IS4

Earth and Space Sciences Instructional Segment 4: Water and Farming

California is the largest agricultural producer in the country. Its farming success depends on three main natural resources: its climate, fertile soil, and the availability of massive amounts of water for irrigation. Previous instructional segments in this course have discussed the climate system and the source of its fertile soils. This instructional segment focuses on the availability of water and how humans have impacted that availability.

EARTH AND SPACE SCIENCES INSTRUCTIONAL SEGMENT 4: WATER AND FARMING

Guiding Questions

- Why do droughts have such a strong impact on California and other parts of the world?
- How will changes in climate affect our water resources?

Performance Expectations

Students who demonstrate understanding can do the following:

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [*Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.*]

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*]

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

EARTH AND SPACE SCIENCES INSTRUCTIONAL SEGMENT 4: WATER AND FARMING

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

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

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 [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	ESS2.C: The Roles of Water in Earth's Surface Processes ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change ETS1.A: Defining and Delimiting Engineering Problems ETS1.C: Developing Possible Solutions	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-7] Stability and Change Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World

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: N-Q.1–3; MP.2, MP.4

CA CCSS for ELA/Literacy Connections: RST.11–12.1, 2, 7, 8, 9; WHST.9–12.2a–e, 7

CA ELD Connections: ELD.PI.11–12.1, 5, 6a–b, 9, 10, 11a

The instructional segment begins by drawing on the knowledge students gained about the hydrologic cycle in the middle grades (MS-ESS2-4). They should already know that agriculture is by far the number one user of developed water (>75 percent of all consumed) and that the state gets its water from a combination of groundwater pumping (20-40 percent, depending on the year) and surface water from dams and reservoirs (Legislative Analyst's Office 2010). Articles about California's water supplies along with some hands-on demonstrations of the groundwater storage capacity of different Earth materials can serve as valuable review of these topics (see *Liquid Gold: California's Water* at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link55 and the EPA's, *Water Sourcebook: a Series of Classroom Activities for Grade Level 9–12* at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link56).

The high school performance expectations from the CA NGSS do not add any additional content knowledge tasks related to the internal processes of the hydrosphere. Instead they press students to apply the knowledge from previous grades to situations involving hydrosphere–anthrosphere interactions (EP&Cs I, II, & III). The focus of this instructional segment is to understand how California's water supply is limited and will be strongly influenced by climate **change [CCC-7]**. California is not alone in this situation, with water supplies being an increasing issue worldwide as populations and agricultural demands grow.

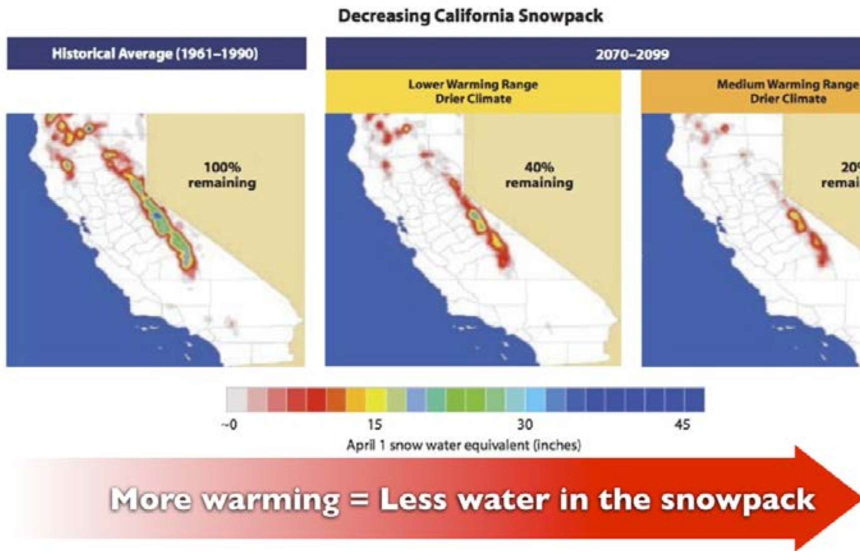
Climate Projections

Computer **models [SEP-2]** of global climate change predict that California is likely to be warmer and drier on average than at present. The California Natural Resources Agency publishes an assessment of projected climate impacts regularly as scientists constantly develop more accurate models. The 2012 report summarizes the projected changes as follows:

- The average annual temperature is projected to rise 2.5-8.5°F by 2100, and the range depends in part on how much greenhouse gas is emitted by humans around the world.
- Rainfall is projected to drop by as much as 10 percent below the historical levels, on average (Moser, Ekstrom, and Franco 2012).

