1.8: Lab 8 - Water Resources

This lab contains potentially inaccessible interactive resources. Please work with your instructor and local campus resources to identify accommodations for these resources.

Learning Objectives

- Identify key processes in the hydrologic cycle.
- Describe the distribution of water around the world and in the United States.
- Analyze water consumption patterns.
- Define watershed and describe watershed pollutants.
- Analyze water budget data.

Introduction

You have likely heard before that there is more water on Earth than there is land. In fact, more than 70% of Earth's surface is covered by water. Water is composed of two hydrogen atoms and one oxygen atom and it is known as a "universal solvent". Water is called the universal solvent because it is capable of dissolving more substances than any other liquid. It is water's chemical composition and physical attributes that make it such an excellent solvent. Water molecules have a polar arrangement of oxygen and hydrogen atoms—one side (hydrogen) has a positive electrical charge and the other side (oxygen) has a negative charge. This allows the water molecule to become attracted to many other different types of molecules. Water can become so heavily attracted to a different compound, like salt (NaCl), that it can disrupt the attractive forces that hold the sodium and chloride in the salt compound together and, thus, dissolve it. This is important to every living thing on Earth. It means that wherever water goes, either through the air, the ground, or through our bodies, it takes along valuable chemicals, minerals, and nutrients.[122]

In this lab, we will discover where water is held on Earth and how it cycles through the planet. We will learn about how we access freshwater and how our actions impact natural water systems.

Part A. The Hydrosphere

As you have learned, there are four main spheres on Earth: the biosphere, the atmosphere, the lithosphere, and the hydrosphere. All water on Earth exists within the **hydrosphere** Figure 8.1). Water exists in three states at Earth's ambient temperature and atmospheric pressure: as a solid, as a liquid, and as a gas. In addition, water does not only exist as freshwater, but also as salt water. In fact, the percentage of freshwater is much lower than the percentage of salt water, which means the amount of freshwater available for human consumption is actually quite low.

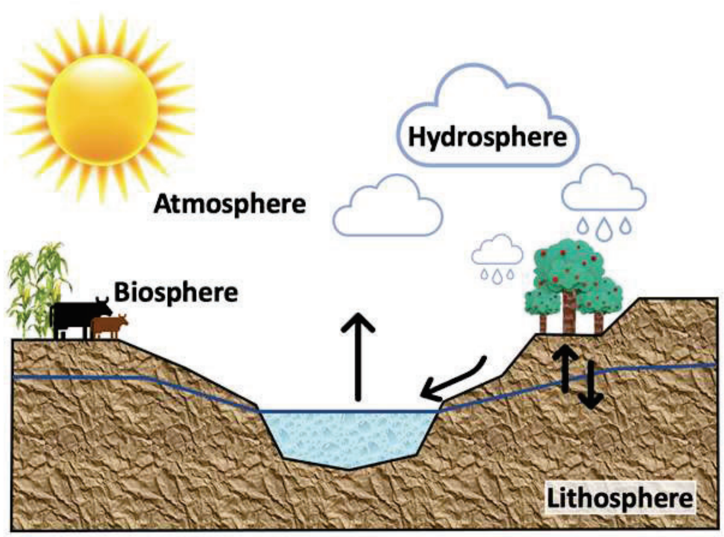


Figure 8.1: The Four Spheres of the Earth. Figure by Jeremy Patrich is licensed under CC BY-NC-SA 4.0

Water cycles through Earth in something called the **hydrologic cycle**, also known as the water cycle. Much like energy, water cannot be created nor destroyed, it simply changes form. In fact, the very first water ever to exist on Earth is still here today!

Water moves in a variety of ways within the hydrologic cycle. First, water is evaporated from the Earth in two ways: through evaporation from the surface (such as from oceans, lakes, streams, surfaces, and reservoirs) and through **transpiration,** a process in which water leaves a plant through its leaves. Recall that **evaporation** occurs when water changes from a liquid to water vapor. The combination of these two processes is called **evapotranspiration** and accounts for all water that leaves the surface of the Earth. As water evaporates into the atmosphere as a gas, it cools and condenses in a process called condensation. **Condensation** occurs when water vapor changes into a liquid. This liquid water falls back onto Earth in a process called **precipitation**. Once the water reaches the surface of the Earth, it can either runoff along the surface or infiltrate into the ground, which is called **groundwater flow**. Water that does not infiltrate into the ground is called **runoff**. Water enters into the ground through a process called **infiltration** and moves through the soil into deeper depths of the water table in a process called **percolation**. Some water is also stored underground in layers of permeable rock, called **aquifers**.

? Exercise 1.8.1

1. Refer to the hydrologic cycle diagram below (Figure 8.2). What is the correct process for each of the labels on the diagram? Tip: you will use all but one of the terms shown in **bold-faced** type in the previous paragraph.
    a.
    b.
    c.
    d.
    e.
    f.
    g.
    h.
    i.

