, but found that it didn't grow well in their new envrionment. However, they discovered that rice did grow well. The Cajun people adapted to using rice their dishes instead of wheat. Over time, rice became a staple in the culture of Cajun cooking.

Adaptation examples from the present:

Information below from LA SAFE: Regional & Parish Adaptation Strategies (https://lasafe.la.gov/)

- LA SAFE - Louisiana's Strategic Adaptations for Future Environments (all LA SAFE info used from Terrebonne adaptation plan)
- Mission: Working together for community resilience, economic prosperity, and a better quality of life for everyone in Louisiana.
- Goals:
  - To generate parish-wide, community-driven adaptation plans focused on opportunities for residents and stakeholders to proactively adapt and prepare for anticipated environmental changes over the next 10, 25, and 50 years.
  - To implement a catalytic project in each of the six parishes that demonstrates adaptive development practices that conform to current and future flood risks. Furthermore, LA SAFE is intended to identify and support the development of resilience-building projects and practices that can serve as models for the entire region.
  - To create a statewide adaptation model that enhances long-term sustainability and resiliency for all Louisiana parishes.
- To help address these complex issues in a holistic manner, the National Disaster Resilience Competition (NDRC), sponsored by the U.S. Department of Housing and Urban Development (HUD) and the Rockefeller Foundation, awarded funding for LA SAFE—Louisiana's Strategic Adaptations for Future Environments. The LA SAFE program supports an inclusive public process to identify adaptation strategies and provides funding for at least one catalytic project in each parish.
- The LA SAFE planning process focuses on six parishes that were heavily impacted by Hurricane Isaac in 2012: Terrebonne, Plaquemines, Lafourche, St. John the Baptist, Jefferson, and St. Tammany, as well as the region as a whole.
- Project examples:
  - Buyout programs
  - Education centers
  - Harbors of Refuge
  - Mental Health and Substance Abuse Programs

Part 3: Reducing the Risks

Materials

- Project Resilience Slide Deck (slides 73-78)
- Projector & Computer
- Risk Reduction Student Sheet (PDF)

Preparation

- Print out copies of the Risk Reduction Student Sheet, one copy per group.

Directions

Learning about different kinds of restoration projects (40 min)

1. Review the list of restoration projects within the Coastal Master Plan (Slide 73). Explain that the plan also includes some adaptation projects in addition to protection and restoration projects. *What comes to mind when you hear of a risk reduction project?*
2. Introduce the two categories of risk reduction projects: Structural protection and nonstructural protection (Slide 74). What is the difference between the two projects? *What are some examples of a structural protection project? Nonstructural protection?* Introduce the Morganza to the Gulf levee system as a structural protection project (Slide 75).
3. Discuss the examples of nonstructural protection: floodproofing, elevated houses, voluntary acquisition. *Have you seen any elevated houses? Where? Do you know anyone that has moved due to their flood risk increasing? Do you know of anyone who has moved due to rising flood insurance costs?*
4. If a community's flood risk increases dramatically and they face permanent inundation in the next 50 years, a community resettlement plan may be necessary. *What would you need to take into consideration for a community resettlement plan? What factors would influence a nonstructural project?*
5. Pass out the *Risk Reduction Student Sheets* and have students divide into pairs. Explain to students that each color represents a different flood depth. Using the color key (with the elevated house), students can see how the flood risk changes throughout the region. Have the students read the parish description and answer the questions for Scenarios 1-3. They should be able to list at least four factors and at least one risk reduction project recommendation for each scenario.
6. Discuss as a class what factors each pair has recorded and which projects they recommend (scenario maps are included in Slides 76-78). Ask students: What long term environmental problems may affect these adaptation projects? Would the group's project be successful in the long term?

Revisit Driving Question Board (10 min)

- Have students revisit the class Driving Question Board (DQB). You might consider doing this in small groups and then share out as a whole class. Ask the following questions:
  - *Are there any questions that we can now answer?*
  - *Do we want to re-arrange any of the questions?*
  - *Are there any connections between topics that we should show on the DQB?*
  - *Would anyone like to add any additional questions?*

Assign Journal Prompt #14

- **Prompt #14:** Many different types of projects are being constructed along the Louisiana coast, including both restoration projects and risk reduction projects. What type of factors will officials need to consider when designing risk reduction projects? What different factors would they need to consider constructing structural protection projects versus nonstructural?

Background Information

Risk Reduction:

- Structural Protection: reduce flood risk by acting as a physical barrier against storm surge. Examples include:
  - Levees
  - Floodgates are needed where levees or concrete walls cross a road or railroad or where they intersect waterways.
  - Floodwalls are typically located at points along earthen levees that have a high potential for erosion, or insufficient space for the wide slopes of an earthen levee. Floodwalls were specified at junctions with water crossings, railroads, and major roadways (i.e., interstates and state highways).
  - Pump stations are needed in enclosed risk reduction systems to allow water that enters a polder to be pumped out. Pumps were included as features of most of our protection measures.

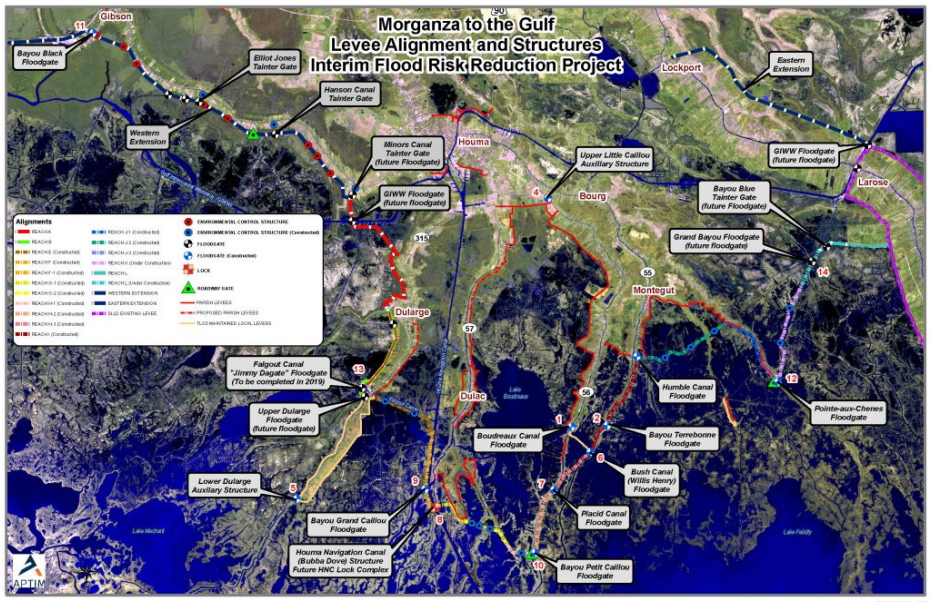
Background Information (continued)

- Nonstructural Protection: elevate and floodproof buildings, help property owners prepare for flooding, or move out of areas of high flood risk. Examples include:
  - Elevation of residential structures is recommended in areas with a projected 100-year flood depth of between 3 and 14 feet so that their lowest floors are higher than projected flood depths.
  - Floodproofing of non-residential structures is recommended in areas with projected 100-year flood depths of 3 feet or less, so they can be resistant to flood damage. Floodproofing of a residential building does not affect the flood insurance rating. Frequently asked questions about nonstructural protection: http://coastal.la.gov/wp-content/uploads/2017/04/Nonstructural-FAQs_FINAL_2017-10-11.pdf
  - Voluntary Acquisition of residential structures is recommended in areas where projected 100-year flood depths make elevation or floodproofing infeasible, and where residential structures would need to be elevated higher than 14 feet.
  - Examples:
  - Buyouts for Permanent Resident Households (LA SAFE)
  - Elevated homes (houmatoday.com/news/20170424/council-approves-use-of-federal-funds-for-home-elevations)

Morganza to the Gulf Levee System

(Morganza Action Coalition: http://www.morganza.org/morganza-to-the-gulf-description/)

- The Morganza-to-the-Gulf Hurricane Protection System is a levee, lock, and floodgate system designed to provide 100-year, Category 3 storm surge protection to more than 150,000 people living in coastal Terrebonne and Lafourche Parishes (60 miles southwest of New Orleans) as well as over 1,700 square miles of fresh and saltwater marsh.
- The tentatively selected plan in the PAC report consists of:
  - approximately 98-miles of earthen levees ranging from 9 – 15 feet
  - 22 floodgates on navigable waterways
  - 23 environmental water control structures
  - One lock complex consisting of a lock in the Houma Navigation Canal measuring 110-ft wide by 800-ft long, an adjoining floodgate measuring 250 feet wide, and a dam closure
  - Nine road gates
  - fronting protection for four existing pump stations.
- No Federal funds have been appropriated for construction of the Morganza to the Gulf project; however, the non-Federal sponsor is using state and local funds to construct interim features along the authorized alignment in advance of the Federal project.
- As of December 2017, approximately 45 miles of levees and floodgates along the Morganza to the Gulf alignment from Cut Off to Bayou Dularge are permitted, under construction, or completed. All with only local and state funding.
- $450 million in local and state funds have been invested to date in the Morganza system, and projects totaling $500 million are in the planning phase.



Extensions

Field Trip

1. See an example of a resilience field trip to Isle de Jean Charles, Louisiana (a copy is below and at scied.ucar.edu/activity/field-trip-finding-resilience-your-community).
    - This field trip included examples of coastal land loss and adaptation projects at both the community and the individual level.
2. Research potential field trip locations that would provide an example of resiliency within the community. Depending on the locations, you may be able to include multiple locations in one field trip. At least one field trip location should include a constructed resilience project. If possible, determine two field trip locations. One field trip location without a resilience project and the second location with a resilience project.
3. Once you determine the locations, research the individual projects or potential projects for that specific location. Determine why the project was constructed and how it will impact the area into the future. If possible, invite one of the project coordinators to speak with the students during the field trip.
4. Develop a field trip schedule. If you have two locations, begin with the resilience project location (with the guest speaker if included) and then visit the second location. Students may have to remain on the bus depending on the project locations. If students cannot walk around the field trip location, include a short stop with available restrooms. Include a lunch stop (such as a park) if you will be returning after the school's normal lunch hour.
5. Set your field trip date. Follow your school's policy for bus reservations and student permission forms.
6. Have students bring paper and pencil on the field trip. Encourage students to write down observations about the field trip locations and their community. Students could also take pictures of the resilience projects or of areas that would benefit from a resilience project.
7. Have students think about the following questions:
    - What is the history of this area?
    - What environmental problems will this community face in the future? (These problems will be very similar to the problems addressed in Lessons 1-3)
    - Why did they construct this resilience project? How will it help the community?
    - What other locations in the community would benefit from a resilience project?
    - How will your school resilience plan tie into the resiliency of the community?

Field Trip Example: Finding Resilience in Your Community

Students visit locations of coastal protection and adaptation projects to observe how land loss impacts their community.

Time Required:

- 2.5 to 3 hours
- The total trip time only includes the time spent on Hwy 665 and Island Road. This total time does not include the amount of time to get from the school to Hwy 665 or return from Hwy 665 to the school.

Student Learning Objectives

- Students will observe the impacts of coastal land loss in a local community.
- Students will identify coastal protection and adaptation projects throughout the community and understand the role these projects play in reducing the community's flood risk.

Materials

- Field Trip Maps (1-4) (PDF)
- Field Trip Photo Record (Google Sheet)
- Clipboards and pencils
- Cameras (one for each pair of students, phone camera is okay)
- Computers with internet access

Extensions

Field Trip Example continued

Preparation

- Completed bus request, including field trip locations
- Completed permission slips for each student
- Print out copies of the Field Trip Maps (1-4) and Field Trip Photo Record, one for each pair of students
- Print out a copy of the activity directions to bring with you on the field trip
- Download a mileage app (you will need to track the mile numbers once you turn on Hwy 665)

Directions

Note: The Pointe-Aux-Chene field trip can serve as a reference to help you plan an experience that highlights adaptation projects in your area.

