

THE HYDROFATHOM

LEARN ABOUT WATER

LESSON PLANS



FOREWARD

This booklet contains dozens of separate learning modules. Each module focuses on a short learning topic about water provided in a short concise lesson format. These lessons encourage the learner to independently explore water topics in conjunction with information contained within. We welcome comments to our website listed at the bottom of this page.

The included modules do not attempt to provide all-encompassing knowledge, but instead, provide a base knowledge that allows a person to learn about the water that flows to their taps and grows their food.

The lessons modules are divided into the following sections:

- A. Water Basics
- B. Watersheds
- C. Aquifers
- D. Infrastructure

HydroFathom teaches in a manner that integrates artistic expression with scientific knowledge. If used in a structured learning environment, instructors should pre-screen the subject matter to assure the appropriateness for selected audience. This booklet expounds upon the concepts our founding document, *The Water Chain*, which can be downloaded from our website.

We thank readers for joining our forum and HydroFathom wishes all people abundant access to fresh clean water

Our content is free. We operate off donations.

Please support HydroFathom at:

www.hydrofathom.org

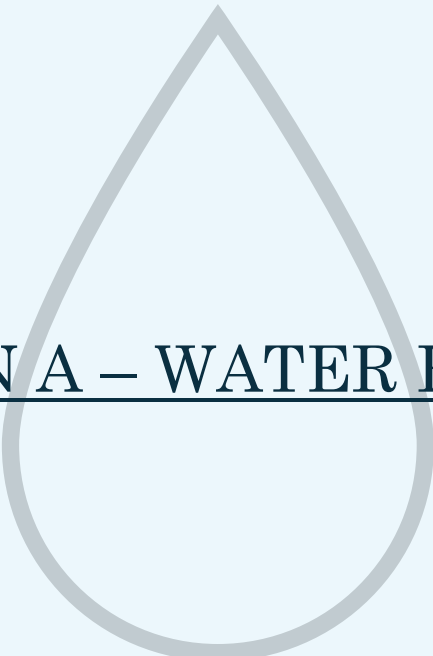
SECTION A

WATER BASICS



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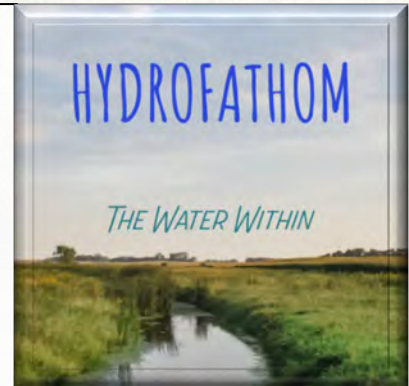
SECTION A – WATER BASICS

The Water Within

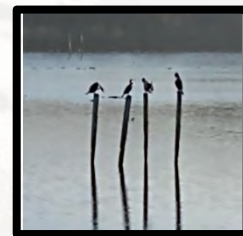
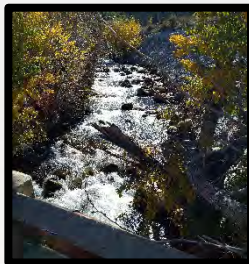
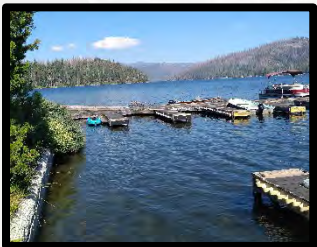
HYDROFATHOM INTRODUCTION

Mission

HydroFathom operates as a non-profit organization dedicated to providing water education to the public. Our educational material teaches people about the water needed for their lives, specifically, the water that flows from their home taps and the water that grows their food.



HydroFathom uses a blended teaching style that uniquely combines technical principles with an artistic style. Our unique brand allows HydroFathom to quickly teach the average person about their water while offering people the chance to witness the power, mystery and beauty of natural water.



DONATE TO HYDROFATHOM AND SUPPORT THIS LEARNING AT:

WWW.HYDROFATHOM.ORG

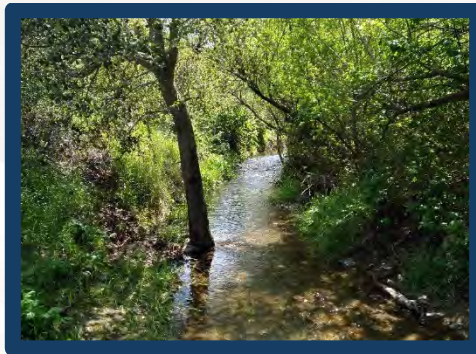
The Water Within

HydroFathom provides free content to the public through our website at

www.hydrofathom.org

The website also provides links to HydroFathom videos which are posted to our YouTube channel: @hydrofathom. HydroFathom first released videos in Fall 2024 initially publishing a video series called, 2023 California Watershed Series. This initial video series focuses on an exceptionally wet rain year in California. HydroFathom makes some videos available in short one-minute format labeled, *A HydroFathom Water Minute*.

Waterisms, some listed at the bottom, are sayings teach a fundamental truth about our water supply.



The website also offers access to our founding paper, *The Water Chain*, links to external articles and a wide range of services like references to literature about water.

There is No Dry Life

We All Touch at the Tap

Where Water Flows, Life Grows

One Drop Shows the Way

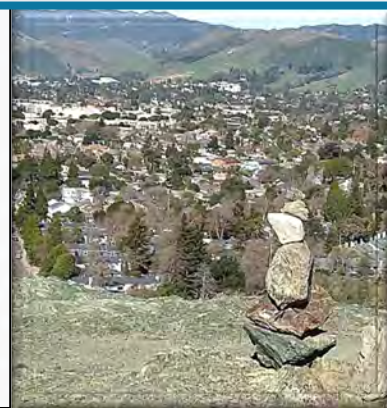
The Water Within

HYDROFATHOM WATER CHAIN

HydroFathom focuses our teaching program into three main learning modules. These three study areas, Watersheds, Aquifers, and Infrastructure, reflect the major links in the chain required to deliver water to humans. Visit our website at www.hydrofathom.org to download your copy of *The Water Chain*, the foundational document of our organization. After this basics section, the lesson plans continue with focus on our major teaching areas, laid out like this:

Learning Booklet Section B, Watersheds

Watersheds define an area of land. Their overall shape and size determine the amount of water gathered and funneled by a watershed. Average yearly precipitation in a watershed determines the total amount of water that falls in a watershed. Watersheds funnel flow to a single point, usually a path to the ocean. A watershed map shows how water flows over a specific area of the globe. All humans on dry land live within a watershed. Further activity: Find the watershed for your house.



Learning Booklet Section C, Aquifers

Water gets trapped in the crust of the earth in underground formations that can lurk under several U.S. states. These underground seas of water are called aquifers. These underground sources of water, while seemingly vast, constitute a small amount of the mass of the earth. HydroFathom teaches if the Earth was an orange, all the aquifers would be in the peel, right at the surface. An important link in the water chain, Aquifers power human agriculture.

Learning Booklet Section D, Infrastructure

The first two links of the Water Chain, watersheds and aquifers would exist without humans. Indeed, while the HydroFathom watershed learning modules focus on the glory of nature, the infrastructure modules marvel at the achievements of humans. Using infrastructure, humans bend the intent of nature so that the Earth's natural waters flow to our needs. By weight, humans move water more than any other substance. Infrastructure allows this.



The Water Within

THE ENDURING BOND

Water, it's old

Water forms when two hydrogen atoms bond with one oxygen atom. For most water on Earth, these chemical bonds formed eons ago. Often people refer to a supply of water. Yet, the Earth's waters recycle while cleansing and renewing themselves through the precipitation cycle. An old saying states, "we drink the same water as the Romans drank." However, the water on Earth began circulating long before the Romans. Gravity traps water to Earth's surface where the sun heats it into clouds. These clouds cool, causing rain and snow to fall. Each individual water molecule trapped in this cycle does not change but merely gains energy and moves about, century after century. A single water molecule may have rained down on the dinosaurs, slaked the thirst of a centurion, fell on



Napoleon at Waterloo, and, more recently, helped ruin your last picnic. This continuing cycle of water falling to the ground and then returning to the ocean supplies the water needed for our lives. As water travels along the Earth and through time, it constantly sparks life along the way. However, water only stays with one life form, be it plant, bacteria, or animal, for a brief period. It enters then leaves life forms, often transporting waste away, and later refreshes itself in nature, eventually repeating the same cycle continuously. Interestingly, water does not itself change, but water does change the thing that it contacts, constantly sparking new life, growing things. The water currently in any one person's body will still be here on the face of the earth a thousand years later. In that way, perhaps, water gets older. Nevertheless, it changes little as it ages. Often, humans search for the eternal, the unchanging, the marvelous, without realizing that right there, in any nearby stream, a perpetual wonderful life-giving fluid flows, water.



The only true water supply on Earth = The Ocean



The Water Within

LIFE DEPENDS ON WATER

The Flow of Life



Water sustains humans so intimately that fetuses live for nine months in water prior to taking their first breath. In fact, humans live in contact with water their entire lives. That's why HydroFathom uses the motto, "The Water Within." Humans carry the water that we need inside our body and, for most people, tap water fills their stomach. Humans need, not a supply, but a flow of water. A constant resupply of fresh clean water must reach our lips to replenish the water that leaves our bodies daily.

There is no dry life



Conversely, humans do not know of any life forms that exist without the presence of water. By diverting water, humans choose which life forms flourish and which ones perish. A HydroFathom Waterism states, "Where water flows, life grows." Oppositely, where no water flows, no life grows, which leads to another Waterism, "There is no dry life."

The Water Within

PRECIPITATION



Mountains function as great scrapers of clouds. Mountains force air to compress and move upward towards the cold expanse of space. Both actions wring precipitation, rain/snow, from the atmosphere. Mountains hold much of the freshwater on earth at high elevation where it slowly melts. Some water powering ranges include the Andes, Himalayas, and Sierras.

The ocean ultimately holds most of Earth's water. However, through eons of

Extra Activity: Google "rain shadow."

erosion, salt has entered the ocean, making ocean water unusable to land animals adapted to freshwater. Nevertheless, thermal radiation from the sun constantly bombards the earth heating the ocean, causing ocean water to enter the atmosphere without salt. Winds drive this moisture over land where the water falls to earth salt-free, "freshwater." The rain cycle allows all animals on land to exist, including humans. The HydroFathom Water Chain slightly differs from the water-cycle process since it includes the human element, infrastructure, which mechanizes the use of water for human convenience.

Big Deal, "Atmospheric River"

On. Earth all the water on land fell from the atmosphere

All lakes are filled from the atmosphere, all rivers too

Yearly, over a million-billion gallons of water fall from the sky worldwide

The Water Within

An average hurricane can easily produce 60" of rain across an expansive area



A hurricane of this size generates a hard to fathom amount of rain. Let's try some math.

A hurricane can have a rain path of 500 square miles with rain sheathes which can generate up to 60" of rain. So:

500	Square Miles, area of small hurricane
X	
<u>27,878,400</u>	Sq. Ft. in a sq. mile
= 13,939,200,000	Sq. Ft. of land with rain falling overhead during an average hurricane
Wow that's 13 BILLION	
13,939,200,000	Sq. Ft., area being drenched with 60" of rain
X	during an average hurricane (5Ft.)
5'	Feet
=	
69,696,000,000	Cu. Ft. of Rain from one hurricane
Wow that's 70 BILLION	
X	
7.48	Gallons/Cu. Ft.
= 500,000,000,000	Gallons of Water in 1 Hurricane (1/2 trillion)

Several hurricanes form off the Gulf coast of the U.S. each year, along with dozens of tropical storms. We explore this more later in Watersheds.

Extra activity: [Goggle U.S. Precipitation Map](#)

The Water Within

NO PURE WATER



A Waterism from HydroFathom states, “There is no Pure Water.”
Still, you see “pure” on lots of water bottles. This bottle clearly states:



Yet the fine print clarifies:



“Purified water with minerals and electrolytes added for taste”

The Water Within

Fun fact about pure water.... it can kill you.



Wait. Is it “pure” or “purified.” The label seems to imply that someone created pure water and then added minerals for your pleasure. Some labels make other claims like the one at left:



Although water possesses many powers, it surely lacks intelligence. Perhaps buying the bottle makes the purchaser “smart”, perhaps. Some bottled water purveyors display a more direct approach. They just clearly list the product as purified water.

Some, labels on the back of bottles, list, “purified by reverse-osmosis (RO).” Others hedge by integrating the word “pure” differently, like “Pure Life.” Some advertise deionized (DI), others distilled. Regardless, none of these treatment types ever produce pure water, DI-no, RO-no, distilled-no. RO and DI systems treat water by passing it through a membrane to purify it. Often, normal tap water feeds RO and DI systems, not magical mountain springs. These filtration systems then remove some number of impurities and feed the purified water to a bottling machine. Laboratories produce limited amounts of pure water, but no waters that humans drink regularly are “pure.”

Google video search:

Can I drink 100% pure water?

The Water Within

Some water advertisements focus on pH, but the actual pH adjustments are minimal. Most drinking water has a pH between 6.5 and 8.5. Below 7, water is slightly bitter and above 7 a mineral taste develops. Astonishingly, humans can sense impurities in water at the parts-per-billion range, a thimble-full in a tanker car of water. Some natural contaminants cause no harm, like geosmin, a biological byproduct that gives rain an earthy smell but can be sensed at minute levels by humans. The importance of clean water cannot be overstressed. Lead can contaminate a child's drinking water and cause them trouble later in life learning math. The renowned movie, *Erin Brockovich*, features a town in California where cancer rates increased due to water contamination caused by a chemical used to clean cooling towers. Nonetheless, truly pure water possesses the ability to dissolve many substances. Consequently, drinking pure water eventually leads to de-mineralization of bones and other potentially fatal maladies. Most references to "pure water" serve only as propaganda in sales campaigns. The water we drink contains many substances; some our body needs. others cause no harm and others that may cause harm. In San Luis Obispo, the home of HydroFathom, we slowly steamed water in a pan refilled three times by tap water.



Clean Pan





Minerals Left Behind after 3 boils



Enough to Gather on a Spoon

This short demonstration shows that most water that humans drink contains some minerals which cause absolutely no harm. All mammals are genetically adapted to natural freshwater. For drinking needs, humans require neither constant hydration nor overly pure water. They just need to daily consume an adequate amount of reasonably clean water.

Finally, we show in this pan, the residue after boiling off three pans of “Pure Water” purchased from the local convenience store. Considerably less minerals remain in this pan of pure water boil off than in the tap water pan, but certainly some minerals were in the “pure water.” You see....



There is no Pure Water!

LIVING IN BALANCE



Life generally needs four items to survive: water, energy, chemicals (including minerals and gases), and seed (a piece of existing life). Yearly, in any area on Earth the supply of each is limited. Rainy and dry seasons exist. The tilt of the Earth causes variance in solar energy. Minerals deplete and plants wither while animals live and die. Such is life. Organisms adjust to nature. Plants sprout when the rain comes and the earth warms. They flower and shed seeds for next year's rain. Then, they shrivel and die, sure to be replaced by their seedlings next year.