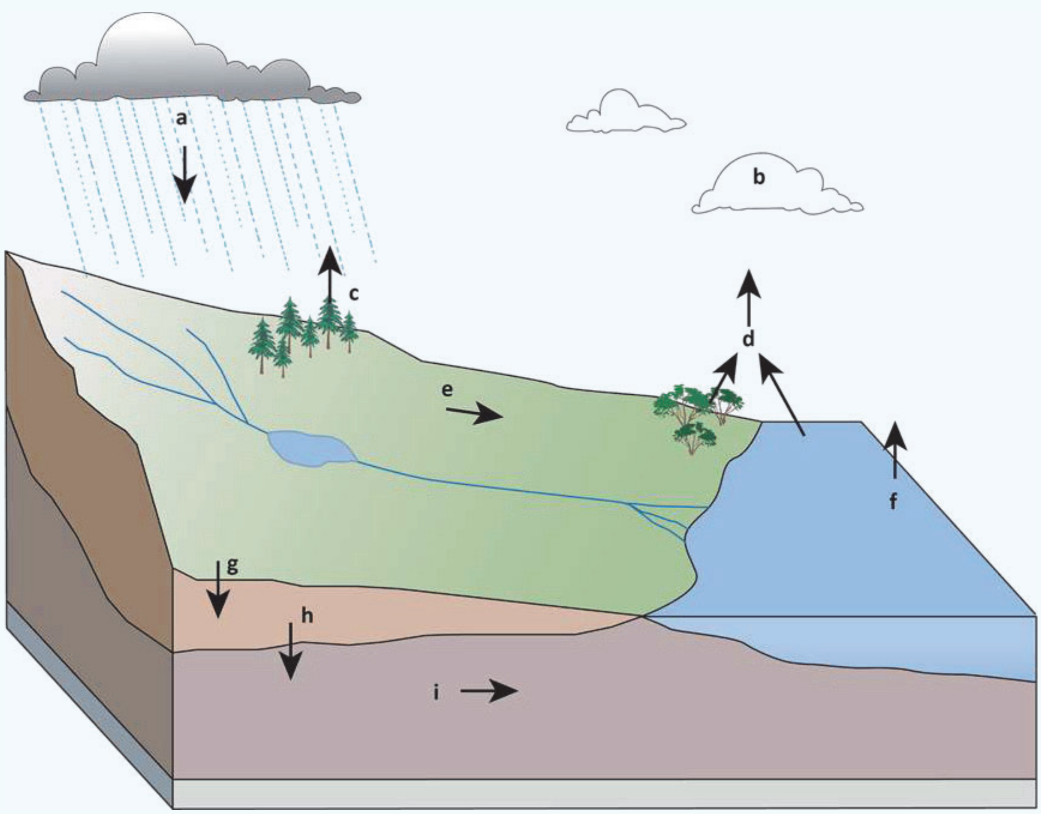


Figure 8.2: The Hydrologic Cycle. Figure by Scott Crosier is licensed under CC BY-NC-SA 4.0

The Global Distribution of Water

Figure 8.3 shows the distribution of water on Earth. As you can see, only 2.5% of water on Earth is freshwater and of that amount, only 30.1% is groundwater. This means that 0.08% of all water on Earth is available to humans as freshwater for irrigation, drinking, and sanitation! Water is stored on Earth in five main reservoirs: oceans (holding 96.5% of all water on Earth), glaciers and ice caps, groundwater, surface water (water in lakes, rivers, and soil), and atmospheric water.

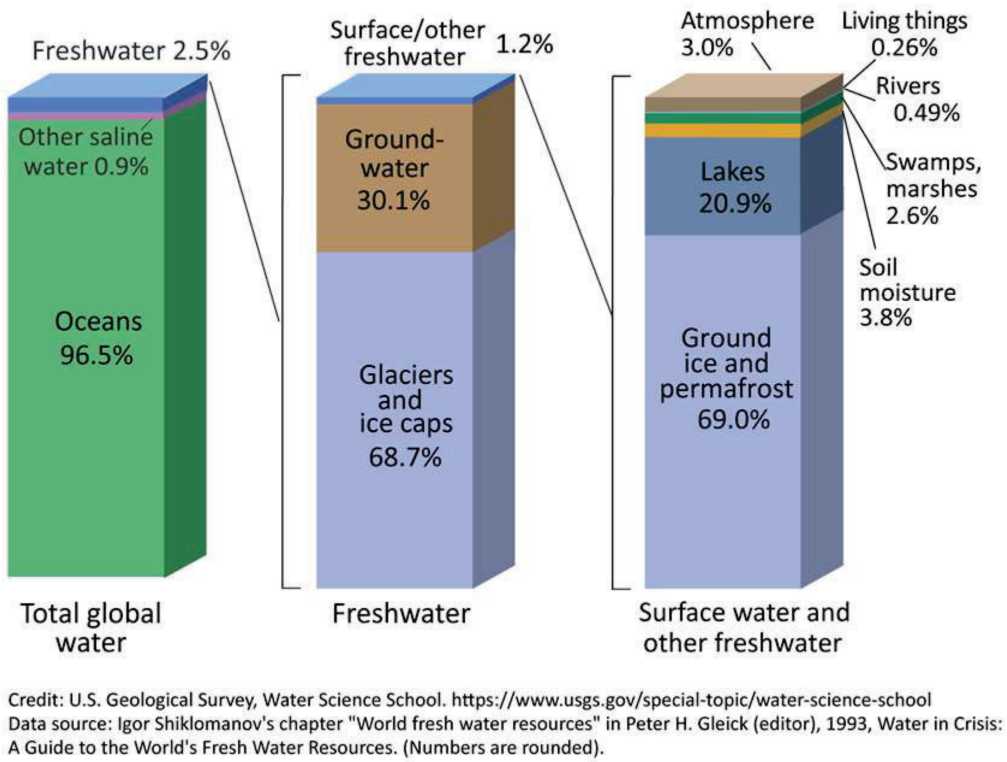


Figure 8.3: Global Distribution of Water. Figure by USGS Water Science School is in the public domain

? Exercise 1.8.2

2. Refer to Figure 8.3.

   a. What percentage of water on the planet is freshwater?

   b. What percentage of water on the planet is in glaciers and ice caps? Tip: notice that the percentage of water in glaciers and ice caps globally is 68.7% of 2.5%. So, you need to calculate how much 68.7% of 2.5 is. Show your calculation.

   c. What percentage of water on the planet is available as groundwater? Show your calculation.

According to the U.S. Geological Survey (USGS), there is approximately 326 million cubic miles (1.32 billion cubic kilometers) of water on Earth. The distribution of water is shown below in Table 8.1.

Table 8.1: Sources of Fresh and Salt Water on Earth. Data from USGS: Shiklomanov, I. (1993). World freshwater resources. In P.H. Gleick (ed.), Water in Crisis: A Guide to the World's Fresh Water Resources. New York: Oxford University Press.

