California Water and Drought
Subunit for Rock Your World and Nature Trek

Objectives:
The student shall learn:
- The basics of the water cycle and water use in California, including groundwater, snowpack, and surface water.
- What "drought" means and how drought conditions impact various aspects of California life, including agriculture, environment, and urban life.
- How much water is used to perform various actions such as farming, production of goods, and daily activities in the home.
- To think about water consumption and ways that they or their families can conserve water.

Major Concepts:
~ The water cycle
~ Water systems in California
~ Water use in California
~ Drought and water conservation in California

Materials Needed:
~ Raised relief maps of California
~ Supplementary maps and graphics, borrowed from the Public Update for Drought Response
~ How Much Does It Take? True or False Fact Cards

Supplemental Resources:
- A Look At California Agriculture
  www.agclassroom.org/kids/stats/california.pdf
- California Department of Water Resources
  www.water.ca.gov
- California Drought
  www.ca.gov/drought
- California Water Foundation : Land Subsidence From Groundwater Use in California
  www.californiawaterfoundation.org/uploads/1397858208-SUBSIDENCEFULLREPORT_FINAL.pdf
- Dobson, Clive and Gregor Gilpin Beck, Watersheds: A Practical Handbook for Healthy Water, 1999.
- H2Ouse: Water Saver Home
  www.H2ouse.org
- Public Policy Institute of California: Just The Facts: Water Use in California
  www.ppic.org/main/publication_show.asp?i=1108
- Public Update for Drought Response - November 2014
  www.water.ca.gov/waterconditions/docs/PublicUpdateforDroughtResponse_GroundwaterBasins.pdf
- Save Our Water
  www.saveourwater.com
- U.S. Drought Monitor
  www.droughtmonitor.unl.edu
- USGS: California drought, visualized with open data
  http://cida.usgs.gov/ca_drought/
- What is a Watershed?
  http://water.epa.gov/type/watersheds/whatis.cfm

California Water and Drought - Introduction

According to the San Joaquin Valley Water Year Index, water year 2014 was the second driest on record (after 1977). The year immediately followed two consecutive dry years in California, and in response to the drought, California Governor Jerry Brown declared a State of Emergency on January 17, 2014. **Water year** is the term used to describe the twelve-month period of time in which water is measured, between October 1 and September 30 of the following year. Water years are named for the second of the two calendar years.

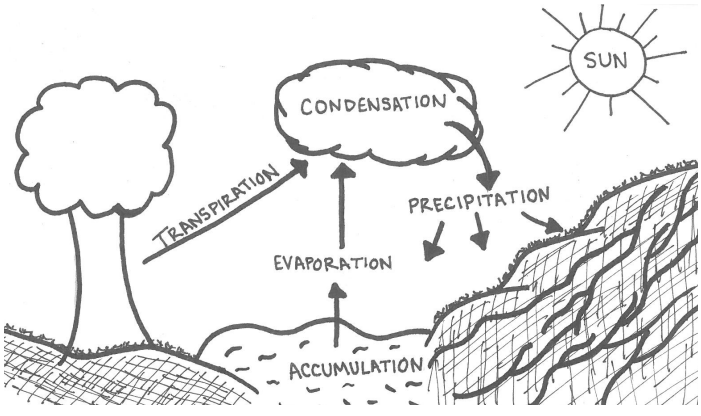
As water year 2015 is looking like another unusually dry year, this subunit has been designed to supplement existing curriculum to help students understand drought conditions and ways they can make lifestyle changes to help in the statewide effort to reduce water use in California. Students will learn the basics of the water cycle, water use in California and in general, and the impacts of drought in California, as well as discuss actions that can be taken by individuals, families, and communities to conserve water.

This subunit is designed to supplement the Rock Your World and Nature Trek curriculums. In Rock Your World, students will learn about snowpack and runoff in the mountains and groundwater in the Central Valley. In Nature Trek, students will learn how drought conditions and human response to drought impacts the environment at large. Therefore, some information included in this subunit may be repeated from other curriculum packets.