In history, vast civilizations sprang up around humans that learned to live harmoniously with nature. Some ancient people specifically focused on the seasonal water cycle, like the Egyptians. The ancient Egyptians surrounded by harsh desert prospered to the point that they built the pyramids. They lived in balance with a water cycle based on the Nile River.

The Egyptians anticipated the rainy season in the summer, trapping water for later irrigation. When the floodwater receded, the naturally inundated soil, laden with fresh silt and minerals, served as the ideal crop growing location. The tropical Egyptian temperature allowed an October to March growing season. The next year, the process repeated. This productive natural agrarian cycle permitted the development of a ruling class in a country overflowing with foodstuffs. The proper conditions formed so that humans possessed the time and organizations to become massive civilizations. What made all this possible? The Egyptians found balance with nature.

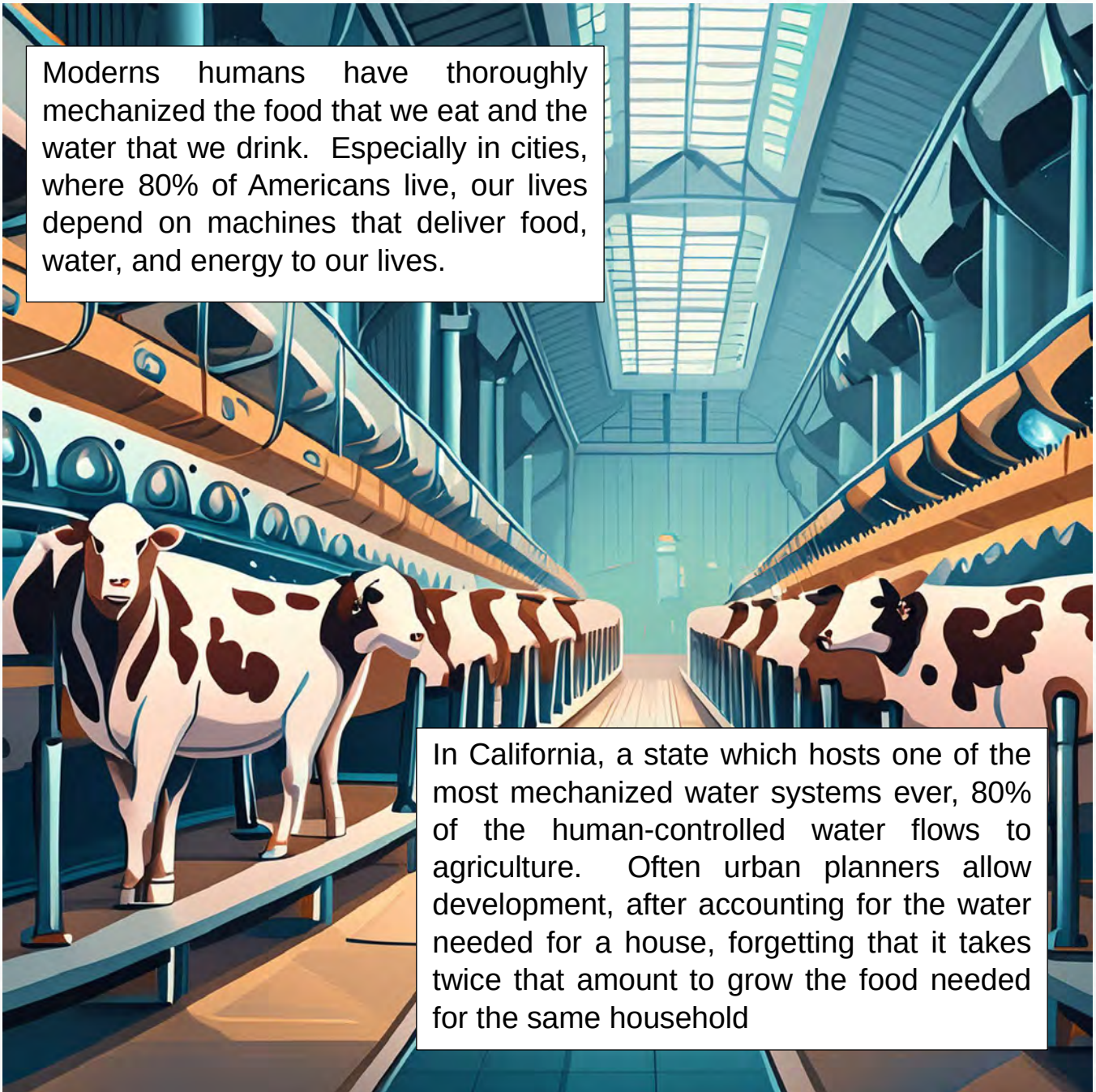
Like the Egyptians, native-Americans developed a profoundly harmonious relationship with the environment around them. Like the Egyptians, their adaptations proved long-lasting. Some modern native-Americans may speak of being the 55th generations of a tribe, many date farther back. On the central coast of California, the Chumash tribe thrived along the majestic coastline between Ventura and Monterey. The original surf dudes, the Chumash, were a rare ocean-going tribe. Their charming habitat suffered from a yearly period where no rain fell for months. The Chumash compromised by living near a series of year-round creeks. Seasonal rains fed a yearly mass explosion of acorns from oak trees that allowed the collection of the nuts which the Chumash ground into paste that provided one of their diet staples. Trout runs provided by rain also fed them. Tribes flourished throughout California in the pre-Spanish days. Tribes like the Mono and Yokut also pioneered specific solutions to their environment, solutions that powered life for untold centuries.



EXTRA ACTIVITY: GOOGLE A MAP OF CALIFORNIA TRIBES PRE-EUROPEANS

MANUFACTURED LIFE

Moderns humans have thoroughly mechanized the food that we eat and the water that we drink. Especially in cities, where 80% of Americans live, our lives depend on machines that deliver food, water, and energy to our lives.



In California, a state which hosts one of the most mechanized water systems ever, 80% of the human-controlled water flows to agriculture. Often urban planners allow development, after accounting for the water needed for a house, forgetting that it takes twice that amount to grow the food needed for the same household

Networks support human lives. A world population of over 8 billion people requires the domination of the Earth's resources, altering natural balances. Here are some networks the modern humans need for life:

- Water Distribution Systems
- Ammonia Pipelines
- Meat Packing Plant
- Railroads
- Farm Road Systems
- Natural Gas Networks
- Electrical Distribution Grid
- Flood Control
- Petroleum Supply Networks
- Telecommunications
- Trucking Distribution
- Transportation Networks
- Ocean Shipping and Ports
- Healthcare Systems
- Sewage Systems

Any interruptions in any of these networks and humans could suffer. Modern wars cause considerable suffering, not only through direct casualties, but also through indirect casualties associated with the interruptions of any one of these networks. While HydroFathom focuses on water, the interrelation to these other systems cannot be ignored. For example, the water distribution system depends on the electric power grid and railroads which deliver chlorine.

Human technology altered the natural life cycle on earth to support humans along with the plants and animals that we prefer. Plants like corn, potatoes, and tomatoes went from the diets of specific regions to staples around the world. A single county in California, Tulare County, a naturally dry region, now hosts over 300,000 dairy cows.

DID YOU KNOW:



According to the *Proceedings of the National Academy of Sciences*, the total weight of humans exceeds that of all wild animals by a ratio of 10-to-1. Domesticated animals outweigh humans by 2-to-1. By total weight on earth, cattle outweigh all other animals, followed by humans, and other livestock. Humans have so perfected life production, and altered the natural course of this production, that the total weight of all domesticated cats exceeds the total weight of all African savanna elephants.

Humans at one point, reduced the total weight of bison in the United States from around 60 billion pounds to about 500,000 pounds (516 animals).

The perfection of agricultural technology, from fertilizer to farm implements, means the U.S. citizens now depend on less than 2% of our population to make the food that feeds the entire nation. This same type of specialization and work-skill concentration can be found throughout the human workforce. Human life no longer depends so much on what nature brings, but rather how effectively we can control the Earth's resources. Each human typically depends on many others to perform a specific task that drives the machines that feed human life.



Currently, in the world, some major cities face, “Day Zero.” This day denotes when a water distribution system cannot adequately intake enough water to serve the needs of every customer. In these learning modules, we stress the eternal nature of water and that the amount of water on Earth remains fixed through time. Though the Earth always contains water, nothing guarantees your access to this water, especially in congested urban areas like Mexico City.



Mexico City contends with problem that touches on all three main themes of HydroFathom learning, watersheds, infrastructure, and aquifers. Currently, many residents rely on water trucks for delivery, and the city stands as the largest bottled water market in the world. How's the water supply? “We're scared”, one resident told the New York Times. This learning module uncloaks a primary motivator of the organizers of HydroFathom, to encourage people to learn where their water originates and how it arrives to them.

SOME CITIES WITH WATER CRISIS TO EXPLORE ON YOUTUBE:

[Chennai, India](#)

[Sao Paulo, Brazil](#)

[Cape Town, South Africa](#)

[Pixley, California](#)

The Water Within

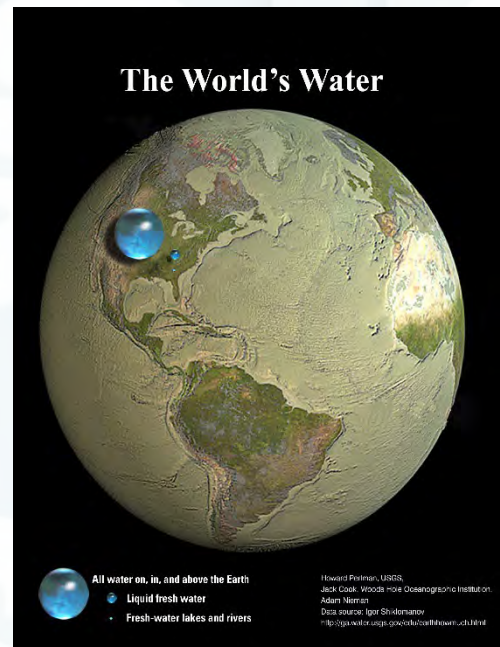
WATER SCIENCE, STATISTICS, AND MEASUREMENTS



Earth's waters deceive when viewed from space water covers 70% of the earth's surface. However, this misleads because by weight, water only forms .002% of the Earth's mass. This relatively small amount of matter fuels all life on Earth, on dry land and in the ocean. In comparison to other celestial locations, like our nearby arid lifeless neighbor Mars, our slim aqueous allotment allows us to luxuriate in water.

For most humans water makes up over 60% of their weight. A classic sci-fi saying labeled humans, "ugly giant bags of mostly water." The water in our blood contains almost the exact same salt ratio as seawater, about 3% salt, reflecting life's ocean roots.

For humans, water presents one ongoing challenge: weight. We mostly measure water by volume but sometimes weight provides more information. One gallon of water weighs 8.34 lbs. The metric system simplifies the conversion by making one liter of water equal to one kilogram of weight. Relatively heavy, water requires great effort to move.



*The blue sphere shows the mass of Earth's water
The tiny blue dot represents the fresh water*



In agriculture, water assumes another measure, the acre-foot. Farmers use this measure because it simplifies the math required for irrigation. To properly grow corn requires a minimum of 24" (2') of rain per year. So, to raise a one-acre plot of corn, a farmer requires 2 acre-feet (1 acre land, 2 feet water) of water yearly, either from rain or irrigation. Irrigation is fed by wells or canals. An acre-foot of water equals about 300,000 gallons, or 2.5 million lbs. An acre of corn yields about 4 tons or 8,000 lbs. of grain. Accordingly, it takes over 300lbs. of water to grow one pound of corn.

The Water Within

The crust of the Earth reaches about 40 miles deep at the thickest point. Yet, the earth continues down for another 3,900 miles to the center. In this light, a HydroFathom Waterism states, “if the Earth was an orange, all the water would be in the peel”. Fresh water on land only makes up about 3.5% of the water on earth. Although seemingly limited, fresh water constantly recycles from the ocean to the land and then back. Consequently, a small sliver of Earth supplies all the lakes, rivers, creeks, and rain clouds one ever encounters. Like a bowl being slowly filled and constantly spilling, the rain on Earth constantly replenishes the fresh water on land. About 20% of the freshwater on Earth, lays in the U.S. Great Lakes. The water in these lakes flows out through the St. Lawrence Seaway, constantly being renewed from above. The Great Lakes hold over 90% of the freshwater in the U.S., or six quadrillion gallons. Here is six quadrillion written out:



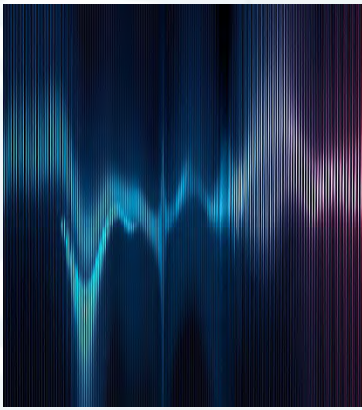
6,000,000,000,000,000 GALLONS



In water quality analysis, where chemists measure the amount of foreign substances in water, measurements are made in parts-per-million, or even parts-per-billion. Humans can sense by taste and smell pollutants in these tiny ranges. To dose a water tanker, 10,000 gallons, with one part-per-million of vinegar, one would add 1.25 ounces, slightly more than a shot glass of vinegar to a rail car of water. A large wheelbarrow holds about one million grains of sand. Imagine putting one grain of salt atop this sand. This one grain of salt would now rest atop a million grains of sand. Humans can sense water contaminants in this range.