Before leaving the school: Divide students into pairs and give each pair a clipboard with a set of Maps (1-4). Students will need to take turns being the map holder/recorder and the photographer during the field trip.

Map 1 of 4

1. Use the provided directions to reach LA Hwy 665 (Pointe-Aux-Chene Road). Once you reach La HWY 55 at the Klondike stoplight, have students look at Map 1. Explain that many people have adapted their homes due to the increased flood risk the area is experiencing. Tell students that once they turn on to Pointe-Aux-Chene Road, they will follow the directions for Map 1. They will only need to consider the houses on their side of the bus. Have students note on their maps if these houses were to the east or the west of the road.
2. Once you turn on to the road, begin the mileage counter. Mile 0 should be the beginning of Pointe-Aux-Chene Road. Do not stop the mile counter. Mile numbers will be used throughout the lesson to point out locations along Pointe-Aux-Chene Road. Students should begin tallying the houses on their side of the bus with Map 1 until they reach the Pointe-Aux-Chene Elementary School (Mile 2.6). Students should total up the number for each category. They will refer back to these numbers once they return to school.

Map 2 of 4

3. Students should now turn to Map 2. This map begins at the Pointe-Aux-Chenes Supermarket (Mile 3.2). As you pass the supermarket, students should begin looking for signs of coastal land loss problems. These could include signs of hurricanes/tropical storms, saltwater intrusion, erosion, etc. The map holder will record these notes on their map, and the photographer will take a picture. Students should mark on their map approximately where the picture was taken. As students add these coastal land loss signs to their map, students should develop a key of symbols to differentiate between each coastal land loss problem.
    - Dead trees from saltwater intrusion will be the first sign of coastal land loss issues. As you pass the supermarket, the dead trees will begin becoming visible to the east and the west.

Map 3 of 4

4. Once the bus reaches The Father's House Church (Mile 5.9), students should turn to Map 3. Students will continue to look for signs of coastal land loss problems but should also begin to look for signs of coastal projects. As students find these projects, the projects should be included on their maps with a new symbol. Students should also add this new symbol to their map key. As you reach Mile 6 on your mileage app, begin looking for a road on the right. At Mile 6.3, slowly turn right and park the bus outside of the gate to Reach J-1 levee. A sign will be next to the gate explaining the Morganza to the Gulf levee system. Have students exit the bus (leaving their clipboards on the bus) and walk through the side gate towards the levee. Have students gather at the base of the levee and ask them what they notice. Ask students what they remember about Morganza to the Gulf. Explain the importance of the levee system.
5. Walk to the top of the levee. Ask students to describe what they see. Students should also take pictures of anything they find important. These pictures will be used once they return to the classroom.
6. Return to the bus. Give students ~5 minutes to record any of their thoughts on Map 3. Turn right on to Pointe-Aux-Chene Road. Continue down the road. Students should continue to look for evidence of coastal land loss problems and record any they see.

Field Trip Example continued

Map 4 of 4

7. At Mile 8.5, turn onto Island Road. Have students swap to Map 4. Students should begin recording evidence of any coastal protection, restoration, or adaptation projects on the map.
8. As you approach the levee, ask students if they know which levee system the levee is a part of. Remind students of Morganza to the Gulf levee system. Ask students what they notice as they drive down Island Road. Have them record any thoughts on their map along with any projects they see.
9. Point out the terracing to the right of the road. Let students know that they should keep an eye out for these types of projects.
10. As you reach Mile 11.3 (you will be entering Isle de Jean Charles), have students look to the right at the canals. Remind students of the impacts of canals and have them look for any other canals along the way.
11. Continue down the road until you reach the Isle de Jean Charles Marina at Mile 12.7. Turn the bus around and return to Pointe-Aux-Chene Road. As you leave Isle de Jean Charles, tell the students the history of the Island, including the Island's rapid land loss. Have students think about the impact of storms, major or minor, on the island's community.
12. At Mile 16.9, turn right off of Island Road and continue to the Pointe-Aux-Chene Floodgate. Let students know this is still part of the Morganza to the Gulf system. Pull the bus to the end of the parking lot and point out the canals. Remind students to note and take pictures of any coastal land loss problems. Point out the dead trees along either side of the canal.
13. Turn around in the parking lot and return to Pointe-Aux-Chene Road. Continue up the road until you get to the LDWF Pointe-Aux-Chene headquarters office (Mile 20.3). Turn right over the bridge to the office and park the bus by LOCATION. Students can exit the bus and sit underneath the pavilion for lunch.
14. After lunch, return to the school.
15. Once settled back in the school, have each pair of students use Google Earth to pull up Pointe-Aux-Chene Road and the Pointe-Aux-Chene Road PowerPoint. Have students add their notes from their paper maps into the Pointe-Aux-Chene Road PowerPoint along with any pictures they may have taken. Once they have added their notes, have students explore the road on Google Earth. Have them record any thoughts on their PowerPoint.

Assign the following journal questions:

- Would you consider these communities resilient? Why or why not?
- What are some ways these communities can adapt for the future?

Extensions

If time allows, students can use their pictures and notes to create an ArcGIS Story Map using the links below.

- Learn more about ArcGIS Story Maps (https://storymaps-classic.arcgis.com/en/)
- Create an ArcGIS account and a Story Map (https://storymaps-classic.arcgis.com/en/app-list/)

Background Information (additional information for field trip)

Isle de Jean Charles (Welcome to Isle de Jean Charles, http://www.isledejeancharles.com/)

- Isle de Jean Charles is a narrow island in the bayous of South Terrebonne Parish, Louisiana. A place of immense physical beauty and great biodiversity, it is most importantly home to the Isle de Jean Charles Band of Biloxi-Chitimacha-Choctaw Tribe.
- Isle de Jean Charles is in Terrebonne Parish, Louisiana, situated between Bayou Terrebonne and Pointe-aux-Chene. Bayou Pointe-aux-Chene is the boundary between Terrebonne and Lafourche Parish. Before the establishment of Terrebonne parish in 1822, Terrebonne Parish was once part of Lafourche Interior Parish. The Island is split down the middle by Bayou St. Jean Charles.
- Until the "Island Road" was built in 1953, the only sure method of transportation to and from the Island was by boat. Previously, there had been a wagon path along a narrow ridge going to Point Farm and Bayou Terrebonne, but it was impassable at times of high water, which came in when the wind blew from the south or southeast.
- In 1953, a road connecting Isle de Jean Charles to Pointe-aux-Chene was built through the marshland. For several decades, the marshland has eroded and turned into the open water, leaving the road vulnerable to erosion and flooding. Tribal elders today believe that the location of the road was not only an unwise one, but the construction has added to the erosion of the Island as well. After years of advocating that the road be repaired and built higher, the parish finally completed a $6.24 million restoration and elevation of the road in June 2011. However, we were informed at this time that it would be the last time they fix the road, and now just six years after this victory, the road floods regularly during tropical storm systems, high tides, and even just on days with a strong southern wind. When the road is flooded, we worry that elders who live on the Island will be unable to get medical services they need when an ambulance is unable to pass.
- The Morganza to the Gulf Flood Protection System is being built to protect communities along the Louisiana Coast but will pass north of the Isle de Jean Charles because the Army Corps of Engineers determined in1998 it was not cost-effective to include the Island. This leaves our Tribe and our ancestral homelands more vulnerable to the encroaching Gulf waters.
- For our Island people, it is more than simply a place to live. It is the epicenter of our Tribe and traditions. It is where our ancestors survived after being displaced by Indian Removal Act-era policies and where we cultivated what has become a unique part of Louisiana culture. Today, the land that has sustained us for generations is vanishing before our eyes. Our tribal lands are plagued by a host of environmental problems — coastal erosion and saltwater intrusion, caused by canals dredged through our surrounding marshland by oil and gas companies, land sinking due to a lack of soil renewal or "crevasse," because of the construction of levees that separated us from the river, and rising seas. These environmental changes have led to increasing flood risks and changes in our way of life. For example, our Island needed a levee, but the small levee that protects our Island during high tide has also led our bayou to become stagnant, killing the ecosystem we once had. The need for reliable access to jobs and services up the bayou have forced many of our people to nearby areas, including Pointe-aux-Chenes, Bourg, Montegut, Chauvin, along Bayou Grand Caillou, and Houma. For over fifteen years, we have been planning a Tribal Resettlement in order to bring our people back together, rejuvenate our ways of life, and secure a future for our Tribe.

Part 4: Analyzing Adaptation Plans

Materials

- Project Resilience Slide Deck (slides 79-81)
- Projector & Computer
- Terrebonne LA SAFE Student Sheet (PDF)
- CPRA Terrebonne Parish Fact Sheet (PDF) (from Part 1)
- Terrebonne LA SAFE Proposal Summary (PDF)
- Terrebonne Project Boards (PDF)

Preparation

- Make copies of the Terrebonne LA SAFE Student Sheet, CPRA Terrebonne Parish Fact Sheet, Terrebonne LA SAFE Proposal Summary, and the Terrebonne Project Boards. One copy for each group.
    - Use legal size paper for the Terrebonne Project Boards.

Directions

1. Pass out the *CPRA Terrebonne Parish Fact Sheet*. Review the impacts of coastal land loss on Terrebonne Parish. Pose the following questions for students to consider as they read (Slide 79): *Why has Terrebonne parish lost such a large amount of land? What are the largest environmental threats in the parish?*
    - The Terrebonne Basin has one of the highest land loss rates in the state of Louisiana due to high subsidence rates, sea level rise, and saltwater intrusion.
2. Explain how coastal communities in Terrebonne Parish have already begun adapting to an increase in flood risk due to land loss within the parish. Explain that many of these adaptations are on an individual level, and a long term adaptation plan for the parish is needed. Remind students of the goal of LA SAFE and the LA SAFE process.
    - Individuals in a high-risk flood area may elevate their homes to prevent flooding (Slide 80).
3. Break students into groups. Pass out the *Terrebonne LA SAFE Proposal Summary*. Introduce the students to the six proposed projects in the *Terrebonne LA SAFE Proposal Summary*. Explain how these proposed projects would help the communities in the parish become more resilient. Give each group a copy of the Terrebonne Project Boards and the *Terrebonne LA SAFE Student Sheet*. While reviewing the proposals, students will use the student sheet to evaluate the projects.
4. Have students complete Part 1 of the student sheet. Part 1 will allow students to analyze each proposed project. Once they have completed Part 1, students can move to Part 2 and begin rating the proposals. Remind groups that they will need to be able to explain their reasoning behind their ratings.
5. Once all of the groups have rated the proposals, ask each group what their top proposal was and why that proposal was chosen. *What environmental problem or threat does this proposal face? Would this proposal work as a long term adaptation plan? Will this proposal need any maintenance or monitoring down the road? Who will specifically be impacted by this proposal? How would your top-ranked proposal make the communities within the parish more resilient?* (Slide 81)
6. Have the students shift now to thinking about their school. Explain to students that just as LA SAFE worked to develop resilience projects for coastal communities, they will develop a resilience plan for their school community. What parts of the LA SAFE process may help develop your school's resilience plan? Direct students to look back at their *LA SAFE Adaptation Student Sheet* from Part 2. Would you be able to use these same questions to help develop your school's plan?
    - As LA SAFE developed community adaptation plans, they held both large parish meetings and small community discussions to understand the residents' concerns. Each new meeting introduced the work LA SAFE had completed and asked for residents' input to ensure the creation of a beneficial adaptation plan for the community.
7. Explain that students will first need to identify environmental problems affecting their school community. What types of environmental problems affect your school? Are there any areas on campus that flood frequently? Have the students begin a list of environmental threats (including long term) that may have an impact on their school. Many of these environmental threats should come from their list of environmental problems from Lesson 4 Part 1. Write these problems on a board at the front of the room. This list will be used in the following activities.
    - Examples of environmental threats affecting your school could include an increase in campus flooding due to erosion, subsidence, or heavy rainfall.
    - Ask students if there are any problems that were mentioned by school community members that should be included in the list. Students should discuss the possible environmental threats behind these campus problems and include these threats on the list at the front of the room.

