Concrete Questions: Engineering Solutions for a Changing Coast

A California Coastal Voices Teacher-Guided Project

Main Beach, Laguna Beach. Photo: Mitch Ridder

Challenging Question:

How can we use engineering practices to protect natural and human communities on sandy shores?

For this Project:

Golden Gate Bridge, Photo: Kim Aikawa

Challenging Question:

How can we use engineering practices to protect natural and human communities on sandy shores?

This unit supports learning in the following Next Generation Science Standards Performance Expectations:

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ESS2-1: Develop a model to illustrate how Earth's surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Concrete Questions: Engineering Solutions for a Changing Coast

Overview

A variety of natural processes and human factors have combined to damage and even occasionally eliminate California beaches and coastal recreation opportunities and threaten backshore development such as homes, roads, and other structures. With climate change causing sea level rise and increasing extreme storm events, the challenge will only grow in the foreseeable future. When the sea level rises, a beach will shift inland, but only if it has space to do so. If a beach is backed by a seawall, the rising ocean results in a "coastal squeeze" as the beach is prevented from migrating inland. In communities where private homes are located in close proximity to popular coastal recreation areas and on eroding coastal bluffs and beaches, there can be a clash between the interests of residents and the interests of others who use the area. For example, surfers maintain that certain shoreline protection methods have negative consequences upon surf quality, wave patterns, and ecosystems. While coastal property owners may not disagree, some may feel that protecting their homes should be prioritized above protecting sandy beaches and surf spots. Transforming these conflicts into broadly agreed upon, technically sound plans for balancing coastal priorities is an ongoing challenge for California.

In *Concrete Questions* students will develop an understanding of the Earth systems and human factors that sculpt the shoreline and result in beaches with unique characteristics, answer technical questions about coastal processes, communicate with explanatory models, and evaluate methods for protecting natural and human communities along our sandy shores.

Students will work in groups to evaluate place-based solutions for protecting both sandy beaches and adjacent beachfront structures in real world locations along the California coast. Students will investigate a specific coastal community of their choosing and evaluate a solution that has been implemented in the past or is proposed for the future. Each group will present their evidence, arguments, and conclusions in the final session of the unit.

At the end of this unit you will find further standards connections, including the three dimensions of *NGSS* and California's *Environmental Principles and Concepts*.

Students will provide evidence of learning by:

- Conducting a presentation of their evaluation of a planned or already implemented coastal erosion solution.
- Developing a conceptual model of beach-building coastal processes.

Find images for download, links to videos, and other resources referred to within this project on the *Coastal Voices Website*: www.coastal.ca.gov/coastalvoices

Prior to Beginning the Activities:

Students should read the *Making Sense of Images* and familiarize themselves with the *Guiding Questions for Image Analysis* worksheet, both found in the Readings and Resources section.

Activities

These activity descriptions are structured to provide core content learning and support the open-ended inquiry process of the project.

1. Invitation to Engage: What Forces Act on Beaches?
2. Exploration: A Home on the Edge
3. Explanation: Teacher-Led Earth Systems Lab
4. Elaboration: Student-Led Earth Systems Lab
5. Extend and Evaluate: Crafting Consensus at Surfers Point
6. Evaluation: Communicating Science Concepts

Sunset Cliffs Natural Park, San Diego. Copyright (C) 2013 Kenneth & Gabrielle Adelman, California Coastal Records Project

Activity

Guiding Questions:

- What forces act on beaches?
- What are some options for protecting beachfront homes and beaches?

Materials Required:

- Individual student notebooks
- *Making Sense of Images* and *Guiding Questions for Image Analysis*, found in the Readings and Resources section
- Note cards
- Poster paper

Download from or access on the *Coastal Voices Website*:

- Daily Phenomenon #1
- "Swept Away: Paradise in Peril," 2011 KCET news clip
- Coastal armoring article from California Sea Grant

Concrete Questions Invitation to Engage: What Forces Act on Beaches?

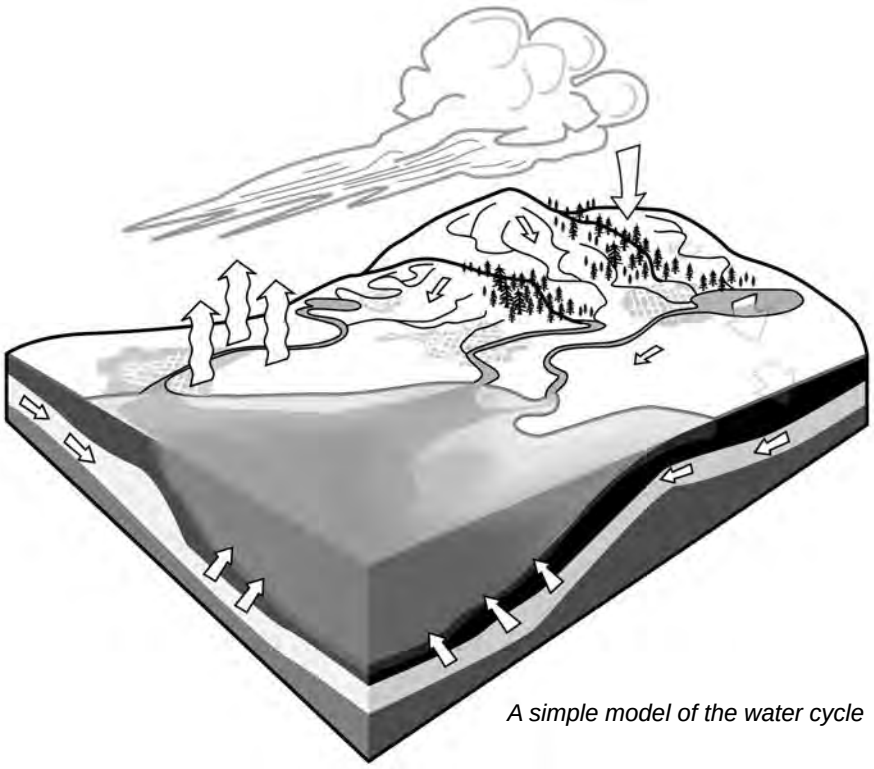
During this session students draw and revise an explanatory model of the forces that act upon beaches.

Daily Phenomenon

Ask students to examine the sediment bloom image (Daily Phenomenon #1) using the *Guiding Questions for Image Analysis* worksheet. In their notebooks, students should propose answers to the following questions: What is a beach? Where does the sand come from? What makes these dynamic places special, and potentially tough to manage from an engineering perspective? Students respond in their notebooks in prose writing, artistically, or with a conceptual model.

Explore - Beach Models

1. In three minutes, students individually respond on note cards to the following: How can groups reach consensus on difficult science and policy questions? Cards are turned in to the teacher.
2. Teacher leads a brief discussion on the development of conceptual models. The *Next Generation Science Standards*



A simple model of the water cycle

Conceptual Models Should Include:

- Components of the system under investigation. Label each depicted component and note boundaries.
- Relationships between components. Identify and label quantities, units, and energy conversions.
- Connections to scientific theories and crosscutting connections.
- Revisions. Use a distinct color from the original draft. Once the model is too cluttered for easy comprehension, use another page.
- A statement about the model's predictive power.

provides this explanation: "In science, models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others...In engineering, models may be used to analyze a system to see where or under what conditions flaws might develop, or to test possible solutions to a problem. Models can also be used to visualize and refine a design, to communicate a design's features to others, and as prototypes for testing design performance." Teacher demonstrates a conceptual model using a familiar concept of the water cycle as an example.

3. Following this, the class brainstorms responses to the guiding questions for this activity: What forces act on beaches? What are some options for protecting beachfront homes and beaches? Teacher captures student thinking by writing out ideas on a board or poster.
4. Form groups of four students. These groups will work together throughout the project on evaluating a coastal erosion solution and presenting their conclusions during the final class session.
5. Students meet in their groups to draw a first draft conceptual model of how forces act on beaches. It is understood that creative guessing may be required.
6. Students perform a gallery walk to view other groups' models and collect ideas to add to their own explanatory model.
7. Students watch KCET's 2011 news clip "Swept Away: Paradise in Peril" (as a whole class or in groups depending on classroom resources) and read California Sea Grant's coastal armoring article.
8. Students decide how to revise their models based on this new information and perform another gallery walk.
9. Hang models on the wall, if possible, and have groups share insights or questions.

Reflect on Thinking

In their notebooks, students individually write a Reflective Summary that responds to the guiding questions of the day. Teacher guides, prompts, and evaluates student thinking.

Initiating the Project

Transition back to groups. Each group will choose a California coastal location to study. It should be a location that is dealing with or has dealt with a coastal erosion problem. Groups will evaluate a solution that has been implemented in the past or is proposed for the future, in relation to issues that may include cost, safety,

reliability, effectiveness, aesthetics, and social, cultural, and environmental impacts, taking into account expected sea level rise. Given that current projections show sea level rising by as much as two feet by 2050, this issue will have significant impacts on coastal development and must be of primary concern in future planning. Groups will provide reasoning for their answer to the question: If I were a California Coastal Commissioner, would I approve this project? (See the Readings and Resources section for an *Introduction to the California Coastal Act*. You may choose to lead your students in the activity from *Coastal Voices: Speaking up for the Beach*, "Interpreting the California Coastal Act," to introduce them to the law.) Students should begin their research through searches of news reports and local government and community plans, and on the California Coastal Records Project website, where they will find historical and recent photos of the coast.

Groups may consider these coastal locations or find others:

- Ocean Beach, San Francisco
- Sunset Cliffs Natural Park, San Diego
- Solana Beach
- Isla Vista Beach, Santa Barbara

This work may continue to out-of-class time.