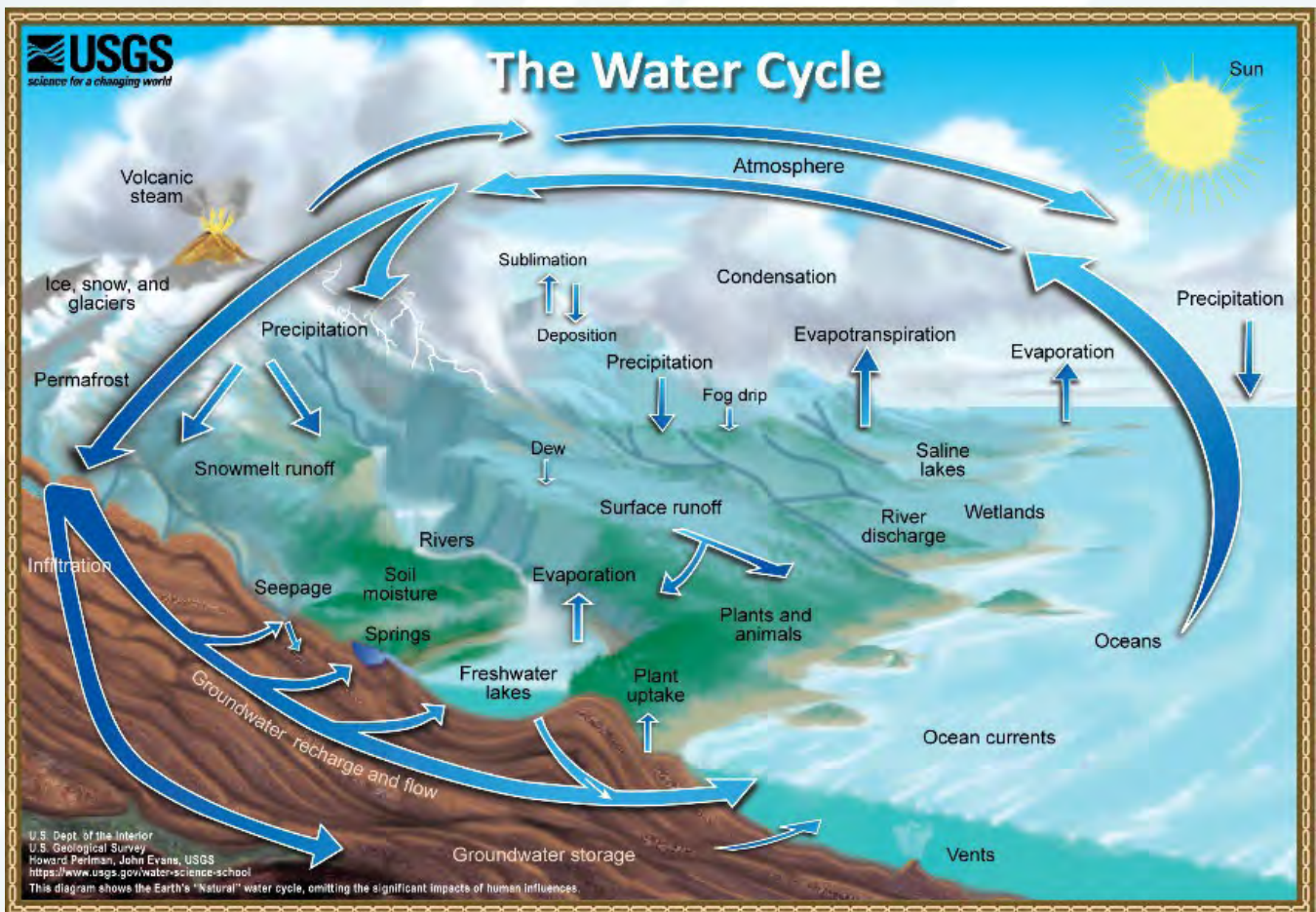
Still Waters Run Deep

The Water Within



Water pressure matters. For every foot of water depth, .43 pounds-per-square inch of pressure is felt. This is why when diving deep, your ears pop. The water pressure in a pipeline increases as it runs downhill. Humans measure many aspects of water including pressure, flow, volume, clarity, pH, and temperature. Humidity measures the amount of water in the air. In the Infrastructure Section, HydroFathom explores the devices that measure water qualities, instruments.

This graphic below shows all the paths that water naturally travels between land and the ocean. Some water even travels underground to complete the journey back to mother ocean



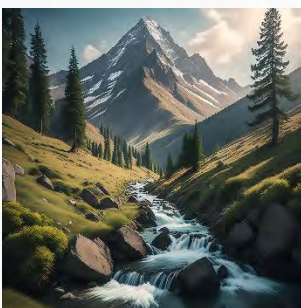
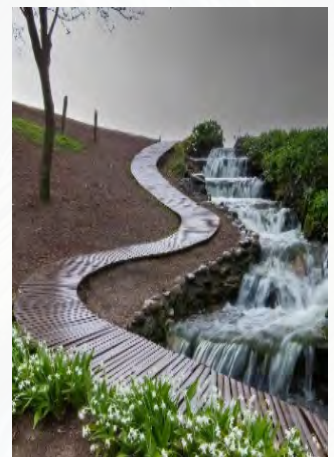
Pathways that water takes back to the ocean: seepage, runoff, precipitation, condensation, river discharge and vents.

DOWNHILL GRAVITY, UPHILL EVAPORATION



It may seem as if water flows directionally, for example, north-to-south. People often comment about the direction that a river flows. However, water truly flows, not along the compass, but simply from high to low, that means from high ground to low ground.

To give examples, the Mississippi flows for North-to-South, the Nile from South-to-North, the Congo from East-to-West and the Amazon from West-to-East. The Amazon, the largest river on earth, receives flows from snowmelt in the Andes which slides down the land from two miles high. This melted snow marches downhill from these dizzying heights, powered by gravity, down to sea level at the Atlantic Ocean. The Amazon River travels across the entire South American Continent due to the relentless tug of gravity



Elevation creates an ongoing obstacle to humans because once water flows to a lower level, it can only return to the higher level through energy-intensive pumping or simply by being carried back up to the sky through evaporation. The absorption of heat by the ocean powers precipitation and this process consumes more energy than all the power plants on Earth produce.

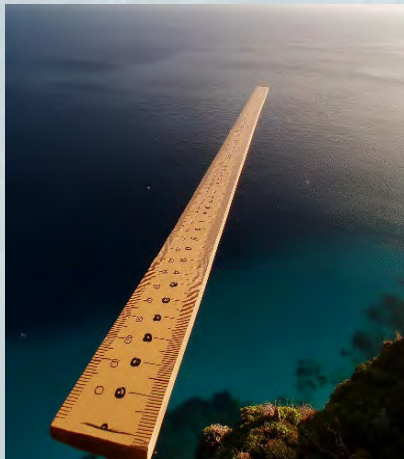
Point of interest: Google images of 3d topography maps of the U.S.

FOLLOW WATER UP HILL TO FIND THE SOURCE AND DOWN HILL TO FIND THE OUTLET



The uneven surface of the earth forms peaks and valleys. Humans measure the relative height or depth of a location on the surface of the earth using, “elevation.” Mt. Everest stands as the highest point on Earth and the Dead Sea as the lowest. Elevation readings are, “above sea level.” The surface of the ocean is zero elevation. Mean seal level denotes the average sea level, adjusted for tides

Mt. Everest stands at 29,029 feet elevation and the Dead Sea lays at -1,341 feet elevation. If, somehow, a rock could fall straight from the top of Everest to the surface of the Dead Sea, it would fall 5.75 miles down.



At any point higher than the surface of the ocean, water can still flow by gravity back to the ocean. Water that reaches a negative elevation cannot flow to the ocean and must return to the ocean through evaporation. Humans use canals to transport water from higher elevations to lower elevations but must use pumps connected to pipes to move water from a lower elevation to a higher elevation. Some water flows to low points and then becomes trapped in the earth, groundwater.

GOOGLE IMAGES OF WATER SEEKS IT’S OWN LEVEL

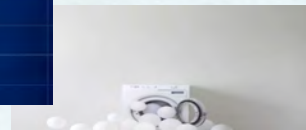
AVERAGE AMERICAN USER

When people think about their water use, they usually account for the 6-8 cups that they need for their daily drinking needs.



However, that is just the start. Obviously, most users need several gallons per day to flush the toilet. Cleaning and cooking weigh in, as does laundry. In dry states, irrigation consumes a healthy share of the water budget for most households. The Philadelphia Water Department lists the following usage for an average user daily:

- Toilet, 18-24 gallons
- Shower, 20 gallons
- Washing Machine, 15 gallons
- Dishwasher, 4-10 gallons, varies by setting and machine
- Hygiene, 2.5 gallons
- Drinking 1 gallon



Amazingly, about 15% of our water supply leaks every day. We call municipal water drinking water, but personal hydration forms a small part of our daily water budget, even exceeded by leakage.

The Water Within

The USDA 2017 Census of Agriculture reported total U.S. irrigated cropland at 58 million acres. The top states for irrigated farmland are Nebraska, California, Arkansas, Texas, and Idaho, with corn, soybeans, alfalfa, orchards, and cotton topping the list of irrigated crops. The U.S. agriculture industry consumed 83.4 million acre-feet of irrigation water in 2018. Doing some calculations, that averages about 200 gallons per person, per day, in the U.S. This is the most overlooked part of the average water budget, the agricultural portion. You've got to eat.



Most days, the water that you drink outweighs the food that you eat.

At times, people fail to consider the portion of water needed to make their personal products. Water intensive industries include, Textiles, chipmaking, automotives, energy and construction. We'll cover this later.

So, the truer number for daily water use for an average American user, for all uses, included growing food and industrial uses approximates as:

300 Gallons



A 200 POUND PERSON NEEDS 2500 POUNDS OF WATER DAILY TO EXIST

Google: U.S. Agricultural Irrigation Map

The Water Within

WATER IN THE ARTS

In our approach to the arts, HydroFathom focuses on literature, paintings, photos, videos, and sculptures. Many of our members have been influenced by authors like Rachel Carson, whose article *The Silent Spring*, early in the modern age, showed the potential for humans to unknowingly contaminate the Earth's waters.



When I think of great American art movements, I think of the Hudson River School.

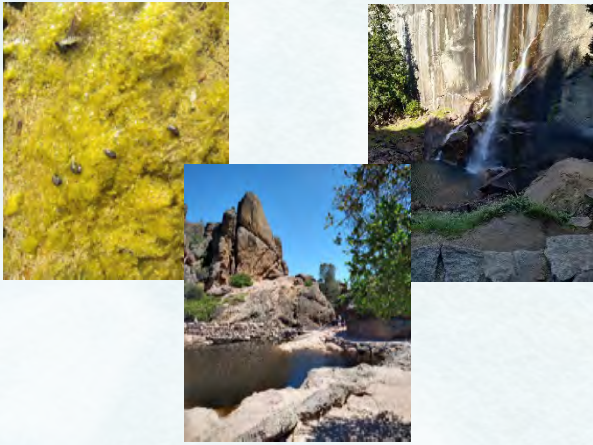


TO EXPLORE FURTHER, GOGGLE IMAGES OF THIS MOVEMENT

The influence of water on artists extends back millennia. Claude Monet stands as a quick reference as an artist heavily influenced by water. His paintings include images of water lilies, bridges, the River Seine, the River Epte, boaters, and the Thames. He often produced series of paintings inspired by rivers. Monet's personal garden at Giverny demonstrates his fascination with nature, flowers and water.

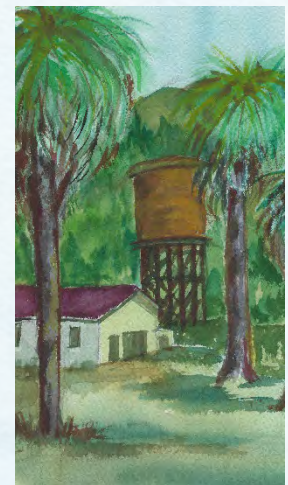


In 1937, the Rivers of America book series began with the printing of, *Kennebec, Cradle of America*, featuring a 137-mile Maine river. The series continued until 1974 growing to sixty-five books by dozens of authors. *The Everglades*, *The River of Grass* one of the most well-known books by Marjorie Stoneman Douglas, helped gain protection for these wetlands.



Copyright laws prevent HydroFathom from reprinting great artist paintings. Consequently, we encourage readers to examine these paintings on the internet. In a modern twist, HydroFathom uses AI generated images frequently in this Lesson Plan. We also use our originally produced photos and videos in our water education efforts.

Artists render not only nature in their art but also infrastructure such as bridges and even water towers. The modern California painter Isabel Emrich produces expressionistic paintings that colorfully and boldly depict humans immersed in water. The en plein-air school of painting often depicted river scenes, boaters, or bathers. Renoir, simply titled one of his famous paintings, *By the Water*. Renoir and Monet pioneered the concept of diffuse reflection while painting light and water en plain air. The pointillism genius George Seurat often depicted humans recreating by water including his paintings, *A Sunday Afternoon on the Island of La Grande* and *Bathers at Asnières*. Vince van Gogh painted the water-centric painting, *Starry Night over the Rhone*. One of the most famous Americana paintings, of course, portrays, *Washington Crossing the Delaware*





Water makes sounds, the thunder of waterfalls, the babbling of a brook, the drip-drop of falling rain, the trickling sounds of rapids, and the whoosh of a good dive. These sounds have inspired musical artists over the years to write water themed music. Bruce Springsteen's fifth album not only includes a track called *The River*, but this song also names the entire album. Along with Springsteen, other artists that included river in a song title include Eminem, Garth Brooks, Joni Mitchell, Al Green and Neil Young.

Because a nearby flowing river made noise that resembled a singing woman The native-American Yuchie tribe called the Tennessee River, The Singing River. Many artists have recorded at the famous Muscle Shoals music studios, next to the Tennessee, and have credited the melodious rippling waters with inspiring them to pen chart-topping tracks at the "Hit Recording Capital of the World."

Artist that recorded in Muscle Shoals included:

- Elvis
- The Rolling Stones
- Lynyrd Skynyrd
- Aretha Franklin
- The Osmonds
- Percy Sledge
- Wilson Picket
- Cher
- Rod Stewart
- Willie Nelson.



See our website at www.hydrofathom.org for more references.

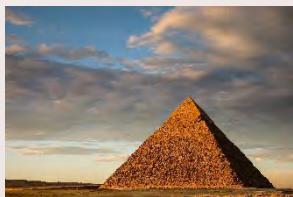
WATER IN RELIGION



Water connects to so many religions in so many ways that this module can only address a modest slice of the overall world religious theology. Nonetheless, the spiritual connections between humans and water bears a brief review. HydroFathom teaches in a non-denominational fashion. Consequently, here follows a select overview of several world religions and their water connections:

CHRISTIANITY – The connection between water, man, and God begins early in the Christian Bible, in the first few verses of Genesis. Using the King James Version, one can read to the second verse of the Bible, “and the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.” If a person counts from the start, they will find “water” as the 39th word in this Bible. The word “water” appears sixty-seven more times in Genesis. Regrettably, many of the Genesis water references, describe the great flood where God sent flood waters to cleanse the Earth.

Jesus went into the river Jordan and received baptism from John the Baptist who cried, “Behold! Look! The Lamb of God, who takes away the sin of the world.” Ever since Christians baptize themselves with holy water to symbolize their bond to Jesus Christ. Jesus later walks on water, turns water into wine and uses his own hair and water to wash the feet of his disciples. In John 4, Jesus stops at Jacob’s well and in an act of acceptance engages a Samaritan woman whom he offers “living water.” In their conversation Jesus states, “Everyone who drinks this water (from the well) will be thirsty again, but whoever drinks the water I give them will never thirst. Indeed, the water I give them will become in them a spring of water welling up to eternal life.”



EGYPTIANS – An earlier module examined how the ancient Egyptians lived in harmony with Egypt’s natural water cycle. In their culture, Tefnut, the goddess of moisture, moist air, dew and rain was related to the gods of earth, sky, and air. Hapi was the god of Nile flooding, which lead to the yearly replenishment of their soil.

The Water Within

ISLAM – The Zamzam well sits within the Great Mosque of Mecca, near the Kaaba, the holiest site in Islam. Multitudes drink from this well yearly during their hajj or umrah pilgrimages. Also, in Islam, charitably offering water stands as a gracious form of giving.