Water Source	Freshwater Volume (cubic kilometers)	Salt Water Volume (cubic kilometers)
Ice Sheets, Glaciers, and Permafrost	24,364,000	0
Surface Water	122,210	85,400
Subtotals	**35,029,110**	**1,350,955,400**
Grand Total (rounded)		**1,386,000,000**

Exercise 1.8.3

3. Refer to Table 8.1.

   a. Which water source contains the highest amount of freshwater?

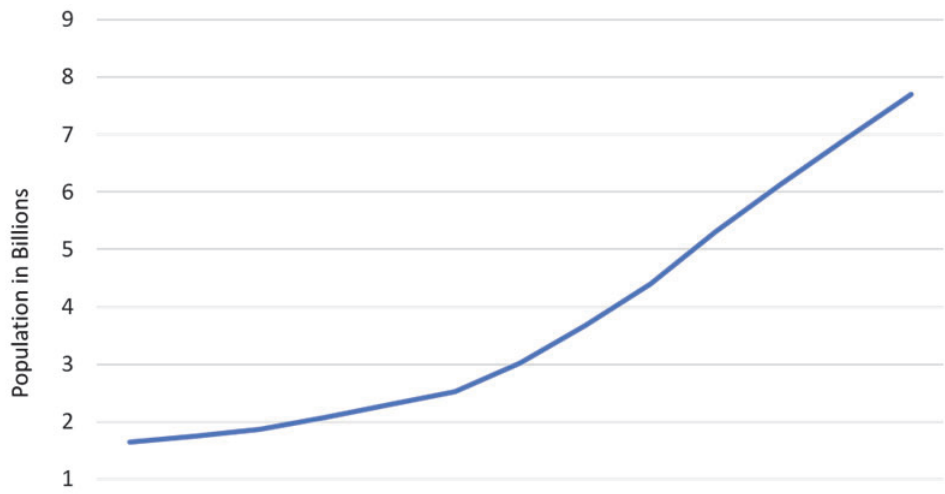
   b. Does salt water exist in all 5 water sources? Explain why or why not.

   c. If frozen water on the planet does not contain salt water, where does the water from a floating iceberg over the sea come from?

   d. What happens to the freshwater that drains into the sea from a melting ice sheet or glacier?

Human Population and Water Use

As we can see from Figure 8.3 and Table 8.1, there is minimal freshwater water available to people. The distribution of water on Earth changes over time and is dependent upon climate. For example, as Earth warms, more water is stored in the ocean as salt water and as Earth cools, more water is stored in snow, glaciers, and ice sheets as freshwater. Currently, Earth is experiencing a global warming period and the snow, glaciers, and ice sheets are melting rapidly and draining into the sea. This decreases the amount of freshwater available to people. As the amount of freshwater available to people continues to decrease, Earth's human population is increasing at an extraordinary rate (Figure 8.4). How might this impact water supplies for people?



Year	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
Population in Billions	1.65	1.75	1.86	2.07	2.30	2.53	3.02	3.68	4.40	5.31	6.13	6.93	7.7

Figure 8.4: Population of People on Earth over the Last 120 Years. Figure by Waverly Ray is licensed under CC BY-NC-SA 4.0

Exercise 1.8.4

4. Refer to Figure 8.4.

   a. What does Figure 8.4 tell you about Earth's human population?

   b. What other information might be helpful to add to this figure?

   c. What is the difference in population between 1920 and 2020? Tip: subtract the 2020 population from the 1920 population. Show your calculation.

      i. What percent did the population increase during this period? Tip: divide your answer from 4c by the 1920 population. Then, multiply that number by 100 to get the percentage. Show your calculation.

   d. What decade experienced the largest increase in population and by how much?

Figure 8.4 provides basic statistics for population and is useful for determining a general idea of what population looks like on the planet. However, in order to plan sustainably and ensure that all of humanity has access to resources like water on the planet, it is important that we look at various factors that influence how water is used and where.

The distribution of water varies globally and in order for us to manage water supplies and ensure all humans have access to water, it is important that we understand the global distribution of water as well as how it is used. One way to geographically display information is by using a cartogram. A cartogram is a map in which the geometry of the regions is distorted in order to show information for a particular variable, such as the distribution of population or income. In this section we will evaluate cartograms that show water usage around the world. Figure 8.5 is a cartogram of water use. The territory size shows the proportion of the worldwide water use occurring in a country. Countries that have enlarged territory sizes have higher rates of water usage. Figure 8.6 is a world population cartogram for comparison.

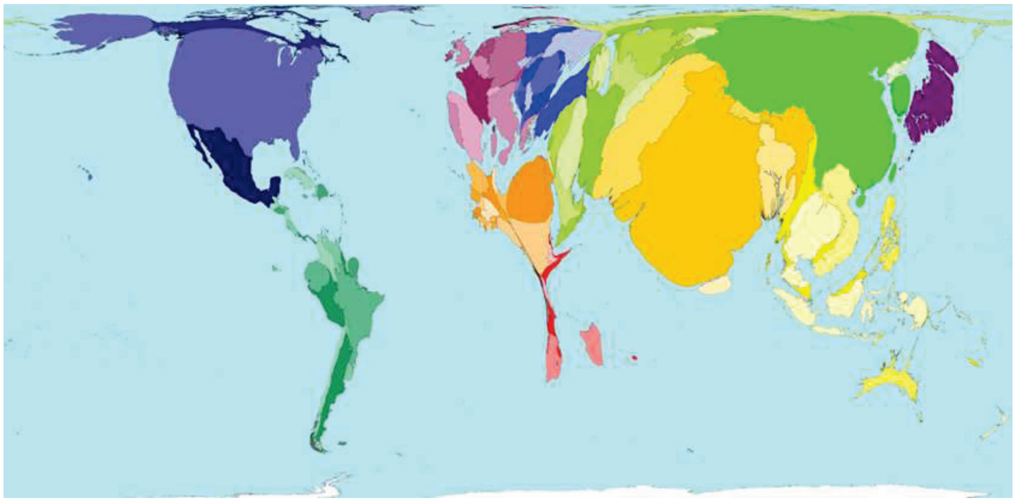


Figure 8.5: Water Use Cartogram. Figure by Worldmapper is licensed under CC BY-NC-ND 3.0