This combination of warmth and dryness will cause significant changes to the amount of snow in the mountains. California relies on this snowpack because it uses more water during the summer but receives the majority of its precipitation in the winter. The state needs a way to store water for the hot summers. It currently depends on nature's storage system, snow that falls in the Sierra Nevada. The snow stays frozen until spring when warm weather melts it, filling our reservoirs just when we need them. A warmer and drier climate will cause a severe reduction in the snowpack (figure 8.57), so the state will need to come up with a new strategy for storing water for the hot summer.

Figure 8.57. Projected Decreases to California's Snowpack

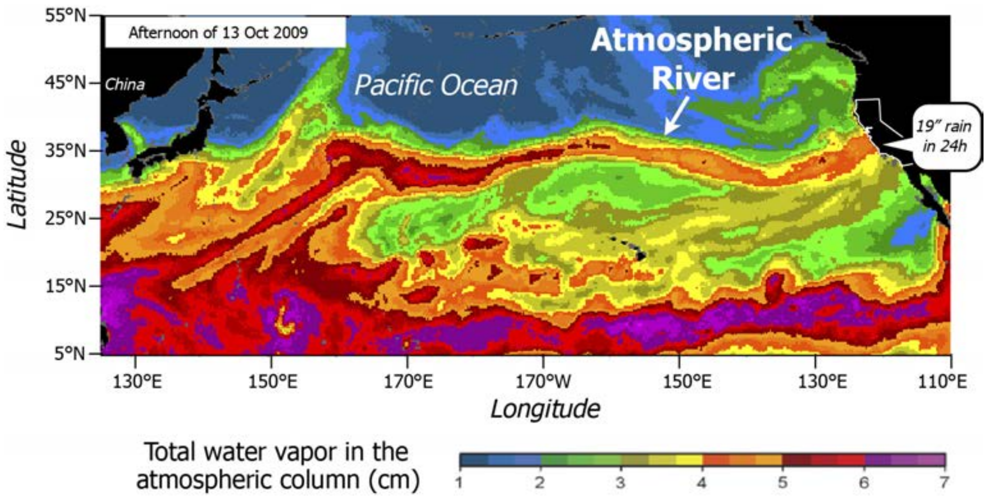


California should expect less water in the snowpack in the second half of the twenty-first century.
Source: California Climate Change Center 2006.
Long description of Figure 8.57.

California happens to lie in a unique position on the globe where even a small **change [CCC-7]** to the average rainfall amount may have a dramatic impact. Even though California receives less rainfall in an average year than many other states, the range between the wettest years and driest years is much more extreme than just about anywhere else in the country. This occurs because most of the state's rainfall arrives in relatively few short and intense storms. Despite our overall dryness, California receives some of the largest three-day storms in the country, rivaling the hurricane belt of the southeastern United States in rainfall intensity. "Thus, whether just a few large storms arrive or fail to arrive in California can be the difference between a banner year and a drought" (Dettinger et al. 2011). This dependence makes us particularly sensitive to small **changes [CCC-7]** in global climate.

California seems to receive these intense storms due to a unique atmospheric effect termed atmospheric rivers (figure 8.58). While it is common to have lots of moisture in the air over the Equator and tropics, there is typically less moisture in the air at the mid-latitudes where California lies. When unique conditions set up in the ocean and atmosphere, these atmospheric rivers act like narrow conveyor belts that push air containing excessive amounts of water vapor thousands of miles. Not all of California's storms are caused by atmospheric rivers, but many of the largest and most intense ones are. Scientists are still trying to figure out the exact conditions that give rise to atmospheric rivers, but small **changes [CCC-7]** in climate are likely to have substantial impact on whether or not they form and send moisture towards California. As a result, climate change will likely cause some years to be dramatically wetter than the past while other years will be much drier. The average will balance out to a smaller overall change, but our droughts could become even more severe.

Figure 8.58. Satellite Image of Atmospheric Water Vapor Reveals an Atmospheric River



Sources: National Oceanic and Atmospheric Administration, Earth System Research Laboratory 2015
Long description of Figure 8.58.