HINDU – The confluence of the Ganges River and the Yamuna River attracts millions of Hindu adherents during a forty-five-day festival where people bathe in the river during one of the largest gatherings of people on Earth. Participants strive to wash away their transgressions and renew themselves. The deity personification of the river Ganges, Ganga, rides a makara, a creature which may take the form of half crocodile/half dolphin.

Throughout history when used in a religious context, water often stood for universal concepts like:

Renewal

Forgiveness

Purification

Absolution

Relief

Wikipedia served as the source for the above depictions please send comments or corrections through our website: www.hydrofathom.org.

Praised be You, my Lord, through Sister Water who is so useful, humble, precious, and pure.

St. Francis Assisi

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COMPARING COUNTRIES



Precipitation falls unevenly over the Earth. We often forget most rain falls over the ocean, but for humans, water falling on land enables life. If a person examines a worldwide precipitation map, one easily spots the uneven distribution of precipitation over the earth. Few global land locations receive the rain required to naturally grow food. Some that do are South America, The eastern coast of North America, the plains of Europe, central Africa, eastern Asia, and the east coast of Australia.

Wikipedia contains a page titled, “List of countries by average annual precipitation”, a list of 180 countries total. One may think, “where does my country rank?” HydroFathom operates from the United States which ranks 112th among countries. Yes, the U.S., the breadbasket of the world, ranks as the 112th wettest county in the world. More on this later in this module. The rainiest country, Columbia, receives 128” of rain yearly. The U.S. receives a relatively sparce sprinkling of 28” of rain yearly.



The first column below lists the most populated countries among the top 25 wettest countries....

- Malaysia
- Indonesia
- Bangladesh
- Singapore
- Philippines

Continuing with the five driest countries...

- Egypt
- Cambodia
- Libya
- Saudia Arabia
- Qatar

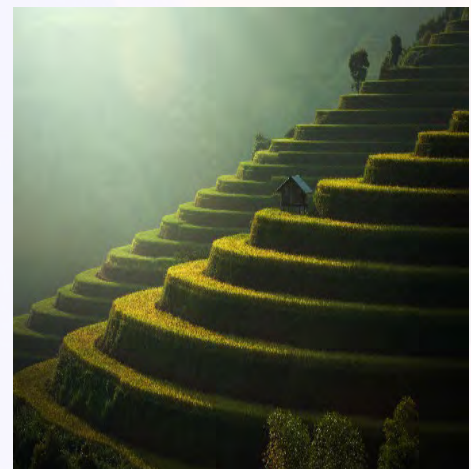
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Some more data gleaned from the same Wikipedia page:

THE WETTEST COUNTRIES BY CONTINENT			THE DRIEST COUNTRIES BY CONTINENT		
CONTINENT	COUNTRY	YRLY. RAINFALL	CONTINENT	COUNTRY	YRLY. RAINFALL
Africa	São Tomé and Príncipe	125"	Africa	Egypt	.7"
Asia	Malaysia	113"	Asia	Saudia Arabia	2.3"
Europe	Iceland	76"	Europe	Moldova	18"
North America	Panama	115"	North America	Canada	21"
South America	Columbia	128"	South America	Argentina	23"
Oceania	Tuvalu	126"	Oceania	Australia	21"

Many populous countries lack rainfall but have large land masses that can feed water to particular areas making productive agriculture possible. Previous modules mentioned how Egyptians survived for centuries living in balance with their natural environment. This balance sustained a vast country through agriculture centered on the relatively small Nile delta. Indeed, ancient Egypt, a mostly arid country sustained itself on rain that fell hundreds of miles away to the south. Luckily for Europe, North America and South America, most of their countries receive over 24" of rain on average. This rain level makes large scale agricultural more likely.

Even in ancient times, civilizations often prospered due to fortuitous flows reaching their populations. The Egyptians flourished from the Nile, Mesopotamia sprung up between the Euphrates and the Tigris while the Chinese bloomed between the Yellow and the Yangtze. The Chinese further helped themselves by inventing a whole class of infrastructure based around digging canals, damming watersheds, employing terraced farming and pioneering water moving systems like the water wheels.



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Here we have a peek at
the largest countries in the world:

TEN MOST POPULOUS COUNTRIES IN THE WORLD

COUNTRY POPULATION VS. RANFALL RANKING VS. PER CAPITA GDP			
COUNTRY	POPULATION RANK	RAINFALL RANK	PER CAPITA GDP RANK
INDIA	1	87	125
CHINA	2	123	73
UNITED STATES	3	112	11
INDONESIA	4	10	96
PAKISTAN	5	145	137
NIGERIA	6	81	142
BRAZIL	7	43	79
BANGLADESH	8	11	126
RUSSIA	9	146	55
MEXICO	10	110	70

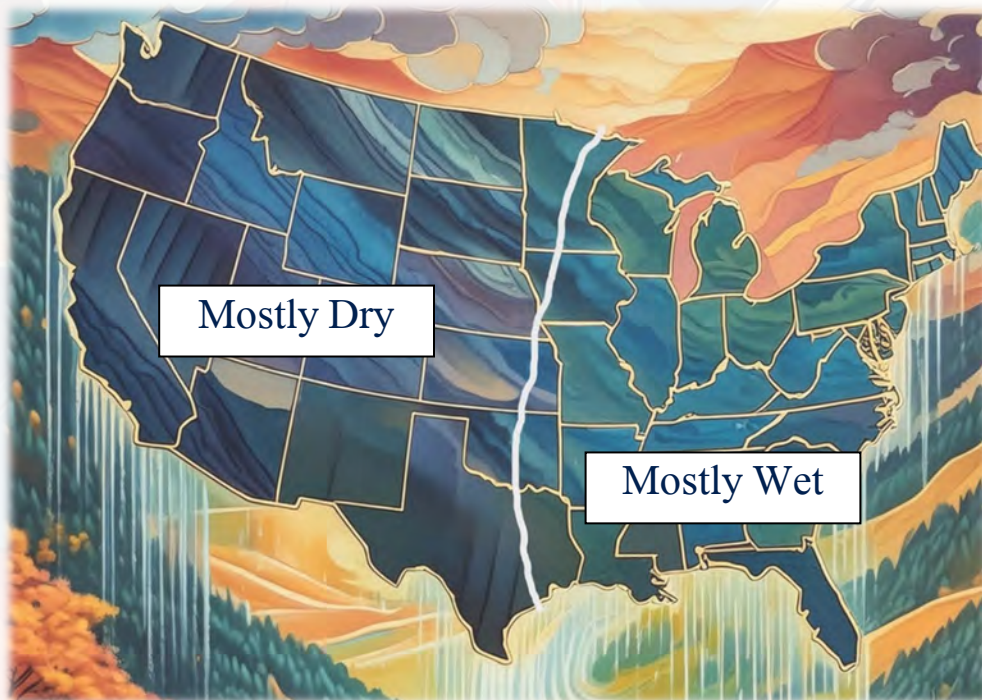
Interestingly, this table shows no correlation between rainfall, population, or financial well-being. This table does show that population growth mainly requires rain falling either over a large area, or regularly in certain areas. Rain often gathers over a wide area and then funnels into watersheds that direct water to productive agricultural areas which can support massive populations. To exceed economically requires development of infrastructure to exploit watersheds and aquifers. Even countries with vast deserts in areas, like the United States and China, thrive if other areas of the country receive precipitation which then can be funneled to productive agricultural areas.

Please support Wikipedia by visiting their website and donating: www.wikipedia.org

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COMPARING STATES

How rainy is the state that you live in? The U.S. cleaves into two distinct regions. The eastern U.S. receives considerable rain, and the western U.S. receives much less. The snowy mountains of California, Oregon and Washington stand as the only notable exceptions to this rule. In a previous section, we suggested examining a U.S. precipitation map. Examining this map exposes a wet/dry divide approximately following the 100th parallel, running north to south in the U.S., a slightly curving line stretching from upper Minnesota to the Gulf below Houston, TX.



In this module, HydroFathom examines the rain patterns in the United States. Some facts may surprise. For example, fathom this question, which city receives more annual rain Seattle, WA or Beaumont, TX. See the end of this module for the answer.



Americans often note the cultural divide between north and south. Yet, perhaps, the greatest divide separates east from west. Eastern U.S. states receive enough annual precipitation to naturally support agriculture; most western states receive insufficient rain to grow most crops. This water imbalance led naturally to an eastern agrarian society and a western ranching culture, one side more sedate, the other nomadic. Lacking natural rain to grow crops, water-starved societies often rely on foraging, pasturing, and hunting animals which can survive on natural dry scrub grasses. In the western U.S., these included buffalo, deer, and elk.



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By combining energy, infrastructure, and natural waters, humans have bent the natural water cycle to serve our needs. Consequently, in the western U.S., colossal interventions, such as the Hoover Dam, dictate the outcomes of water fortune, the who, what, when where, of human desires mostly replacing uncertain weather patterns. HydroFathom labels these dry western states, sprinkler states, states dependent on human intervention to grow the food needed to sustain life and provide water for other human uses. According to human will, crops grow where deserts stood, lakes dried and blew away, livestock flourished in lands devoid of rainfall, and lawns sprung up in previously dusty yards. Cactus died and lettuce flourished. In later modules, we will continue to explore the interrelation of watersheds, aquifers, and infrastructure which allows life to flourish in historically rain-starved places.



A QUICK LOOK AT SOME U.S. WATER STATS

Stat	Driest City	Wettest City	Driest Spot	Wettest Spot
Place	Yuma, AZ	Hilo, HA	Death Valley, CA	Mt. Waialeale, Kauai, HA
Yearly Rainfall	2.65 Inches	130 Inches	>2 Inches	460 Inches



Note the direct association of the driest place, Death Valley, with morbidity. While eastern states survive off natural rain, out west, Americans require the interruption of the natural water cycle, not just for drinking but for agricultural uses. California especially dominates their natural water cycle, manipulating the Sierra Nevada (snowy mountains) snowpack by diverting the natural run-off to power the largest agricultural state in the nation while fueling some of the largest cities in America, including arid southern California where over 20 million people reside in a semi-desert environment.

The table on the next two pages shows the complete ranking of states by their yearly precipitation amounts, listing the wettest states at the top and the driest at the bottom. This table further takes the average state rainfall times the area of the state to calculate the total volume of water falling over each state yearly, on average. We then use that data, combined with population counts, to determine how much water drops from the sky yearly in each state for each person in the state.

TABLE SORTED BY STATE WITH MOST AVERAGE YEARLY PRECIPITATION

RANK	STATE	YRLY. RAIN (Inches)	AREA (sq. mis.)	WATER BUDGET (Billions of Gallons)	POPULATION	GALLONS/YR./PERSON
1	Louisiana	59.15	52,378	50,066	4,601,049	10,881,485
2	Mississippi	56.48	48,432	44,205	2,984,345	14,812,195
3	Alabama	56	52,420	47,438	4,817,678	9,846,653
4	Florida	54.73	65,758	58,159	19,361,792	3,003,792
5	Tennessee	51.85	42,144	35,312	6,451,365	5,473,615
6	Hawaii	50.33	10,932	8,891	1,392,704	6,384,238
7	Georgia	50.22	59,425	48,227	9,907,756	4,867,567
8	Connecticut	50.07	5,543	4,485	3,592,053	1,248,594
9	Rhode Island	49.96	1,545	1,247	1,053,252	1,184,295
10	Arkansas	49.72	53,179	42,728	2,947,036	14,498,638
11	South Carolina	49.24	32,020	25,479	4,727,273	5,389,768
12	Massachusetts	48.42	10,554	8,258	6,657,291	1,240,468
13	New Jersey	48.02	8,723	6,769	8,874,374	762,767
14	North Carolina	46.92	53,819	40,807	9,750,405	4,185,163
15	Kentucky	46.27	40,408	30,214	4,383,272	6,893,024
16	Delaware	45.82	2,489	1,843	917,060	2,009,665
17	Maine	45.49	35,380	26,008	1,328,535	19,576,819
18	New Hampshire	44.84	9,349	6,774	1,321,069	5,127,983
19	West Virginia	44.36	24,230	17,369	1,853,881	9,369,242
20	Oregon	43.62	98,379	69,347	3,900,343	17,779,790
21	New York	42.87	54,555	37,795	19,594,330	1,928,852
22	Pennsylvania	42.77	46,054	31,831	2,758,729	11,538,223
23	Virginia	42.76	42,775	29,558	8,185,131	3,611,133
24	Maryland	42.7	12,406	8,561	5,887,776	1,453,951
25	Vermont	42.58	9,616	6,617	626,358	10,563,768
26	Missouri	42.52	69,707	47,897	6,028,076	7,945,702
27	District of Columbia	42.17	68	46	633,736	73,122
28	Indiana	41.86	36,420	24,637	6,542,411	3,765,674
29	Ohio	39.24	44,826	28,425	11,560,380	2,458,828
30	Washington	38.67	71,298	44,555	6,899,123	6,458,014
31	Illinois	38.52	57,914	36,050	12,868,747	2,801,399
32	Oklahoma	37.62	69,899	42,494	3,818,851	11,127,520
33	Texas	35	268,596	151,918	26,092,033	5,822,386
34	Iowa	34.5	56,273	31,373	3,078,116	10,192,378
35	Wisconsin	33.11	65,496	35,044	5,724,692	6,121,575

TABLE SORTED BY STATE WITH MOST AVERAGE YEARLY PRECIPITATION						
RANK	STATE	YRLY. RAIN (Inches)	AREA (sq. mis.)	WATER BUDGET (Billions of Gallons)	POPULATION	GALLONS/YR./PERSON
36	Michigan	32.79	96,714	51,247	9,889,024	5,182,254
37	Kansas	32.43	82,278	43,119	2,882,946	14,956,691
38	Alaska	29.03	665,384	312,148	728,300	428,598,292
39	Minnesota	28.61	86,936	40,194	5,383,661	7,465,883
40	Nebraska	26.66	77,348	33,323	1,855,617	17,958,177
41	California	22.97	163,695	60,763	38,066,920	1,596,210
42	South Dakota	22.02	77,116	27,441	834,708	32,875,214
43	North Dakota	18.59	70,698	21,239	704,925	30,129,017
44	Colorado	16.98	104,094	28,563	5,197,580	5,495,454
45	Idaho	16.91	83,569	22,837	1,599,464	14,277,616
46	Utah	15.79	84,897	21,663	2,858,111	7,579,433
47	Montana	14.92	147,040	35,452	1,006,370	35,228,000
48	New Mexico	14.24	121,590	27,980	2,080,085	13,451,420
49	Wyoming	13.23	97,813	20,912	575,251	36,353,012
50	Arizona	11.8	113,990	21,737	6,561,516	3,312,729
51	Nevada	9.46	110,572	16,904	2,761,584	6,120,958

Total gallons of water that fall from the sky every year in U.S.: 1,915,950,505,868,800 Gallons.....or 2 Quadrillion

Water falling each year in the U.S. for each person: 17,470,170 Gallons.....or 17 Million

State with smallest water budget per capita, New Jersey, at: 762,767 gallons, exempting D.C.

