changes affect other organisms throughout the ecosystem? Students can develop new system models for each case study ecosystem. As they compare system models for multiple ecosystems, they begin to see and describe **patterns [CCC-1]** recurring in the relationships between organisms (MS-LS2-2). Students should be able to identify relationships common to most ecosystems such as (1) organisms that compete for resources because they both have biomass arrows originating from the same source; (2) predatory relationships where the biomass from one animal goes to another; and (3) mutually beneficial relationships where arrows of energy, mass, or other benefits point in both directions between a pair of organisms. The goal is that students should be able to use ecosystem models to predict which organisms will compete if resources become scarce (MS-LS2-2).

## IS4 Integrated Grade Seven Instructional Segment 4: Sustaining Biodiversity and Ecosystem Services in a Changing World

### INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 4: SUSTAINING BIODIVERSITY AND ECOSYSTEMS SERVICE IN A CHANGING WORLD

**Guiding Questions**

- What natural processes and human activities threaten biodiversity and ecosystem services?
- How can people help sustain biodiversity and ecosystem services in a changing world?

**Performance Expectations**

Students who demonstrate understanding can do the following:

**MS-LS2-4.** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

**MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

**MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

## INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 4: SUSTAINING BIODIVERSITY AND ECOSYSTEMS SERVICE IN A CHANGING WORLD

**MS-ESS3-2.** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]

**MS-PS1-3.** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*] (Assessed after being introduced in IS1 and IS3.)

**MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

**MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

## INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 4: SUSTAINING BIODIVERSITY AND ECOSYSTEMS SERVICE IN A CHANGING WORLD

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

| Highlighted Science and Engineering Practices | Highlighted Disciplinary Core Ideas | Highlighted Crosscutting Concepts |
|---|---|---|
| [SEP-1] Asking Questions and Defining Problems<br>[SEP-4] Analyzing and Interpreting Data<br>[SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)<br>[SEP-7] Engaging in Argument from Evidence<br>[SEP-8] Obtaining, Evaluating, and Communicating Information | LS2.C: Ecosystem Dynamics, Functioning and Resilience<br>LS4.D: Biodiversity and Humans<br>ESS2.A: Earth Materials and Systems<br>ESS2.C: Roles of Water in Earth's Surface Processes<br>ESS3.B: Natural Hazards<br>PS1.A: Structure and Properties of Matter<br>PS1.B: Chemical Reactions<br>ETS1.A: Defining and Delimiting Engineering Problems<br>ETS1.B: Developing Possible Solutions<br>ETS1.C: Optimizing the Design Solution | [CCC-1] Patterns<br>[CCC-2] Cause and Effect: Mechanism and Explanation<br>[CCC-3] Scale, Proportion and Quantity<br>[CCC-6] Structure and Function<br>[CCC-7] Stability and Change |

**Highlighted California Environmental Principles and Concepts:**

**Principle I** The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

**Principle II** The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

**Principle III** Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

**Principle IV** The exchange of matter between natural systems and human societies affects the long-term functioning of both.

**Principle V** Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

**CA CCSS Math Connections:** MP.2, MP.4, 6.EE.6, 6.RP.3, 7.EE.4

**CA CCSS for ELA/Literacy Connections:** RI.7.8, RST.6–8.1, 7, 8, WHST.6–8.1, 2, 9, SL.7.5

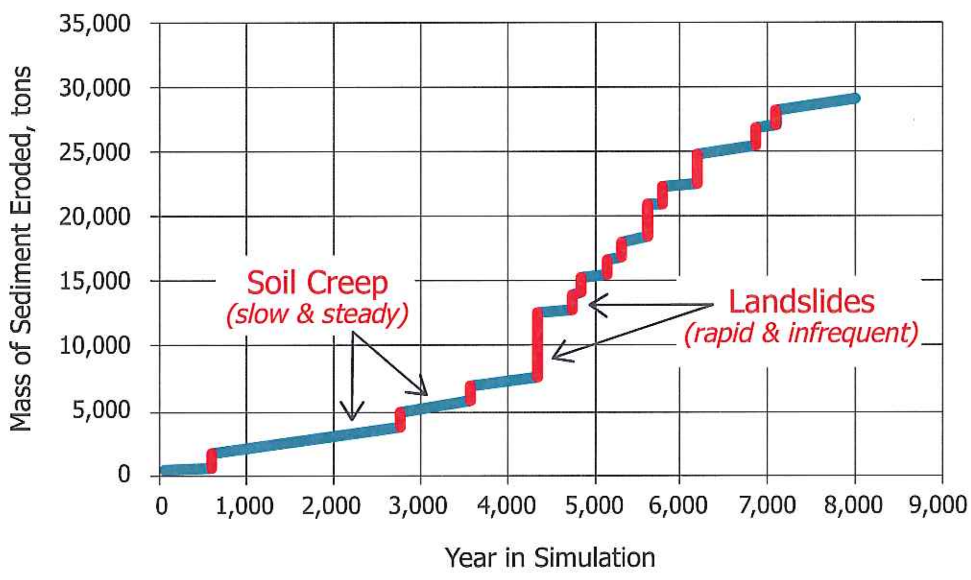
**CA ELD Connections:** ELD.PI.6.1, 5, 6a–b, 9, 10, 11a