Managing Water Supplies

Computer simulations [SEP-2] serve as bookends to this instructional segment in which students explore issues in aquifer management (see The Basin Challenge at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link57 (HS-ESS3-3). When they engage in the activity at the beginning of the instructional segment, they can explore parameters and discover some of the issues and choices that affect water supplies. By the end of the instructional segment, they should have a more specific understanding of the processes involved in water availability, storage, and use. As a culminating assessment, students can conduct a role-playing negotiation in which they determine how much groundwater different communities are able to extract (HS-ESS3-1) (see the Environment and Sustainability Negotiation Role-Play from Harvard Law School's Program on Negotiation at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link58). Such scenarios are increasingly realistic as the demands of a growing urban population in California's Central Valley, agriculture, and protection of aquatic ecosystems have become increasingly competitive. Students can explore some of these issues of water supply and demand in several articles such as *Liquid Gold: California's Water* (https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link59). They can analyze the human impacts resulting from the methods used to move large amounts of water and examine EP&C V. Appendix 3 of this framework provides a complete vignette guiding teachers through a way to teach skills of computer science in tandem with ESS DCIs. According to the developmental progressions in appendix 1 of this framework, high school students should be able to "create and/or revise a computational model or simulation" as part of **computational thinking [SEP-5]**.

Because agriculture is so dependent on water, it makes sense to explore the impact of climate **change [CCC-7]** on different crops (HS-ESS3-5). Students may select one of California's signature agricultural products (such as grapes, almonds, oranges, dairy, and avocados) and research the optimal growing conditions including the temperature and moisture requirements for such crops. They will **investigate [SEP-3]** where each crop is grown in California and why it is grown there. They can then refer to results from climate change **models [SEP-2]** that show how different regions will be affected by climate change. Will this increase or decrease productivity? Published simulations for specific crops are already available (Parker 2007; Hanson et al. 2010; Joyce et al. 2006), so students could compare their own assessment to these scientific models. By running their own climate simulations using published educational climate models, students can explore a range of different emissions scenarios to try to figure out if there is an acceptable threshold at which the crop would still achieve high productivity (HS-ETS1-4).

Water Quality

Even when California has enough water available, there are issues of water quality and contamination. Strict state and federal laws protect water, but the combination of accidents and infrastructure that predates those laws leave us with an ongoing legacy of contaminated water. Teachers should tailor activities about water quality around the local issues faced by their community.

Contamination comes from both individual sites (point sources) and the cumulative effect of water running off over large areas and picking up contaminants across these areas (nonpoint sources). The reason for making this distinction is that point sources are easy to identify and therefore eliminate. Industry, oil and gas production, and mining are the most common sources of point-source pollution. In most cases, nonpoint sources are actually caused by many individual point sources, but they are too small to track down. Lawns in a suburban neighborhood and farms in rural regions, both of which supply pesticides and excess fertilizer to runoff, are usually considered nonpoint sources, but it is important to note that individual people are actually responsible for all of these pollutants and could be educated to reduce this impact. In many cases in urban and suburban California, individual homeowners are partly responsible for water contamination. Students can prepare a brochure **communicating [SEP-8]** strategies for reducing water pollution and distribute it to homes in the neighborhood.

Students could obtain water-quality test kits and make measurements in natural waterways or in urban runoff. If they identify unacceptable levels of pollution, they can plan a more detailed investigation with strategically located water-quality samples that can help pinpoint the source(s).

Students can also **obtain information [SEP-8]** about larger pollution sources by looking up EPA Superfund sites in their area (that frequently have contaminated water; see https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link60).

Engineering Connection: Water Filtration

California is home to state-of-the art water treatment plants and rigorously enforced regulations, but much of the rest of the world struggles to find clean and safe water. Students could **obtain information [SEP-8]** about water treatment and purification systems in their community, or be given engineering challenges to design water purification systems (such as Engineering is Elementary, *Water, Water Everywhere* at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link61). These systems have a lot in common with the natural groundwater system, which is an excellent filtration system. This is why digging groundwater wells can dramatically decrease health risks from waterborne pathogens in third-world countries (HS-ETS1-1). This framework calls on students to perform a similar design process in fifth grade, but students can return to the problem in high school with a broader understanding of the properties of water.