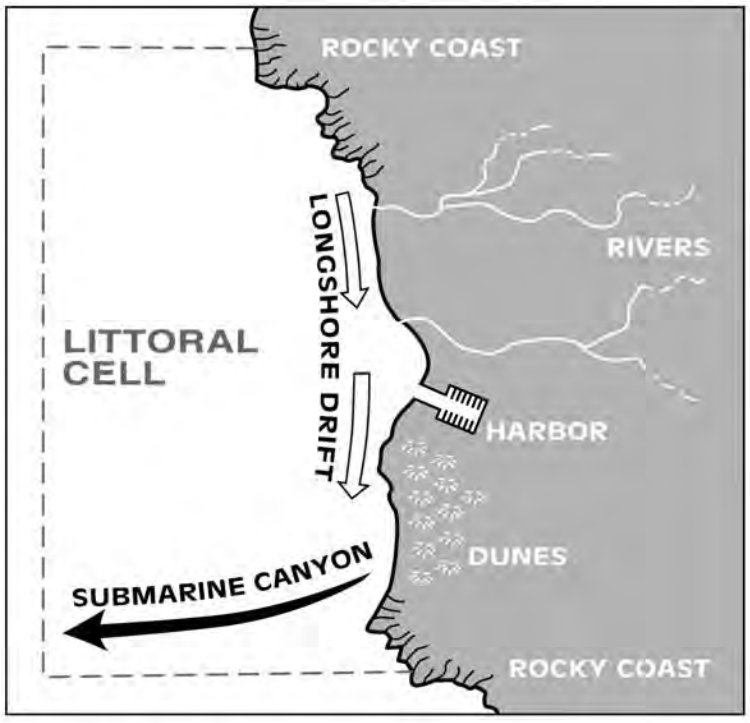
GO DEEP...

Find links on the Coastal Voices Website at www.coastal.ca.gov/coastalvoices for the following:

Read an article about sand movement on the coast from California Sea Grant.

Explore KQED's *Coastal Clash* interactive website, specifically "How Beaches Work" and "Coastal Armoring." The *Coastal Clash* 60 minute DVD looks at issues of beach access, development, erosion, and the many sides of the struggle for California's beaches, and can be borrowed from the California Coastal Commission.

Review *Littoral Cells, Sand Budgets, and Beaches: Understanding California's Shoreline*, a report for the California Department of Boating and Waterways.



Watch *Beach: A River of Sand*, a video by Encyclopaedia Britannica Films. Watch online or borrow a copy from the Coastal Commission.

Examine a littoral cell diagram to understand longshore drift of sand along the coast.

Activity

Concrete Questions Exploration: A Home on the Edge

Guiding Question:

- What is the best approach for reaching a community consensus on difficult science and policy questions?

Materials Required:

- Individual student notebooks
- *Making Sense of Images* and *Guiding Questions for Image Analysis*, found in the Readings and Resources section
- *A Home on the Edge* scenario and stakeholder roles
- *Dealing with a Retreating Coastline* reading

Download from or access on the *Coastal Voices Website*:

- Daily Phenomenon #2
- Pacifica bluff image set

GO DEEP...

Naturally Resilient Communities presents a variety of nature-based solutions to flooding and erosion on their website:

nrcsolutions.org

In this activity students play a coastal stakeholder role, consider a range of viewpoints, and debate the merits of coastal protection structures.

Daily Phenomenon

Teacher presents the image of Torrey Pines State Beach (Daily Phenomenon #2) to the class. Students examine the image using the *Guiding Questions for Image Analysis* worksheet and take notes in their notebook. They should revise their definitions of a beach, and propose a preliminary model for how waves will act upon beach sand. How do wave direction and strength interact to build sandy beaches in California?

Explore - Coastal Stakeholder Activity

Teacher presents the Pacifica bluff images as a real-life example of bluff erosion threatening a structure. Allow time for class conversation about the images, then transition to *Home on the Edge* activity:

1. Arrange chairs in the classroom in two concentric circles facing inward. Each student in the outer circle partners with a student in the inner circle. Teacher assigns each pair a *Home on the Edge* role. Student pairs read the scenario and prepare a position statement to present during discussion circle.
2. The inner circle of speakers assume their specified role for the case study and discussion. Outside observers will watch silently and coach the speakers at intervals.
3. Observers prepare to coach their partners by keeping track of their performance; for example, by tallying how many times the student participates, asks a clarifying question, or acts to encourage everyone's voice be heard. When discussion concludes, partners debrief privately.
4. Student pairs read and discuss *Dealing with a Retreating Coastline*, and then reverse roles. Be sure all students have turns as both the speaker and the observer during the learning activity.
5. Whole Group Critique: How did it feel to be a speaker inside the circle, or an observer outside the circle? Students share questions and insights into how to best develop consensus.

Construct Explanations and Models

In their notebooks, students individually write a Reflective Summary, stepping away from their assigned stakeholder role and describing what kind of engineering solutions they personally support. Students should cite evidence from the case study and structured academic conversation. Students revise their explanatory model of beach-building coastal processes.

Managing the Project

Students work in groups to research their chosen California coastal location and its existing or planned erosion control solution. In what ways is the solution appropriate or inappropriate for the location and the community? This work may continue to out-of-class time.

GO DEEP...

The MARE program at UC Berkeley's Lawrence Hall of Science has developed a hands-on sea level rise activity as part of their *Ocean Sciences Sequence for grades 6-8: The Ocean-Atmosphere Connection and Climate Change*. This activity, which can be downloaded from the *Coastal Voices Website*, will enhance students' understanding of the factors impacting coastal habitats and development.

Piedras Blancas. Photo: Gary O'Neill

A Home on the Edge

In this activity you will take on one of four stakeholder roles in a fictional situation, consider a range of viewpoints, and debate the merits of coastal protection structures. Improvise where appropriate, but please no messing with the facts or evidence as they are presented to you.

Scenario:

Al Jordan is worried about his home, and for good reason. The single family home he owns is on a bluff facing the ocean, and the bluff is eroding. The house was constructed during the last century and his family has lived there for the last five years. Jordan's house is currently 30 feet from the bluff face, but when he bought the property it was 50 feet back. Then strong storms and waves during the previous winter eroded the base of the bluff and 20 feet fell from the top in a sudden collapse.

The Jordan property is 0.2 acres in a small, well-to-do neighborhood, bordered by the bluff and beach to the west, a road to the east, and county parkland on north and south. The house is set 100 feet back from the road and the house itself is one story and 2,400 square feet. The bluff it sits on is 20 feet above the beach below.

Jordan's hired expert has determined that the average retreat rate for this bluff is nine inches per year since the house was constructed. However with an El Niño predicted for the following year, and more extreme storms expected due to climate change, Jordan is worried that the bluff retreat could happen faster.

The beach below the house is well-used by the public, particularly in the summer months. There is public access from the parks to both the north and south of the Jordan property. In the summer there is a sandy beach about 200 feet wide, which sometimes disappears during large, winter storms as the waves crash against the bluff. With sea levels in the area predicted to rise by as much as two feet by 2050, there is concern for the future of this beach.

Jordan invited interested and informed members of the community to his home for an informal gathering to discuss what to do about his property.

Coastal Zone Stakeholder:

I am Danielle Garamond, a coastal engineer with Protective Engineering, LLC. My interest lies in protecting the rights of property owners to preserve their assets by building coastal protection structures. I especially value the cherished oceanfront homes that define the good life in California. With respect to arguments about public beaches, it is clear to me that legal property rights are of higher value. Besides, there are many beaches in California.

Claim: Coastal armoring preserves homes, increases the tax base in coastal communities, and rewards hard working citizens who have earned the right to live on the coast. There is a relationship between coastal armoring and loss of sandy beaches, but the higher value is the protection of homes and other coastal structures. No precedent should be set limiting coastal armoring activities.

Evidence: Seawalls and other coastal protection structures have been shown to preserve oceanfront property values. In addition, the US Army Corps of Engineers has spent decades building such structures, investing billions. Would they do this if it did not make sense? At least 10% of California's coastline is protected by armoring. Why should a homeowner in need of a sea wall today be denied protection?

Reasoning: My evidence supports a goal of retaining the right to build any type of coastal protection that will serve a property owner's needs.

Coastal Zone Stakeholder:

I am Bob Larkin, a coastal engineer with Tomorrow's Engineering, LLC. My interest lies in protecting the rights of property owners by using soft engineering solutions that increase biodiversity and the quality of a beach, even as property rights are respected. Nature provides value to our society through ecosystem services.

Claim: By mimicking natural processes we can protect structures while enhancing the coastal environment and increasing recreational opportunities. Beach nourishment (bringing more sand to the beach), dune building, and planting vegetative cover are my preferred methods. It will be necessary to repeat the beach nourishment as the sand is naturally washed away over the years, but it preserves the beach where hard solutions do not.

Evidence: Experts in the field (like me) can design soft engineering solutions that protect the shoreline. Even when sand that has been deposited is moved offshore by the current, it can still protect the shore by causing waves to break farther out. FEMA has recognized the value of soft engineering by reducing flood insurance premiums in some instances, and the US Army Corps of Engineers has undertaken beach nourishment projects on the eastern US coast for decades.

Reasoning: While soft engineering solutions take expertise, time to implement, and maintenance commitment, they protect the beach and private property so my belief is that they are worth the investment.

Coastal Zone Stakeholder:

I am Mary Chang and I represent the local surfers' group. Our interest is in protecting the beach for public enjoyment and as a thriving habitat. We understand that private property owners care about and enjoy their homes, and that they've invested significantly in them. However, when someone chooses to purchase a structure on an eroding bluff, they are choosing to take significant risks. Oceanfront property owners enjoy the benefits of dramatic ocean views, waves, and easy access to the water; they should not then be allowed to destroy these pleasures for the public when natural forces do what they have always done. We place more value on the rights of a community of beach-goers than on those of a property owner who knew what he was getting into.

Claim: Coastal bluff collapse and retreat are natural processes. Sea walls fix in place the back of the beach instead of allowing it to move as it would otherwise. As sea level rises, it is particularly important that beaches be able to move landward. Sea walls also prevent a naturally eroding bluff from contributing sand to the beach.

Evidence: California Sea Grant as well as other coastal experts has made it clear that coastal armoring can increase erosion on the beach itself, which not only has recreation impacts but can reduce or eliminate habitat on the beach for shorebirds and other animals.

Reasoning: My evidence supports the goal of allowing the shoreline to retreat, even at the expense of private property owners. Local governments should act now to plan for the necessary removal of at-risk structures and where possible, existing coastal armoring in light of sea level rise forecasts due to global warming.

Dealing with a Retreating Coastline

The beach at Santa Cruz was a 10-mile hike to the west 18,000 years ago at the end of the last Ice Age. As glaciers retreated and ice sheets melted over the following centuries, sea level rose about 400 feet and gradually flooded the edge of California, moving the beach inland. The coast retreated about 300 feet per century during that era of warming and melting. Throughout this 18,000-year period, the sea cliffs marching back three feet every year didn't matter much. Although the Ohlone used the coast, harvesting fish and shellfish and hanging out on the beach, they didn't have permanent dwellings so the precise location of the beach and sea cliff didn't greatly impact their lives.