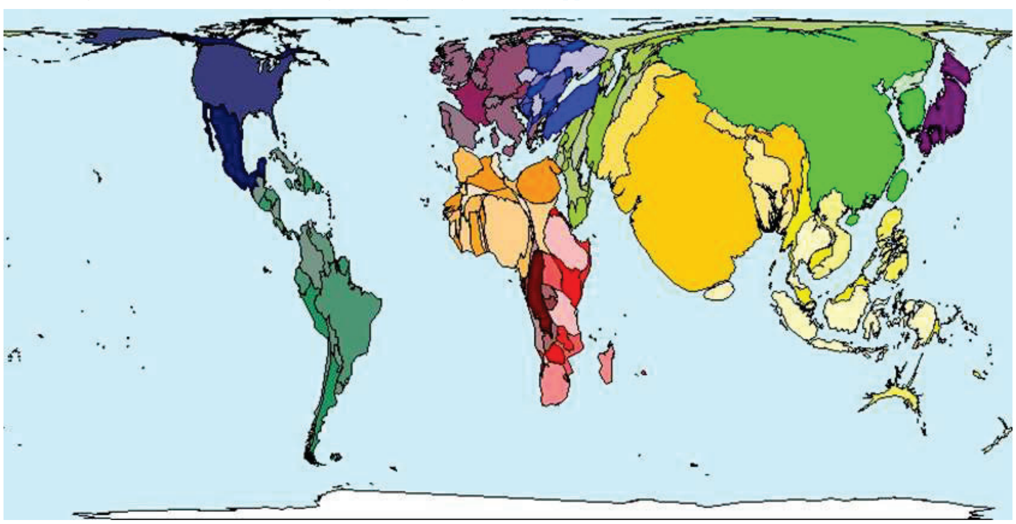


Figure 8.6: World Population Cartogram. Figure by Worldmapper is licensed under CC BY-NC-ND 3.0

The Worldmapper brief on water use explains that:

> Four thousand cubic kilometres of water are used by people each year around the world, for domestic, agricultural and other industrial purposes. This does not include non-consumptive uses such as energy generation, mining, and recreation.
>
> China, India, and the United States use the most water. These are also the territories where the most people live. But water use per person is about three times higher in the United States than it is in India and China.

While everyone needs water,the quantity used varies widely. On average, people living in Central Africa individually use only 2% of the water used by each person living in North America.[130]

Figure 8.7 maps countries based on per capita water usage, measured in cubic meters per year. The data includes water withdrawals from agricultural, industrial, and household/public services uses.

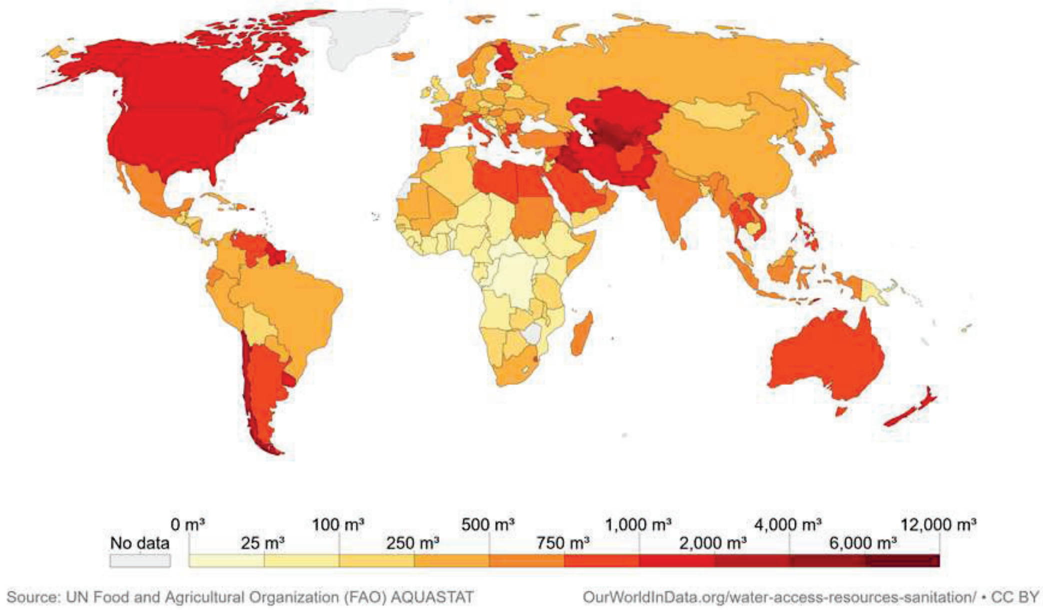


Figure 8.7: Water Withdrawals per capita (2005). Figure from AQUASTAT and Our World in Data is licensed under CC BY 4.0

Exercise 1.8.5

6. Refer to Figure 8.7.
   a. Do you notice any spatial patterns on the map? Which regions have the most water withdrawals and which regions have the least? Explain your response in three to four sentences.
   b. Use Your Critical Thinking Skills: List factors that might explain why some countries have high levels of water withdrawals.
   c. Use Your Critical Thinking Skills: List factors that might explain why some countries have low levels of water withdrawals.
   d. Use Your Critical Thinking Skills: List strategies governments and schools could use to improve water conservation practices.
7. Use Your Critical Thinking Skills: How does food play a role in water supplies? Explain your response in one to two sentences.