Erosion is a part of everyday life in ecosystems, and plant root systems have evolved to help keep plants stable and soil in place. Every so often, erosion events become dramatic in the form of landslides. And even more rarely, a single event can trigger thousands of landslides at once. That was the case in 1994 during the Northridge Earthquake when the shaking triggered 11,000 simultaneous landslides in the mountains of Southern California (USGS 1995), each one tearing up root systems and completely transforming both the shape of the landscape and the life on it. These mega-landslide events are the anchoring phenomenon for this instructional segment, and they do not just happen during earthquakes. Over just three days in 1982, heavy rains triggered more than 18,000 landslides in the San Francisco Bay Area (USGS 1988) and landslides following wildfire are a constant concern throughout the state. After students **obtain information [SEP-8]** about these mega-landslide events, they can **ask questions [SEP-1]** about the factors that **cause [CCC-2]** landslides and how they affect the environment.

Students can examine case studies of smaller landslides, rock falls, and mud flows. While standard textbooks spend quite a bit of time discussing types of landslides, that terminology is not the focus. Instead, the emphasis is on process. What patterns do students recognize in the locations where landslides hit? They should be able to identify steep slopes, weakness of material, and often (but not always) some sort of triggering mechanism. As a preview for MS-PS2-2 in grade eight, students can review the core idea that multiple forces act on stationary objects, and those objects start moving when forces are no longer balanced (PS2.A, 3-PS2-1). Students can treat the block of soil or rock as a single object (the "landslide mass'") and identify the forces acting on it including gravity and some sort of friction or cohesion that keeps it in place. Students can use this information to begin to build a **pictorial model [SEP-2]** of what **causes [CCC-2]** landslides that will allow them to predict when and where landslides will occur. Students can also create **physical models [SEP-2]** of the situation by placing blocks on ramps and changing the angle. If they shake the ramp simulating an earthquake or add mass to the upslope side of the block, they add to the forces driving the block downslope; finding some way to lubricate the ramp reduces the force restraining the block. The added mass of rainwater and the construction of a large building are real-life examples of adding mass to a slide block. Rainwater percolating into pores can "lubricate" landslides, but far more common ways of reducing resisting forces are when material on the downhill side of a landslide block gets eroded away by rivers or cut away by people building roads or buildings. Students can use their physical model to consider general approaches that people can use to reduce landslide hazard. What would a plant root do to this situation? Vegetation predominantly reduces landslide hazard because roots spread through the soil like anchored netting, but roots also have a competing effect where they weaken material by breaking rocks apart. In some situations, the latter may become more important than the former. Students have to struggle with this apparent contradiction and add both processes into their model of landslides.

The clarification statement for MS-ESS2-2 emphasizes one of the key Earth and space science DCIs for middle grades that geologic processes can cause change that is slow, rapid, or combinations of both. Like all natural hazards, landslides happen infrequently, vary in size, and are caused by specific physical conditions that allow us to forecast where they will occur (ESS3.B). Smaller landslides are more common just like small earthquakes or smaller storms occur more frequently than destructive earthquakes and hurricanes. Since the magnitudes of hazards are important, students can look at landslides through the lens of **scale, proportion, and quantity [CCC-3]** and ask other interesting questions. For example, which form of erosion is more "important" in a landscape, the slow and steady wearing away of material or the sudden catastrophic movement of large landslides? Students can **analyze data [SEP-4]** about the amount of material eroded by each process from actual scientific observations (Swanson, Fredriksen, and McCorison 1982; Pearce and Watson 1986) or computer simulations (figure 5.37).

**Figure 5.37. Landslides and Slow Processes Both Contribute to Erosion**




In a computer simulation of a watershed, scientists recorded over a period of 8,000 years how much sediment moved by slow and steady processes, like soil creep, and how much by rapid and infrequent landslides. Which process caused more erosion in this simulation? Does the simulated watershed have hills or is it mostly flat? *Source:* M. d'Alessio using simulation results of Benda and Dunne 1997.