Lesson 1: The Basics of the Water Cycle

A. Ask students how much water they think there is on Earth. Get several guesses and then give them the following information: Nearly 75% of the world's surface is covered by water. The Earth has about 329,000,000 cubic miles of water. Of that amount, 97.2% is found in the oceans and 2 % is locked up in polar ice caps and glaciers. Thus, less than 1% of the world's water is available as freshwater - and the majority of that is underground.

B. Ask students if they have heard of the water cycle. Allow students to describe the water cycle and then briefly describe it to reinforce or correct their ideas. The **water cycle** is the dynamic movement of water on the Earth. Water moves through the atmosphere, on the surface, and underground in an ongoing, continuous cycle. Water can move as a liquid, a solid, or as a gas. The basic steps of the water cycle are as follows:



1. **Evaporation:** Water is changed from a liquid to a gas as it is heated. (Think: boiling water.)
2. **Transpiration**: As plants "breathe," they give off oxygen and water vapor.
3. **Condensation**: As water vapor cools, it changes from a gas to a liquid (Think: formation of clouds.)
4. **Precipitation**: Water falls back to the earth in the form of rain, hail, sleet, or snow.
5. **Accumulation**: Water that comes down in the form of precipitation collects in creeks, rivers, lakes, ponds, oceans, and underground. (Some water has been previously accumulated into glaciers as well.)

Point out how the sun is the source of energy that powers the water cycle. It is the sun's energy, in the form of heat that causes the evaporation of water into water vapor. It is also the sun's heat that causes wind, which moves the clouds of condensed water vapor from over the oceans towards the mountains where they precipitate in the form of rain and snow. The sun heats up the air, and heated air moves upwards (like when you light a match) creating a vacuum or empty space in which other air moves in to fill it – creating wind.

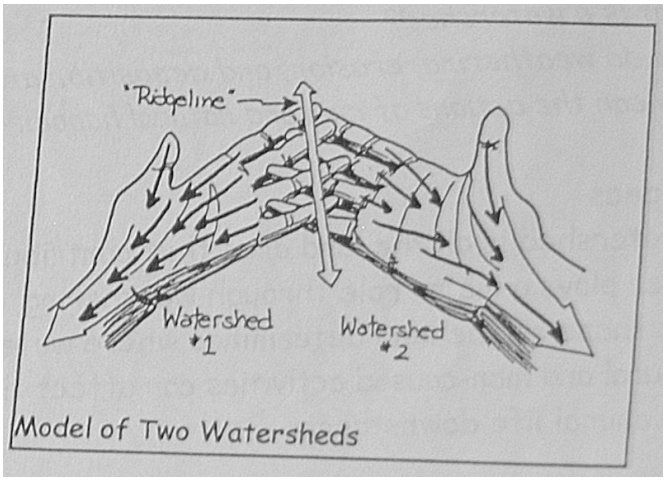
C. Explain that there is, in a sense, only one body of water on the Earth. All water, everywhere, is somehow connected - through the atmosphere, rivers, lakes, groundwater, seas, and oceans. Every single molecule within our bodies - which are about 75% water- has been part of the atmosphere, rivers, lakes, groundwater, seas, and oceans at some other point in time, and it will be again as it leaves our bodies. (Have students could think about breathing on a cold window on a frosty morning to realize that every time we breathe we exhale some water.) All living things are partly made of water, and all life depends upon water in some way.

D. Ask students to look around them and think of evidence of the water cycle that they see at outdoor school and every day at home. Some examples include: Nelder Creek, the lake at Calvin Crest, clouds passing overhead, muddy ground, snow on the ground, experiencing rain, snow, or fog, etc.