Check It Out! Water Withdrawals by Sector

Find out how countries compare in terms of water withdrawals in the agricultural, industrial, and household/public services sectors by going to the Our World in Data website and scrolling down through the maps.

Water Use in the United States

Now that you have a better understanding of how water is used globally, let us take a look at how water is used in the United States. Approximately 87% of the water used in the United States is freshwater, the remaining water used is salt water from the ocean or brackish water bodies such as lagoons and estuaries. According to the USGS, the United States used 322 billion gallons of water per day in 2015. The distribution of that usage is shown in Figure 8.8.

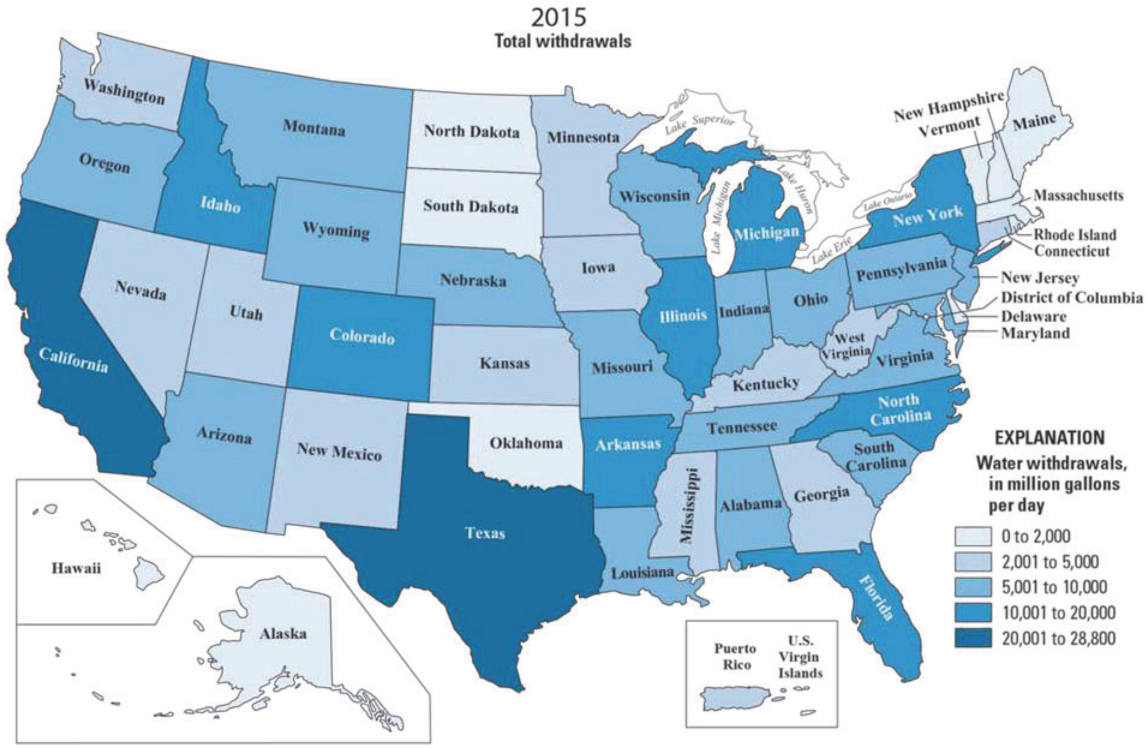


Figure 8.8: Surface and Groundwater Withdrawals in 2015. Withdrawal displayed in millions of gallons per day. Figure by USGS is in the public domain

? Exercise 1.8.6

8. Refer to Figure 8.8.

   a. Which states use the most water?

   b. Which states use the least water?

   c. Use Your Critical Thinking Skills: List reasons why some states use more water than others.

Do you think population plays a role in your state's water usage? How does the United States use the water it withdrawals from natural systems? Figure 8.9 shows the distribution of how the 322 billion gallons per day of water was used in 2015. Seven categories were selected for top water usage in the United States by the USGS. We can see that 118 billion gallons per day of water is used for irrigation, and according to the USGS all of this water is pulled from freshwater sources. In other words, the second largest usage of freshwater in the United States is used to provide water for plant growth. This plant growth accounts for all agriculture uses, including chemical application, crop cooling, and harvesting. In addition, irrigation is used for plant growth in golf courses, cemeteries, nurseries, and parks.

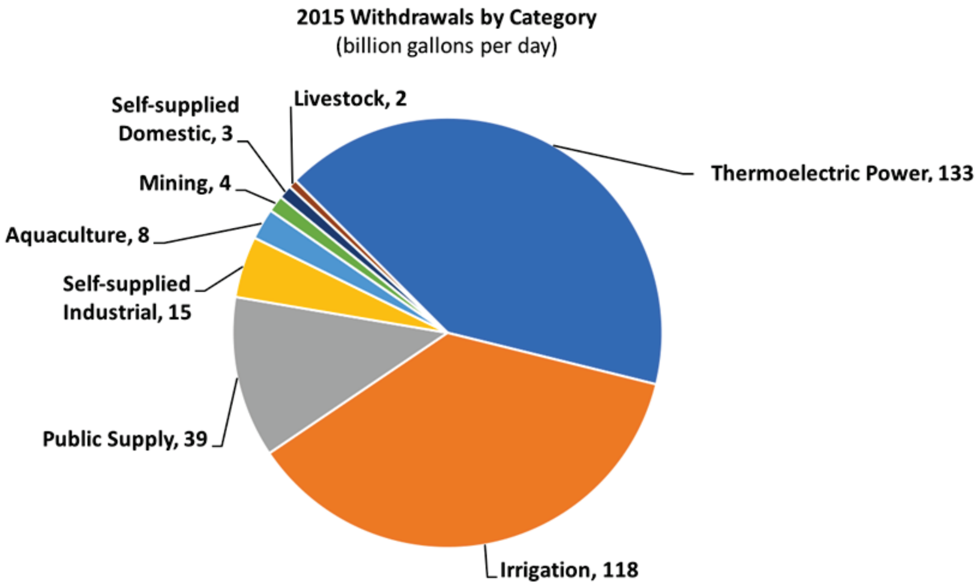


Figure 8.9: Distribution of Total Surface and Groundwater Withdrawals in the United States; Withdrawals displayed in billions of gallons per day. Figure by Taya Lazootin is licensed under CC BY-NC-SA 4.0