Assign Journal Prompt #15

- **Prompt #15:** Looking at today's LA SAFE pilot proposals for Terrebonne Parish, your group may have compromised while rating the proposals. Which proposal do you consider the most important or the most effective? What community problem(s) does this proposal address? Describe if this proposal represents a long term or short term adaptation plan. List five points below to support your chosen proposal.

Background Information

LA SAFE- Louisiana's Strategic Adaptations for Future Environments (about the Terrebonne adaptation plan)

Information below from LA SAFE: Regioinal & Parish Adaptation Strategies (https://lasafe.la.gov/)

- Goals:
  - To generate parish-wide, community-driven adaptation plans focused on opportunities for residents and stakeholders to proactively adapt and prepare for anticipated environmental changes over the next 10, 25, and 50 years.
  - To implement a catalytic project in each of the six parishes that demonstrates adaptive development practices that conform to current and future flood risks. Furthermore, LA SAFE is intended to identify and support the development of resilience-building projects and practices that can serve as models for the entire region.
  - To create a statewide adaptation model that enhances long-term sustainability and resiliency for all Louisiana parishes.

Project Resilience Teacher Guide

Lesson 7 > Resilience in Action

Students explore resilience toolkits to better understand their value. They draw upon these toolkits to design a resilience plan for their school campus as the culminating task of *Project Resilience.* Lesson 7 is divided into five parts, each intended for about a day of instruction time, though extra time may be required as students develop projects for the school resilience plan.

Lesson 7: Part 1: Breaking Down Resilience Toolkits - Students will investigate various adaptation plans used throughout Louisiana to understand the necessary steps for designing an adaptation project.
Lesson 7: Part 2: Making Our School More Resilient - Students will identify environmental problems affecting their school campus, which is the first step in creating a school resilience plan.
Lesson 7: Part 3: Project Design - Students use the resilience toolkit to design a detailed plan for adaptation projects that would benefit their school campus.
Lesson 7: Part 4: Present and Revise - Students present their group adaptation project to the class and then revise their plan based on peer-review.
Lesson 7: Part 5: Creating Our School Resilience Plan - Students create a school resilience plan with their revised adaptation project plans.

Time Required

- Teacher Preparation Time: estimated 1-3 hrs
- Part 1: 50 minutes
- Part 2: 50 minutes
- Part 3: 50 minutes
- Part 4: 50 minutes
- Part 5: 50 minutes

Learning Goals

- Students will become familiar with several adaptation plans used throughout Louisiana *(Part 1)*
- Students will identify the environmental problems that are impacting their school campus *(Part 1)*
- Students will brainstorm projects that would make their school campus more resilient *(Part 1)*
- Students will analyze the school campus through the lens of environmental problems that affect the school community. *(Part 2)*
- Students will begin planning projects to address environmental issues on their school campus. *(Part 2)*
- Students will examine two examples of adaptation projects to inform their own project development. *(Part 2)*
- Students will analyze and appreciate the value of resilience toolkits. *(Part 3)*
- Students will design projects to address environmental issues on their school campus as part of a school resilience plan. *(Part 3)*
- Students will present their project plans to the class and provide feedback about the other group's presentations. *(Part 4)*
- Students will revise their project plans based on peer feedback. *(Part 4)*
- Students will analyze and appreciate the value of resilience toolkits. *(Part 5)*
- Students will design projects to address environmental issues on their school campus as part of a school resilience plan. *(Part 5)*
-

Lesson Format

- Class discussion
- Design activity

Science Standards

Louisiana Student Standards for Science:

- HS-EVS1-3: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Additional Dimensions:

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: ETS1.C: Optimizing the Design Solution

Part 1: Breaking Down Resilience Toolkits

Materials

- Project Resilience Slide Deck (slide 81)
- Projector & Computer
- Student access to computers/tablets (optional)
- Example School Resilience Plan (PDF)
- Identifying Potential Projects Student Sheet (PDF)
- Adaptation Recommendations (PDF)
- Strategies and Best Practices for Coastal Louisiana (PDF)
- Terrebonne Parish Adaptation Plan- Goal 1: Manage Flooding and Subsidence (PDF)

Preparation

- Arrange for a member of the school's administration to stop by for 15 minutes of this lesson to discuss any environmental problems the school has experienced throughout the years. They will only need to stay for the question and answer period.
- Do research to help support your students as they begin exploring environmental problems at your school campus. Ask members of the school's administration, other teachers, or the maintenance team if they know of any problems on the school's campus that may be related to environmental factors (for example, flooding in a particular part of campus after a storm). Other members of the school community might be able to help you identify campus problems.
- Make copies of the readings, one copy for each group. Alternatively, provide links to the readings and have student access them digitally.
    - Adaptation Recommendations
    - Strategies and Best Practices
    - Terrebonne Parish Adaptation Plan: Goal 1
- Make copies of the *Example School Resilience Plan* and the *Identifying Potential Problems Student Sheet,* one copy for each group.

Directions

Introduce the School Resilience Plan (10 min)

1. Break students into groups and pass out a copy of the *Example School Resilience Plan* to each group. Explain that students will be creating a similar resilience plan for their school campus. Have the students review the project from the example. Ask: *How does this project make the school more resilient? What environmental threat do you think the school was trying to address?* Students can refer back to this example as they create their own resilience plan.
    - The example plan only lists one school project example. Remind students that their class will have three or more projects in their resilience plan.
2. Review the lists of environmental threats affecting the school from Lesson 6: Part 4.
3. Have students make a list of any questions they have about these problems and explain that they will have the opportunity to ask a school administrator their questions. Questions included on this list should help students understand the impacts of these environmental problems on their campus. Students will be able to use the answers to develop their school's resilience plan. Encourage each group to have at least three questions.

Learn About Environmental Problems at Your School (20 min)

1. Have a member of the school's administration join the students for approximately 15 minutes of this lesson. Using the question list that they just developed, have groups take turns asking questions to further their understanding of the environmental problems affecting their school campus. Remind students that these questions and answers will help them with their plan.
    - If possible, take your class on a tour of the school's campus. During the tour, ask students to identify problem areas.
    - After the administrator leaves, have students summarize what they learned about the environmental problems facing the school. Ask: *Do we have any new school problems to add to our list? Which of the problems on our list is the most troublesome for the school campus? Is there an area on campus that is more affected by one of the school problems?*

Directions (continued)

Explore Adaptation Planning (20 min)

1. After the students finish with their questions, introduce the students to the steps of a resiliency toolkit. Explain that identifying the risks or hazards is the first step to developing an adaptation plan. Students have already completed Step 1 and part of Step 2. Step 3 will allow them to investigate various practices and strategies used to help communities adapt.
    - Steps to Resilience:
    - Step 1. Explore Hazards
    - Step 2. Assess Vulnerability & Risks
    - Step 3. Investigate Options
    - Step 4. Prioritize & Plan
    - Step 5. Take Action
2. Provide each group a copy of the *Adaptation Recommendations from CPEX reading*. Explain that adaptation options vary depending on the type of environmental threat and the community level. Adaptation projects at the state level will vary from projects at the local level and the residential level. From this list, have students identify which threats may pose the biggest problem for their school community.
3. Have the students then look through the state, local government, and residential adaptive actions. Ask: *Do any of these projects stand out to you? Are there multiple projects that address a single issue? Are there any that really interest you or that you would like to see? Would you be able to do any of the local or residential adaptive actions at your school?*
4. Provide each group a copy of the *Strategies and Best Practices for Coastal Louisiana* reading. Explain that this reading has broken up adaptation strategies and practices based on the different regions of the coast. Ask: *What projects or plans stand out to you? What do you think of the options? What type of strategies are listed for our area? What is the difference between this reading and the previous reading (Adaptation Recommendations)?*
    - The Strategies and Best Practices reading recommended projects based on specific regions along the coast.
5. Explain that many of the strategies listed for our area relate to managing the effects of subsidence and flooding. Provide each group a copy of the *Terrebonne Parish Adaptation Plan: Goal 1- Managing Flooding & Subsidence* reading. Explain that each strategy listed will hopefully combat the problems of increased flooding and subsidence. Ask: *How do these projects relate to the other strategies listed in the previous reading? What do you think about the strategies? Are there any that you really like? Could you use any of this for your school community?*
6. Have students review their list of environmental problems from the beginning of the lesson. Give each group a copy of the *Identifying Potential Projects Student Sheet*. Using their list of environmental problems, have students fill out questions 1 and 2 of the student sheet. Students will use questions 1 and 2 to identify environmental threats that may have led to their school problems and will refer back to this student sheet in the next few lessons.
    - Remind students that their goal is to create a plan to make their school more resilient by addressing the school's environmental problems.

Assign Journal Prompt #16.

- **Prompt #16:** Today's lesson focused on exploring the different types of adaptation strategies used in Louisiana. Do you agree with the strategies listed in the Terrebonne Parish Adaptation Plan reading? What actions would you add or remove? Explain your thinking.

Background Information

Steps to Resilience: *(Information from U.S. Climate Resilience Toolkit, toolkit.climate.gov/videos/building-resilience-getting-started)*

- Explore Hazards
- Access Vulnerability & Risks
- Investigate Options
- Prioritize & Plan
- Take Action

Part 2: Making Our School More Resilient

Materials

- Project Resilience Slide Deck (slide 84)
- Projector & Computer
- Student access to computers/tablets
- Green Infrastructure Elements (PDF)
- Rethinking Parking Lots (PDF)
- Youth Resilience Expo (PDF)
- Project Planning Student Sheet (PDF)
- Teacher Resource: Example Project Planning Sheet (PDF)
- Resiience Project Development Rubric (PDF)

Preparation

- Make copies of the *Green Infrastructure Elements* and *Rethinking Parking Lots* readings. One for each group.
- Make copies of the *Project Planning Student Sheet* and the *Resilience Project Development Rubric*. One copy for each student/group.
- Review the Teacher Resource: Example Project Planning Sheet

Directions

Try Out the Resilience Toolkit (20 min)

1. Remind students of the toolkit steps and adaptation strategies used in the state. Introduce the concept and benefits of green infrastructure. Split the class into two groups. Give one group the Green Infrastructure Elements reading and the other group the Rethinking Parking Lots reading. Have each group read and discuss how their reading's projects relate to their school campus. Once they are finished, have the Green Infrastructure group present a summary of their reading and their recommendations based on the reading's information to the rest of the class. Repeat these steps with the second group. Ask students to consider if your school would benefit from any of the strategies in the two readings.
    - Green Infrastructure addresses excess stormwater by using plants, soil, or permeable materials to restore or mimic the water cycle.
2. Explain that green infrastructure and parking lot changes are included in Louisiana's adaptation strategies. Ask: *How would these strategies help in areas with increased flood risk due to coastal land loss?* Review what the students remember about Louisiana's coastal land loss problem by asking the following question: *What environmental problems would lead to this increased flood risk?*
3. Have students begin walking through the toolkit steps by reviewing their answers for questions 1 and 2 on the *Identifying Potential Projects Student Sheet*. Ask: *Have you thought of any new environmental problems affecting the school campus?* Remind students to think about their talk with the school administrator in the previous lesson. Students should also discuss how the problems could change over the next 50 years due to Louisiana's coastal land loss.Once all groups have completed questions 1 and 2, have each group share their answers to question 2 with the rest of the class. Use the groups' answers to make a new list of the school problems at the front of the room with their corresponding environmental threat.
    - Example: If campus flooding is a problem, will climate change or sea level rise worsen this problem? Use the NOAA Sea Level Rise Viewer to explore how sea level rise would impact the school campus.
4. Using their new school problems list, have students break back into groups and fill out question 3. Question 3 will help the students identify possible solutions for their school problems. Once they identify solutions for the problems, students will need to decide if their solutions will be considered beautification projects, resilience projects, or maintenance projects. Explain that resilience projects can address many issues, including beautification or maintenance issues, but the school's resilience plan will address problems from environmental threats.
    - Students may develop projects that address multiple issues. For example, a rain garden project would address an environmental issue but could also be considered a beautification project.
    - If students have trouble thinking of projects, open and project the Youth Resilience Expo document. Provide background on the project and talk to the students about the adaptation projects listed in the document.