State with largest water budget per capita, Alaska, at: 428,598,292 gallons

Our research shows that, across the U.S., about 47,000 gallons of water falls from the sky daily for each person in the U.S.

All bottom 10 states in the table, the driest states, lay west of the 100th parallel

Google wettest cities in the U.S. and explore

Seattle receives 37.7 inches of rain per year and ranks 37th in rainfall among the top 50 largest U.S. cities. Beaumont, TX receives 93.7 Inches of rain yearly, the most.

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LARGEST RIVERS IN THE WORLD AND THE U.S.

Rank	River	Discharge (Cu. m/sec) Average	Length (Miles)
1	Amazon	224,000	4,344
2	Ganges– Brahmaputra– Meghna	43,950	2,466
3	Congo	41,400	2,716
4	Orinoco	37,740	1,398
5	Yangtze	31,900	3,915
6	Negro	30,641	1,390
7	Madeira	30,173	2,100
8	Rio de la Plata	27,225	180
9	Brahmaputra	21,993	1,800
10	Mississippi	21,300	2,340

Source: Wikipedia

Note, the Amazon outflows the Mississippi by ten-to-one, yet the Mississippi outflows the Colorado by ten-to-one.

Before looking at river statistics, some ground rules need review. People use several factors when assessing rivers: discharge flow, length, and basin size, being a few. The measure that leads to the most formidable rivers is discharge flow. The Colorado River, in the United States, provides an example. People often call this river “mighty.” However, the Colorado River, ranks as the 38th largest river in the U.S., draining a mostly dry area. By flow, almost all state rivers exceed the Colorado River, including the Arkansas, Mississippi, Ohio, Tennessee, Alabama, and Missouri. The Colorado surpasses the Connecticut yet cannot surpass the city-named Detroit and Mobile Rivers. The Colorado’s length of 1,450 miles gives the façade of bulk. Yet, the Arkansas River, a river of similar length to the Colorado doubles the flow of the Colorado and seldom receives acclaim as mighty. With clarification provided, here we list the ten highest flowing rivers in the world with their lengths.

The Amazon discharges
59 million gallons per second
The Mississippi discharges
5.6 million gallons per second

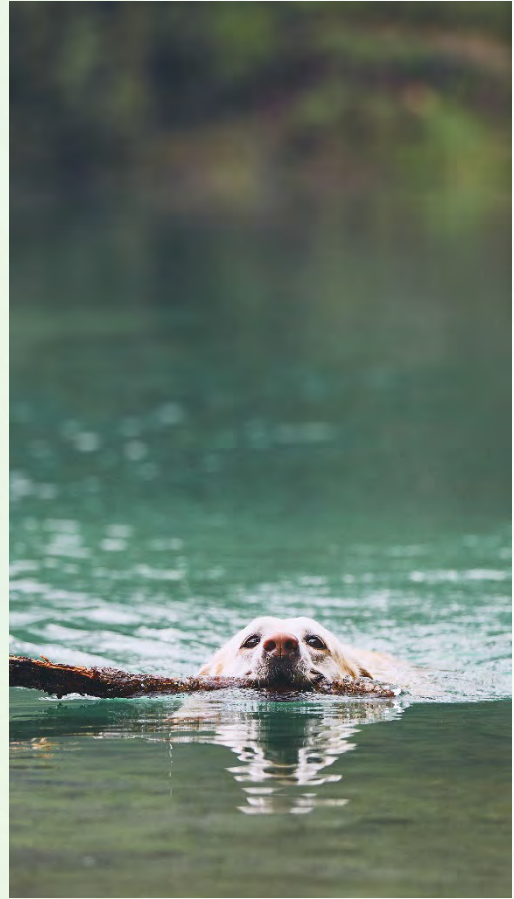
The largest river in the United States, the Mississippi drains 41.1% of the country's land. Here are top ten U.S. rivers:

RANK	RIVER	LENGTH	DISCHARGE (Cu. m/sec)
1	Mississippi River	2,320	593,000
2	Ohio River	979 ¹	281,500
3	St. Lawrence River	600	348,000 (275,000 at U.S.- Canada boundary)
4	Columbia River	1,243	273,000
5	Yukon River	1,980	227,000
6	Atchafalaya River	137	225,000
7	Niagara River	36	204,700
8	Detroit River	32	188,000
9	St. Clair River	39	183,000
10	Missouri River	2,34	86,300

We expand upon this subject later in our Watershed section.

A MIGHTY MISSISSIPPI SNAPSHOT

- ❖ MISSISSIPPI RIVER TRIBUTARIES
- ❖ WITH STATES FEEDING THE WATERSHED
 - o Upper Mississippi
 - Minnesota
 - Wisconsin
 - Iowa
 - Illinois
 - Missouri
 - o Arkansas River
 - Colorado
 - Kansas
 - Oklahoma
 - Arkansas
 - o Illinois River
 - Illinois
 - o Missouri River
 - Montana
 - North Dakota
 - South Dakota
 - Nebraska
 - Iowa
 - Kansas
 - Missouri
 - o Ohio River
 - Pennsylvania
 - Ohio
 - West Virginia
 - Kentucky
 - Indiana
 - Illinois
 - o Red River of the South
 - Texas
 - Oklahoma
 - Arkansas
 - Louisiana



Live near a river?

Goggle it and find out the flow of your river.

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LARGEST FARM STATES IN THE U.S.



HydroFathom originated from water professionals tracing the sources of natural water and following this water from its source on to the ultimate human use. Water accounting leads directly to the nations farms. In the United States, agriculture consumes about two-thirds of our human-controlled water, rightfully so, since we all have to eat. Yet, most citizens may ignore agricultural water consumption, oblivious to their food production, obscured by supermarkets, food distributors, food processing plants, slaughterhouses, and industrial farming.



The current agricultural production explosion that affords a human population of eight-billion people began around 1900. At the commencement of the twentieth-century, humans married together fossil-fuel, machines, fertilizer production, water management, and factory production into a new colossus that could essentially manufacture food. In our introductory paper, *The Water Chain*, HydroFathom introduced the four essential elements of life: water, chemicals, energy and part of an existing life (seed). Since the dawn of humankind, nature determined whether enough of each essential ingredient would appear during each growing season. Modern humans learned to use fuels which created energy and used that energy to change the environmental equation. They so perfected the management of natural resources that they could nearly guarantee that water and chemicals would meet in a manner that assured agricultural production. Still, we slowly deplete non-renewable water sources and must depend on fate for natural energy, the needed solar energy (sun) to grow food.

Google: Haber-Bosch Process, Making food from air

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Top 10 Agricultural States in the U.S.

Rank	State	Average Rainfall	Top Five Ag Products
1	California	23"	Dairy, Grapes, Lettuce, Cattle Almonds
2	Iowa	34.5"	Hogs, Corn, Soybeans, Cattle, Dairy
3	Nebraska	22.6"	Beef, Corn, Dairy, Beans, Hay
4	Texas	35"	Cattle, Poultry, Dairy, Corn, Cotton
5	Illinois	36.7"	Corn, Soybeans, Hogs, Cattle, Dairy
6	Minnesota	28.6"	Corn, Soybean, Hogs, Cattle, Dairy
7	Kansas	32.4"	Cattle, Wheat, Corn, Sorghum, Soybeans
8	Indiana	41.9"	Corn, Soybean, Hogs, Dairy, Turkey
9	North Carolina	46.9"	Soybeans, Corn, Sweet Potatoes, Tobacco, Hay
10	Wisconsin	33.1"	Dairy, Cattle, Corn, Soybeans, Potatoes

Humans bent the natural water cycle allowing for the on-demand placement of water onto crops, re-routing natural water flows through dams, canals and pipelines while also pumping water from underground aquifers.

Top 10 Calorie Sources in the American Diet

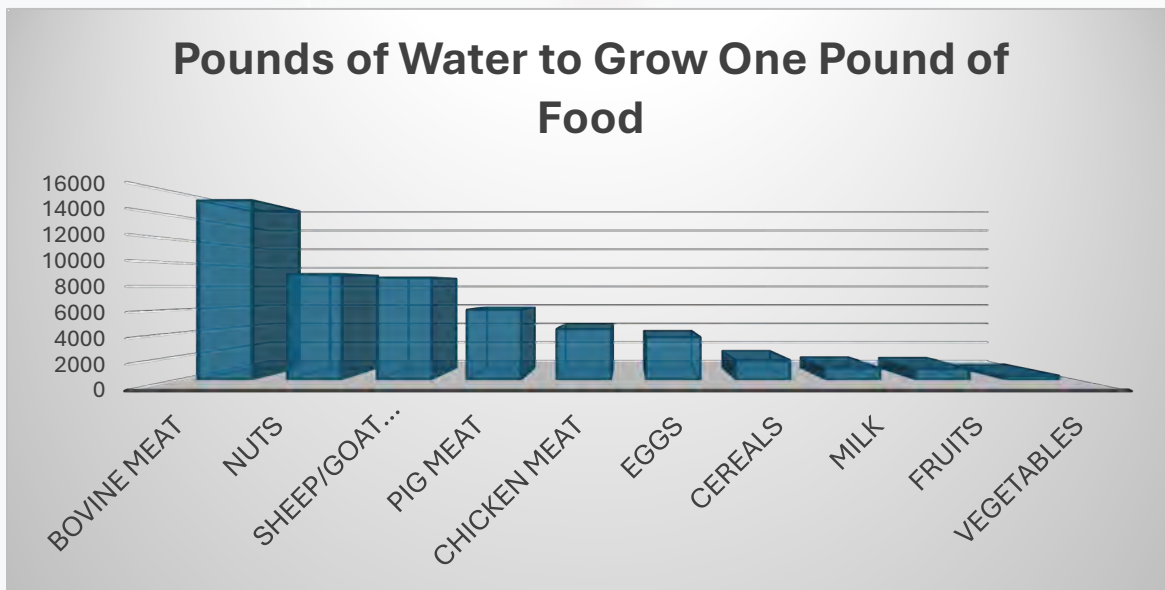
1)	Grain-Based Dessert
2)	Yeast Bread Breads
3)	Chicken and Chicken Dishes
4)	Soda
5)	Pizza
6)	Alcoholic Beverages
7)	Pasta and Pasta Dishes
8)	Mexican Dishes
9)	Beef and Beef Dishes
10)	Dairy Desserts

Source: Harvard Health Publishing

The Water Within



We often order water by volume, ounces and gallons, maybe liters. Many times, weight, not volume, serves as the better parameter for measuring water. Growing food requires water. The amount, or weight, of water to grow any food varies. The chart below shows that some foods, like vegetables, require significantly less water to produce one pound of product than other foods such as meat. Human choices about diet affect the natural water cycle. Generally, the more humans divert water, the more wild animals and natural flora/fauna suffer. All foods require a multiple of their own weight in water to grow. One pound of carrots may take 300lbs. of water to grow while one pound of meat may take 14,000lbs. See chart.



The amount of water required to make a cup of coffee includes not only the water poured over the roasted grounds, but also includes the water needed to grow the beans. Coffee plants require 60- 90 inches of rain per year, meaning coffee thrives best in high rain locations like Columbia. Consequently, these thirsty plants need 37 gallons of water to grow the beans for one cup of coffee.

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The true water budget of some common foods:

Loaf of Bread – 240 gallons

Small Soda – 46 gallons

Small serving of Chips – 12 gallons

Gallon of Tea – 108 gallons

Gallon of Beer – 300 gallons

This data provided by: the71percent.org



Help support HydroFathom as we explore this subject. Visit our website at: www.hydrofathom.org. Follow along as we develop our calorie-per-gallon metric that explores how many calories a food yields for each gallon of water expended. In short: how many calories for how much water.

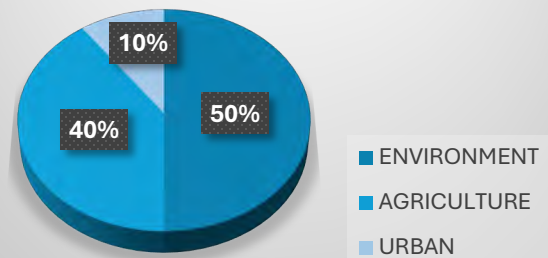
Nine percent of the human controlled water in California grows nut trees, most of the nuts are exported to other countries.

The Water Within

CALIFORNIA WATER USAGES

According to the Public Policy Institute of California, the Golden State uses between 18 and 31 trillion gallons of water annually. The institute approximates that half the water routes to the environment with forty percent to agriculture and ten percent to urban uses.

USES OF CALIFORNIA WATER

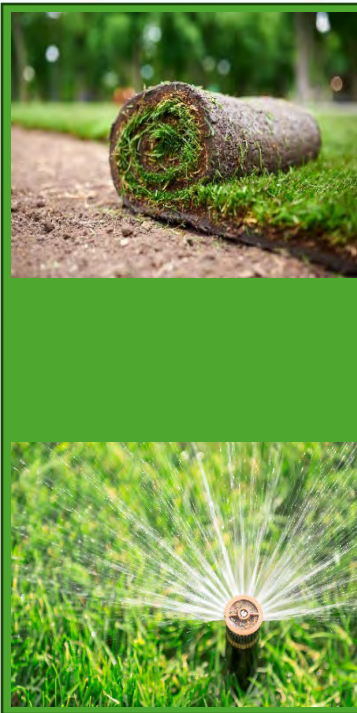


California possesses sufficient aspects of each Water Chain element to allow for natural water domination. Two of the most massive water projects in the U.S. lay in California. The California State Water Project and the federal Central Valley Water Project. A somewhat dry state, indeed, a state with the driest spot in the country, nevertheless hosts the highest mountain in the lower forty-eight as part of the snow scraping Sierra Nevada Range which powers a concentrated and chaotic precipitation map that humans have altered beyond recognition. In the middle of California, the original San Joaquin Valley now stands half-covered with human-grown mostly non-native plants. In this valley, due to an ancient history of inland water bodies, substantial aquifers underly the land and power an ultra-efficient agricultural machine that would be impossible without pumped water and access to energy. Seventy-five percent of the water in California falls in watersheds in the north. Vast stretches of southern California and the central valley receive little yearly rainfall. However, the coordinated movement of water and the associated government bureaucracies have re-shuffled the natural water supply to a new water world order. These government bureaus include Westland Water District, the largest agricultural district in California, which serves 1,000 square-miles of farmland and the Metropolitan Water District, the largest supplier of treated water in the U.S., serving 19-million people.

The Water Within

Further Exploration:

How many species of palm trees are native to California?



About half of the urban use of water in California, 5% overall, goes to irrigate urban plants, mostly lawns and gardens. Urban horticultural water consumption taxes the natural water supply while gobbling energy so city-dwellers can have ornamental plants around their homes, neighborhood, and even highway medians. Just 100 years ago, cactus, chaparral, manzanita, and dry grass naturally filled the state. Now, thanks to water machines, Chinese elms flourish amid patches of Kentucky bluegrass, growing beside middle eastern date palms. Consequently, California dominates growing another plant type, ornamental. Such plants mainly allow a single human generation to enjoy imported, non-natural plants growing around their homes while erasing the natural environment and contributing CO₂ to the atmosphere.