? Exercise 1.8.7

9. Refer to Figure 8.9.
   a. In the United States, which two categories use the most water?
   b. What percentage of water is used for irrigation and livestock? Tip: Add the two values and then divide by the total amount of water withdrawals (322 million gallons) and then multiple by 100 to get the percentage. Show your calculation.
      i. What are some ways the United States could lower this percentage?
      ii. What are some actions you could take to help lower this percentage?

Part B. Watersheds and Groundwater

A **watershed** is the area of land where all of the water that falls in it and drains off of it goes to a common outlet, such as a river, a lake, or the ocean (refer to Figure 8.10). Watersheds exist everywhere and everyone lives within a watershed. Notice in Figure 8.10 how elevation plays a role in where water drains. Gravity pulls water toward the center of the Earth, so the water at higher elevations will naturally drain to lower elevations. This means that all of the water that falls at the top of a watershed will flow over or seep into the ground downstream. Some of this water flows directly to the sea or a nearby water body, and some of it seeps into the ground. This water either flows underground or is stored in an aquifer.

Search the internet to learn about your watershed. You may want to use the How’s My Waterway? website from the Environmental Protection Agency.

? Exercise 1.8.12

22. What is the name of the watershed where you live?
23. Are there any water bodies that are listed as impaired under the Clean Water Act?
24. What pollutants are found in your watershed?
25. Use Your Critical Thinking Skills: What are some ways that you could help decrease pollutants in your watershed and in nearby watersheds? List at least three ideas.

Part C. Water Budgets

Earlier, you learned that nearly 120 billion gallons per day of water are used in the United States for agriculture and plant growth. In order to manage our water supply for food consumption, we need to understand; how much water enters a watershed; how water is processed in the watershed; how much water leaves the watershed; and how water leaves the watershed.

This information is provided in a water budget. A **water budget** calculates the total inputs and outputs of water in the watershed. Water budgets are useful because they help land managers and the agriculture industry to identify the frequency and duration of water needs for irrigation of crops and vegetation. Water budgets vary based on location, soil, climate, and land use distribution in the watershed. Each hydrologic area within a watershed requires a water budget and most water budgets are calculated monthly and analyzed over time, generally from year to year.

To calculate a water budget you need to know the factors that influence water movement in the system you are studying.

➢ **Field capacity** refers to the total amount of water a soil can hold. This is important because certain soils will not retain as much water as others. Soils with large particle sizes and coarse textures will not hold as much water as soils with smaller particle sizes and smoother textures. Remember that water also leaves the system so we must consider evaporation, including transpiration from plants!

➢ The maximum amount of water that could be lost to evapotranspiration is called **potential evaporation PE)** and is primarily dependent upon the overall temperature of a region.

➢ The amount of water that is actually lost to evapotranspiration is called **actual evapotranspiration AE).** Precipitation is the amount of water that enters the watershed from the sky and will determine AE. If precipitation increases in a system with a low PE, then more water is available than can be lost through evapotranspiration. If precipitation decreases in a system, there is less water available for evapotranspiration and the system experiences a water deficit.

At the end of a month, once AE and PE are known, the amount of water remaining in the soil shows how much water the soil retains over time. During a heavy or unpredicted rain event, precipitation could be greater than potential evaporation, and water is then added to the system. This is usually beneficial because the system experiences a **water surplus S)**. The opposite occurs during a dry season or a drought. When precipitation is less than potential evaporation, water is removed from the system and the system experiences a **water deficit D)**. Agriculture is often negatively impacted by systems that experience prolonged water deficits.

? Exercise

Below are water budgets for two cities in California: Eureka located in Northern California and San Diego located in Southern California. The goal of this exercise is to plot and analyze the water budget data in order to understand how water moves through the hydrologic cycle in two different watersheds.

Table 8.3 provides water budget data for sandy loam soil in Eureka, California. This soil type has a field capacity of 3.5 inches and the total annual precipitation is 34.22 inches.

Table 8.3: Water Budget Data for Eureka (2019) data shown in inches

Variable	Jan	Fed	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P	4.85	4.60	3.90	2.60	2.00	1.75	1.22	1.00	1.60	3.30	3.80	3.60
PE	0.50	0.50	1.00	1.50	1.90	2.75	3.30	3.50	3.60	1.75	1.30	0.45
AE	0.50	.50	1.00	1.50	1.90	3.00	3.12	2.90	2.80	1.75	1.30	0.45