Directions (continued)

Choose Projects for the School Resilience Plan (30 min)

1. Once all of the groups have finished question 3, have each group share their possible solutions with the rest of the class and explain how their solutions help the school become more resilient. List all of the resilience solutions at the front of the room. As a class, have students begin to narrow down the list of possible solutions and decide which solutions to include in their school's resilience plan, which should contain at least three projects. Remind students that their school resilience plan will need to include attainable resilience projects with the goal of helping the school adapt or overcome future environmental problems. Using the final list of solutions, create a student group for each project. Each group will focus on developing a plan for their specific project.
    - The project plans will be combined to create the final school resilience plan.
2. Hand out the copies of theProject Planning Student Sheetand the Resilience Project Development Rubric Introduce the culminating task as an opportunity for students to apply what they have learned about coastal Louisiana's environmental challenges and resilience to improve their school campus. Go through the Project Planning Student Sheet with students, explaining that the student sheet will help them develop their project plan.
    - Each group will develop a plan for their chosen project and present their project plan to the class. Presentations are an opportunity for students to receive feedback from their peers and revise their plans before they are included in the final resilience plan . Each group will prepare a visual aid for use in their presentation.
    - Each group will turn in one final (revised/edited) version of their plan using the Project Planning Student Sheet. Once all of the project plans are completed, the projects will be combined to form the school's resilience plan.
3. Have the groups begin working on the first section of the Project Planning Student Sheet. Using Section 1 (Define the Problem), students will define the environmental problem that will be addressed with their resilience project. Students can refer back to their Identifying Potential Projects Student Sheet and the new problem list at the front of the room.
    - Groups may have different answers for Section 1 if their projects address multiple school problems.

Note: The E*xample Project Planning Sheet* is provided as a teacher resource to help you guide students as they work through the *Project Planning Student Sheet*. This resource is not intended to be shared with students.

Assign Journal Prompt #17.

- **Prompt #17:** Think about the Resilience Toolkit steps from today's lesson. Steps 1 and 2 wanted you to identify environmental problems affecting your school and assess the risks to your school. What challenges did you experience when thinking about how coastal land loss has impacted your school campus? How do you think coastal land loss will impact your school campus in the future? Explain your thinking.

Background Information

Green Infrastructure

- Excerpt below from the EPA: What is Green Infrastructure? (epa.gov/green-infrastructure/what-green-infrastructure)

"Section 502 of the Clean Water Act defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapo-transpirate stormwater and reduce flows to sewer systems or to surface waters.

"Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts and provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.

"When rain falls in natural, undeveloped areas, the water is absorbed and filtered by soil and plants. Stormwater runoff is cleaner and less of a problem. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments. At the city or county scale, green infrastructure is a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the neighborhood or site scale, stormwater management systems that mimic nature soak up and store water."

Part 3: Project Design

Materials

- Student access to computers/tablets
- Project Planning Student Sheet (PDF) (from Lesson 7: Part 2)

Preparation

- Talk to the school administration about the students' projects. Let them know the students may be contacting them with questions about the impacts of environmental problems on their school campus. Students may also ask about the feasibility of their adaptation project designs on campus.
- Review the *Project Planning Student Sheet*

Directions

Dig in to project planning (50 min)

1. Students will use Sections 2 and 3 of the Project Planning Student Sheet to outline their resilience projects. Have students begin with questions 1 and 2 of Section 2.
    - With question 1, students should identify a goal for their project. This goal should be attainable and address their school problem. Let students know this goal may shift as they design the actual project, but the goal will help them design their project.
    - Question 2 focuses on identifying possible secondary benefits of their projects (educational components, improving water quality, providing green space, etc.).
    - Students should also make a sketch of their project. Have them label their sketch to identify the parts of the project (this will be a basic sketch to help students envision their ideal project and will not be part of their final presentation).
2. Once students finish questions 1 and 2, they will move on to the project plan. Questions 3 through 5 ask students to outline their project, including the project's location, steps for completion, and necessary materials. Have students divide responsibilities within their groups to complete the project plan and to prepare for the presentation. The presentation will need to follow the Project Planning Student Sheet and include the visual. Consider having each group fulfill the following roles:
    - **Visual Artist-** This student will create a project sketch to serve as a visual in their presentation. The visual should be detailed and include all parts of the project.
        - Students may need access to the internet to look up images of project examples and access to supplies to make a large sketch (poster board, etc.).
        - The visual (or a picture of it) will be included in the final school resilience plan.
    - **Materials & Services Researcher**- Will require two students. These students will create a detailed list of necessary materials for their project. If professional help is needed, students should also include a list of professionals and their contact information (contractors, engineers, etc.).
        - Students may need access to the internet to look up similar projects and possible materials.
    - **Editor**- This student will revise the plan document and create an outline for the presentation.
        - They might need to do additional research online or by reviewing content from Project Resilience Lessons 1-6.
3. Before beginning the project plan (questions 3 through 5), have students look at Section 3 of the Project Planning Student Sheet document. As a group, they should brainstorm answers to the Thinking Deeply About Your Project section of the planning document to determine what roles are needed throughout the project as well as address any special considerations, anticipate challenges, pose questions that need to be answered, etc.
4. Students should spend the remainder of class time working on their tasks for the project plan and presentation. By the end of class time, students should have a fairly complete rough draft of their project plan and presentation. Out of class time will likely be needed to complete the plans and prepare for presentations. Students will present their plans and have the opportunity to revise them based on peer feedback in the next lesson.

Assign Journal Prompt #18.

- **Prompt #18:** Today's lesson asked you to brainstorm possible adaptation plans for your school campus. What was challenging about making a list of adaptation projects? If unlimited funds were available, how would you adapt your school campus to face Louisiana's land loss problem? List the projects that would be included in your adaptation plan and describe each project's benefits to your school. Why are these projects not possible right now?

Note: Students will continue working on this journal entry for the next two parts.

Part 4: Present and Revise

Materials

- Project Planning Student Sheet (PDF) (from Lesson 7: Part 2)
- Resilience Project Development Rubric (PDF) (from Lesson 7: Part 2)

Preparation

- Make copies of the *Resilience Project Development Rubric* for the peer-review process. Each student will need one copy for each presenting group.
- Review the list of projects with the school's administration.

Directions

Share project plans with the class (50 min)

1. Pass out several copies of the *Resilience Project Development Rubric* to each student.
2. Groups will take turns presenting their adaptation project plan. If time is limited, consider holding a modified gallery walk, with one group member present to explain and ask questions as students consider the plans. During the presentations, students in the audience will use the *Resilience Project Development Rubric* to provide feedback and comments/notes about each group's plan.
    - Remind students to keep the following in mind while providing feedback:
        - Don't include only problems with the other group's project. Include what parts you like or think will work well.
        - Focus the feedback on the design itself and not on the group that completed the design.
        - If part of the plan is confusing, include questions in your notes/suggestions to help the group clarify.
        - Be specific. If you don't like the design, list what you specifically don't like or don't think will work. Focus on things that could be improved. Give recommendations.
3. After the presentations are completed, provide time for each group to collect and discuss their peer feedback. They should revise their project plans, incorporating the peer feedback as necessary. In the next lesson, students will combine their project plans to create the school's resilience plan.

Remind students to continue working on Journal Prompt #18.

- **Prompt #18:** Today's lesson asked you to brainstorm possible adaptation plans for your school campus. What was challenging about making a list of adaptation projects? If unlimited funds were available, how would you adapt your school campus to face Louisiana's land loss problem? List the projects that would be included in your adaptation plan and describe each project's benefits to your school. Why are these projects not possible right now?

Part 5: Creating Our School Resilience Plan

Materials

- Project Planning Student Sheet (PDF) (from Lesson 7: Part 2)

Preparation

- Review the *School Resilience Plan* document.

Directions

Turn adaptation projects into a school resilience plan (50 min)

1. Have students review their project plan and finalize any changes to their project plan. After finalizing changes, hand each group a project copy of *Our School Resilience Plan*. Each group should use their project plan from the previous lesson to fill out their part of the *Our School Resilience Plan* document.
    - If able, you may also consider creating a digital shared version of *Our School Resilience Plan* that students can directly type into, instead of a paper copy.
2. Once each group has finished with their part of the plan, collect each group's project plan for the final copy of the resilience plan. Review the class's overall project list with the students, including the descriptions of each project, and discuss the potential impacts of the plan. Ask: How will this plan help our school handle problems in the future? If constructed, how would these projects impact future school classes? What can we do to fund one or more of these projects?
3. As a class, fill out the site description and the resilience plan goal on page 1 of the School Resilience Plan. Explain to students that this plan may be given to potential funders or professionals outside of the school, so the school description needs to be as detailed as possible.
    - Include a map of the school campus, if possible.

Remind students to continue working on Journal Prompt #18.

- **Prompt #18:** Today's lesson asked you to brainstorm possible adaptation plans for your school campus. What was challenging about making a list of adaptation projects? If unlimited funds were available, how would you adapt your school campus to face Louisiana's land loss problem? List the projects that would be included in your adaptation plan and describe each project's benefits to your school. Why are these projects not possible right now?

Extensions

- Have the class present their resilience plan to the administration and school board, if possible. Students could also present their plan to other student groups that may be interested in helping implement a part of the resilience plan (student council, environmental clubs, athletic clubs).
- Before moving to Lesson 8:
    - Discuss possible fundraising ideas with the class. Have students outline a list of potential school fundraisers or potential sponsors.
    - Contact local engineers or contractors that may be interested in volunteering as an expert during the proposal process of Lesson 8. These experts will help the students develop a detailed project proposal and implement their project.
    - Introduce students to the project budget template and explain the process of completing a project budget completing a project budget.
    - Talk to the school's administration about any potential problems with implementing the projects in the students' resilience plan.

Project Resilience Teacher Guide

Lesson 8 > Project Implementation

This is an extension lesson to the Project Resilience curriculum in which students finalize and implement one of the adaptation projects from their school resilience plan. It is dependent upon obtaining funds and the appropriate approval from school administration to implement a project on the school campus. Lesson 8 is divided into two parts. The time needed for Part 2, the implementation of a project, will vary because each project is unique.

Lesson 8: Part 1: Finalizing the Adaptation Project - Students finalize their adaptation project(s) and select one to be implemented.
Lesson 8: Part 2: Implementing the Project - Students implement an adaptation project from their school resilience plan.