Lesson 2: Water in California

A. Explain to students that a **watershed** is the area of land that contributes runoff to a particular body of water.

Demonstrate how students can extend their hands, palm-up, and make a model of two watersheds separated by a ridge. (See illustration.) Have each student hold his/her hands as shown. Point out that the **ridgeline** forms a border between two separate watersheds, with water flowing down towards the upturned palms.



Model of Two Watersheds

Explain that no matter where you are on Earth, you are in a watershed. Water either flows away from where you are, towards where you are, or settles where you are. Watersheds follow the way that the natural landscape is organized and divided.

B. Show students raised relief maps of California and have them observe how the entire Sierra Nevada mountain range acts as an enormous watershed that drains into the Pacific ocean through the San Francisco Bay.

a. Explain that erosion from the Sierra Nevada and Coast Range has deposited sediments in the Central Valley - *that is why the valley is so flat*. Note the uniformity of the valley from south of Bakersfield to north of Redding, a distance of 400 miles. Generally, only the finest sands, silts, salts, and clays have been deposited over the entire valley. Only the smallest, lightest particles stay suspended in water over the great distances from high in the Sierra down to the Central Valley. This accounts for the rich agricultural soils of the valley made up of sands, clays, silts, and minerals from the surrounding mountains. Heavier rocks and boulders settle out on stream

bottoms in the mountains. As they continue to be weathered and eroded, the much smaller sediments generated are carried away. The raised relief map shows how weathering and erosion has created the extensive mountain canyons and valleys as sediments are carried away and the water carves ever deeper into the surface over which it flows. Have students observe the western slope of the Sierra on the maps to see those canyons shaped by the geologic forces of nature.

C. Show how the Central Valley used to be an inland sea, surrounded by mountains.
   a. Imagine that the valley was a large bathtub. Where is the drain? (The narrow channel of the Sacramento River where it empties into the San Pablo and San Francisco Bays).
   b. Now imagine this bathtub is full of water and that you are going to use wheelbarrows full of dirt to "fill the tub." As the tub is slowly filled with dirt the water is gradually displaced until the only water that remains is that which was trapped and absorbed by the dirt (or that which now flows over the hard-packed surface). That is what happened to form the soils of the Central Valley. It is this trapped water, water transported by canals from dammed reservoirs in the foothills, and water flowing underground from the Sierra that serves the needs of people who live and work in the Central Valley.

D. Remind students that all of the water that is on earth has been - and will continue to be - the only available water. In California, there are 3 main sources of freshwater: mountain snowpack, stored reservoir water, and groundwater.
   a. **Snowpack** is the term used to describe snow and ice that is compacted together on the ground. In California, high mountain areas accumulate snowpack over the course of the cold winter. In an average year, 75% of the annual precipitation in California falls between November and March. (Half of that falls between December and February.) As spring and summer temperatures rise, snow melts and runs into creeks, streams, and rivers. On average, snowmelt accounts for one third of the state's water supply.
   b. **Reservoirs** are natural or manmade lakes used as water supply. Reservoirs may receive some water from precipitation, but are primarily filled by melting snowpack. Thus, reduced snowpack in an area will also shrink the amount of water in reservoirs. California residents rely on natural and artificial reservoirs to supply water throughout the year, but the combination of near-constant human use, decreased precipitation, and warm temperatures that lead to evaporation results in smaller reservoirs of water to draw from.
   c. In an average year, close to 40% of California's urban and agricultural water use comes from groundwater supplies. **Groundwater** is water that has seeped underground through cracks in rock or porous surfaces and soil that is stored in **aquifers**, which are porous layers of sand, gravel, and rock. Aquifers have a layer of impenetrable clay or rock underneath them that holds the water in place. Groundwater is accessed by building wells and pumping water to the surface. In years where there is little precipitation, more groundwater is used by the population to meet water needs. Show students the supplementary map "Figure 2: bulletin 118-03 Alluvial Groundwater Basins".