Fathom this: Can a plant not be “green”, not good for the environment. Consider that according to the California League of Women Voters, “Water conveyance, treatment, delivery, heating, and sewage treatment account for about 20% of California’s electricity and 30% of natural gas use.” When a plant grows while being fed water pumped from vast distances away, the energy required to deliver the water likely exceeds the ability of the plant to absorb the corresponding CO₂.

California leads the nation in production of a variety of crops, including:

- Almonds
- Artichoke
- Celery
- Figs
- Garlic
- grapes for raisins
- kiwifruit
- honeydew melons
- nectarines
- olives
- clingstone
- peaches
- pistachios
- plums
- rice
- walnuts

One county in California, Kern County, receives about 9" of rain per year, yet produces about \$9 billion of agriculture products per year including:

- Grapes
- Citrus
- Milk
- Almond
- Pistachios
- Carrots
- Cattle
- Potatoes

In 2020, Kern raised 250,000 cows, and 81,000 sheep and lambs

Source 2022 Kern County Ag Report

Since HydroFathom originated in California, much of our research centers on this state, but California also demonstrates the extreme level of water control possible by humans in the modern world. This control allows the state to access the largest water supply in the U.S. We will return to the home-state of HydroFathom often in our lessons.

EXTRA ACTIVITY: **Google the World's Largest Pump Station**

The Water Within

INDUSTRIAL NEEDS

This module returns again to examining an average individual's water needs. Now, fathom this. What item in your immediate possession needs the most water to produce? Are you reaching for your phone? A cell phone requires about 3,500 gallons of water in manufacturing. Specifically, computer chips must be deeply washed with ultra-pure water repeatedly during production. According to Statista, In 2022. Tiawan Semiconductor Manufacturing Company, a gargantuan chip manufacturer, consumed about twenty-five billion gallons of water. One could ask, how many gallons per selfie?

SNAPSHOT OF WATER REQUIRED FOR SOME RANDOM THINGS

Cotton Shirt = 713 Gallons
Ton of Steel = 62,000 gallons
Blue Jeans = 1,000
A diaper = 9
Leather Shoes = 2,113
Sheet of Paper = 3
2 x 4 Board = 6

Source: The Alton Telegraph

The Water Within

One could easily overlook water needed for industry since most folks just see the finished products, not the manufacturing process. According to the U.S. Environmental Protection Agency, these following eight industries require substantial inputs of water:

- ✓ Agriculture
- ✓ Apparel
- ✓ Beverages
- ✓ Biotechnology/pharmaceuticals
- ✓ Electric Power
- ✓ Forest Products
- ✓ High-Tech
- ✓ Metals and Mining



Most of the electric power water use comes from man-made reservoirs releasing water back to the environment while producing hydropower electricity. So even this original green energy influences the flow and balance of the natural water cycle.

Want to do some research on your water usage?

Check your water bill.

Remember, your bill misses food and industrial.

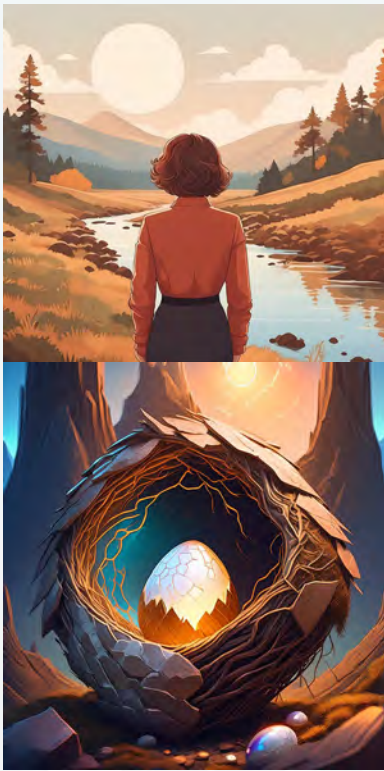
The Water Within

POLLUTION

Since about the mid-1800s, humans earnestly began discovering and manufacturing new chemicals. These chemicals previously did not exist, and life had evolved without them. In the last century, humans discovered millions of chemicals which interact with life forms and can damage them. This module looks at the dispersal of human-made chemicals into natural waters, water pollution. We start with a real-world example from aquifers and then follow with another about watersheds.



The location pictured above hardly evokes water pollution, being near the Mojave Desert. However, this location, a gas compressor station outside Hinkley, CA, contributed to one of the most infamous water pollution incidents in the nation. Initially gazing at the picture, most people may struggle to fix this incident. Even hearing the location, nothing may be recalled. Yet for many people, the name, Erin Brockovich, almost instantly explains the events. From 1952 to 1966 Pacific Gas and Electric used a chemical in the cooling towers of their compressor stations. They later disposed of the chemicals in ponds on their property. Water from these ponds leached into the ground and poisoned the wells of nearby Hinkley, CA with a “genotoxin”, hexavalent chromium. Genotoxins may damage a person's cells and cause cancer. The referenced movie documented the related litigation. This incident demonstrates a pattern where relatively minute amounts of foreign chemicals poisoned a massive water supply used to supply people. Examine the water math. Some chemicals cause harm in miniscule ratios. In another module, HydroFathom discussed that contamination levels as low as one-part-per-million may be troublesome. Imagine, contaminating a million gallons of water with just one gallon of contaminant. That’s the challenge with water pollution, it don’t take much.



Carson subtitled her New Yorker Article, *If we are living so intimately with chemicals, we had better know something about their power.*

In the above example, HydroFathom explored one hero of our organization and in this section, we examine another, Rachel Carson, a brilliant author and environmental scientist that proved the relationship between the widespread spraying of DDT and bird population reductions. In her writing, Ms. Carson describes the theoretical impact of chemicals on bird life, “It was a spring without voices. In the mornings, which had once throbbed with the dawn chorus of robins, catbirds, doves, jays, and wrens, and scores of other bird voices, there was now no sound.” She continues by explaining how chemicals accumulate by draining down watersheds and collecting in the natural waters. In one biting line, she describes what may cause humans to be over-contaminated with hazardous chemicals, “No witchcraft, no enemy action had snuffed out life in this stricken world. The people had done it themselves.” Her work in the early 1960s faced harsh attacks by the corporate and government organizations that promoted DDT in the first place. Her courageous pursuit of the truth expanded the knowledge of all humanity.

EXTRA ACTIVITY: Google Rachel Carson, New Yorker Article, Silent Spring

Even some natural processes can pollute water. One specific problem, nitrates and nitrites, originates from natural biological processes. However, humans now supercharge the production of nitrates/nitrites through fertilizer production used to enhance soils. Generally, livestock produce pollution through their waste which farmers also deposit onto fields. Excess fertilizer slips off fields and contaminates surface water by collecting in watersheds. Nitrates and nitrites spoil groundwater by simply leeching into the soil.



A manure spreader in action

The Water Within

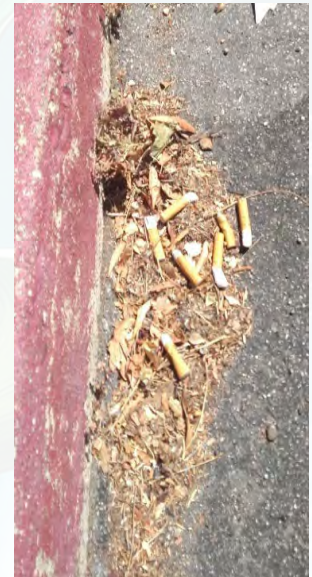
Farming runoff causes much of the dead-zone that yearly forms in the Gulf of Mexico.

MICROPLASTICS



Human-made chemicals, generally called plastics, have now contaminated almost all the water on earth. Originally, the production of plastics blossomed in the mid twentieth century. Many of these human engineered substances do not biodegrade. They do not break down into other substances under biological processes. Thus, they may persist in the environment for centuries, slowly accumulating to dangerous levels. In 2019, about 400 million tons of plastic were manufactured worldwide, 100lbs. per person. Much of this plastic enters watersheds, breaks down into smaller particles, and becomes permanently trapped in our water supply.

The urban street gutter sends a surprising amount of waste into the natural watersheds. Curbs route water to natural watersheds and storm drains funnel tire dust, shattered plastic, spilled gas, and other pollutants into our natural waterways. The cigarette butt stands out as the most noticeable urban water pollutant. Each butt contains about 50,000 strands of plastic micro-fiber that easily degrade into the microscopic particles known as microplastics. Incredibly, humans discard about 4.5 trillion butts each year, many right into the gutter. This leads to over 750,000 tons of plastic waste





entering the environment each year. The ubiquitous cigarette butt holds the title of the most littered item on earth.

A substance need not be human-made or sophisticated to cause harm. For example, lead, a natural fundamental elemental metal, causes many health issues when ingested. According to the World Health Organization, lead exposure can harm the brain, liver, kidney and bones, and is especially hazardous to young children and women of child-bearing age. Childhood lead exposure directly correlates to inhibited adult brain function. As an example, if a child consumes lead contaminated water, they may struggle to learn math later in life. Any level of lead exposure causes harmful consequences. Some ways that humans are exposed to lead:

Old Lead Paints

Old Lead Pipe Solder

Mining and Smelting

Lead in Ceramic Glazes

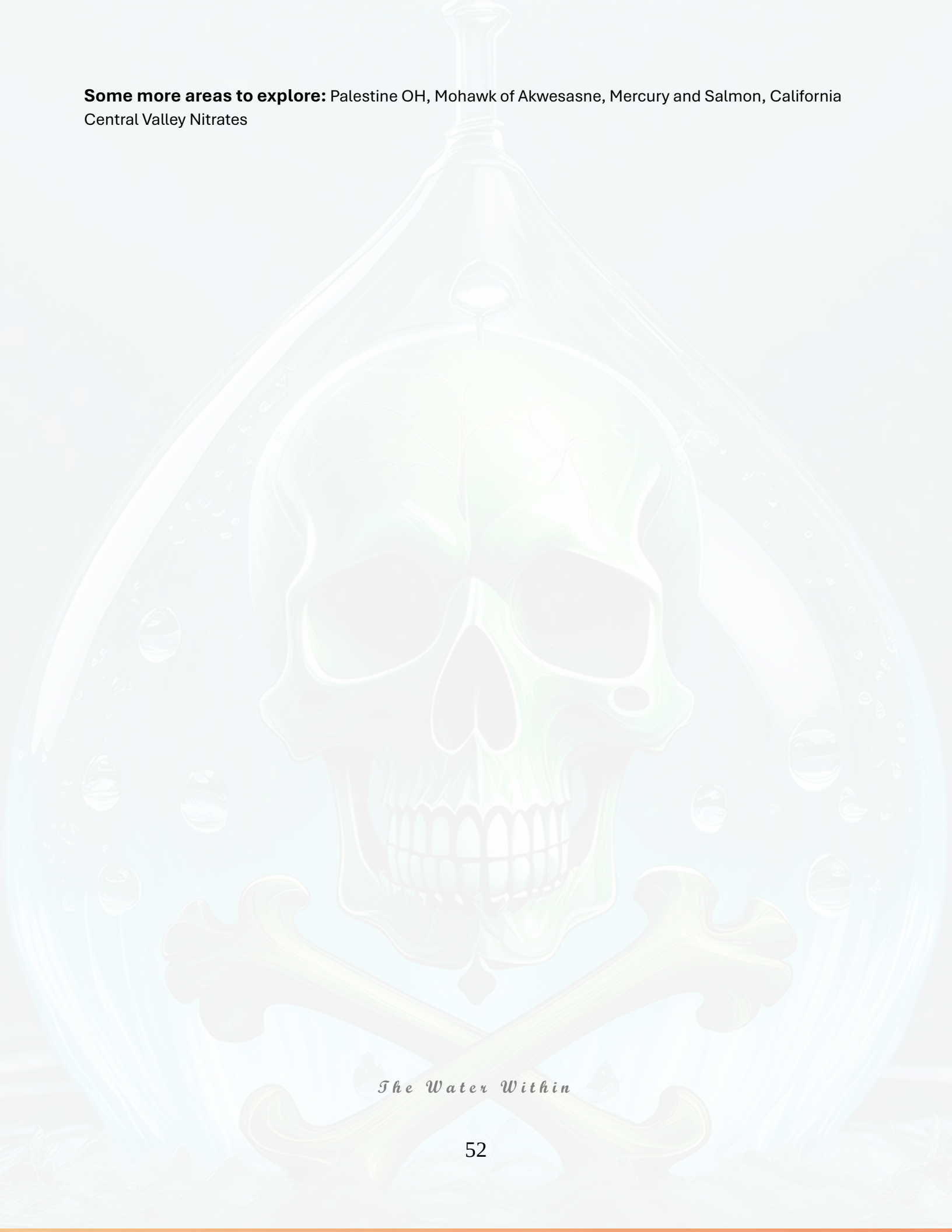
Water Delivered in Lead Pipes

Yearly, lead shortens the lives of up to 1 million people globally. Drinking water systems mainly become contaminated by old lead pipes or lead containing solder. The National Institute of Health denotes that most lead pipe installations in the U.S. stopped about 1920, but plumbing codes allowed lead to be used until the 1970s, lead solder longer. These silent killer pipes still poison water supplies, especially in older cities and many states have laws requiring their eradication from water systems. In the mid-1900s chemical companies created chemicals called PFAs, forever chemicals. PFA molecules persist so long that they have been dubbed, “forever chemicals.” The National Institute of Health lists a likely relationship between PFA exposure and altered immune and thyroid function, liver disease, lipid and insulin dysregulation, kidney disease, adverse reproductive and developmental outcomes, and cancer. The blood of almost all citizens of developed countries contains some PFAs due to their common use in items like non-stick pans, firefighting foam, and stain resistant fibers. These chemicals currently remain in widespread use.



The Water Within

Some more areas to explore: Palestine OH, Mohawk of Akwesasne, Mercury and Salmon, California
Central Valley Nitrates



The Water Within

WATER DEBT

Prior to about 1850, humans did not master the technology required to greatly alter the Earth's water. Since then, powered by the application of energy, humans have mastered the technology to alter the natural water cycle. We have chained water, pulling it to our needs. A quick review of ways that humans altered nature, the human links of the Water Chain:

Dams, Canals, Pipelines, Pump Stations, Treatment Plants, Water Distribution Systems, Chemical Production

These systems interrupt the natural ebb and flow of water which existed for eons prior to the industrial age. Now, the human species cannot only modify the Earth's waters, but humans can also decide whether they will help or harm the water of future generations. The same old thinly bound water on the surface of our planet must sustain all life forms in the future.

HydroFathom staff explores many trails researching watersheds, and we often spot signs in the national parks like, "leave only footprints" or "carry it in, carry it out." These signs subtly suggest that one leave things as good or better than they found them, such a simple moral concept, but what if that doesn't happen? The last several generations of humans pumped aquifers to lower levels and widely polluted our natural waters while likely altering our weather patterns. Our aquifers drop and our glaciers melt, while colossal plastic islands slowly rotate in the Pacific. We've ceased leaving things as found. In generation water accounting, grandfather runs a debt to grandson. Undoubtedly, if you read this in the first half of the twenty-first century, the Earth's water will be worse when you die than when you were born. This type of cycle defines non-sustainable, so came forward HydroFathom. Our organization recognized the need for everyday people to educate themselves about their water supply, so that future generations may enjoy the same access to clean water that we currently enjoy.