### Engineering Connection: Landslide Early-Warning System

With this model of landslide causes, students consider a small region, predict where the landslide hazards are greatest, and design a warning system to minimize their damage (MS-ESS3-2). Using computer-based map layers (such as in Google Earth) showing slope steepness, rock strength, annual rainfall, and/or expected ground shaking in an earthquake, students can identify areas that are most likely to slide. They can compare their predictions to published maps of landslide hazard for California or the locations of actual catastrophic landslides in 1982 or 1994 (USGS 1988, 1995). Students could use this information to **design [SEP-6]** a landslide warning system that works in conjunction with the National Weather Service weather forecasts (such a system actually exists, http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link15). Students need to **define the problem [SEP-1]** by figuring out what information could minimize loss of life in landslides and how to get the information to the community (MS-ETS1-1).

Landslides cause major disruption to ecosystems. They can temporarily dam rivers, uproot vegetation, bury habitat, and increase the sediment in rivers so much that aquatic life "chokes." Students can examine case studies of the effects of landslides on steelhead trout populations, including short-term concerns about the spawning habitat of local salmon (Cornwell 2014; Ruggerone 2008) or a landslide that blocked a river for hundreds of years and forced a major genetic shift in two populations of steelhead (American Geophysical Union 2011; Mackey, Roering, and Lamb 2011). On the land itself, landslides create a sudden availability of new resources in the ecosystem (such as space, sunlight, and broken up soil). Students can predict what they think will happen in the ecosystem and then obtain information about how the succession of vegetation following major ecosystem disruptions like landslides, fires, or volcanic eruptions (ecosystem change following the 1980 Mount St. Helens volcanic eruption is particularly well studied). Students should use these examples as evidence to **construct an argument [SEP-7]** that changes to physical or biological components of an ecosystem affect populations of organisms within that ecosystem (MS-LS2-4).

### *Human-Induced Changes to Ecosystems*

Sometimes the major changes to ecosystem components are not caused by natural hazards, but by humans who now impact the environment at the scale of the planet as a whole. Students in Integrated Grade Six analyze evidence that human activities, especially combustion of fossil fuels, have caused global temperatures to increase over the past century. Students in Integrated Grade Eight explore the impacts of increasing human populations and increasing per-capita consumption of resources.

Designing and testing solutions to these kinds of environmental challenges require a different kind of engineering design. Students' prior experiences with engineering design probably focused on specific devices, such as the calorimeter highlighted in IS2. At the middle grades level, the challenges can be at a higher level of generality, and also more strongly connected with personal and societal values. In challenges involving protecting biodiversity and ecosystem services (MS-LS2-5), some of the criteria, evaluations, and decisions will inevitably be strongly influenced by ethical, economic, and cultural valuations.

California's Environmental Principles and Concepts (EP&Cs) can provide guidance in implementing these design challenges. All five of the environmental principles apply to IS4. Students can refer to these general principles and the specific concepts associated with each principle as part of their analyses, evaluations, and argumentation. Having extensively investigated **cycles of matter [CCC-5]** and ecosystem processes, students are primed to apply California's EP&Cs. For example, there are three concepts associated with Principle III:

- Natural systems proceed through cycles and processes that are required for their functioning.
- Human practices depend upon and benefit from the cycles and processes that operate within natural systems.
- Human practices can alter the cycles and processes that operate within natural systems.

The **systems [CCC-4]** thinking and **modeling [SEP-2]** embedded within Integrated Grade Seven provide a scientific framework evaluating design solutions. The models students made of energy **flow and matter cycles [CCC-5]** at the ecosystem scale apply to planetary scale problems as well with one significant difference: some matter (e.g., carbon dioxide and water) enters and leaves an ecosystem, but when considering the planetary scale, matter essentially does not leave or enter. All of Earth's ecosystems are linked with each other through their sharing of the atmosphere and the hydrosphere. Each of the elements vital to life on Earth exists in a closed loop of cyclical changes.

The environmental human impacts that students explore throughout the middle grades ultimately relate to the effects of human activities on Earth's cycles of matter, flows of energy, and web of life. In some challenges, such as habitat destruction or introduction of exotic species, the main direct impacts are on the local web of life. This local web of life is also often impacted by pollution. Essentially all pollution issues result from activities that contaminate or disrupt Earth's natural cycles of matter. In many cases, the pollution includes adding synthetic materials to the natural system. Even though these materials have been produced from natural resources and materials, humans altered them by chemical processes such that some of them can now harm ecosystems, and in turn harm humans (EP&Cs I–IV).