E. Share with students how freshwater is used in California. If time permits, you can have them think of ways that Californians use water and how that might fit into the following categories. (Also consider ways that Californians utilize water that does not change the availability of water, like recreation on lakes and rivers or hydroelectric power plants.)
   a. Water use in California is 50% environmental, 40% agricultural, and 10% urban on average, statewide. These percentages vary depending on drought conditions, active conservation efforts, and different areas of the state.

1. Environmental use: water protected by federal and state laws as "wild and scenic," water necessary to maintain habitat, water in wetlands at wildlife preserves, and water needed to maintain quality of water used for other reasons (below). Most of the water reserved for environmental use doesn't impact other water use in the state.
2. Agricultural use: approximately 80% of human water use in California goes towards irrigating California farmland.
3. Urban use: many areas of California depend on water from other parts of the state. Roughly 75% of rain and snow falls on northern California, while about 75% of the state's population lives in central and southern California. This means that some water must be brought into populated areas by aqueducts and other means. Residential and commercial landscaping represent about half of urban water use. Though the population in California continues to grow, the amount of water used in urban areas has remained about the same over the last 20 years, due to conservation efforts and water-saving technologies.

Lesson 3: Drought in California

A. A **drought** is a period of time in which an area receives less precipitation and, as a result, a shortage of normal available water. Drought periods can last over a period of months or years. Explain to students that drought, unlike other natural disasters, usually occur slowly over time, leaving residents in an area time to react and prepare. Unlike earthquakes, fires, and tornadoes, for instance, residents in a place experiencing a drought can take measures to conserve water and reduce water usage until such a time as the area can recover with (an) especially wet year(s), which would recharge aquifers, increase snowpack, and refill reservoirs and other areas of surface water. If water-saving practices continue in wet years, future years of drought may not be as detrimental.

B. Explain how a lack of precipitation in the Sierra Nevada affects the Central Valley and how a statewide drought affects the rest of California.

Precipitation in California comes from the Pacific Ocean. Changes in land and water temperatures dictate both high- and low air pressure zones around the world, which cause various weather phenomenon. When a ridge of high pressure air sits over the Pacific, evaporated water is pushed further north and clouds travel across places like Alaska and British Columbia instead of California. In addition, these high pressure ridges cause an increase of cold and wet weather to the East Coast. It is not uncommon for high-pressure zones to build above the Pacific in the winter, but they usually break apart and allow California to receive winter rain (snow in higher elevations). When there is a persistent high pressure zone, there is a tendency for a very dry period.

The winter of 2013-2014 saw a resilient high pressure zone off of the West Coast which was almost 4 miles high and 2,000 miles long and stayed in place for over a year. The winter of 2014-2015 has seen a similar anomaly, in a ridge that is similar in structure but located slightly further east than the ridge of the previous year. Until this high-pressure ridges above the Pacific breaks apart, or the pattern in recent years of high-pressure ridges discontinues, most of the state of California is likely to remain in critical drought conditions.

C. Teach the students about current drought conditions in California:

a. Water years 2012-2014 have been increasingly dry:
   - On January 17, 2014, when Governor Brown declared a State of Emergency, the Sierra Nevada had 14% of the normal amount of snowpack for that date.

- Shasta Lake is California's largest reservoir, located just shy of 200 miles northwest of Sacramento. On December 31, 2014, it was 66% of the historical average. Between August 2011 and August 2014, Shasta Lake saw a 47% reduction in area.
- Show students the supplementary graphic "Figure 1: Sacramento Valley and San Joaquin Valley Water Year Types - 1906 to 2014"

b. The California state climatologist at the Department of Water Resources estimated that 150% of average precipitation would be necessary in water year 2015 to exit drought conditions and begin recovery. January 2015, however, saw the driest start of the calendar year on record. In December 2014, snowpack in the Sierra Nevada was at 50% of the historical average, and in late January 2015, snowpack was 25% of the historical average.