This module ends the basic instruction section of the HydroFathom Learning Lessons. The next three sections focus on watersheds, aquifers, and infrastructure. Hopefully, these initial modules taught the reader new facts about their water and inspired study about their own water. At HydroFathom we promote a learning philosophy which urges a person to contemplate simple questions. What causes water to emerge from my home taps? How do the plants and animals that become my food get water? Where does the water for my needs come from? How do I affect Earth's water? HydroFathom believes a person must fathom these issues to ensure the long-term water supply needed for future generations. After all, when it comes to water, nobody wants to get caught a little short.

Help improve Earth's water

Visit us on the web at:

www.hydrofathom.org

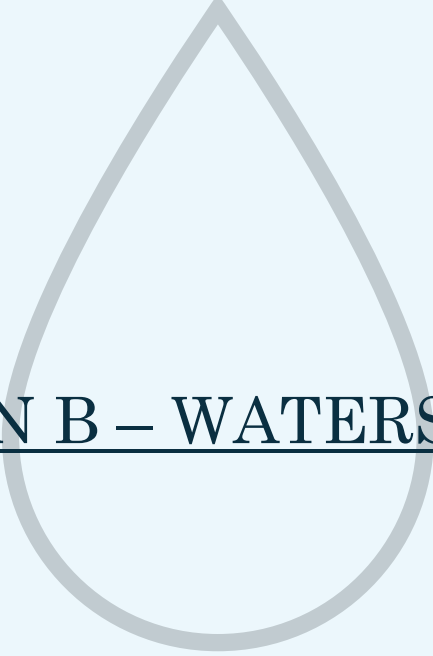
SECTION B

WATERSHEDS



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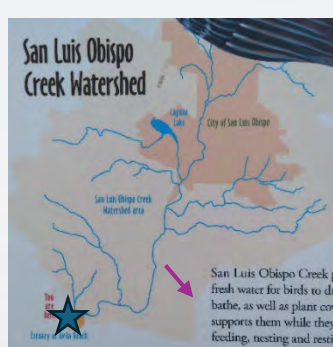
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SECTION B – WATERSHEDS

The Water Within

SIZE/TOPOGRAPHY



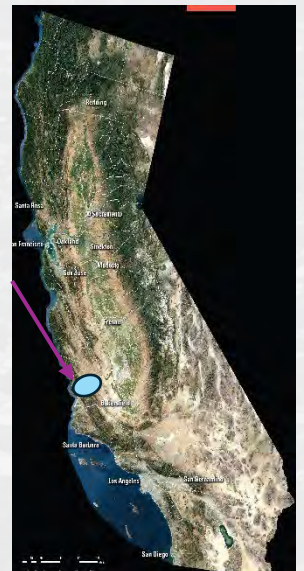
The San Luis Obispo watershed reaches the Pacific Ocean at Avila Beach, blue dot below



The San Luis Obispo Watershed

The graphic at left depicts the watershed of San Luis Obispo Creek, the hometown watershed of HydroFathom. Our local watershed is modest sized, 84.8 square-miles, shown as the blue dot down on the California map below. Whenever rain falls in the blue dot (we get little snow), the rain slides along the land into the creek which then consolidates the flow into a water flow that reaches the Pacific Ocean near Avila Beach, California. The San Luis Obispo Creek watershed lies in the traditional land of the Chumash native-Americans. In pre-European days, countless Chumash generations sustained themselves along this creek. Other species thrived alongside the Chumash including trout, waterfowl, sea otters, clams, bears, deer, elk and fox. These native species sustained themselves through hundreds of generations using this modest watershed. The entire city of San Luis Obispo lies in this watershed so any rain that falls in our hometown flows to the ocean a few miles away. The creek runs all year around, even though no rain falls for several months per year. Pre-Industrial age, life depended on a year-round natural water supply. San Luis Obispo was such a place. In essence our humble watershed forms an ancient mini ecosystem.

As demonstrated above, a watershed funnels all the water in a certain area to a common point. Over a certain land area, the topography of the Earth determines the watershed for that area. As discussed earlier, water flows downhill. Along a path purely influenced by gravity. It may be hard to judge this descending route by observation, but water traces the path clearly. As previously reviewed, water cannot overcome hills. So, certain geographical areas form watersheds dictated by the topography of the surrounding land. All land that funnels water to the same discharge point lies in the same watershed. Watersheds range in size from a few acres up to 2.4 million square-miles. Often people refer to watersheds as drainage basins. On Earth, land-based life-forms evolved around watersheds. Surprisingly, the modern San Luis Obispo citizens rely little on their namesake creek for water, instead choosing to import water through an extended water supply chain that leads to other watersheds. By examining the map at the right, one can easily spot the watersheds of the San Jaquin and the Sacramento Rivers, the giant oblong bowl in the middle of the state. This large watershed forms the delta east of San Francisco and the famous bay where the Golden Gate bridge stands.



The overwhelming source of water in California is snow in the Sierra Nevada Mountains, shown to the right of the map.

SIZE –INFLUENCES THE AMOUNT OF WATER THAT A WATERSHED CAN TRAP – THE BIGGER THE BETTER TOPOGRAPHY – DETERMINES WHERE WATER FLOWS WHEN IT REACHES LAND

List of the Largest River Drainage Basins in the World

RIVER	OUTLET	SIZE IN SQ. MILES
Amazon River	Atlantic Ocean	2,400,000
Congo River	Atlantic Ocean	1,440,501
Nile River	Mediterranean Sea	1,256,706
Mississippi-Missouri River	Gulf of Mexico	1,236,371
Ob River	Arctic Ocean	1,151,547
Yenisei River	Arctic Ocean	986,255
Lena River	Arctic Ocean	890,638
Niger River	Atlantic Ocean	873,263
Ganges–Brahmaputra	Bay of Bengal	772,000
Amur River	Pacific Ocean	745,160

Source Wikipedia



The Great Salt Lake in U.S.

As the list above demonstrates, most large watersheds reach the ocean. However, in previous modules, we recounted that some the water in some watersheds becomes entrapped on land in pools referred to as endorheic (terminal) basins. In Africa, the largest such basin, the Chad Basin, fills Lake Chad at the junction of Chad, Nigeria, Niger and Cameroon. Like some other terminal lakes, Lake Chad contains freshwater. The lake provides an important source of freshwater fish for the area. Like many similar lakes, Lake Chad suffers shrinkage due to humans diverting the natural water flow that fills the lake. South America hosts another impressive terminal lake, Lake Titicaca. Called the highest navigable lake in the world, standing at 12,000 ft. elevation, the lake contains mountain-fed pristine waters and has also been slowly sinking in recent decades, while suffering growing pollution problems.

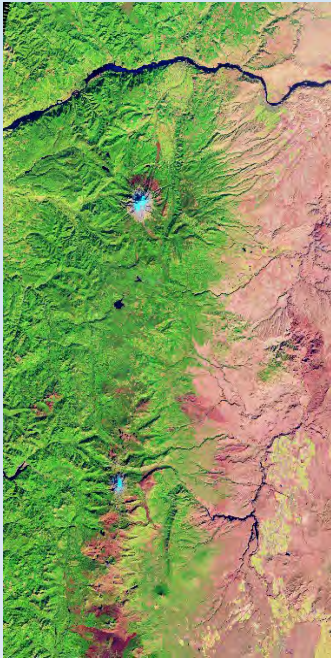
The sign pictured below stands on Highway 101 in Central California, just north of San Luis Obispo. HydroFathom often uses this sign to demonstrate a point between two watersheds. If water falls in front of this Cuesta Pass sign, then the water flows into the San Luis Obispo Creek watershed and the creek. However, just a behind this sign, past the peak of the road, the watershed switches to the Salinas River.



Consequently, rain drops falling from this sky, separated by just a few feet, returns to the ocean by two different routes. In front of the green sign, water will slide into the creek, then go steeply downhill and return to the ocean about 17 miles away. Under the right conditions, the creek route may be completed in one day. Just behind, by the yellow sign, water flows to the Salinas River watershed which runs 140 miles north reaching the Pacific Ocean near Monterey. The second longer river trip might take months to complete. The San Luis Obispo creek meets the ocean at Avila Beach and the Salinas River at Salinas River State Beach. These two points lie 148 miles apart. A short summary: rain falling by the green sign flows to the ocean differently than water falling on the yellow sign in back.

The Water Within

LOCATION/PRECIPITATION



In real estate they stress location, location, location, but for watersheds location matters too. Look at a map of U.S. precipitation. The real rainy states line the Gulf, near a large oceanic body of water. The gulf manufactures storms due to a shallow depth that allows higher ocean water temperatures. Any land near the gulf receives prodigious precipitation due to gulf generated storms and hurricanes that reach land. Sometimes in these modules, we refer to rain. However, we really mean snow and rain. Snow changes the precipitation equation since it provides natural frozen storage. The slow melting of snow extends the time that water lingers and produces water flow during dry periods. Earthly locations near mountain ranges, lying far north have natural advantages for snowfall.

Mountain ranges also deplete areas behind them by a phenomenon called rain shadow. The satellite picture above shows the sodden western section of Oregon where the Cascades face the wind. The blue dot on the map shows Mt. Hood. The brown eastern side represents Oregon's high dessert. The big island in Hawaii possesses a profound rain shadow, with the windward side of the island receiving up to ten times the rain of the other side of the island. The winds off the Pacific Ocean blow mostly west to east, driving moisture rich air against the Cascades and Sierra Nevada Mountains, creating location among the snowiest in the United States. The largest rain shadow in the world stands behind the highest mountains range in the world the Himalayas which wrings water from Indian Ocean air before it can reach the vast Gobi Desert or the Tibetan plain.

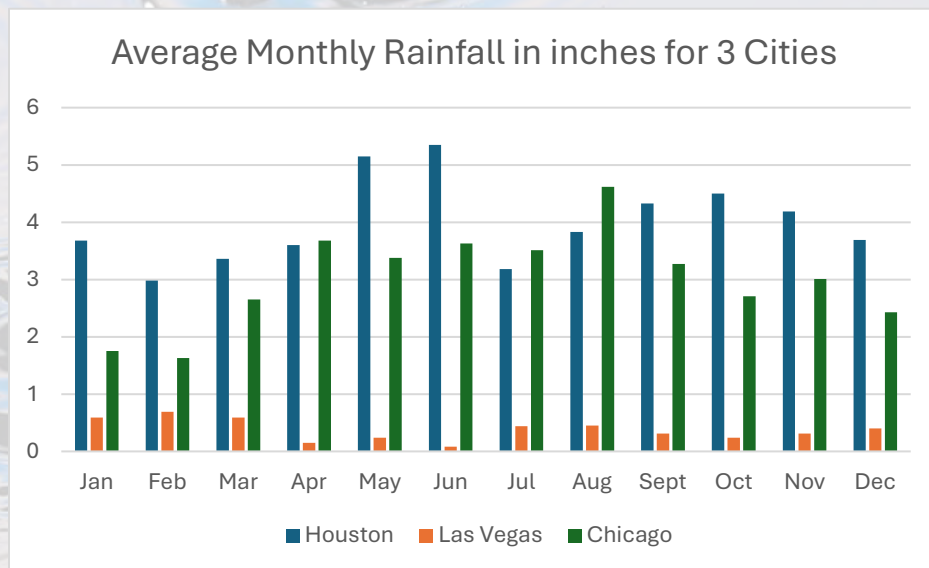


The Water Within

A quick look at the snowiest places in the U.S.,
per Wikipedia:

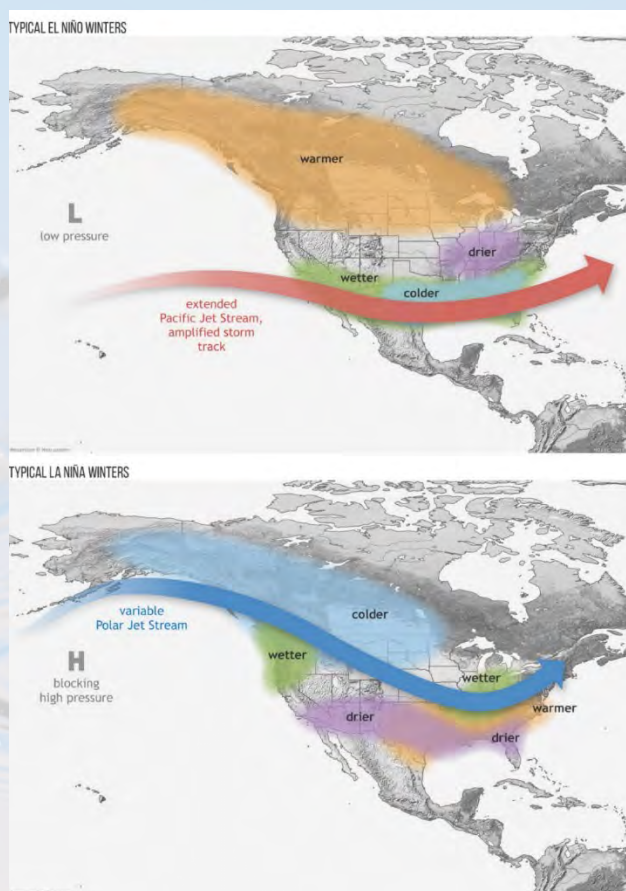
Location	State	Avg. Yearly Snowfall	Elevation
Mount Rainier	Washington	645"	5400'
Timberline Lodge Ski Area, near Mt. Hood	Oregon	551"	5960'
Alta	Utah	457"	8730'
Soda Springs, near Truckee	California	412"	6885'
Valdez	Alaska	314"	95'
Mount Washington	New Hampshire	282"	6270'
Climax	Colorado	274"	11350'
Burgess Junction	Wyoming	256"	8050'
High Market (West Turin)	New York	214"	1816'
Herman	Michigan	214"	1667'

Note that seven of the ten snowiest places listed above lie at upper elevations in mountain ranges. The low-lying Valdez, AK receives the fury of the Bering Sea storms that first approach land along the Alaskan coast. High Market, NY and Herman, MI sit in cold states that receive lake effect snow.