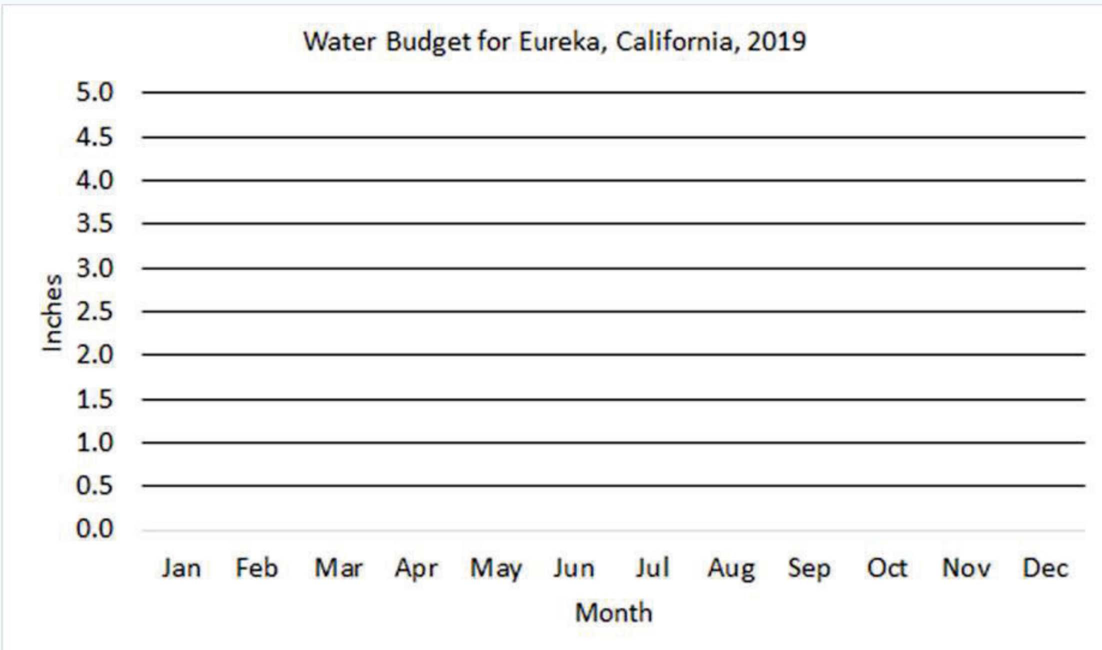


Figure 8.13: Water Budget for Sandy Loam Soil in Eureka, California (2019). Figure by Taya Lazootin is licensed under CC BY-NC-SA 4.0

27. Refer to Figure 8.13.
    a. During which months is actual evaporation (AE) less than potential evaporation (PE)?
        i. During these months is there a water surplus or a water deficit?
        ii. Shade this area red.
    b. During which months is precipitation (P) greater than actual evaporation (AE) and potential evaporation (PE)?
        i. During these months is there a water surplus or a water deficit?
        ii. Shade this area blue.
    c. Which months of the year would industries that rely on local groundwater supplies for agricultural needs have to plan ahead?

Now let's analyze a water budget for San Diego in Southern California. Table 8.4 provides water budget data for silty clay loam soil in San Diego. This soil type has a field capacity of 2.2 inches and the total annual precipitation is 10.39 inches.

Table 8.4: Water Budget Data for San Diego (2019) data shown in inches

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P	2.26	1.83	2.15	0.78	0.20	0.08	0.04	0.04	0.20	0.35	1.13	1.33

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PE	1.37	1.60	1.79	2.26	2.81	3.39	4.06	4.21	3.71	2.81	0.91	1.37
AE	1.76	1.33	1.79	0.78	0.20	0.08	0.04	0.04	0.20	0.35	1.13	1.33

28. Create a plot on the graph below (Figure 8.14) using the P, PE, and AE data for all 12 months of data from Table 8.4. Use a blue pencil for P, a green pencil for PE, and red pencil for AE. Make sure you connect the points for each of the three variables (you should have three lines on your graph). Also, create a legend by your plot.

Figure 8.14: Water Budget for Silty Clay Loam Soil in San Diego, California (2019). Figure by Taya Lazootin is licensed under CC BY-NC-SA 4.0

29. Refer to Figure 8.14.
    a. During which months is actual evaporation (AE) less than potential evaporation (PE)?
        i. During these months is there a water surplus or a water deficit?
        ii. Shade this area red.
    b. During which months is precipitation (P) greater than actual evaporation (AE) and potential evaporation (PE)?
        i. During these months is there a water surplus or a water deficit?
        ii. Shade this area blue.
    c. Which months of the year would industries that rely on local groundwater supplies for agricultural needs have to plan for ahead of time?
30. Review Figures 8.13 and 8.14. What are three key differences between the water budgets for Eureka and San Diego?
31. Apply What You Learned: Why doesn't a water budget include data about a location's groundwater supplies?
32. Use Your Critical Thinking Skills: As global temperatures continue to increase over the next several decades, what are some potential problems agricultural industries could face in regards to water supplies?
33. Use Your Critical Thinking Skills: What are some actions people could take locally and globally to prevent the negative impacts of water deficits?

One difference between Eureka and San Diego is the amount of annual precipitation for each city in 2019: 34.22 inches and 10.39 inches, respectively. If water supply to residents depends on local water supplies, then cities with large populations would need to have larger amounts of surface water and groundwater available for drinking, sanitation, and irrigation. The population of Eureka is 26,998 people and the population of San Diego is 1,426,000 people.

34. How many times larger is San Diego's population compared to Eureka's? Show your work.

35. What percentage of Eureka's precipitation did San Diego receive in 2019? Show your work.

Many cities in California don't rely on local water supplies to support their populations. In San Diego, 85% of its water supplies come from outside the local area. Figure 8.15 shows the major surface water features and water infrastructure in California, along with whether a region is a net importer or exporter of water.