Things are different today. The shoreline and sea cliff from San Diego to Santa Barbara is almost completely urbanized. In Santa Cruz County, homes, businesses, roads, parks and parking lots cover the coastline from Manresa to Natural Bridges. It's probably fair to say that California's most valuable real estate is right on the edge. But that edge is never in the same place for more than a few decades. The shoreline moves back and forth over millennia as sea level rises and falls in response to climate change.

Around the Mediterranean Sea, civilizations have dealt with this phenomenon for thousands of years. In California, however, our coastal development and construction history is much more recent. Photographs of coastal bluffs in Santa Cruz County from the late 1800s reveal that people didn't build right at the edge. But today, it's pretty much continuous development of one sort or another. The closer to that ocean view, the more valuable the house and land.

So how have we dealt with the erosion and retreat over the past 50-100 years and what are we going to do in the future? This is a messy and emotional issue involving expensive and difficult questions, and it's not going to get any easier.

Historically there have been three basic options for dealing with coastal retreat: 1. retreat or relocation of development; 2. armor or protection; or 3. beach nourishment. These are not simple decisions.

Nobody with an oceanfront location is excited about moving back from the edge, but it has happened and will likely happen more often in the future. On Depot Hill in Capitola, six cliff top apartments were taken down after the Loma Prieta earthquake when concrete caissons were undercut, and foundations cracked and partially failed. Twenty years earlier, a house next to the apartments was picked up and moved back several blocks and put on a new foundation.

In other cases, failure to relocate houses led to cliff collapse and homes ending up on the beach below, which is what happened along the Esplanade in Pacifica in 1998. Sea level rise and a more severe storm climate claimed 28 villages along the southeast coast of England during the Middle Ages.

What Causes Shoreline Retreat?

Large waves arriving at high tide are the major force behind most coastal erosion and storm damage. Shoreline retreat may take different forms, however.

The change from low-energy summer waves to high-energy winter waves leads to beach erosion every winter. Sand is scoured off the beach in December and January and stored offshore, only to return again the next spring and summer when winter storms have abated and calmer waves return. This is an expected and normal process we can all observe.

Stilwell Hall, Fort Ord. Facing bluff erosion, this World War II era building was demolished in 2003. Copyright (C) 2003 Kenneth & Gabrielle Adelman, California Coastal Records Project

The coastal erosion that concerns cliff top residents as well as coastal communities isn't the seasonal beach erosion, however, but the erosion and permanent retreat of the cliff or bluff. This is not recoverable, at least within our lifetimes or by natural processes.

The rate at which cliffs or bluffs have historically eroded along the California coast varies from a surprising ten feet per year at some unfortunate locations, to a few inches or less in others. The former is obviously a cause for concern, especially if it's your front yard or patio.

Several different factors affect how rapidly a given cliff will retreat. The cliff's strength or resistance to wave attack is usually the most important. Rock strength varies widely, depending on the type of rock, the hardness or degree of consolidation or cementation, and the presence of weaknesses such as fractures or joints.

The amount of wave energy reaching any particular area of coastline is also a key factor, and while the waves approaching the central coast on any given day come from the same storms, nearshore bottom conditions or bathymetry will increase or decrease wave heights at specific locations along the shoreline.

A final factor is the regional rate of sea level rise, a natural phenomena that is accelerated by human influence via global warming from the accumulation of greenhouse gases in the atmosphere.

"Dealing with a Retreating Coastline" and "What Causes Shoreline Retreat" excerpted from *Our Ocean Backyard, Collected Essays*, by Gary Griggs

Activity

Concrete Questions Explanation: Teacher-Led Earth Systems Lab

Guiding Question:

- How do land features such as points, sea stacks, islands, and mountains influence nearshore ocean circulation?

Materials Required:

- Individual student notebooks
- For each group: 1 shallow tray, 3 rocks, 1 mixing stick, chart paper
- Food coloring (optional)
- Video camera/phone (optional)

Download from or access on the *Coastal Voices Website*:

- Daily Phenomenon #3
- Sea surface temperature image
- Teacher background information on currents

What is a Bight?

A bight is a long, gradual bend or recess in the shoreline that forms a large, open bay.

In this Earth Systems lab, students physically explore the movement of water around rocks. They use this hands-on experience and examination of remote sensing images to expand their understanding of California coastal processes.

Daily Phenomenon

Using the Southern California Bight image (Daily Phenomenon #3) as a reference, students draw an outline of the Bight in their notebooks. Instruct students to include coastal land features such as points or islands. Students then draw a preliminary model of how currents circulate in the Bight, labeling physical features and speculating about the driving mechanisms. It is understood that students will be guessing about mechanisms.

Explore - Waves and Rocks Lab

Teacher leads an interactive discussion and introduces key concepts of currents, wind-driven waves, and wave reflection and refraction. Teacher background information on current circulation can be found on the *Coastal Voices Website*.

1. Convene groups and place a water-filled tray at each group's table. Put rocks representing shoreline features into the tray and ask students to explore how water moves around the rocks. Teachers may add food coloring to the water to aid observation. Mixing sticks may be used to propel the water or students may gently blow upon the surface. If the technology is available, film the water movement and play it back in slow motion. Students then draw sketches of the results.
2. Students share existing knowledge of currents as groups sketch out a revised model of Southern California Bight circulation on chart paper. Teacher ensures that details are added, especially with respect to labeling mechanisms.
3. Hang chart paper and have students perform a gallery walk comparing models. Teacher encourages students to share evidence-based ideas, asks probing questions, and reminds students to think about the Guiding Question.
4. Groups explore a sea surface temperature image and notice the visible patterns. Teacher guides students toward exploring the connection between currents and thermal patterns.

5. Student groups estimate direction of the surface currents and speculate about the relative ability of water in motion to move sand, resulting in accretion or erosion. Students use graph paper to revise their Southern California Bight model with vectors showing the direction of currents.

Construct Explanations and Reflect on Thinking

In their notebooks, students individually write a Reflective Summary that responds to the Guiding Question. Students revise their explanatory model of beach-building coastal processes.

Managing the Project

Transition back to groups, which continue to develop their arguments and conclusions regarding their coastal location's erosion solution, and begin preparing their presentation and visual materials. This work may continue to out-of-class time.

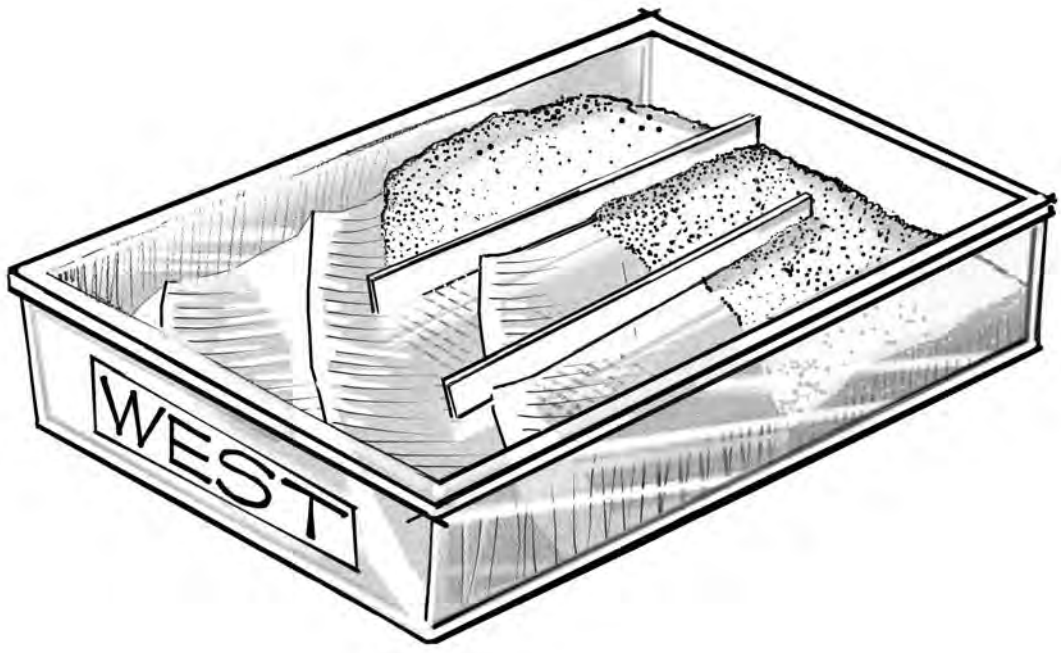
Student Preparation for Next Session

Students preview *Building a Beach Model* and review the *Presentation Rubric*.

Pfeiffer Beach. Photo: Dale Mead

Building a Beach Model

1. Label the shorter sides of a rectangular pan for the ocean and inland directions of the section of the coast you would like to represent. "East" and "West" are used as examples here. Pour up to four inches of sand into the east (inland) end of the pan.
2. Gently add tap water up to two inches deep on the west end of the pan. Draw your experimental model. Throughout this lab, be sure to label all elements of your drawings.
3. Use a ruler to create a gentle wave action in the pan, in a general west-to-east movement. Draw how the model appears after wave action. What are the effects of erosion? How has the coastline changed?
4. Position the sand to its original model configuration. Set two to three rulers on-edge into the sand lengthwise about four inches apart, representing groins. Use a ruler to create the same gentle west-to-east wave movement. What happens in between the groins? What happens to the shoreline? Draw the model. Make waves coming from the northwest. Do the beaches in between the groins change? Draw the model to indicate how the beaches look after completing this wave action.
5. Determine a way to model a seawall in the pan. What happens to the shoreline after wave movement? Gently add additional water to the pan and observe how "sea level rise" in your model impacts a beach in front of a sea wall. Draw the model before and after.



Activity

Guiding Questions:

- What forces act on beaches?
- What are the consequences of building concrete shoreline protection structures?

Materials Required:

- Individual student notebooks
- *Building a Beach Model*

For each group:

- Rectangular pan or plastic bin (9" or 12" deep, more than 12" long)
- All-purpose sand
- 4, 12" rulers
- Tap water
- Camera/phone (optional)

Download from or access on the *Coastal Voices Website*:

- Daily Phenomenon #4
- Spreadsheet of global absolute sea level change

Concrete Questions Elaboration: Student-Led Earth Systems Lab

In this Earth systems lab, students use a physical model to explore the movement of sand and water as they interact with coastal protection structions.

Daily Phenomenon

Instruct students to individually examine the image of Capitola Beach (Daily Phenomenon #4) and propose in their notebooks a preliminary model for how waves interact with coastal protection structures to build/erode sandy beaches in California.