Time Required

- Teacher Preparation Time: approximately 100 minutes
- Part 1: 100 minutes
- Part 2: *will vary depending on the project selected

Learning Goals

- Students will take on specific roles to finalize the project plan. *(Part 1)*
- Students will understand and take on specific roles to implement the project plan. *(Part 2)*

Lesson Format

- Design activity

Science Standards

Louisiana Student Standards for Science:

- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Additional Dimensions:

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: ETS1.C: Optimizing the Design Solution

Part 1: Finalizing the Adaptation Plan

Materials

- Campus Resilience Project: Detailed Plan (PDF)
- School Resilience Plan (created by students in Lesson 7)

Preparation

- Secure funding that can be used to implement an adaptation project at your school. Sources of project funding may be: project sponsors, student fundraisers, school budgets, or grants. ***Note: It is strongly advised that funding is secured before beginning the Project Resilience Curriculum.***
- Share the School Resilience Plan (from Lesson 7) with your school's administration to obtain approval to implement one of the adaptation projects at your school campus. Be sure to discuss any potential problems with implementing the projects.
  - Arrange for a member of the school's administration to visit the class for the final project presentation.
- Recruit a volunteer engineer or contractor from your community who is able to help you create a rough estimate of the cost of the School Resilience Plan projects. You will need a cost estimate for each project prior to beginning Lesson 8 to help you determine which projects will be feasible, based on the amount of funds you have available. Students will use these cost estimates to complete the project budget as well. ***Note: It is strongly advised that you find a volunteer expert who would be willing to work directly with students to advise them as they create the detailed plan (project steps, materials list, and budget will likely be unfamiliar tasks to students). If possible, arrange for the volunteer expert to speak with students via phone, video conference, or in person.***
  - Consider asking your administration or building maintenance supervisor to refer an engineer or contractor who may already have experience working with your school.
- Consult with school maintenance staff from your building who may be able to assist in a variety of ways, including: brainstorming with students about the project plan steps, advising as students create the materials list, providing a list of vendors, assisting with labor tasks during project implementation, etc.
- Provide students access to the School Resilience Plan they created in Lesson 7, either digitally or printed copies.
- Make a copy of the *Campus Resilience Project: Detailed Plan* for each group.

Directions

Note: After creating a *School Resilience Plan* in Lesson 7, you can use Part 1 of this lesson to guide your students through the development of a detailed proposal for one of the projects. Depending on the scope of the projects within your *School Resilience Plan*, and how much funding is available, you may be able to implement more than one project. Part 2 of this lesson will help students take an active role in the implementation of their project. Lesson 8 assumes that just one project will be implemented. Modify instruction as needed.

Select a project to implement (100 min)

1. Ensure that you have secured funding to implement a resilience project at your school, and that you have approval from your school administrators to proceed.
2. Review the School Resilience Plan, along with the cost estimates for each project that you obtained with the help of volunteer professionals (see Preparation steps), with your students. Record the name and estimated cost of each project on the board. Explain that funds are available to construct one of the projects and add the total fund amount to the board. Tell students that next we will choose one of the projects and begin creating a detailed implementation plan.
3. To choose the project for implementation, have the students identify which project or projects we can afford, based on the funding amount. If multiple projects are identified, ask students to rank the projects based on which will create the most resilience for their school. The highest-ranked project will be implemented.
   - Remind students of the potential to implement additional projects from their School Resilience Plan, should additional funds become available in the future.
4. Circle the selected project on the board and direct students to review the details about their selected project included in the School Resilience Plan. Explain that students will be creating a detailed version of this plan, including a budget for the project. Ask: What initial questions do you have about this project? List these questions on the board. Students will include these questions in their final proposal.
5. Pass out the *Campus Resilience Project: Detailed Plan.* Review the detailed plan document with students, explaining that they will use this document to develop the project plan. Explain that once the detailed project plan is complete, the class will present the project to the school administration for final approval.

Directions (continued)

6. Divide the class evenly into the groups below:
   Note: groups will need resources beyond what is provided here. Consider what help students will need to be successful as they plan for specific details about the project, like materials and cost. If possible, work with school maintenance and/or volunteer experts who can provide guidance.
   - **Construction**- These students will develop a detailed list of project steps. They will also develop the project timetable and a list of any necessary professional help.
   - **Supplies**- These students will create a detailed list of necessary materials and services needed for the project using the Materials Needed table, including the supplier information (website links, store locations).
   - **Budget**- These students will develop the project budget. They will work with the Construction and Supplies Groups to form the project budget, using the Budget table.
   - **Marketing**- Students will design materials to share with the student body and the community to inform them about the adaptation project. These students will also create a presentation for the school administration.
7. Students should spend the remainder of class time and the next class period working on their tasks for completing the plan and preparing for the presentation. *Note: Out of class time will likely be needed to complete the detailed project plan and presentation.*
8. Arrange for a member of the school's administration to visit the class. Have students present their project to the administration and ask for any feedback. Students should use the remaining class time to incorporate the feedback into their project plan.
9. Meet with the administration after the presentation and get approval for the project timeline. You will also need to discuss the following implementation questions:
   - What is the administrative process for project implementation on the school campus?Who will you need to contact (school maintenance, approved contractors)?
   - What process is necessary to purchase supplies and access the project funding?

Part 2: Implementing the Project

Materials

- Poster board or bulletin board paper
- Sticky notes
- Markers

Preparation

- Create a Kanban board to keep track of progress during project implementation. The board should have five rows and four columns.
  - Column headlines: To-Do, In Progress, Done
  - Row headlines: Planning, Execution, Performance & Monitoring, Closure
- Review how to use Kanban boards as a team-work management tool.

Directions

Work as a class to implement the project plan.

1. Review the detailed project plan with the class.
2. Introduce the implementation groups (or teams) below and the purpose of each group. Have the students divide into their groups, and each group should select a group leader. This leader will guide the group and will provide updates on the group's progress.
   - **Project Manager:** Will require one student. Responsible for the overall success of the project. Leads class meetings with the team twice a week or as needed. They should create a system for checking in regularly with the other group leaders and helping to ensure that there is good communication between the various groups.
   - **Construction team:** Will require three students. Responsible for the coordination of labor needed to complete the project in a timely manner, whether contract workers or school maintenance staff. They should create a system for tracking construction needs, including: contact information, schedule of work to be done, hours estimated, actual hours worked, etc. They will need to communicate regularly with the Budget Team.
   - **Budget team:** Will require three students. Ensures that the project stays within budget. They will need to communicate with the Construction and Supplies Teams and report out about budget status at class meetings. If needed, they should be ready to suggest where project modifications need to be made to stay within budget.
   - **Supplies team:** Will require three students. Ensures that materials are ordered, purchased, and will be available when needed. They should create a way to organize and track materials, using a spreadsheet for example. They will need to work closely with the Construction and Budget Teams.
     - Talk to your administration for the school's policy on purchasing supplies.
   - **Volunteer/ student team:** Will require two students. Responsible for organizing any volunteer or student activities, including: recruiting volunteers, creating volunteer schedules, training (if needed), and communicating about volunteer activities and needs during class meetings.
   - **Historian team:** Will require two students. Responsible for documenting the process through photos, videos, and written reporting for use by the marketing team. They should create a plan for cataloging the content they gather, including editing, sharing of files, and crediting where necessary (tagging people in photos, for example).
   - **Marketing team:** Will require three students. Responsible for keeping the larger community informed about progress during the project. They will generate content that can be shared through avenues such as: the school newspaper, daily announcements, school social media accounts, and local media outlets, including newspapers, radio, etc. They should create a plan for how and when they will share this content.
   - **Evaluator team:** Will require two students. Responsible for identifying what worked well during the project and where improvements could be made. They should create a plan for how they will conduct their evaluation (survey, interviews, etc).
3. Show students the class Kanban board. Explain the process of the Kanban board and how students will use the board to track progress.
   - Students will write each task for the project on a sticky note. These sticky notes will be placed in the "To-Do" column. When students begin working on the task, they will move the task to the "In Progress" column. Once the task is completed, the note will be moved to the "Done" column.
4. Give each group time to brainstorm all of the project tasks their group is responsible for. Have them write each task on a sticky note (one task per note). Circulate throughout the room, checking in with each group to approve the tasks they have decided upon and provide prompting where needed.

Directions (continued)

5. Have students place their tasks in the "To-Do" section of the appropriate row on the Kanban board. These tasks will vary depending on the selected project.
    - "Planning" tasks will include meeting with any necessary professionals. (Students have already completed many of the planning steps with the project design).
    - "Execution" tasks will include purchasing necessary supplies and completing any necessary contracts.
    - "Performance & Monitoring" will include any construction tasks.
    - "Closure" will include tasks necessary to determine the project's completion.
6. Use the Kanban board to hold a discussion about how to begin the project implementation phase. Groups should leave the discussion knowing which tasks to begin first and who is responsible for them. Add names to the task sticky-notes so it is clear who is responsible for completing them.
7. From this point forward, students will need flexible class time to work on their project implementation tasks, including time to meet with their team. Some groups may have tasks to work on every day, while others may only have tasks on some days. Consider how to best manage these needs. Successful project implementation will require close oversight by the teacher.
8. Have a class meeting each day (for about 5 minutes at the start of class) to discuss the Kanban board. Use this time for groups to report on their project work and update the Kanban board. Not all groups will necessarily need to report out each day. Continue these class meetings until the completion of the project.
    - If necessary, students can also add to or revise the Kanban board.
    - You will be able to use the Kanban board to track each group's progress. If a group is unable to provide updates at the class meetings or their tasks are not progressing on the Kanban board, use class time to meet with the group about the lack of progress.

Additional Resources included in this section

Journal Resources:

- Journal Prompts
- Journal Scoring Rubric

To assist with assessing your students, we have provided the following rubric templates:

- Discussion & Participation Scoring Rubric
- CER & Presentation Rubric
- Resilience Project Development Rubric

Example Project Planning Student Sheet (Teacher Resource)

Journal Prompts

Optional Activity

Students have a journal assignment as a reflection at the end of each day. The intention of the journaling exercises is to give a voice to internal processing and for students to express their own individual experience, as well as a way to assess and track student understanding of the curriculum. Journal topics can be presented as a booklet that the teacher collects to review periodically throughout the unit, or students could wait to turn it in until the end of the unit. Student responses will vary in length and structure.

Prompt #1

Think about the environmental challenges facing coastal Louisiana that were presented today. Choose one of these issues and zoom in to focus on one small part of the problem that is important to you. Describe that one small part as if it was the only problem. Why is it important to you? What questions do you have about it? Now zoom out and consider the small part in the context of a bigger problem. How do your feelings about the problem change when you consider it on a larger scale?

Prompt #2

In today's lesson, you learned about how important the river was in the formation of the land you live on. Think about a natural area or specific place in coastal Louisiana that is special to you. Describe the place and share what you like about it. From your understanding of how the Mississippi River Delta has changed over time, explain how this area might have formed.

Prompt #3

Think about the ecosystem services that an estuary provides to the environment and describe how the environment you live in could change if the estuary were no longer there. Come up with your own metaphor for what an estuary is like and describe it.

Prompt #4

Hydrologic modification is an issue that can be represented as a tug of war. Draw a line across your paper to represent a rope for our 'hydro' tug of war scenario. Give a name to each end of the rope that reflects two opposing viewpoints that might be taken in this issue, such as "Hydrologic modification is good because…" on one end, and "Hydrologic modification is bad because…" on the other end. On one side, what are the "tugs" or reasons that support it? You might not personally agree with the tugs, but you can still identify them. On the other side, what are the "tugs" that support it? Write the "tugs" along the rope and consider how the reasons compare with one another. Stronger reasons should be closer to the ends, while reasons that may not be clearly on one side or the other can be closer to the middle.