As part of the design challenge, students should gather any relevant information about how synthetic materials have affected the ecosystem and society (MS-PS1-3).

In this design challenge, students need to identify a specific problem in an ecosystem (MS-ETS1-1) that considers the relationship between people and the natural environment. This problem may be based on a large-scale investigation as described in the snapshot below. The goal is to "improve" an ecosystem by reducing human impacts, and two measures of a healthy ecosystem are biodiversity within the ecosystem and the richness of services the ecosystem provides to people. Students should choose some aspect of biodiversity or ecosystem services as measurable criteria they can track to evaluate the progress of their proposed solutions (MS-LS2-5). Students should be able to use a system model of their ecosystem to evaluate the relative merits of different solutions (MS-ETS1-2).

## Integrated Grade Seven Snapshot 5.5: Planning a Large-Scale Investigation

**Investigative problem:** How can we restore a habitat so that it is less influenced by human activities?

Motivated by an article they read about kids making a difference, Mr. R's class decided to plan a habitat restoration project. Mr. R explained that to be effective with habitat restoration they needed to learn more about the ecosystems. He asked the class, "How would we begin a scientific study of our local ecosystems so we learn enough to work on a restoration?" Students responded that the best way to begin an investigation was to **ask scientific questions [SEP-1]**. Students began writing questions about local ecosystems at the nature center or that they had experienced in other ways. Soon the teams had numerous questions to share so they began posting them on their team flipcharts. While the teams were writing their questions, Mr. R visited and guided their discussions, as needed.

With all the questions posted, Mr. R asked the students if they noticed any **patterns [CCC-1]** among the questions. Several pointed out that some of the questions seemed to focus on the plants and animals, and others were more focused on things like the soil, rocks, water, and other parts of the physical surroundings. Mr. R asked the students to return to their flipcharts and put a big "P" next to questions that involved physical components and a big "B" next those that involved the biological components of ecosystems. Students had to provide **examples and reasoning [SEP-7]** about how these different components could **affect [CCC-2]** the population of organisms (MS-LS2-4); their reasoning referred to **models [SEP-2]** of the **flow of energy and cycling of matter [CCC-5]** in their ecosystem (MS-LS2-3) and geoscience processes that alter the physical environment (MS-ESS2-2).

## Integrated Grade Seven Snapshot 5.5: Planning a Large-Scale Investigation

Returning to the students' concerns about the effect of human activities on the local ecosystems, Mr. R decided to initiate a discussion related to California Environmental Principle II: *The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies*. He suggested that the teams think about some additional questions that would help them learn how human activities were affecting the functioning and health of ecosystems.

The class and Mr. R had been talking about the difference between conducting an investigation that someone else had created compared with **planning and conducting your own investigation [SEP-3]**. Students reminded Mr. R about that discussion, and said they wanted to plan their ecosystem investigation. With student teams standing near their charts, each team shared one or two of their questions. He mentioned that the class would have the opportunity to vote on which questions they wanted to investigate. Mr. R then reminded students to think about the question scaffolding process they had learned about in their English language arts class, making sure that, when put all together, their questions and data should help them better understand populations and biodiversity, the physical and biological components of ecosystems, and how ecosystems are affected by human activities.

The class continued to discuss which questions would be best and soon realized that they would need data to compare the disturbed ecosystem they wanted to restore with a more natural example of that same ecosystem. The students pointed out that this process would help them plan how their restoration work might mitigate the effects of human activities at their study sites. Following much discussion, the students selected five questions for their class investigation:

- What plants and animals live in the disturbed and undisturbed ecosystem study sites?
- What are the physical and biological components of the two study sites?
- What natural processes and ecosystem services in the two study sites support the ecosystems?
- What natural processes and ecosystem services in the two study sites help humans?
- What human activities are occurring in the two study sites?

Students realized that both natural and disturbed ecosystems were changing; they hoped to be able to document how the rates of natural **change [CCC-7]** compared to the rates of human-induced changes (ESS3.C). Mr. R shared these questions with the volunteers at a local nature center who had tried to help him prepare the investigation. Mr. R couldn't make the logistics work out, but he started planning for next year. Even if it never worked out, Mr. R decided that the activity of planning the investigation was worthwhile for his students. He thought about how to frame the activity next year so that it would feel authentic but also so that the students wouldn't feel disappointed if they couldn't actually implement their project. His goal was to eventually have students propose design solutions for their habitat restoration and then evaluate the different proposals (MS-LS2-5). Their restoration plans would require attentiveness to the biosphere as well as the other Earth systems.