It is important to note that approximately half of the years in historical records regarding the northern Sierra Nevada caught up to average precipitation by the end of the water year. Experts will have a better understanding of how much water is available to Californians by the end of April 2015.

D. Discuss the impacts of drought conditions in California. Less snowpack and depleted reservoirs mean that there is less freshwater available to supply California's residents. California Governor Jerry Brown and other agencies have called residents to use less water at home and in the workplace. Right now, it means voluntary lifestyle changes in addition to mandatory water regulations. Some counties have ordinances in place that require people only water their lawns on certain days of the week. In the future, if the drought continues, it may mean stricter regulations on water use in private and public settings.

a. Groundwater: Residents have shifted much of their reliance on snowpack and reservoirs to rely more heavily on groundwater than usual. This shift in groundwater use has and will continue to have a deep impact on life in California. Show students the supplementary map "Figure 2: bulletin 118-03 Alluvial Groundwater Basins" again.

1. More wells: In 2014, over 350 new wells were dug in Fresno and Tulare Counties, and over 200 were dug in Merced County. Of all new wells dug in 2014, 50% were for domestic use, 47% for irrigation, 3% for public use, and less than 1% for other uses.
2. These new wells, and increased use of existing wells has meant a change in the level of groundwater in underground aquifers. Aquifers are measured throughout the year. In the spring, after winter storms and the beginning of snowmelt, but before crop irrigation, groundwater levels are typically highest. In the fall, after irrigation of crops but before winter precipitation, groundwater levels are usually at their lowest. Groundwater levels, compared at the same time each year, have been going down in recent years. Since 2008, many underground aquifers have been reaching all-time lows. The water table, the top of the water saturation zone, declined 155 feet between 1980 and 2011. Show students the supplementary maps "Figure 5: Change in Groundwater Levels in Wells - Spring 2013 to Spring 2014" and "Figure 6: Change in Groundwater Levels in Wells - Spring 2010 to Spring 2014."
3. If groundwater is being used at a greater rate than it is being "recharged" by precipitation and runoff (called overpumping or overdraft), there can be several problems:
    1. Water in specific areas can run out, causing residents to go without water or bring it from somewhere else by a costly means.

2. Plants that depend on groundwater to grow and live may die, potentially causing a chain reaction in the natural world, if those plants are a primary food supply for an animal species.
3. As water is drained from aquifers, the area experiences **land subsidence**, where the layers of clay and sediments compact together and settle. The ground surface area around where the water is being pumped can sink, sometimes dramatically, which results in cracked or broken buildings, pipes, and roads. In addition, the soil can harden and become impenetrable, making the aquifer permanently smaller and impossible to recharge to its former volume. This is called inelastic land subsidence. "Land subsidence from groundwater extraction in the San Joaquin Valley has been called the greatest human alteration of the Earth's surface." (Galloway et al., 1999. Referenced in "Land Subsidence from Groundwater Use in California. See "Supplemental Resources" above.)

b. Agriculture and Livestock: There are 81,700 farms in the state of California. Nearly half of the nation's fruits, vegetables, and nuts are grown in California. All crops need water to grow - some more than others, and farmers rely on irrigation. When there isn't as much precipitation as normal, more irrigation is needed. Farmers rely more heavily on groundwater than before. Negative impacts of overusing groundwater are described above. Below are other impacts the drought has had on farming and ranching.

    1. Explain to students that there hasn't been enough water in California to sustain the normal number of crops. NASA, the U.S. Geological Survey, the U.S. Department of Agriculture, and the National Agricultural Statistics Service have been given a grant to study idled land in the state of California. Using a combination of satellite imagery and people on the ground checking the truth of what the satellites appear to portray, the government can asses how many acres of cropland is being used to grow crops, and how much is left idle.