Explore - Beach Model Lab

In groups, students take on the following roles for this lab: investigation leader, data collector, note-taker and asker of probing questions, and photographer/videographer.

Earth Systems Lab Procedure:

1. Before beginning the lab, review with the class the definitions of independent, dependent and controlled variables. Ask students to think about what variables influence the natural systems of a beach.
2. Group members consider the sandy shore environment and identify something interesting they have previously noted or observed during the Daily Phenomena. Students should then reframe these observations into testable questions (e.g. what is the relationship between _____ and _____?), or a hypothesis, taking care to consider the null hypothesis (that there is no relationship).
3. Each group performs the lab following the instructions in "Building a Beach Model." Groups may choose to modify the procedures after consultation with the teacher. Revise explanations and repeat procedure as many times as time allows. Photograph or film and record all data for subsequent interpretation.

Construct Explanations and Reflect on Thinking

In their notebooks, students individually write a Reflective Summary that responds to the Guiding Questions. Students should revise their developing explanatory model of how coastal processes sculpt beaches, adding color, detail, and labels.

In their Beach Models, students are investigating the impacts of groins and seawalls. What is a seawall, what is a groin, and how is it different from a jetty?

Seawall:

A structure built on a beach, parallel to the shoreline, designed to protect buildings form the action of waves.

Groin:

A structure built perpendicular to the shoreline designed to trap sand moving along the shore due to the longshore current. A groin or group of groins usually extend to the end of the surf zone and are used primarily to replenish or stabilize beaches.

Jetty:

Structures built in pairs that extend further into the ocean than a groin, to stabilize a navigation channel and keep the water calm for harbor entrances.

Working with the Numbers

Working individually or in groups, during class or as homework (depending on resources and teacher preference), download a spreadsheet from the *Coastal Voices Website* containing global absolute sea level change from 1880-2015. Global sea level is rising, mainly due to the expansion of ocean water as it warms and from the addition of freshwater to the ocean from melting land-based ice. Have students graph the change in sea level over time. Why is the adjusted sea level zero in 1880? What is the slope of change in sea level rise during the time period shown? Using this slope to extrapolate to 2040, what sea level rise amount would you expect? Have students make a claim as to whether this extrapolation produces a plausible prediction. Students should provide evidence for their claim. What environmental factors in the present and future are influencing the slope of the data and impacting the accuracy of their extrapolation? Starting in 1993, the spreadsheet shows data collected by satellite. What are the implications of using satellite data versus tide gauge data for sea level rise projections?

Managing the Project

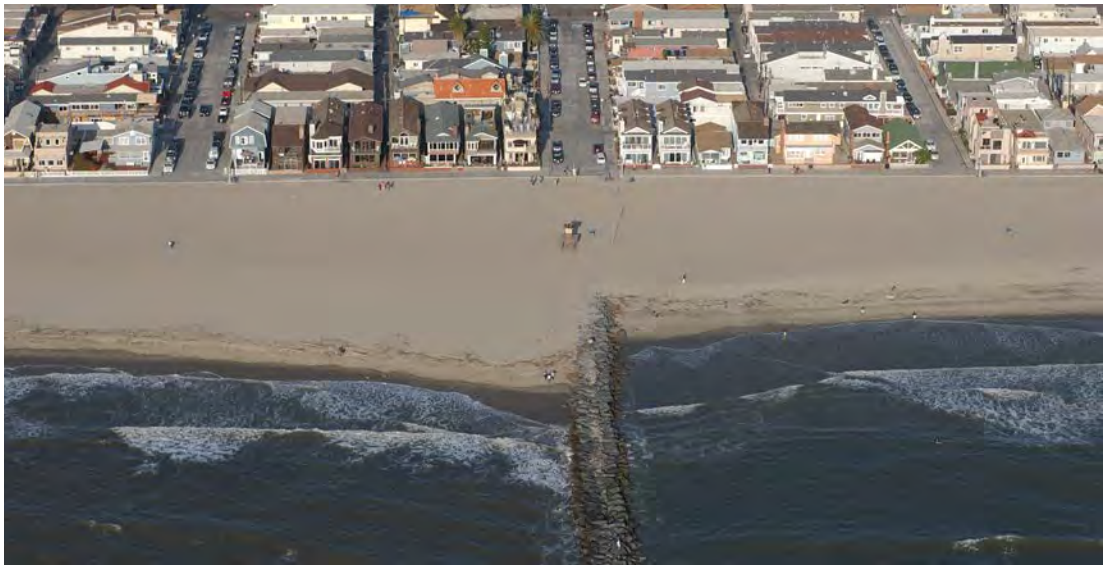
Transition back to groups to continue work on presentations.

Student Preparation for Next Session

Students use the rubrics (as assigned by the teacher) for self and peer evaluation and write a plan of improvement as directed by the teacher.

Read Case Study on Surfer's Point (see *Coastal Voices Website*).

Watch the California Coastal Trail episode, "Restoring Surfer's Point at Seaside Park" (see *Coastal Voices Website*).



Groin, Newport Beach. Copyright (C) 2004 Kenneth & Gabrielle Adelman, California Coastal Records Project

Activity

Concrete Questions Extend and Evaluate: Crafting Consensus at Surfers Point

Guiding Question:

- How have coastal communities successfully reached science-based community consensus on difficult science and policy questions?

Materials Required:

- Individual student notebooks
- *Making Sense of Images* and *Guiding Questions for Image Analysis*, found in the Readings and Resources section

Download from or access on the *Coastal Voices Website*:

- Daily Phenomenon #5
- Case Study Reading on Surfer's Point
- California Coastal Trail episode, "Restoring Surfer's Point at Seaside Park"
- Spreadsheet of Relative Sea Level Change Along U.S. Coasts

After learning about a real-world community response to coastal erosion, students will analyze the process and outcome and engage each other on the topic of consensus building.

In preparation for class, students have read the case study of Surfer's Point and viewed the California Coastal Trail episode "Restoring Surfer's Point at Seaside Park."

Daily Phenomenon

Teacher presents the images of Surfer's Point (Daily Phenomenon #5). Individually in their notebooks, students examine the images following the *Guiding Questions for Image Analysis* worksheet, revise their definitions of a beach, and propose a preliminary model for how wind will act upon beach sand. How do wind direction and strength interact to build sandy beaches in California?

Explore - Surfers Point Case Study Analysis

Students analyze the outcome at Surfer's Point via the reading and video and consider potential applications to other managed retreat controversies.

1. Teacher leads a review of assigned reading and responds to questions from homework before posting the following set of questions for the student groups to explore. Encourage students to use any available technology.

   What problem is being addressed in the case study?

   What obstacles were especially challenging?

   Who were the key players?

   What role did they play?

2. Each student group writes on chart paper a suggested procedure for guiding community groups to science-based consensus.
3. Teacher guides students in responding to the next set of questions:

   How did the community monitor progress on the project?

   Was funding for the proposed solution found?

   How did the group reach consensus?

4. Groups revise their proposed consensus-building procedures and post for peer review. Teacher leads a gallery walk.

5. Ask groups to consider whether they might do anything differently from the approach in the case study. Why?
6. To conclude the activity, speakers from each group argue for their proposed model of consensus building. Teacher evaluates.

Working with the Numbers

Show students the image titled "Relative Sea Level Change Along U.S. Coasts 1960-2015," available on the *Coastal Voices Website*. Land in different locations rises and falls due to causes such as tectonics and groundwater extraction, and that combined with ocean and atmospheric circulation patterns results in relative local sea level rise rates that may be higher or lower than the global average. From the data shown in the image, how much has sea level changed relative to land in the area closest to Surfer's Point? How does that compare to the absolute change in global sea level shown in the data analyzed in the last activity? How might future sea level rise impact the erosion solution at Surfer's Point? How might the erosion solution itself effect how sea level rise impacts this stretch of the coast?

Construct Explanations and Reflect on Thinking

In their notebooks, students individually write a Reflective Summary describing what kind of engineering solutions they support, citing evidence from the case study and structured academic conversation. Students complete their final explanatory model of beach-building coastal processes, due at the next session.

Managing the Project

Transition back to groups to complete preparations for their presentations, including all visual aids.

Surfer at Steamer Lane. Photo: Richard Osugi

Activity

Guiding Question:

- How can science concepts be communicated to public audiences?

Materials Required:

- Individual student notebooks
- *Creativity*, *Presentation*, and *Collaboration Rubrics*, found in the Readings and Resources section.

Concrete Questions Evaluation: Communicating Science Concepts

Each group will present their evaluation of a coastal location's erosion solution in a gallery walk.

Evaluate and Defend

Each group will be evaluated by rotating groups of peers. For a large class, consider a more formal theatre-style presentation.

1. Immediately upon entering the room, groups set up multimedia aids in their assigned spot.
2. Each group takes a few minutes to practice responding to questions with evidence.
3. Groups hang a large sheet of butcher paper next to their assigned spot, placing markers nearby so classmates can post comments.
4. Groups conduct presentations for a portion of the class. If possible, rotate students so that each group's work is presented once by each group member. Audience members complete the presentation evaluation rubrics.

Construct Explanations and Reflect on Thinking

In their notebooks, students write a Reflective Summary that responds to the guiding question of the day.

At-Home

Students use the full rubric set (or as assigned by the teacher) for self and peer evaluation to reflect upon performance.