Prompt #5

In today's lesson about land loss, you were asked to consider a claim about how brown shrimp and other wildlife might be affected. Write a headline, similar to what you would see in a newspaper, that describes how you feel or what you think about this. A headline should be brief but also contain carefully selected words that serve to summarize the main idea. Explain your headline.

Prompt #6

Reflect on today's lesson about sinking land and sea level rise. How do you think you and your family will respond to the changes brought about as a result of sea level rise? Do you think your life will be affected a lot, a little, or not at all? What feelings come up for you when you think about the future with respect to sea level rise?

Prompt #7

What is the tale of a hurricane that has affected your family or community? If you have not experienced a hurricane yourself, ask a family member or friend who has to tell you about it. Describe what you or they remember the most, and how things were different in the months and years after the storm. Imagine what it might be like to experience hurricanes in coastal Louisiana 20-30 years from now. How and why might things be different?

Prompt #8

Step inside the perspective of someone who is connected to the challenges brought by changing ecosystems in coastal Louisiana. Imagine yourself as this person, and list your responses to the questions below from that perspective:

- What would this person see or notice about their ecosystem?
- What challenges might this person face?
- What might be important to this person?
- What might this person wonder about?

Journal Prompts continued

Prompt #9
Think back to when we began this unit about coastal Louisiana and reflect on how your thinking has changed. First, recall the ideas you used to have about the environmental problems facing your community. Write down what it is that you used to think, starting with the words "I used to think…" Next, think about how your ideas have changed as a result of what we have been studying. Write down a few lines to capture where you are in your thinking now, starting with the words "Now, I think…"
Prompt #10: Describe a time when you have been resilient. What skills did you need in this situation? What was the most challenging? How could the lessons you learned from your own resilience be applied to the larger idea of a resilient community? Explain your thinking.

Prompt #11
Reflect on the communities from today's lesson. Many of these communities are facing increased flood risk due to Louisiana's coastal land loss crisis. What makes some Louisiana's coastal communities more or less resilient than others? Explain your thinking.

Prompt #12
Think of a coastal project in or around your community. How has this project affected your community? (The Coastal Projects in Louisiana Student Sheet from today's lesson lists the different types of coastal projects.

Prompt #13
To form parish adaptation plans, LA SAFE held several rounds of community meetings. The goal of these meetings was to receive input from the residents about what type of adaptation projects they wanted to see in their community. Do you think this is an effective process for developing community adaptation plans? Why or why not? What aspects of your community would you want to protect with an adaptation project?

Prompt #14
Many different types of projects are being constructed along the Louisiana coast, including both restoration projects and risk reduction projects. What type of factors will officials need to consider when designing risk reduction projects? What different factors would they need to consider constructing structural protection projects versus nonstructural?

Prompt #15
Looking at today's LA SAFE pilot proposals for Terrebonne Parish, your group may have compromised while rating the proposals. Which proposal do you consider the most important or the most effective? What community problem(s) does this proposal address? Describe if this proposal represents a long term or short term adaptation plan. List five points below to support your chosen proposal.

Prompt #16
Today's lesson focused on exploring the different types of adaptation strategies used in Louisiana. Do you agree with the strategies listed in the Terrebonne Parish Adaptation Plan reading? What actions would you add or remove?

Prompt #17
Think about the Resilience Toolkit steps from today's lesson. Steps 1 and 2 wanted you to identify environmental problems affecting your school and assess the risks to your school. What challenges did you experience when thinking about how coastal land loss has impacted your school campus? How do you think coastal land loss will impact your school campus in the future? Explain your thinking.

Prompt #18
Today's lesson asked you to brainstorm possible adaptation plans for your school campus. What was challenging about making a list of adaptation projects? If unlimited funds were available, how would you adapt your school campus to face Louisiana's land loss problem? List the projects that would be included in your adaptation plan and describe each project's benefits to your school. Why are these projects not possible right now?

Journal Scoring Rubric

Optional Activity

Journal #:

Name:

JOURNAL SCORING RUBRIC: PROJECT RESILIENCE				
	Beginning (0)	**Developing (1)**	**Accomplished (2)**	**Exemplary (3)**
Completeness	Response excludes essential components and/or does not address the requirements indicated in the prompt.	Response is missing some components and/or does not fully meet the requirements indicated in the prompt.	Response included all components and mostly meets requirements indicated in the prompt.	Response includes all components and meets or exceeds all requirements indicated in the prompt.
Depth of Reflection	Response demonstrates a lack of reflection or attends to ideas not relating to the prompt. Viewpoints and interpretations are missing, inappropriate, and/or unsupported.	Response demonstrates a minimal reflection of relevant ideas. Viewpoints and interpretations lack thoughtfulness and are unsupported or supported with flawed arguments.	Response demonstrates a general reflection of relevant ideas. Viewpoints and interpretations are thoughtful and somewhat supported.	Response demonstrates an in-depth reflection of relevant ideas. Viewpoints and interpretations are thoughtful and well supported.
Connection to Main Ideas	Response shows no evidence of the synthesis of ideas presented in the lesson.	Response shows little evidence of the synthesis of ideas presented in the lesson.	Response shows some evidence of the synthesis of ideas presented in the lesson.	Response shows strong evidence of the synthesis of ideas presented in the lesson.
Timeliness	Turned in late	Turned in on time	n/a	n/a
Comments				
Score:				

Discussion & Participation Scoring Rubric

Teacher Resource

Name: _____

Activity: _____

DISCUSSION & PARTICIPATION SCORING RUBRIC: PROJECT RESILIENCE				
	Unacceptable (0)	**Developing (1)**	**Proficient (2)**	**Exemplary (3)**
Frequency of participation	The student did not contribute to the class discussion or activity, even when prompted by the instructor.	The student contributed to the discussion or activity only when prompted by the instructor.	The student contributed to the discussion or activity at least once.	The response includes all components and meets or exceeds all requirements indicated in the prompt.
Quality of contributions	Comments were uninformative, lacking in the appropriate terminology.	Comments were sometimes constructive, with occasional signs of insight, not always relevant to the discussion.	Comments mostly insightful and constructive.Occasionally comments are too general or not relevant to the discussion.	Comments were always insightful and constructive. Comments balanced between general impressions, opinions and specific, thoughtful criticisms, or contributions.
Preparedness	The student was not all prepared for the discussion or activity.	The student was somewhat prepared for the discussion or activity.	The student was mostly prepared for the discussion or activity.	The student was fully prepared for the discussion or activity.
Listening Skills	The student did not listen to others, talked while others were speaking, did not pay attention while others were speaking, and/or detracted from the discussion or activity.	The student was often inattentive and needed a reminder to focus on the discussion or activity. Occasionally made disruptive comments while others were speaking.	The student was mostly attentive when others were sharing ideas. Occasionally needed encouragement or reminder to focus on the discussion or activity.	The student listened attentively when others were sharing ideas, as indicated by comments that reflect and build on others' remarks.
Comments:				
Score:				

CER & Presentation Rubric

Lesson 4

	POINTS		
	0	**1**	**2**
Claim	The claim is incorrect or missing.	The claim is accurate but incomplete.	The claim is accurate and complete.
Evidence	Evidence is not provided, or evidence is incorrect.	Some evidence is provided but not enough to support the claim.	Evidence provides adequate support for the claim.
Reasoning	Reasoning is not provided, or reasoning is incorrect.	Some reasoning is provided but not enough to explain the evidence fully.	Reasoning provides an adequate explanation of the evidence.
Solution	No solution is provided or solution does not match the problem.	A solution is provided, but it is inadequate or lacks a demonstrated understanding of the problem.	A thoughtful solution is provided, that demonstrates an understanding of the problem.
Presentation	No group members were able to clearly explain the group's ideas.	Presentation of ideas was sometimes hard to follow.	Presentation of ideas was clear and easy to follow.
Participation during presentations	Group members were not participating or courteous during presentations and giving feedback.	Group members were mostly participating and courteous during listening and giving feedback, but needed some redirection.	Group members overall actively and courteously participated in listening and giving feedback to peers.
Comments:			
Score:	**/12**		

Resilience Project Development Rubric

Lesson 7

DEFINE THE PROBLEM:				
	1	**2**	**3**	**4**
Problem Statement	No statement describing the problem is present.	The problem is mentioned but not described.	The problem is mentioned but not clearly described.	The problem is clearly described in a statement.
Problem Causes	No causes for the problem are identified.	A cause(s) is/are mentioned, but does not relate to the problem.	The cause(s) of the problem is/are identified, but are not complete.	The cause(s) of the problem is/are correctly identified.
Relationship to Environmental Issues	Relationships to larger environmental problems are missing.	Relationships to larger environmental problems are vaguely mentioned.	Relationships to larger environmental problems are partially defined.	Relationships to larger environmental problems are clearly defined.
Impacts of Problem	The impacts of the problem are missing.	The impacts of the problem are listed but not described.	The impacts of the problem are listed but not clearly described.	The impacts of the problem, including the future, are clearly defined.
Comments				
Score:				

Resilience Project Development Rubric continued

Lesson 7

CREATE A GOAL FOR YOUR PROJECT:				
	1	**2**	**3**	**4**
Goal Statement	No statement describing the goal is present.	The goal is mentioned but not described.	The goal is mentioned but not clearly described.	The goal is clearly described in a statement.
Desired Outcomes	Desired outcomes are not listed.	Desired outcomes are mentioned but not described.	Desired outcomes are partially defined.	Desired outcomes are clearly defined in the goal statement.
Comments				
Score:				

CREATE A PLAN FOR YOUR PROJECT:				
	1	**2**	**3**	**4**
Project Location	The project location is not listed.	The project location is vaguely described.	The project location is identified but not possible.	The project location is clearly identified and possible.
Project Steps and Schedule	Project steps and the schedule are not listed.	Project steps and the schedule are vaguely described.	Project steps are listed, but the schedule is vaguely described.	Project steps and the schedule are clearly described.
Project Challenges	Project challenges are not listed.	Project challenges are vaguely mentioned.	Project challenges are partially described.	Project challenges are clearly listed and described.
Special Considerations	Special considerations are not included.	Special considerations are vaguely mentioned.	Special considerations are partially described.	Special considerations are clearly described.
Comments				
Score:				

Resilience Project Development Rubric continued

Lesson 7

PROJECT PRESENTATION:				
	1	**2**	**3**	**4**
Image of Project Site	The project site image is not included.	The project site is vaguely mentioned.	The project site is clearly described, but an image is not included.	The project site is clearly described along with an image.
Project Design	Project steps and a sketch of the project are not included.	Project steps are vaguely mentioned, but a sketch is not included.	Project steps are clearly described, but a sketch is not included.	Project steps are clearly described and a sketch is included.
Project Benefits	Project benefits are not listed.	Project benefits are vaguely mentioned.	Project benefits are partially described.	Project benefits are clearly listed and described.
Future Impacts	Future impacts are not included.	Future impacts are vaguely mentioned.	Future impacts are partially described.	Future impacts are clearly described.
Comments				
Score:				

Example Project Planning Student Sheet (Teacher Resource)

Lesson 7 > Part 2 > Making Our School More Resilient

Note: This resource provides an example of a project to address flooding of school parking lots by installing pervious pavement and is intended for the instructor only. Use the sample answers and tips to help you guide students as they create their project plans.

Respond to each prompt with at least two sentences and with as much detail as possible. Some prompts will require a more lengthy response than others. Your answers on this worksheet will be included in the final school resilience plan.

Project Title: *Improving Our School Parking Lots with Pervious Pavement*

(Title should be appropriate for the project and provide insight into the problem addressed as well as what the project is)

Section 1: Define the Problem

Your specific project will address a problem on your school campus. Use the questions below to provide more details about the problem.