       Idled land, sometimes known as fallowed land, is land that is not planted during the growing season, usually crops that are not planted after June 1. There are many reasons why land might be fallowed. One of these is crop rotation - it is common for farmers to let one field "rest" for a season so that the soil can recover the nutrients necessary to have a good crop. Another factor may be that a farmer is focusing more time, energy, and money on a different crop, and didn't plant in part of his or her fields in order to focus on that crop. The drought, however, has caused many farmers to idle more land than normal. Because there is less precipitation, crops need to be irrigated more. Farmers have limited water with which to irrigate, so they have been forced to choose which crops to use that irrigation water on, and which to let go for the season. Farmers will typically choose permanent crops (fruit trees, for example), and crops that will produce a higher yield. According to the study mentioned above, the estimated peak idling of cropland in 2014 was 1.7 million acres, which is almost 700,000 more acres than in 2011, the last wet year.

    2. Farmers and ranchers who raise animals also need to be conscious of the amount of water that they need to raise livestock. A cow, for example, can drink up to 35 gallons of water a day! In addition, crops that livestock eats - like alfalfa and corn - must be grown somewhere in addition to food crops grown for human consumption. Free-range livestock can also suffer when the lack of precipitation means less plants for the animals to graze on.

3. Discuss with students other possible implications of the drought's impact on agriculture and livestock. Some ideas include: inability to feed livestock, eventual food shortage, food prices, loss of land, loss of jobs, more difficult to re-plant on dried out/unworked soil, death of fruit and nut trees that take much more time to grow and produce fruit, etc.

c. Wildlife: Habitats are in a delicate balance. If there is no longer water in a stream, for instance, there is nowhere for fish and other water creatures to live, there isn't water for animals to drink, or for water-plants to grow. Discuss with students possible implications of drought on wildlife. Some examples are listed below:
    1. Dried up streams, rivers, lakes, and ponds. Loss of habitat that is temporary but could turn permanent if the drought persists. This could result in animal deaths, threatened or even extinct species, or overcrowding of wet habitats that still exist as animals move to locations where there is still water.
    2. If humans try to create new reservoirs by damming a river that still has water flowing through it, there are several potential negative impacts. The habitat above and below the dam will change into very different habitats. For instance, the riparian habitat will turn into a pond habitat. In addition, fish like salmon will no longer be able to swim upstream to spawn (unless there is also an investment in fish ladders to help the salmon swim past the dam).
    3. Lack of precipitation in the mountains could force some animals to move closer to humans to seek water. This could increase roadkill and/or alter the way a species behaves as they adapt to living in an environment that is heavily populated by humans.
    4. There are freshwater basins along the coast of California. If these basins do not have enough water in them to keep salty ocean water out, the habitats will change from a freshwater habitat to a brackish or even a saltwater habitat. Different animals are able to live in different types of water. Freshwater fish can not live in brackish water or salt water, so ocean encroachment would be detrimental to species living in the freshwater basins.

d. Humans: Discuss how the drought might impact humans in ways not already discussed above. Some examples include: lack of water recreation (dried up lakes and rivers, potential necessity to leave pools unfilled); rising prices for water in the home; changes in landscaping; lack of available water in certain places; increased threat of wildfire; etc.

E. Ask students what they think might be potential alternatives for Californians acquiring water. Ask them to consider potential pros and cons of each method. Some ideas are discussed below.

a. Bringing water in from another location: It costs a great deal of money to draw water from other places and bring it to California by pipe, truckload, or other means. While it is possible to bring water in from other places (and parts of California rely on outside water), it is costly for California and for the places where the water is removed (for the same reasons that depleting water sources have an impact on people and the environment in California). Water is a finite resource, so there is only so much that can come from another place before that place starts to have the same types of problems that California is experiencing.
b. The world's oceans hold most of the water on earth - why not turn that into drinking water? Desalinization is possible, but costly. Not only does it cost to build desalinization plants and keep them running, but the salt removed from ocean water must be put somewhere. It is often dumped back into the ocean, which threatens to disrupt the delicate ocean ecosystem. There

are, however, some places in California that utilize desalinization technology. Santa Catalina Island, for example, produces 25% of its drinking water by means of desalinization.