Pacifica. Photo: Jack Sutton

Connecting to the Standards

***Concrete Questions: Engineering Solutions for a Changing Coast* supports the following *Next Generation Science Standards* Performance Expectations.**

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ESS2-1: Develop a model to illustrate how Earth's surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Environmental Principles and Concepts	Specific Connections to Unit / Activity Designation
Principle II—People Influence Natural Systems	• Obtain and evaluate information from a video and an article on shoreline erosion and armoring solutions. (Invitation to Engage) • Argue stakeholder roles in a coastal erosion scenario, and analyze an article about real erosion incidents and responses. (Exploration)
Principle II—Decisions Affecting Resources and Natural Systems are Complex and Involve Many Factors	• Obtain and evaluate information from a video and an article on shoreline erosion and armoring solutions and consider methods of consensus building. (Invitation to Engage) • Argue for coastal erosion solutions within stakeholder roles with different priorities. (Exploration) • Analyze a coastal erosion case study. (Extend) • Evaluate a real worldcoastal erosion solution. (Evaluation)
Principle III—Natural Systems Change in Ways that People Benefit from and can Influence	• Perform a wave analysis lab and explore data to create a predictive model to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration) • Analyze a coastal erosion case study. (Extend) • Evaluate a real coastal erosion solution. (Evaluation)

Dimension	NGSS Citation / Grade Progression	Specific Connections to Unit / Activity Designation
Disciplinary Core Ideas	ESS2.C – The planet's dynamics are greatly influenced by water's unique chemical and physical properties. (9-12)	• Perform a hands-on lab to investigate wave reflection and refraction, and incorporate knowledge gained from a coastal satellite image and sea surface temperature data. (Explanation) • Use a hands-on lab to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration)
	ESS3.B – Mapping the history of natural hazards in a region and understanding related geological forces can help forecast the locations and likelihoods of future events. (6-8)	• Evaluate a real world case study of a coastal erosion solution. (Evaluation)

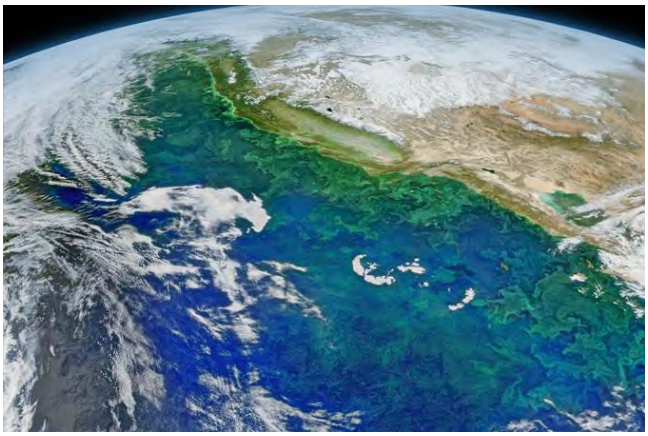
	ESS3.B – Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales. (9-12)	• Obtain and evaluate information from an article about historic and recent coastal erosion. (Exploration) • Analyze a coastal erosion case study. (Extend) • Evaluate a real world coastal erosion solution. (Evaluation)
	ETS1.B – There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (6-8)	• Obtain and evaluate information from a video and an article on shoreline erosion and armoring solutions and consider methods of consensus building. (Invitation to Engage) • Argue stakeholder roles in a coastal erosion scenario, and read an article about real erosion incidents and responses. (Exploration) • Evaluate a real coastal erosion solution. (Evaluation)
	ETS1.B – When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (9-12)	• View a video and read an article on shoreline erosion and armoring solutions and consider methods of consensus building. (Invitation to Engage) • Argue stakeholder roles in a coastal erosion scenario, and read an article about real erosion incidents and responses. (Exploration) • Analyze a coastal erosion case study. (Extend) • Evaluate a real world coastal erosion solution. (Evaluation)

Dimension	NGSS Citation / Grade Progression	Specific Connections to Unit / Activity Designation
Crosscutting Concepts	Cause and effect relationships may be used to predict phenomena in natural or designed systems. (6-8)	• Analyze an article about historic and recent coastal erosion. (Exploration) • Perform a hands-on lab to investigate wave reflection and refraction, resulting in revision of the student's model of a beach. (Explanation) • Use a hands-on lab to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration)
	Systems can be designed to cause a desired effect. (9-12)	• Argue for coastal erosion solutions within stakeholder roles with different priorities. (Exploration) • Use a hands-on lab to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration)
	Models can be used to represent systems and their interactions. (6-12)	• Draft and revise a conceptual model of a beach. (Invitation to Engage, Exploration, Explanation, Elaboration) • Use a hands-on lab to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration)
	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (9-12)	• Draft and revise a conceptual model of a beach. (Invitation to Engage, Exploration)
	Systems can be designed for greater or lesser stability. (9-12)	• Analyze a coastal erosion case study. (Extend)
	Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (6-8)	• Analyze an article about historic and recent coastal erosion. (Exploration)

	Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (9-12)	• Analyze an article about historic and recent coastal erosion. (Exploration)

Dimension	NGSS Citation / Grade Progression	Specific Connections to Unit / Activity Designation
Science and Engineering Practices	Ask questions that arise from careful observation of phenomena to clarify and/or seek additional information. (6-12)	• Ask testable questions based on prior knowledge to design a hands-on lab investigating beach processes. (Elaboration)
	Ask questions to clarify and/or refine a model. (6-12)	• Draft a preliminary conceptual model of a beach and revise after a gallery walk. (Invitation to Engage)
	Develop and/or use a model to predict and/or describe phenomena. (6-8)	• Draft and revise a conceptual model of a beach. (Invitation to Engage, Exploration, Explanation, Elaboration) • Perform a hands-on lab to investigate wave reflection and refraction, resulting in revision of the student's model of a beach. (Explanation) • Use a hands-on lab to explore the movement of sand and water as they interact with coastal protection structures. (Elaboration)
	Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. (6-8)	• Argue for coastal erosion solutions within stakeholder roles with different priorities. (Exploration)
	Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (9-12)	• Argue for coastal erosion solutions within stakeholder roles with different priorities. (Exploration)
	Construct, use, and/or present an oral argument based on data and evidence. (6-12)	• Throughout the unit during learning conversations. • Argue for a preferred consensus building model after analyzing a coastal erosion case study. (Extend) • Present an evaluation of a real world coastal erosion solution. (Evaluation)
	Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. (6-8)	• Throughout the unit during learning conversations. • Present an evaluation of a real world coastal erosion solution. (Evaluation)
	Communicate scientific and/or technical information or ideas in multiple formats. (6-12)	• Throughout the unit during learning conversations. • Present an evaluation of a real world coastal erosion solution. (Evaluation)

Making Sense of Images



Earth Observatory, NASA

Images can be much more than a snapshot—they are often evidence of choices made, of a culture's impact on the land, and of the natural systems acting upon a place. Images can dramatically document changes over time: coastal weather hazards can be predicted, slow-moving geological processes can become visible, connections between biological communities can be seen. In a fast changing world of many environmental problems, image analysts provide insight into past choices, current conditions, and possible future scenarios that may be used to make sensible choices. Images do more than document problems—they often point the way to solutions.

Thinking Tools for Image Analysis

Coastal image analysts look for evidence relevant to specific questions they are seeking to answer or for a phenomenon they are seeking to explain. Analysts may start by looking for evidence of the following big ideas:

- Patterns
- Cause and effect mechanisms
- Scale
- Natural systems and boundaries/ intersections with other systems
- Structure and function
- Stability and change
- Energy flows and cycles

Observed **patterns** are the foundation of many scientific questions. Consider, for example, the patterns inscribed in beach sand by human activity or on water by wind.

Cause and effect relationships are often the focus of an image analysis. Once a pattern is noticed, the hunt for an explanation can begin. For example, you may have noticed the impact of a holiday on a beach or park. Overflowing garbage cans, plastic bags pinned in the bushes by wind, and footprints covering the beaches are all evidence of heavy human traffic the day before.

Scale and placement within **natural systems** is vital to image analysis. Before interpreting an image, it's helpful to know the general location and a reference for the size of the objects in the image. Considerations of scale, place, and their conceptual boundaries inform how an analyst will model a system. For example, the small beach shown above is on Lake Tahoe, a relatively closed system with an alpine climate. This makes the dynamics different from a beach on the temperate and energetic Pacific shore.

The concept of **structure and function** explores how the form or shape of an object or living thing is related to or depends upon its function, and vice versa. For example, coastal armoring structures (such as seawalls) are sometimes built to function as protection for homes that are too close to eroding bluffs and beaches. Natural rates of erosion within a beach system, angles of surf and currents, and the height of projected sea level rise must be understood to make informed choices as to how and whether to build on the coast or to install coastal armoring to protect existing structures.

Determining the degree of **stability and change** within the beach system is how engineers place parameters around these decisions. When looking at the photo on the right, two questions might be: how is the Pacific Ocean's level changing over time at the location, and what other factors (sand starvation, storms, el Niño) might be destabilizing the beach?

Finally, **energy**, energy flows, and the consequences of moving energy are a frequent focus of image analysis investigations of the natural systems in coastal zones. The moon, the atmosphere, the ocean, and adjacent land areas all impart energy to beaches. Energy is conserved, meaning that energy can't be created or destroyed, so typically the task of the image analysis becomes describing how the energy is flowing within a given place or natural system. Have you ever stood on a beach as a powerful wave breaks upon the shore, sending both vibrations into the sand and sound into the atmosphere?

These seven thinking tools may be used independently or woven together to reflect the complicated nature of natural systems. Your choice of tools will be governed by your purpose. For example, engineers planning to build a power plant will want to know if an area is geologically stable. A policy maker working on enhancing access to a beach would seek images that offer insights into transportation routes. Where to locate bathroom facilities or build low impact trails is another question answered using image analysis. Beach users seek shelter from the wind, so a bathroom could logically be sited near but not in these relatively rare spots. Beach users have historically created damaging informal trails, sometimes visible in aerial photographs. Placing low impact trails and boardwalks along these routes could make access easier and protect vulnerable plant and animal communities. This pathway in Palos Verdes protects sensitive coastal scrub habitat.

Interpretation of Aerial Photographs

The following elaborates on the Guiding Questions for Image Analysis worksheet.

Absolute Location: In what coastal region was this image created?

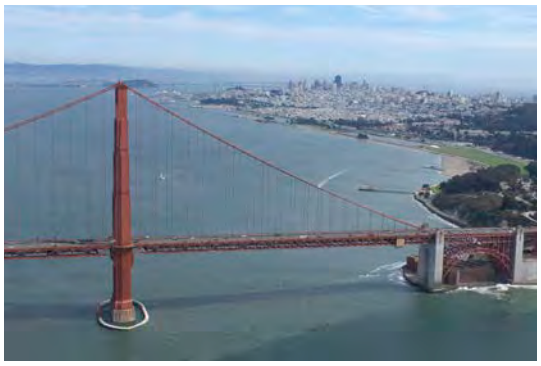
Use clues like plant communities or size of rivers to place the image in either the North, Central, or South Coast regions. Recognizable human-built landmarks can help. Distinctive types of trees (redwoods for example), or distinctively contoured points of land are the most common starting point for an analysis. For example, if the coast has large, impressive trees on both sides of a coastal point, the location is likely in a northern region; by contrast, if only low scrubby plants are visible then a location further south in the coastal scrub biome may be inferred initially. Be careful in your conclusions, as a location completely exposed to the North Coast's incessant winds will also have only low, ground-hugging plants. Piles of large logs on the beach will, however, be a reasonably definitive clue to North Coast beaches.