1. What problem does your project address? How would you describe the problem in 1-2 sentences?

Student answers should provide details about their school problem. For example, if campus flooding is the problem, students should include the location and extent of flooding. They should also explain how the flooding impacts the students and members of the school community. Answers should provide enough detail to explain the problem clearly.

2. What are the causes of the problem?

Student answers will vary depending on the problem their project will address. Students should refer back to learnings from Project Resilience lessons 1-4 about the causes of different environmental problems facing coastal communities, as well as their own community knowledge to answer this question. For example, campus flooding could be related to multiple causes: areas of the school campus subsiding, paving the campus with concrete, increased flooding in the area due to hydrologic modification (levees, dams, channeling) of a nearby river, or the increased severity of storms due to climate change.

3. How does the problem relate to the larger environmental risks facing your community?

Student answers will vary depending on the problem their project will address. Similar to question 2, students should refer back to Project Resilience lessons and their community knowledge. For example, the subsidence that leads to campus flooding is experienced by the larger community as well. Residents of the area surrounding the school campus may also be experiencing increased flooding during storms. Flooding can lead to property damage, and land loss due to subsidence threatens the long term stability of the community.

4. What are the current impacts of the problem? Are there future impacts? What is the level of impact (individual/species, community, etc.)? Make sure to include this problem's sphere of impact (economic, environmental, social, etc.).

Student answers should include an understanding of who/what is impacted now and in the future. Current impacts, if using the subsidence example, include flooding on parts of campus. Future impacts include increased flooding on campus and damages to campus building foundations as the subsidence continues. This flooding due to subsidence is a problem that impacts the school community, the town, and even the parish. It also affects individuals and households. As flooding increases over time, all community members will be affected, some more than others, depending on where they live. Flooding impacts the economy because flood mitigation is expensive, and the potential loss of businesses and structures due to flooding has an economic toll. Sensitive environments, such as wetlands, are also impacted by subsidence. Louisiana is currently losing more wetlands than any other coastal US state.

1. Describe specific example(s) of the problem. Where else has this problem occurred, and what has been done about it?

Students will need to refer back to the previous lessons for examples of their problem. With our subsidence example, students could list Terrebonne Parish as an example of high subsidence rates. They might have a personal story of how flooding has affected a family member or someone from their community. Students could use the Terrebonne Parish Factsheet to provide examples of how the parish residents are addressing these subsidence rates.

Section 2: Project Details

Include as much detail as possible in your answers. Each answer should be at least two sentences long.

1. What is the goal of your project? Your goal must be clear, well defined, and attainable. To be considered attainable, projects must be able to be completed at your school and be relevant to the topic of adaptation. Your goal statement should include a description of the outcome you want to achieve and a description of what you will do to achieve your goal.

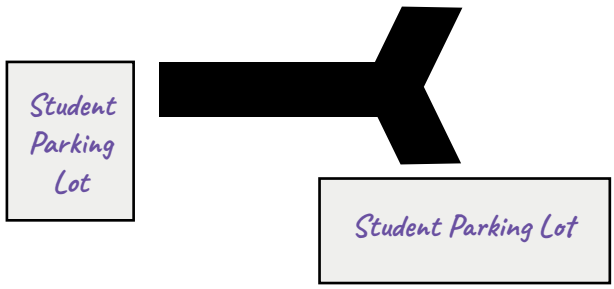
Students should create a goal statement that clearly explains what their project hopes to accomplish. The goal of the Improving Our Parking Lots project is to install pervious pavement in the two school parking lots in order to decrease the amount of flooding on campus. The project will also create green spaces surrounding the parking lots to help absorb water and catch runoff. Decreasing the amount of flooding will allow students to use the front entryway and parking lots safely at all times during the school year.

2. Are there any secondary benefits to your project? For example, does your project include an education component, provide green space, or improve water quality or habitat?

Along with installing pervious pavement, our project will incorporate green spaces into the parking lot design. The green space will come from planting vegetation in the spaces surrounding the parking lot. This vegetation will help to absorb water and reduce runoff.

3. Where will your project take place? Describe your project's location. Include pictures of your project location and a map, if possible.

The project site is the two student parking lots indicated in the image below.



If students are unable to provide a picture of their project location, have them create a drawing or a simple design like the one above.

Example Project Planning Student Sheet (Teacher Resource) cont.

1. How would you complete this project? List the steps that would need to be completed and a timeframe in which the steps would be completed. If your project would need future maintenance or monitoring, include this in your schedule. Include a detailed sketch or diagram of your project. Please attach additional pages if needed.

Note: Students may need help determining the completion dates for their timeline. The completion dates could be specific, like the example below, or a target date range (During the week of February 1st, for example). Creating a table is optional.

Task:	Completed by:
Talk to the school administration and get approval for the project	January 15th
Measure the parking lots & design green space options	February 1st
Research pervious pavement options and vendors	February 15th
Research plants for greenspace	February 15th
Contact vendors for cost	March 1st
Schedule installation	April 1st
Order/purchase plants	April 1st
Plant greenspaces	May 1st

2. What materials or services would be required to complete this project? Please attach additional pages if needed.

Materials & Services needed to install pervious pavement in our school parking lots:

1. Pervious concrete pavement
2. Plants
3. Topsoil
4. Gardening tools
5. Survey of our parking lots by engineer/pervious pavement professional
6. Design of new pervious pavement parking lot by professional
7. Labor to install pervious pavement
8. Labor to install plants
9. etc....

Example Project Planning Student Sheet (Teacher Resource) cont.

Lesson 7 > Part 2 > Making Our School More Resilient

Section 3: Thinking Deeply About Your Project

Provide thoughtful responses to the questions below. Each answer should be at least two sentences long.

1. What excites you about this project? What is the upside?

This answer will vary depending on student interests.

2. How would this project make your school more resilient?

The pervious pavement project will decrease the parking lot flooding at the school. Students will be able to safely use the student parking lots, even during storms.

3. What special considerations would be required for your project? (Do you need permission from the principal, school board, etc.?)

All projects will need approval from the principal. Check with your principal to determine who else will need to provide approval. Many of the projects will need future maintenance, and students will need to have that written into their plan.

4. What challenges may come up with your project? How would you address them?

Potential challenges:

- *Weather delays installation (frequent storms, freezing temperatures)*
- *Supplies are unavailable*
- *Change in project location (if project interferes with school maintenance)*
- *The parking lot could need additional repair before pervious pavement can be installed*
- *The project becomes over budget*

5. What other information would you need before beginning this project's construction? Would you need to consult any professionals for the project?

Other things to think about:

- *Do we need a vendor or contractor to install this project?*
- *Do we need an engineer to design the final project?*
- *Will this project negatively affect another part of campus?*
- *Would the school's maintenance be able to help with the installation of the project?*

PROJECT RESILIENCE

Resilience Project Planning: A Guide for Teachers

> *"The kids were really motivated to do the project. They had ownership of it. They knew that after it was completed, they'd be able to say that they contributed something lasting to their school community."*
>
> -Adrianna Adams, Project Resilience teacher

UCAR CENTER FOR SCIENCE EDUCATION

SOUTH LOUISIANA WETLANDS Discovery Center

Image: Adrianna Adams

scied.ucar.edu/project-resilience

Resilience Project Planning - A Guide for Teachers

Introduction

So you've decided to extend Project Resilience by implementing a student-designed resilience project at your school! Kudos for taking on what is sure to be an exciting and unique learning experience for your students! Your students will likely look back on this project as a highlight of their high school experience. But let's be honest, a task like this can also come with challenges and frustrations. This planning guide is a collection of helpful tips we learned during the pilot program, designed to help set you up for success. Good luck!

First Things First

The resilience project experience will be largely dependent upon creating a growth mindset environment for your students and your commitment as the project manager. Because every project is unique, and the most meaningful projects are those that the students come up with themselves, there are sure to be many unknowns that will require flexibility, resourcefulness, determination, and a degree of comfort with uncertainty. When challenges or setbacks arise, you'll need to be able to coach your students to adapt and have a good attitude, reassuring them that this is all part of the process when you are doing something new. Hopefully, the project will also be fun and rewarding, with lots of opportunities for students to practice real-world skills. The more engaged you are as the project leader, the more engaged your students will be.

Advance planning will increase the success of your project. We recommend beginning the teacher part of the project plan a full school year in advance. This will allow time to get your building administration on board and secure funding for your project. Looking ahead to the next school year can help you determine where to place Project Resilience within your curriculum sequence. Starting the Project Resilience curriculum earlier in the school year is probably best. You'll want to complete Lessons 1-7 of the curriculum with plenty of time left in the school year so that your students can experience the reward of project completion before heading off to summer break.

Make sure to allow extra time for:

- Permissions or permitting
- Creating and revising a design
- Ordering and receiving materials
- Contracting and scheduling laborers
- Organizing volunteers

Keep in mind that some projects will require more time than others to implement. Once you have funding (which is discussed in the next section) and have worked through Lesson 7 with your students to design and select a resilience project, it can take between five to eight weeks to make the project happen. Depending on the scope of your project, there may be steps that take considerable time to implement. For example, the School Deck Case Study (pages 6-8) was put on hold for several months while the students waited for the school board to approve adding a permanent structure onto the school building. They also had to get their plan approved by district maintenance, who knew the location of buried electrical and plumbing lines, and had to wait for the availability of district-approved contractors to do the labor.

Students from South Terrebonne Highshool working together to create their outdoor learning and community space. Image: Adrianna Adams

Resilience Project Planning - A Guide for Teachers

Funding

You need funding to make this happen!

The good news is that there is lots of funding available to support education. The bad news is that it can be a lot of work to find it. Funding for our pilot project that covered student projects was part of the grant we received to develop the curriculum. While we didn't have to secure funding specifically to implement student projects, we expect that securing funding might be a hurdle you will face. We have pulled together the following tips and resources to help you.

- Start with your school and your district. It's possible that building funds could be allocated towards your project, especially if the resilience project your students choose improves an issue that has already been identified by facilities staff. With permission from your principal or supervisor, consider approaching the school board to request funding.
- Work with your PTA. The PTA is there to support you and your students and often has funds for special classroom projects. Team up with them for fundraising, or consider organizing additional fundraising efforts with your students specifically for the project.
- Approach school clubs that might benefit from the improvements your project will make, such as the science club or athletic clubs (for example, if you are improving drainage on a field). Clubs are usually great at fundraising!

Teacher Grant Resources:

- GetEdFunding: www.getedfunding.com
- Grants for Teachers - Grantwatch:
- grantwatch.com/cat/42/teachers-grants.html
- NEA Foundation: neafoundation.org
- NSTA Awards: nsta.org/awards-and-recognition-program
- Fund for Teachers: fundforteachers.org
- Youth Service America: ysa.org/grants
- Toshiba America Foundation: toshiba.com/taf/about.jsp
- Donors Choose: donorschoose.org
- STEMgrants: stemgrants.com

- Find funding within your community. Because companies like to give back to their community, it can be helpful to look locally, at the city or state level. Examples of places that have historically supported education are: insurance companies, banks, Rotary clubs, Lions club, environmental coalitions, your local United Way, or hardware stores (like Lowes or Home Depot). Make a note of businesses listed as sponsors for local festivals, fairs, or community events, and consider asking them to support your project. A business with an established history of community involvement is likely to be interested in supporting a resilience project like this.
- Apply for teacher grants. There are grant opportunities specifically for teachers who are doing innovative work like this. We suggest you look for niche grants that focus on specific topics like science education, environmental action, resilience, or community service. There may be grants specific to your region that your project would be a good match for. Be aware that most grants have strict requirements and application deadlines. If you are new to the grant writing process, look for resources to support you, such as this NEA Foundation Writing Tutorial (https://www.neafoundation.org/for-educators/grant-resources/writing-tutorial/).