c. Can't we just get water from another planet? No other planet in our solar system has water on it. There's a possibility of another solar system having a planet with liquid water on it, but even if it did, it would take too long for us to travel there and back - we couldn't even do it in one lifetime.
d. Drink other fluids! While this may seem like a way to save water, in most cases, more water would actually be used to produce a glass of milk or juice than a glass of tap water. The next lesson will teach the students about the amount of water used in producing certain goods.

Lesson 4: Personal Water Use and Conservation

A. How Much Does It Take? Activity

Materials: Water Use True or False? Fact Cards

What to do: There are three ways to utilize the water use fact cards:

1. Draw a line in the dirt (or choose an existing line, like a line between cement blocks). Establish that one side of the line is "true" and the other is "false." Read the front of one of the cards aloud. Have students move to the "true" or "false" side. Read the back of the card.
2. Hand out fact cards and have each student in turn read the true/false question on the front. Allow students to guess aloud before asking the student to read the back of the card.
3. Read the facts off of the cards and discuss them briefly with the class.

B. Discuss with students why conserving water is important. Discuss ways that they can conserve water at home and at school. On the following page is a list of water-saving facts and ideas.

How Can I Save Water At Home?
Facts and Ideas for Students and Parents

Some of these ideas are easy, others take more planning (and discussion with family members). This sheet is designed to facilitate discussion with a class group and help students think about ways they can save water while at Outdoor School and when they return home.

IN THE BATHROOM:
- Turn off the faucet!
    - When brushing teeth: **save approximately 10 gallons/day.**
    - When lathering soap to wash hands.
- Toilets: Traditional toilets (non-efficient, pre-1990s) use 3.5-5 gallons each time they are flushed! Don't use your toilet as a wastebasket (to flush away tissues, etc.)
- Take shorter showers! Most standard showerheads run 5 gallons/minute. If you take a 5 minute shower instead of a 10 minute shower, you can **save 25 gallons/shower**!
- Turn off the shower when soaping up or shampooing.
- Take (short) showers instead of baths, or don't fill the bathtub full. A full bath can use up to 70 gallons of water.
- As your shower is warming up, collect the water in a bucket and use it to water houseplants or yard plants.

IN THE KITCHEN:
- Don't pour out cups and water bottles when you refill them with water. Just add water to the water that is left in your bottle or cup.
- If you drop ice cubes, put them on a plant inside or outside instead of in the sink.
- Don't run a tap until it is cold for a glass of drinking water. Instead, keep a pitcher cold in the fridge.
- Prep:
    - Rinse fruits and vegetables in a pan of water, rather than under running water. Collect water used to rinse fruits and vegetables and use it to water plants or the yard.
    - Don't thaw food with running water. Thaw it in the fridge instead.
    - Cook food in as little water as possible (this also helps it retain more nutrients!).
    - Cook food in the proper size pan (this cuts down on extra cooking water and washing water).
- Clean-up:
    - If you have a dishwasher, only run it when it is full.
    - If you wash dishes by hand, fill one side of the sink with soapy water and the other with rinse water.
    - Soak pots, pans, and stubborn dishes instead of letting the water run while you scrape them clean.

AROUND THE HOUSE:
- Fix leaky faucets/pipes/sprinklers/etc. Install water-efficient faucets/toilets/showerheads/etc. when they need replacing.
- Don't water your lawn in the middle of the day. Instead, water it early in the morning or later in the evening when temperatures are cooler: **save 25 gallons/each time you water.**
- Only wash full loads of clothes in the washer. When possible, wash with cold water instead of hot or warm.
- Clean driveways, sidewalks, and patios with a broom instead of a hose. **Save 8-18 gallons/minute.**