Place: What would a person in this place see, hear, and feel?

Determine what direction is north. Subsequently, think about the prevailing wind, direction that hills and cliffs face, evidence of precipitation, and plant community.

Normally, you should begin by looking for a reference object to give you a sense of scale. If buildings are present, find a home, school, or road. This will help you develop a good picture of things combined with your prior knowledge.

Human/Environment Interaction: How do humans depend upon and/or influence (positive or negative) the coastal environment in this place? What ecosystem services can you identify? Examples of some of the many ecosystem services include natural shoreline protection, water filtration, food production, carbon sequestration, and recreation.



Movement and Access: How are people accessing this place and how could access be improved? This may be considered from perspectives inside or outside of the study site but keep your purpose in mind. Increasing and enhancing access is one purpose, protecting and enhancing habitat is another. They might or might not be mutually exclusive.

Bio-Region: How and why is one area in this place similar to another? Can you identify any natural geographic boundaries?

Photos courtesy of the California Coastal Records Project.

Guiding Questions for Image Analysis

Place this handout in your project notebook for repeated reference.

Absolute Location: In what coastal region was this image created? What is your evidence?

Place: What would a person in this place see, hear, and/or feel? What is your evidence?

Human/Environment Interaction: How do humans depend upon and/or influence (positive or negative) the coastal environment in this place? What ecosystem services can you identify? What is your evidence?

Movement and Access: How are people accessing this place and how could access be improved? This should be considered from perspectives inside or outside of the study site, but be sure to use remote sensing tools to build your perspective.

Bio-Region: What natural factors influence the biological community found in this place? Be sure to consider climate, geology, geography, and vegetation distribution.

An Introduction to the California Coastal Act

Group 1

Alarmed that private development was cutting off public access to the shore, and catalyzed by a huge oil spill off the coast of Santa Barbara, Californians in 1972 rallied to "Save Our Coast" and passed a voter initiative called the Coastal Conservation Initiative (Prop 20).

Prop 20 created the California Coastal Commission to make land use decisions in the Coastal Zone, while additional planning occurred. Then in 1976 the State Legislature passed the Coastal Act, which made the Coastal Commission a permanent agency with broad authority to regulate coastal development.

The Coastal Act guides how the land along the coast of California is developed, or protected from development. It emphasizes the importance of the public being able to access the coast, and the preservation of sensitive coastal and marine habitat and biodiversity. It dictates that development be clustered in areas to preserve open space, and that coastal agricultural lands be preserved. It prioritizes coastal recreation as well as commercial and industrial uses that need a waterfront location. It calls for orderly, balanced development, consistent with these priorities and taking into account the constitutionally protected rights of property owners.

The Coastal Act defines the area of the coast that comes under the jurisdiction of the California Coastal Commission, which is called the "coastal zone." The Coastal Zone extends seaward to the state's outer limit of jurisdiction (three miles), including offshore islands. The inland boundary varies according to land uses and habitat values. In general, it extends inland 1,000 yards from the mean high tide line of the sea, but is wider in areas with significant estuarine, habitat, and recreational values, and narrower in developed urban areas. Coastal Zone boundary maps are available on the Coastal Commission website.

The Coastal Zone does not include San Francisco Bay, which is under the jurisdiction of a separate state agency, the San Francisco Bay Conservation and Development Commission.

Annotated Reading of Selected Coastal Act Sections

The following is a selection of excerpts from the Coastal Act, which contains many additional policies and procedures not addressed here. To read the entire Coastal Act, visit www.coastal.ca.gov/coastact.pdf. The quoted sections below are each referenced with their identifying section number in the Coastal Act.

The Coastal Act begins with a section (30001) on the **importance of the California coast and its ecological balance**:

> The Legislature hereby finds and declares:
> (a) That the California coastal zone is a distinct and valuable natural resource of vital and enduring interest to all the people and exists as a delicately

> balanced ecosystem.
> (b) That the permanent protection of the state's natural and scenic resources is a paramount concern to present and future residents of the state and nation.
> (c) That to promote the public safety, health, and welfare, and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to protect the ecological balance of the coastal zone and prevent its deterioration and destruction.
> (d) That existing developed uses, and future developments that are carefully planned and developed consistent with the policies of this division, are essential to the economic and social well-being of the people of this state and especially to working persons employed within the coastal zone.

Thus, the law recognizes the importance of both the **natural** environment and **economic** development that is dependent upon the resources of the coast.

The Coastal Act (30001.5) declares that the basic **goals** of the state for the coastal zone are to:

> (a) Protect, maintain, and where feasible, enhance and restore the overall quality of the coastal zone environment and its natural and artificial resources.
> (b) Assure orderly, balanced utilization and conservation of coastal zone resources taking into account the social and economic needs of the people of the state.
> (c) Maximize public access to and along the coast and maximize public recreational opportunities in the coastal zone consistent with sound resources conservation principles and constitutionally protected rights of private property owners.
> (d) Assure priority for coastal-dependent and coastal-related development over other development on the coast.
> (e) Encourage state and local initiatives and cooperation in preparing procedures to implement coordinated planning and development for mutually beneficial uses, including educational uses, in the coastal zone.

Chapter 3 of the Coastal Act contains the policies that are to guide coastal resource planning and decisions on individual development proposals. The Coastal Act recognizes that at times there will be conflicts between these policies, and states that "such conflicts be resolved in a manner which on balance is the most protective of significant coastal resources." (30007.5)

Group 2

The Coastal Act prioritizes the **public's right to access the shoreline** (30210 to 30214):

> [M]aximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.

Coastal development should not impede existing rights of access:

> Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization...

The previous statement makes reference to different ways public access rights are established. The government may establish these rights (such as by purchasing land to create a public path to the beach) or they are sometimes established through historic public use.

Acquisition through historic use is explained in the *California Coastal Access Guide,* published by UC Press:

According to court decisions, in order for the public to obtain an easement by way of implied dedication, the essential elements that must be established are that the public has used the land 1) for a continuous period of five years as if it were public land, 2) with the actual or presumed knowledge of the owner, and 3) without significant objection or significant attempts by the owner to prevent or halt such use.

The ultimate determination of prescriptive rights, if they are challenged, takes place in court. However, Section 30211 of the Coastal Act requires the Coastal Commission to make determinations as to the existence of these rights where there is evidence of historic use of a given area.

New public access is encouraged in the Coastal Act:

> Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where: (1) it is inconsistent with public safety, military security needs, or the protection of fragile coastal resources, (2) adequate access exists nearby, or, (3) agriculture would be adversely affected.

In practice, most new accessways require that an organization (public or private) first accept responsibility for maintenance and liability before being opened to the public.

The Coastal Act (30252) recognizes that it is not sufficient to provide access to the coast; sensible planning for encouraging coastal recreation includes addressing transportation needs and other considerations, such as preventing overcrowding of recreation areas:

> The location and amount of new development should maintain and enhance public access to the coast by (1) facilitating the provision or extension of transit service, (2) providing commercial facilities within or adjoining residential development or in other areas that will minimize the use of coastal access roads, (3) providing non automobile circulation within the development, (4) providing adequate parking facilities or providing substitute means of serving the development with public transportation, (5) assuring the potential for public transit for high intensity uses such as

> high-rise office buildings, and by (6) assuring that the recreational needs of new residents will not overload nearby coastal recreation areas by correlating the amount of development with local park acquisition and development plans with the provision of onsite recreational facilities to serve the new development.

The Coastal Act (30221) calls for **lower cost visitor and recreational facilities**, addressing the concern that coastal recreational opportunities be available to all Californians regardless of income level. In addition, "Developments providing public recreational opportunities are preferred." Also:

> Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

Group 3

The Coastal Act (30230) also **prioritizes ecological resources**. Marine resources, such as wetlands, rocky intertidal areas, and the open ocean are addressed as follows:

> Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

The Coastal Act (30240) includes **special protection for Environmentally Sensitive Habitat Areas**, often referred to as ESHA:

> (a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.
> (b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.

The law recognizes the importance of maintaining adequate **water quality** for coastal zone organisms and human health (30231):

> The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment,

> controlling runoff, preventing depletion of ground water supplies and substantial interference with surface waterflow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.

The Coastal Act **prioritizes certain types of activities and development** over other types in the coastal zone. For instance, visitor-serving commercial recreational facilities designed to enhance public opportunities for coastal recreation are prioritized over private residential, general industrial, or general commercial development, but not over agriculture or coastal-dependent industry (30222). Recreational boating and its related facilities are encouraged in the Coastal Act (30224).

The Coastal Act (30253) dictates that new development be designed and sited to minimize adverse impacts to coastal resources, both natural and visitor-serving, as follows:

> New development shall do all of the following: (a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard. (b) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs. (c) Be consistent with requirements imposed by an air pollution control district or the State Air Resources Board as to each particular development. (d) Minimize energy consumption and vehicle miles traveled. (e) Where appropriate, protect special communities and neighborhoods that, because of their unique characteristics, are popular visitor destination points for recreational uses.

Group 4

Views and local character are protected by the Coastal Act (30251):

> The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas.

The Coastal Act (30235) calls for **limits on the use of shoreline armoring**:

> Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

The issue of whether new shoreline armoring should be allowed will arise with increasing frequency as global warming causes sea level rise. In applying the Coastal Act, the Commission tries to avoid shoreline armoring by locating new development away from hazard areas if feasible.

The Coastal Act (30006) includes a statement on the importance of **public participation** in its implementation...

> The Legislature further finds and declares that the public has a right to fully participate in decisions affecting coastal planning, conservation and development; that achievement of sound coastal conservation and development is dependent upon public understanding and support; and that the continuing planning and implementation of programs for coastal conservation and development should include the widest opportunity for public participation.

...as well as **public education** (30012):

> The Legislature finds that an educated and informed citizenry is essential to the well-being of a participatory democracy and is necessary to protect California's finite natural resources, including the quality of its environment. The Legislature further finds that through education, individuals can be made aware of and encouraged to accept their share of the responsibility for protecting and improving the natural environment.

The Coastal Commission

There are 15 California Coastal Commissioners. Twelve are voting members and three are non-voting members. The voting members are appointed by the Governor, the Speaker of the Assembly, and the Senate Rules Committee; each appoint four Commissioners, of which two are selected from the public at large and two are locally elected officials. The local officials on the Commission represent six coastal regions in California. The Governor's appointments must include at least one representative who resides in and works directly with communities with diverse racial and ethnic populations and communities with low-income populations burdened disproportionately by high levels of pollution and issues of environmental justice. The non-voting Commissioners are the Secretary of the Resources Agency, the Secretary of the Business and Transportation Agency, and the Chairperson of the State Lands Commission.