  Additional considerations when applying for grants

  Many grants will require a project budget as part of your application submission. If you are applying well in advance of starting Project Resilience, this may be challenging because the project has not yet been defined.
  - Consider your school's facility improvement needs that are already identified to see if any of them would be suitable as a resilience project. Put together a budget estimate for one of these projects with the help of your building facilities manager, and use this to define your grant request.
  - Contact funders directly for advice on how to apply for funding to support a project that students will soon be designing. Provide access to the Project Resilience curriculum (lessons 7 & 8 specifically) to help them understand your project goals.
  - When applying, be sure to include the project selection process that your students will undergo to help describe the funding need. Explain how students will develop project proposals using the Project Resilience curriculum and that one project will be selected for implementation with input from key stakeholders (students, school administration, community members, etc.). Explain that the funds will be used to implement the selected project.

Gather support from your community!
There are key stakeholders within your school community (and beyond) that you will need to engage to be successful with this project. It is important to figure out sooner rather than later who will actually be doing the work at each step of the project. Capitalizing on the skills and expertise within your community will not only save you money, but can serve to strengthen your community. The information below is by no means exhaustive, but is a good place to start.

The support of your building principal is key.
The principal can help to make campus and facilities-related decisions, and they will need to approve any permanent changes you intend to make. The principal should be your liaison with the district and will know if approval at that level is necessary. Approach your principal well in advance to explain your goals and vision for implementing a student-designed resilience project. Consider having your principal sign a symbolic document in support of your project that outlines the steps and acknowledges that you, the teacher, are going to be the lead. Consider having your students present the school resilience plan (that they create in Lesson 7) to the principal. Maintain good communication with your principal throughout the entire process. Agree in advance about how this communication will happen, perhaps monthly meetings and then more frequently when project implementation is near.

Your building or facilities manager is another important person to have on your team.
After all, the school campus is ultimately their responsibility. Approval and support of the building manager can help make your students' vision for their project a reality. Plan to meet with the building manager well in advance of starting the Project Resilience curriculum to get ideas about what projects might be needed. Not only will they know where facilities challenges are on your campus, they also know the steps involved with making modifications to campus. For example, they will know where the electrical and plumbing infrastructure is located. They likely know when input is needed from district-level facilities officials. They can get you in contact with contractors and vendors approved by the district to hire for labor or purchase materials from and possibly help source materials. They might even be able to do some of the labor! They can advise your students as they create the detailed list of steps needed to complete their project and their materials list for the project plan (creating the list of steps and materials list is included in Lesson 8: Part 1), and provide invaluable input to make sure you are addressing the needs of all students (e.g., ADA requirements) and are meeting safety requirements. Plan to keep your facilities manager updated about the timeline once the project is underway.

Find people with skills related to your project who are willing to volunteer their time and expertise.
You and your students might find yourselves wearing new hats: engineer, builder, project manager, gardener, etc. Enlisting the help of experts who can look over your project proposals and offer suggestions, help you determine feasibility, or help you create an accurate budget can be invaluable. A good place to identify professionals with the expertise that you are seeking is with contractors that the district uses. Or ask if parents or people in your community or social groups have the skills you are looking for. Look for local organizations that do volunteer work or service work. For example, a local gardening club could help select which plants to install and help with the actual planting. Local colleges and universities might have clubs that could volunteer their knowledge or labor to help. Even school clubs or organizations like the Boy Scouts or 4H who are interested in earning volunteer hours could be helpful support. It doesn't hurt to ask, and this exercise in resourcefulness can be quite valuable for your students.

Plan for student involvement
Involve your students in as many steps of the project as possible. Students can help make calls, send emails, document and report progress, keep track of the budget, and of course, get their hands dirty and provide labor.

If students will be providing manual labor to support the project, ensure that proper safety measures are in place. You may need to create a safety plan and submit it for approval by the school or district. In some cases, you may need parental permission for students to participate. Consider if there are tasks that require training from experts before students begin their work.

Create a variety of roles to allow all students to engage in the project. Some students will prefer using tools to build a garden bed, while others will prefer doing research about which native plants would be best to plant. If your project involves outdoor work or construction, consider administering a skills survey before the project implementation begins to determine the level of experience and interest your students have. Questions could include: Who has used a hammer before? Who has planted a garden before? Who enjoys filming or taking photos?

From the skills survey, you can identify students with experience and skills to fill leadership roles and create groups of students to divide up the responsibilities and tasks. Keeping the student groups consistent throughout the project will lead to self-directedness as students gain confidence and experience with their tasks. Establish a consistent system for check-ins and reporting progress, such as using a Kanban board, https://www.pblworks.org/blog/ultimate-team-work-management-tool-kanban-boards (Kanban board use is discussed in Lesson 8: Part 2).

Image: Adrianna Adams

More tips for success!
Below are a few additional tips that our pilot teachers and administrators shared after going through the project implementation process.

- Be sure to have a plan for all of the labor that is needed, including ordering materials, assembling equipment, and cleaning up the project site at the end.
- Become familiar with your district's spending process. Learn the process for ordering things online, getting quotes or bids, and paying contractors. Figure out if you will need to request purchases from the school finance department and, if so, how much time is needed for purchase approval, or if you need to purchase things and be reimbursed later.
- Choose a project that isn't too far outside of your comfort zone. For example, if you are uncomfortable with power tools, either plan to hire out these tasks or consider steering students towards a project that utilizes skills that you are more comfortable supporting.

Storm Water Management Issues

Students at Terrebonne High School (THS) in Houma, Louisiana, identified an area outside their school that was prone to flooding during typical rainstorms. The area where school buses dropped off and picked up students often flooded, and when water pooled in this area there wasn't a safe, dry spot for students to congregate while they waited for their buses. The students who proposed this project researched the steps it would take to plan and build a deck, and they developed a draft budget for the project. Unlike other student projects, this deck project required working with an external contractor to do the work.

Below are the steps it took to complete this project, along with some lessons learned.

Research Potential Contractors

Obtain a list from the school district of approved contractors eligible to do work on school district property. Reach out to the contractors to get detailed quotes for the work.

Unplanned obstacle: All of the bids from eligible contractors were too high for our budget, and the rising costs of lumber made the initial budget the students developed inaccurate. We needed to get permission from the school district to work with a different contractor who could do the work for a lower cost.

Hire a Contractor

Select one of the approved contractors, work with the school or district administration on any necessary paperwork, and set up a contract for the project.

Unplanned obstacle: The selected contractor for our project needed to increase his insurance coverage in order to be eligible to work for this school district, which he was willing to do, so the district allowed him to do the project.

Agree to a Timeline for the Work to be Completed

Identify the length of time the project will take and agree to dates when this work will happen.

For the TPHS project, the school principal wanted the work to be done during a school break so it wouldn't disrupt the bus schedule. In addition, this work was done during the COVID-19 Pandemic. For public health reasons, the school administration wanted construction to be done when students weren't on campus. The contractor agreed to a one-week project during spring break.

Communicate with All Stakeholders

Have leadership from the school and the school district review and approve all plans before implementing the project.

We kept the school principal and the assistant superintendent in the loop so they were happy with the plans by the time they were finalized. In some projects, the building maintenance group needs to be included in communications as well.

Confirm Work Plans Close to the Start Date

Our team confirmed all project details in the two weeks leading up to the project start date

Purchase Materials and Supplies (if needed)

For our project, the contractor purchased all of the materials and supplies. If it's a project that will be implemented by students, school staff, or volunteers, materials need to be purchased in advance of the start date.

Touch Base with Contractor

During the project implementation, be available to the contractor if needed, check in to see how things are going, and address any challenges.

A potential obstacle could be inclement weather, which fortunately didn't happen during our project.

Project Completion

Do a walk-through to ensure the completed work is satisfactory, including confirming with the school principal and maintenance staff that they are happy with the result.

For this project, everyone involved was pleased with the results, and students began using the deck immediately after returning to school from spring break.

Communicate Results and Successes

Once the project was completed, we shared photos with the school principal, the assistant superintendent, and the community. Communications with the community included social media and the local newspaper. We also gave a presentation to the school board to let them know about all of the student projects that were implemented at each local high school, including the THS deck project.

Post Project: Follow-up and Planning for Upgrades

The students noticed right away that they hadn't planned for seating on the new deck, and they were able to request seating that was in storage at a different school in the district. The project team also decided they want to extend the railing from the edge of the deck to go along one side of the ramp. They have put in a request for the maintenance team to build a railing at a later date.

Rain Garden

Rain gardens are an easy and attractive way to help alleviate drainage problems. By allowing excess water to filter into the soil slowly, they reduce the amount of pollutants entering nearby waterways. Rain gardens are just one example of a project that students can do to help with standing water and other drainage problems at their schools. Since there are many steps involved, the project naturally lends itself to students working together in teams.

Image: LSU AgCenter's Stormwater and Your Rain Garden

The process for creating and maintaining a rain garden

STEP 1: FINDING THE PERFECT SPOT

Students should work together to identify a location for their rain garden that is down slope from buildings. To be effective, the area should also stop and hold the water before it enters a sewer, road, or sidewalk, and be in full sun for at least six or more hours a day. Since digging will be involved, students should contact their local utility company to have utility lines marked, and work with the maintenance or horticulture department at their school to make sure that they have permission to dig in the selected area.

STEP 2: CHOOSING A SHAPE FOR THE GARDEN AND TESTING YOUR SOIL

After students identify their location, they will need to determine the preferred shape for their rain garden (a bean-like shape is fairly common). Marking out the shape of the garden using rope, twine, or other materials will allow the students to visualize the garden's location so they can make adjustments.

The soil will also need to be tested to make sure water will drain (this is another great opportunity for student observation and collaboration). To test the soil, locate the middle of your garden, dig an 8-12 inch hole, and fill it with water. Monitor this hole over 24-48 hours for drainage. Ideally, the water will drain within 24 hours. If the water is still in the hole at the end of 24 hours, one of two things need to happen for your rain garden to be effective at absorbing stormwater: 1) A new site can be located, or 2) you can plan to mix in sand to the soil to increase the rate of infiltration.

STEP 3: DIGGING OUT THE GARDEN AND ADDING SOIL

This will be a team effort! Following the established outline for the garden, students will need to dig down and remove the top 6-8 inches of soil, with the deepest part of the garden located in the center. A berm will need to be created to help direct the water towards the deeper center of the rain garden. Most soil types will require adding new soil or sand to your rain garden to support the native plants you will be adding.

A photo of the berm preparation for a rain garden (left) and a photo of a completed rain garden with a berm along the back side of the garden (right) from The Cornell Lab's Yardmap article, How to Create an Effective Rain Garden.

STEP 4: PLANTING YOUR RAIN GARDEN

One of the advantages of a rain garden is students can be involved in the selection and planting process, which allows them to see instant results. Native plants are ideal to use in rain gardens, and provide an opportunity to discuss the benefits for wildlife.

Photos are from The Cornell Lab's Yardmap article, How to Create an Effective Rain Garden.

STEP 5: MAINTAINING YOUR RAIN GARDEN

Once students have created their rain garden, they will need to help with maintaining the plants. Examples include watering the plants during dry spells, weeding, repairing (erosion), and pruning.

Image: UConn Rain Gardens

This information was compiled as a resource for Project Resilience using the resources from the Habitat Network (content.yardmap.org/learn/how-to-create-effective-rain-garden/) and UConn Rain Gardens (nemo.uconn.edu/raingardens/installation.htm). A step-by-step guide with additional resources is available at https://bit.ly/project-resilience-rain-garden.