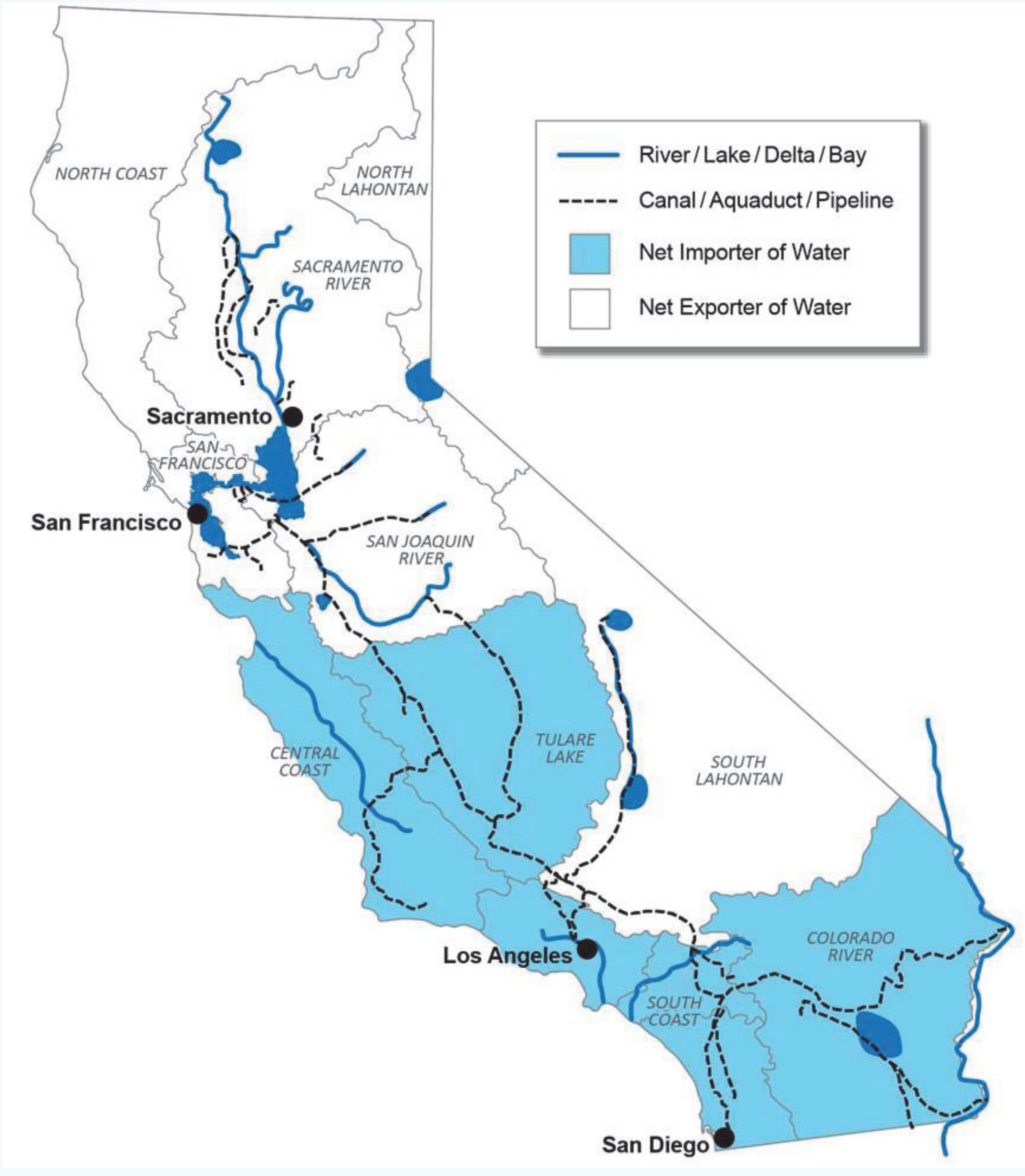


Figure 8.15: Net Importing and Net Exporting Water Regions. Figure by Waverly Ray is licensed under CC BY-NC-SA 4.0

36. Refer to Figure 8.15.

a. Label the major water bodies shown on the map. From North to South:

i. Shasta Lake
ii. Lake Tahoe (one eastern border with Nevada)
iii. California Delta (also known as the Sacramento-San Joaquin Delta)
iv. San Francisco Bay (to the west of the California Delta)
v. San Luis Reservoir (in the San Joaquin River region)

vi. Mono Lake (in the northern part of South Lahontan region)
vii. Owens Lake (in the southern part of South Lahontan region)
viii. Salton Sea

b. Is Eureka in a net exporting or net importing region?

c. Is your location a net importer or net exporter of water?

d. What are two conclusions that can be drawn from the information shown on the map?

e. Use Your Critical Thinking Skills: Why is it important to analyze water resources at different scales (e.g., watershed, water region, state, country)? Explain your response in one to two sentences.

Check It Out! California's Water Policies and Infrastructure

Learn more about California's water polices and infrastructure from the Managing California's Water: From Conflict to Reconciliation report by the Public Policy Institute of California. (This links to a downloadable pdf file).

Part D. Wrap-Up

Consult with your geography lab instructor to find out which of the following wrap-up questions you should complete. Attach additional pages to answer the questions as needed.

Exercise 1.8.14

37. What is the most important idea that you learned in this lab? In two to three sentences, explain the concept and why it is important to know.
38. What was the most challenging part of this lab? In two to three sentences, explain why it was challenging. If nothing challenged you in the lab, write about what you think challenged your classmates.
39. What is one question that you have about what you learned in this lab? Write your question along with one to two sentences explaining why you think your question is important to ask.
40. Review the learning objectives on page 1 of this lab. How would you rate your understanding or ability for each learning objective? Write one sentence that addresses each learning objective.
41. Sketch a concept map that includes the key ideas from this lab. Include at least five of the terms shown in bold-faced type.
42. Create an advertisement to educate your peers on the important information that you learned in this lab. Include at least three key terms in your advertisement. The advertisement should be about half a page in size (about 4 inches by 6 inches).
43. One way to think of physical geography is that it is the study of the relationships among variables that impact the Earth's surface. Select two variables discussed in this lab and describe how they are related.
44. How does what you learned in this lab relate to your everyday life? In two to three sentences, explain a concept that you learned in this lab and how it relates to your day-to-day actions.
45. How does what you learned in this lab relate to current events?
    a. Write the title, source, and date of a news item that relates to this lab.
    b. In two to three sentences, discuss how the news item relates to what you have learned in this lab.
    c. In one to two sentences, discuss whether or not the news item accurately represents the science that you learned. Tip: consider whether or not the news item includes the complexity of the topic.
46. Search O*NET OnLine to find an occupation that is relevant to the topics presented in today's lab. Your lab instructor may provide you with possible keywords to type in the Occupation Quick Search field on the O*NET website.