The Coastal Commission meets each month to hear from the public and make decisions. The meetings are held in different coastal locations and generally last three days. You can find out about these meetings on the Coastal Commission website at www.coastal.ca.gov. Meetings are open to the public as well as streamed live online, and previous meetings can be viewed in a video archive.

CREATIVITY & INNOVATION RUBRIC

Courtesy of the Buck Institute for Education

PROCESS:

Creativity & Innovation Opportunity at Phases of a Project	Below Standard	Approaching Standard	At Standard	Above Standard
Launching the Project: Define the Creative Challenge	• may just "follow directions" without understanding the purpose for innovation or considering the needs and interests of the target audience	• understands the basic purpose for innovation but does not thoroughly consider the needs and interests of the target audience	• understands the purpose driving the process of innovation (Who needs this? Why?) • develops insight about the particular needs and interests of the target audience	
Building Knowledge, Understanding, and Skills: Identify Sources of Information	• uses only typical sources of information (website, book, article) • does not offer new ideas during discussions	• finds one or two sources of information that are not typical • offers new ideas during discussions, but stays within narrow perspectives	• in addition to typical sources, finds unusual ways or places to get information (adult expert, community member, business or organization, literature) • promotes divergent and creative perspectives during discussions (CC 11-12.SL.1c)	
Developing and Revising Ideas and Products: Generate and Select Ideas	• stays within existing frameworks; does not use idea-generating techniques to develop new ideas for product(s) • selects one idea without evaluating the quality of ideas • does not ask new questions or elaborate on the selected idea • reproduces existing ideas; does not imagine new ones • does not consider or use feedback and critique to revise product	• develops some original ideas for product(s), but could develop more with better use of idea-generating techniques • evaluates ideas, but not thoroughly before selecting one • asks a few new questions but may make only minor changes to the selected idea • shows some imagination when shaping ideas into a product, but may stay within conventional boundaries • considers and may use some feedback and critique to revise a product, but does not seek it out	• uses idea-generating techniques to develop several original ideas for product(s) • carefully evaluates the quality of ideas and selects the best one to shape into a product • asks new questions, takes different perspectives to elaborate and improve on the selected idea • uses ingenuity and imagination, going outside conventional boundaries, when shaping ideas into a product • seeks out and uses feedback and critique to revise product to better meet the needs of the intended audience (CC 6-12.W.5)	

CREATIVITY & INNOVATION RUBRIC, PROCESS, continued

Creativity & Innovation Opportunity at Phases of a Project	Below Standard	Approaching Standard	At Standard	Above Standard
Presenting Products and Answers to Driving Question: Present Work to Users/Target Audience	• presents ideas and products in typical ways (text-heavy slides, recitation of notes, no interactive features)	• adds some interesting touches to presentation media • attempts to include elements in presentation that make it more lively and engaging	• creates visually exciting presentation media • includes elements in presentation that are especially fun, lively, engaging, or powerful to the particular audience	

PRODUCT:

	Below Standard	Approaching Standard	At Standard	Above Standard
Originality	• relies on existing models, ideas, or directions; it is not new or unique • follows rules and conventions; uses materials and ideas in typical ways	• has some new ideas or improvements, but some ideas are predictable or conventional • may show a tentative attempt to step outside rules and conventions, or find new uses for common materials or ideas	• is new, unique, surprising; shows a personal touch • may successfully break rules and conventions, or use common materials or ideas in new, clever and surprising ways	
Value	• is not useful or valuable to the intended audience/user • would not work in the real world; impractical or unfeasible	• is useful and valuable to some extent; it may not solve certain aspects of the defined problem or exactly meet the identified need • unclear if product would be practical or feasible	• is seen as useful and valuable; it solves the defined problem or meets the identified need • is practical, feasible	
Style	• is safe, ordinary, made in a conventional style • has several elements that do not fit together; it is a mish-mash	• has some interesting touches, but lacks a distinct style • has some elements that may be excessive or do not fit together well	• is well-crafted, striking, designed with a distinct style but still appropriate for the purpose • combines different elements into a coherent whole	

Note: The term "product" is used in this rubric as an umbrella term for the result of the process of innovation during a project. A product may be a constructed object, proposal, presentation, solution to a problem, service, system, work of art or piece of writing, an invention, event, an improvement to an existing product, etc.

PRESENTATION RUBRIC

Courtesy of the Buck Institute for Education

	Below Standard	Approaching Standard	At Standard	Above Standard
Explanation of Ideas & Information	• does not present information, arguments, ideas, or findings clearly, concisely, and logically; argument lacks supporting evidence; audience cannot follow the line of reasoning • selects information, develops ideas and uses a style inappropriate to the purpose, task, and audience (may be too much or too little information, or the wrong approach) • does not address alternative or opposing perspectives	• presents information, findings, arguments and supporting evidence in a way that is not always clear, concise, and logical; line of reasoning is sometimes hard to follow • attempts to select information, develop ideas and use a style appropriate to the purpose, task, and audience but does not fully succeed • attempts to address alternative or opposing perspectives, but not clearly or completely	• presents information, findings, arguments and supporting evidence clearly, concisely, and logically; audience can easily follow the line of reasoning (CC 9-12.SL.4) • selects information, develops ideas and uses a style appropriate to the purpose, task, and audience (CC 9-12.SL.4) • clearly and completely addresses alternative or opposing perspectives (CC 11-12.SL.4)	
Organization	• does not meet requirements for what should be included in the presentation • does not have an introduction and/or conclusion • uses time poorly; the whole presentation, or a part of it, is too short or too long	• meets most requirements for what should be included in the presentation • has an introduction and conclusion, but they are not clear or interesting • generally times presentation well, but may spend too much or too little time on a topic, a/v aid, or idea	• meets all requirements for what should be included in the presentation • has a clear and interesting introduction and conclusion • organizes time well; no part of the presentation is too short or too long	
Eyes & Body	• does not look at audience; reads notes or slides • does not use gestures or movements • lacks poise and confidence (fidgets, slouches, appears nervous) • wears clothing inappropriate for the occasion	• makes infrequent eye contact; reads notes or slides most of the time • uses a few gestures or movements but they do not look natural • shows some poise and confidence, (only a little fidgeting or nervous movement) • makes some attempt to wear clothing appropriate for the occasion	• keeps eye contact with audience most of the time; only glances at notes or slides • uses natural gestures and movements • looks poised and confident • wears clothing appropriate for the occasion	

PRESENTATION RUBRIC, continued

	Below Standard	Approaching Standard	At Standard	Above Standard
Voice	• mumbles or speaks too quickly or slowly • speaks too softly to be understood • frequently uses "filler" words ("uh, um, so, and, like, etc.") • does not adapt speech for the context and task	• speaks clearly most of the time • speaks loudly enough for the audience to hear most of the time, but may speak in a monotone • occasionally uses filler words • attempts to adapt speech for the context and task but is unsuccessful or inconsistent	• speaks clearly; not too quickly or slowly • speaks loudly enough for everyone to hear; changes tone and pace to maintain interest • rarely uses filler words • adapts speech for the context and task, demonstrating command of formal English when appropriate (CC 9-12.SL.6)	
Presentation Aids	• does not use audio/visual aids or media • attempts to use one or a few audio/visual aids or media, but they do not add to or may distract from the presentation	• uses audio/visual aids or media, but they may sometimes distract from or not add to the presentation • sometimes has trouble bringing audio/visual aids or media smoothly into the presentation	• uses well-produced audio/visual aids or media to enhance understanding of findings, reasoning, and evidence, and to add interest (CC 9-12.SL.5) • smoothly brings audio/visual aids or media into the presentation	
Response to Audience Questions	• does not address audience questions (goes off topic or misunderstands without seeking clarification)	• answers audience questions, but not always clearly or completely	• answers audience questions clearly and completely • seeks clarification, admits "I don't know" or explains how the answer might be found when unable to answer a question	
Participation in Team Presentations	• Not all team members participate; only one or two speak	• All team members participate, but not equally	• All team members participate for about the same length of time • All team members are able to answer questions about the topic as a whole, not just their part of it	

COLLABORATION RUBRIC

Courtesy of the Buck Institute for Education

Individual Performance	Below Standard	Approaching Standard	At Standard	Above Standard
Takes Responsibility for Oneself	• is not prepared, informed, and ready to work with the team • does not use technology tools as agreed upon by the team to communicate and manage project tasks • does not do project tasks • does not complete tasks on time • does not use feedback from others to improve work	• is usually prepared, informed, and ready to work with the team • uses technology tools as agreed upon by the team to communicate and manage project tasks, but not consistently • does some project tasks, but needs to be reminded • completes most tasks on time • sometimes uses feedback from others to improve work	• is prepared and ready to work; is well informed on the project topic and cites evidence to probe and reflect on ideas with the team (CC 6-12.SL.1a) • consistently uses technology tools as agreed upon by the team to communicate and manage project tasks • does tasks without having to be reminded • completes tasks on time • uses feedback from others to improve work	
Helps the Team	• does not help the team solve problems; may cause problems • does not ask probing questions, express ideas, or elaborate in response to questions in discussions • does not give useful feedback to others • does not offer to help others if they need it	• cooperates with the team but may not actively help it solve problems • sometimes expresses ideas clearly, asks probing questions, and elaborates in response to questions in discussions • gives feedback to others, but it may not always be useful • sometimes offers to help others if they need it	• helps the team solve problems and manage conflicts • makes discussions effective by clearly expressing ideas, asking probing questions, making sure everyone is heard, responding thoughtfully to new information and perspectives (CC 6-12.SL.1c) • gives useful feedback (specific, feasible, supportive) to others so they can improve their work • offers to help others do their work if needed	
Respects Others	• is impolite or unkind to teammates (may interrupt, ignore ideas, hurt feelings) • does not acknowledge or respect other perspectives	• is usually polite and kind to teammates • usually acknowledges and respects other perspectives and disagrees diplomatically	• is polite and kind to teammates • acknowledges and respects other perspectives; disagrees diplomatically	

COLLABORATION RUBRIC, continued

Team Performance	**Below Standard**	**Approaching Standard**	**At Standard**	**Above Standard**
Makes and Follows Agreements	• does not discuss how the team will work together • does not follow rules for collegial discussions, decision-making and conflict resolution • does not discuss how well agreements are being followed • allows breakdowns in teamwork to happen; needs teacher to intervene	• discusses how the team will work together, but not in detail; may just "go through the motions" when creating an agreement • usually follows rules for collegial discussions, decision-making, and conflict resolution • discusses how well agreements are being followed, but not in depth; may ignore subtle issues • notices when norms are not being followed but asks the teacher for help to resolve issues	• makes detailed agreements about how the team will work together, including the use of technology tools • follows rules for collegial discussions (CC 6-12.SL.1b), decision-making, and conflict resolution • honestly and accurately discusses how well agreements are being followed • takes appropriate action when norms are not being followed; attempts to resolve issues without asking the teacher for help	
Organizes Work	• does project work without creating a task list • does not set a schedule and track progress toward goals and deadlines • does not assign roles or share leadership; one person may do too much, or all members may do random tasks • wastes time and does not run meetings well; materials, drafts, notes are not organized (may be misplaced or inaccessible)	• creates a task list that divides project work among the team, but it may not be in detail or followed closely • sets a schedule for doing tasks but does not follow it closely • assigns roles but does not follow them, or selects only one "leader" who makes most decisions • usually uses time and runs meetings well, but may occasionally waste time; keeps materials, drafts, notes, but not always organized	• creates a detailed task list that divides project work reasonably among the team (CC 6-12.SL.1b) • sets a schedule and tracks progress toward goals and deadlines (CC 6-12.SL.1b) • assigns roles if and as needed, based on team members' strengths (CC 6-12.SL.1b) • uses time and runs meetings efficiently; keeps materials, drafts, notes organized	
Works as a Whole Team	• does not recognize or use special talents of team members • does project tasks separately and does not put them together; it is a collection of individual work	• makes some attempt to use special talents of team members • does most project tasks separately and puts them together at the end	• recognizes and uses special talents of each team member • develops ideas and creates products with involvement of all team members; tasks done separately are brought to the team for critique and revision	

CRITICAL THINKING RUBRIC

Courtesy of the Buck Institute for Education

Critical Thinking Opportunity at Phases of a Project	**Below Standard**	**Approaching Standard**	**At Standard**	**Above Standard**
Launching the Project: Analyze Challenging Question and Begin Inquiry	• sees only superficial aspects of, or one point of view on, the Challenging Question	• identifies some central aspects of the Challenging Question, but may not see complexities or consider various points of view • asks some follow-up questions about the topic or the wants and needs of the audience or users of a product, but does not dig deep	• shows understanding of central aspects of the Challenging Question by identifying in detail what needs to be known to answer it and considering various possible points of view on it • asks follow-up questions that focus or broaden inquiry, as appropriate (CC 6-12.W.7) • asks follow-up questions to gain understanding of the wants and needs of audience or product users	
Building Knowledge, Understanding, and Skills: Gather and Evaluate Information	• is unable to integrate information to address the Challenging Question; gathers too little, too much, or irrelevant information, or from too few sources • accepts information at face value (does not evaluate its quality)	• attempts to integrate information to address the Challenging Question, but it may be too little, too much, or gathered from too few sources; some of it may not be relevant • understands that the quality of information should be considered, but does not do so thoroughly	• integrates relevant and sufficient information to address the Challenging Question, gathered from multiple and varied sources (CC 6,11-12.RI.7) • thoroughly assesses the quality of information (considers usefulness, accuracy and credibility; distinguishes fact vs. opinion; recognizes bias) (CC 6-12.W.8)	
Developing and Revising Ideas and Products: Use Evidence and Criteria	• accepts arguments for possible answers to the Challenging Question without questioning whether reasoning is valid • uses evidence without considering how strong it is • relies on “gut feeling” to evaluate and revise ideas, product prototypes or problem solutions (does not use criteria)	• recognizes the need for valid reasoning and strong evidence, but does not evaluate it carefully when developing answers to the Challenging Question • evaluates and revises ideas, product prototypes or problem solutions based on incomplete or invalid criteria	• evaluates arguments for possible answers to the Challenging Question by assessing whether reasoning is valid and evidence is relevant and sufficient (CC 6-12.SL.3, RI.8) • justifies choice of criteria used to evaluate ideas, product prototypes or problem solutions • revises inadequate drafts, designs or solutions and explains why they will better meet evaluation criteria (CC 6-12.W.5)	

CRITICAL THINKING RUBRIC, continued

Critical Thinking Opportunity at Phases of a Project	**Below Standard**	**Approaching Standard**	**At Standard**	**Above Standard**
Presenting Products and Answers to Driving Question: Justify Choices, Consider Alternatives & Implications	• chooses one presentation medium without considering advantages and disadvantages of using other mediums to present a particular topic or idea • cannot give valid reasons or supporting evidence to defend choices made when answering the Challenging Question or creating products • does not consider alternative answers to the Challenging Question, designs for products, or points of view • is not able to explain important new understanding gained in the project	• considers the advantages and disadvantages of using different mediums to present a particular topic or idea, but not thoroughly • explains choices made when answering the Challenging Question or creating products, but some reasons are not valid or lack supporting evidence • understands that there may be alternative answers to the Challenging Question or designs for products, but does not consider them carefully • can explain some things learned in the project, but is not entirely clear about new understanding	• evaluates the advantages and disadvantages of using different mediums to present a particular topic or idea (CC 8.RI.7) • justifies choices made when answering the Challenging Question or creating products, by giving valid reasons with supporting evidence (CC 6-12.SL.4) • recognizes the limitations of an answer to the Challenging Question or a product design (how it might not be complete, certain, or perfect) and considers alternative perspectives (CC 11-12.SL.4) • can clearly explain new understanding gained in the project and how it might transfer to other situations or contexts	

APPLICATION OF CONTENT KNOWLEDGE: FORMAL WRITTEN REPORTS AND PUBLIC PRESENTATIONS RUBRIC

Indicators of Achievement Adapted from Costa and Kallick, NCTE, and NGSS

Habit of Mind	Unsatisfactory	Growing to Competency	Competent (State Standard)	Distinguished
Striving for Accurancy	Sloppy or incomplete work with no evidence of revision or editing process. Feedback from peer reviewers and adult colaborators is not incorporated into work.	Student occasionally reviews checklists, rubrics, and peer feedback to enhance wrtten communications. Care is taken to convey significnat science concepts with examples and data.	Student understands and can apply two to three relevant science concepts in a written sequence of claims, evidence, and reasoning. Student works with peers as instructional resources.	Without sacrificing scientific accuracy, student constructs a coherent storyline referencing California places, issues, and connections to his or her own life. Student demonstrates a command of writing mechanics, organization, and ability to revise and edit.
Creative Questioning	Student does not initiate questioning in any written or verbal form. When questions are asked, they focus on meeting minimum requirements as articulated by adults.	Student intiates science-based questioing with support from peers or teachers. The value of questioing is understood, but the habit is still being cultivated.	Student independently produces original questions, considers questions from multiple perspectives, and produces original answers. Student brainstorms with others during the questioning process and listens carefully to arguments made by peers.	Student uses science and engineering practices to develop personalized place-based driving questions with connections to science concepts and to the ideas of classmates. Student considers alternative perspectives and nurtures an inclination to question daily.
Applying Past Knowledge to New Situations	Science notebooks, feedback from peers, and previous experience does not inform actions or writing.	When reminded and supported, prior knowledge is accessed and used to improve speaking and written communications.	Student consistently uses prior knowledge to investigate new phenomena. Reference to previous experience or careful use of analogies may be seen.	Student consistently uses prior knowledge to investigate new phenomena. Reference to previous experience or careful use of analogies may be seen.
Thinking and Communicating with Clarity and Precision	Use of vague and imprecise language leads to confusion about meaning. Science vocabulary is missiing or used incorrectly.	Science concepts and ideas are communicated using analogies from everyday life, but subtle distinctions are lost due to a lack of vocabulary or incomplete grasp of scientific concepts.	Student avoids generalizations and distortions of fact while clearly defining science terms, concepts, and ideas. Student can distinguish between closely related science topics (e.g. weather and climate, or heat and temperature).	Students use exact language to convey science concepts and emerging ideas. Claims are supported with evidence and reasoning that is grounded in place, personal experience, and relevant science concepts. Writing is concise, descriptive, and coherent.

SCIENCE NOTEBOOK AND EXIT TICKET RUBRIC

NGSS Element	**Unsatisfactory**	**Growing to Competency**	**Competent (State Standard)**	**Distinguished**
Crosscutting Concepts	Student does not show connections across content area boundaries. Most learning activity is limited to memorizing facts without context.	Student identifies patterns and classifies relationships as causal or correlational. Student understands that events that occur closely in time may or may not be related.	Student places significant knowledge in context using systems, models, and causal analysis. Student evaluates questions and models for testability, arguments for validity, and solutions for practicality.	Explanatory power of crosscutting concepts is fully utilized to think and write as scientists do while addressing real world environmental problems. Alternative explanations are routinely considered, as is instrument error.
Science and Engineering Practices	Student identifies testable questions and performs simple qualitative investigations, but fails to recognize the many ways that scientists perform their work.	Student specifies relationships, between variables and clarifies arguments, but rarely evaluates or proposes solutions.	Student uses evidence and computational thinking to analyze geoscience data, construct arguments, develop conceptual models, plan investigations, and propose science-based actions.	Science and engineering practices are habitually referenced in writing. System level thinking is demonstrated in reference to boundaries, interactions, and constraints posed by methods, society, or environmental concerns.
Disciplinary Core Ideas	Student does not demonstrate understanding of science content; science vocabulary is wholly absent.	Student can identify components, yet understandings about relationships between components are elusive. Placing knowledge in context, using thinking tools like the crosscutting concepts is rare, but increasing.	Student presents Earth systems that are dynamic, interactive, and composed of both living and non-living features, with feedback effects that may be altered by human activity. Science vocabulary is weilded with precision and clarity.	Writing is precise and clear with no composition or style errors leading to elegant place-based expression of science concepts. Student makes a personal connection to the information and acts upon valid science information.
Conceptual Models	Work is inaccurate, lacking most needed components; messy craftsmanship detracts from overall presentation and obscures meaning.	Poor craftsmanship obscures meaning. Model is missing an element needed to completely understand science concepts or make predictions.	Model is neat; all depictions are accurate, legible, and scientifically defensible. Models have components, relationships, and connections labeled. Predictions about future conditions may be made.	Models can be used to evalute the merits and disadvantages of various actions, generate predictions, and quantify relationships between components or variables.