The Water Within

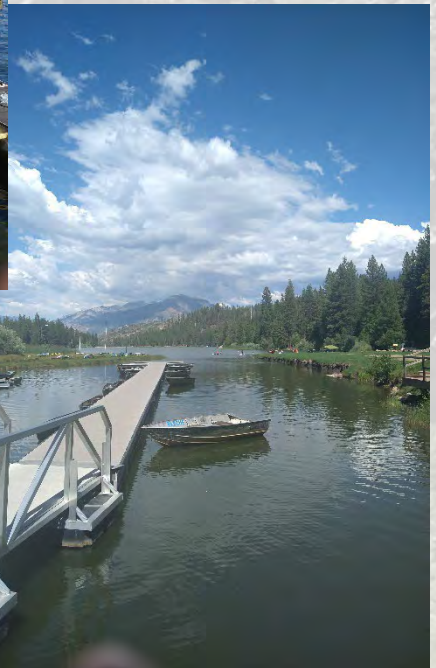
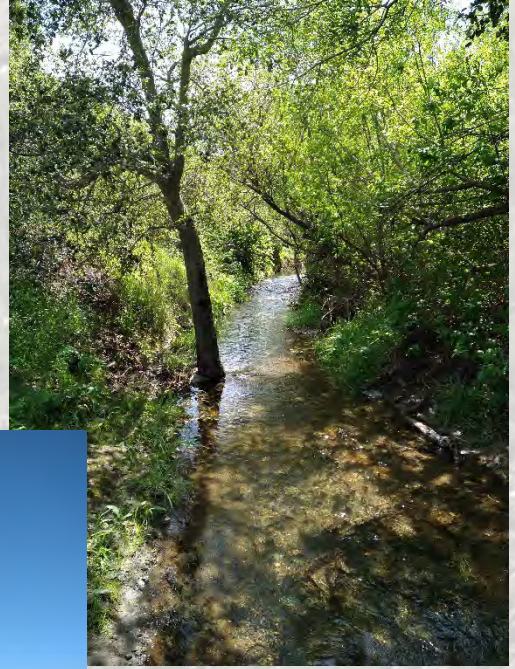
The oceans ultimately supply all the water for precipitation and thus greatly influence the precipitation patterns. The jet stream, in the United States, flows in the upper atmosphere from west to east, bringing moisture across the country. The line of the jet stream nearly traces the precipitation patterns in the U.S. The map below, from the NOAA, shows how precipitation patterns change according to the temperature of the Pacific Ocean.



GOOGLE: RAIN SHADOW

The Water Within

HEADWATERS



The Water Within

Few words needed

At the end of a watershed farthest from the mouth headwaters form, the far borders of a watersheds. Mostly, watersheds lie at higher elevation. Many water seekers arrive at headwaters to discover resplendent, bewitching locales which demand extended observation. In seeking headwater, one looks for the source, the origin of some flow using a simple plan, follow the water flow in reverse. Scamper upwards to some unknown. Eventually, at the headwaters, the climb ends. Awe arrives. Here, the clear rippling waters merge with the fragrant spotless air. Journeys pause at the headwaters, the work mostly over, the downhill portion left, the easy part. Up here, check your watch, “how long can I stay.” Watersheds need few words. Their pictures tell the story. At HydroFathom we have a concise Waterism... **Headwaters Rule.**

Fathom this: When it hasn't rained for months,
Why does the stream still flow?



To picture a watershed, examine a leaf, a big broad leaf, laid flat. At the stem would be the mouth. Follow the stem into the leaf and it branches into several sections. Watersheds follow this pattern in reverse. The outer edges of the leaf represent the headwaters, and the end of the main stem, the mouth. Most watersheds have widely dispersed sources picking up water across their footprint. Place a large leaf flat in your hand then slowly raise your fingers. This could be the shape of a watershed. In this configuration the tip of the raised finger would be the point we headwaters gather.

Another type of headwaters exists because headwaters often incorporate springs. Springs usually contain ground filtered clear, cobalt waters that dazzle the viewer. Some springs run especially clear. One of the largest springs in the nation, Silver Springs, emerges near Ocala, Florida, vaulting from the porous ground powered by steady tropical rains. These artesian springs form when higher land absorbs water and it flows to lower land and springs back out of the ground. The Silver Springs of Ocala feed the Silver River headwaters. Silver Springs produce 500-million gallons of flow per day, making it among the largest in the world.



Google: Glass Bottomed Boats

The Water Within



Simply Google headwaters and select images. You'll see.

Headwaters, simply the birthplace of waters, where streams, creeks, and rivers originate. Scattered all along watersheds, headwaters collect themselves into mighty flows.

The most pristine of all waters, headwaters evade soiling until later in their downhill slide. Then, later, like a once clean shirt, they eventually get dirty, and need the cleansing afforded by evaporation so they may later become headwaters again.

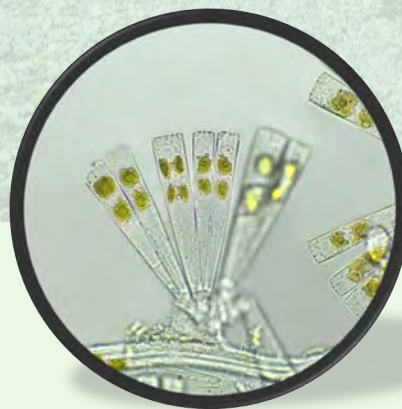


The Water Within

MOUTHS/ESTUARIES/EUPHOTIC ZONE/CARBON SINK

Watersheds flow somewhere. Watersheds possess a release point, often called the mouth. Most watersheds, through some pathway, eventually lead back to the ocean. As they approach the ocean, watersheds flatten, slowing the pace of the water and expanding the area covered by water. These areas called estuaries or deltas host a variety of plant life that, like terrestrial plant life, help remove CO₂ from the atmosphere, trapping greenhouse gases. Overall, the ocean traps more carbon than all the forests on earth. Most of the plant life in the ocean lives in shallow parts, less than 600 feet deep, where the sun reaches the bottom. As river nutrients flow into this zone, they can spur blooms of phytoplankton. Phytoplankton form the base of the underwater food pyramid. They trap carbon as they quickly grow, die, and sink to the bottom while entombing the carbon in their bodies.

The need to generate electricity, grow crops, and raise livestock directly competes with the needs of delta farmers, fish populations, and aquatic birds. With dams and their associated infrastructure, we block silt and divert water flows away from river mouths threatening downstream life. Humans directly intervene to alter decisions once made by nature and luck, affecting both plants, animals, and humans. Some watersheds do not lead to the ocean. They flow to inland locations called terminal lakes. Water may soak into the Earth. We explore terminal lakes next section and underground water in our Aquifer Section.



The Water Within

EXPLORE FURTHER AND TO SEE THE DYNAMIC LIFE POWERS OF WATER

GOOGLE SATELLITE MAP THESE RIVER MOUTH LOCATIONS:

- ❖ YUKON RIVER - NUNAM IQUA - ALASKA
- ❖ MISSISSIPPI RIVER – PILOTTOWN - LA
- ❖ ST. LAWRENCE RIVER - QUEBEC CITY - CA
- ❖ NANTICOKE RIVER/CHESAPEAKE BAY - TANGER SOUND - VA
- ❖ PADMA RIVER, DHAKA, BANGLADESH

FOCUS ON THE GREEN IN OR BELOW THE WATER

EXPLORE JUST OFF THE COAST AND IN THE LAST MILES OF THE RIVERS

OH, THE DESTRUCTION!



Did you know? The food that you eat can influence the ocean. Yearly in the Gulf of Mexico, a large dead-zone forms over about 5,000 square miles. The Mississippi and the Atchafalaya rivers discharge into the gulf. Flows from upstream watersheds carry run-off from cities and farms and excess nutrients supplied by fertilizer and pollution. The nutrients spark an overgrowth of algae that depletes oxygen from the gulf waters forming a “hypoxic” zone. In this zone, fish and other marine life struggle to survive, often dying. Many fertilizers use ammonia as a base. Excess ammonia can degrade into nitrite compounds. Nitrites pose hazards to subterranean water and ocean water. Water flowing down the Mississippi may have fallen from the sky in Montana or Pennsylvania, among many places. Showing the range of tracing the problem. An organization in far-away Iowa, Wings2Water strives to reduce farm run-off to help improve local drinking water quality and improve the health of the Gulf of Mexico.

**To see the powerful beauty of nature, Google:
satellite images of phytoplankton blooms**

The Water Within

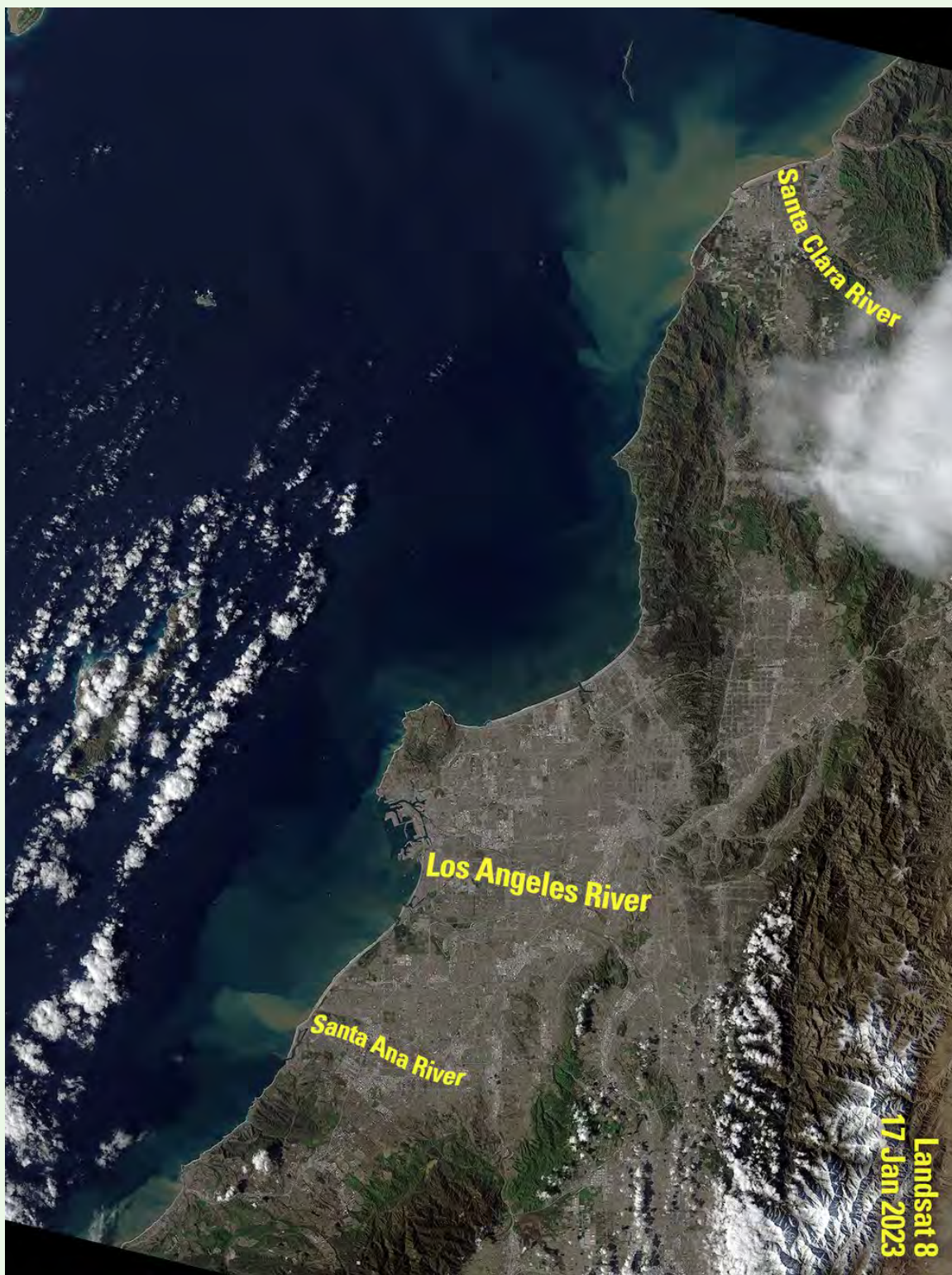


The Mekong River, a narrow steep Asian watershed ending at the ocean in Vietnam, currently experiences human-caused stress that has altered the ancient food balance along the waterway. One of the many mighty waterways driven by Himalayan snow, the river starts at 17,000 feet above sea level, near Chamdo China. Damming of the Mekong causes silt to become entrapped behind the dams, starving the downstream estuary of fertile soil flows, silt, which historically has renewed the delta yearly. The diminished river flow also allows the ocean to encroach inland flooding ancient delta farmlands where 10% of the world's rice supply grows. Once the land becomes salinized by flooding, it may be ruined forever. Reuters in a December 2022 article states that in 2007, 143 million metric tons of silt flowed into the delta, in 2020, 47 million tones reached the delta and Reuters predicted that by 2040 only 5 million tons of silt would reach the delta, a reduction of 138 million tones in twenty years, enough silt to cover 20,000 sq. miles yearly. China, Laos, Thailand, Cambodia, and Vietnam all dam the Mekong. Relatedly, the diminished silt flow also reduces the algae growth needed to supply the bottom of the delta aquatic food chain, thus reducing the fish population in a river that traditionally fed millions. Even tangential industries like construction suffer due to the reduced deposits of sand.

To see silt in action, Google Map Chamdo China, which lies near the origination of the Mekong. There near the Karou District, two rivers with different color silts merge

The Water Within

This USGS photo shows silt entering the Pacific Ocean driven by high run-off periods during the rainy season along the coast



TERMINAL WATERSHEDS



Since “endorheic” challenges pronunciation, HydroFathom usually refers to “terminal” lakes or watersheds. Terminal lakes often lie below sea level, like Lake Manly at Death Valley, an ethereal lake that only briefly, occasionally forms, shown above. The Great Basin in the western U.S. forms the greatest collections of endorheic basins in the world, spanning from the Great Salt Lake west to Lake Tahoe and south to the Salton Sea

Endorheic Watershed - An endorheic basin is a drainage basin that normally retains water and allows no outflow to other, external bodies of water; instead, the water drainage flows into permanent or seasonal lakes and swamps that equilibrate through evaporation. Endorheic basins are also called closed watersheds.

Source: Wikipedia



A terminal lake stands at the lowest point on earth, the Dead Sea. Some lakes accumulate salt from the surrounding land. The salt accumulates in the lake water and kills most marine life, making them “dead.” Other terminal lakes, lacking salt, collect fresh water and eventually any silt sinks to the bottom making them strikingly clear. One can see down into the water seventy feet at Lake Tahoe where the water approaches 99% purity. People often call terminal lakes seas, as in the Salton, Aral, Caspian and Dead Seas. However, all these so-named seas are terminal lakes.

The Water Within

Near the headquarters of HydroFathom lies the Carrizo Plain where two mountain ranges trap water over 2000 feet above sea level.

One of our favorite terminal lakes, Soda Lake:



Terminal Lakes often accumulate salts and mineral earning names like Soda Lake, Salt Lake or Badwater

**A HEALTHY ENVIRONMENT OR UNHEALTHY? – EXTRA ACTIVITY –
GOOGLE THESE LOCATIONS AND EXPLORE THEIR HEALTH:**

- ❖ ARAL SEA - BETWEEN KAZAKHSTAN AND UZBEKISTAN
- ❖ LAKE VAN – TURKEY
- ❖ QINGHAI LAKE – CHINA
- ❖ LAKE TURKANA – KENYA AND ETHIOPIA

The Water Within

URBAN/RURAL CONNECTION



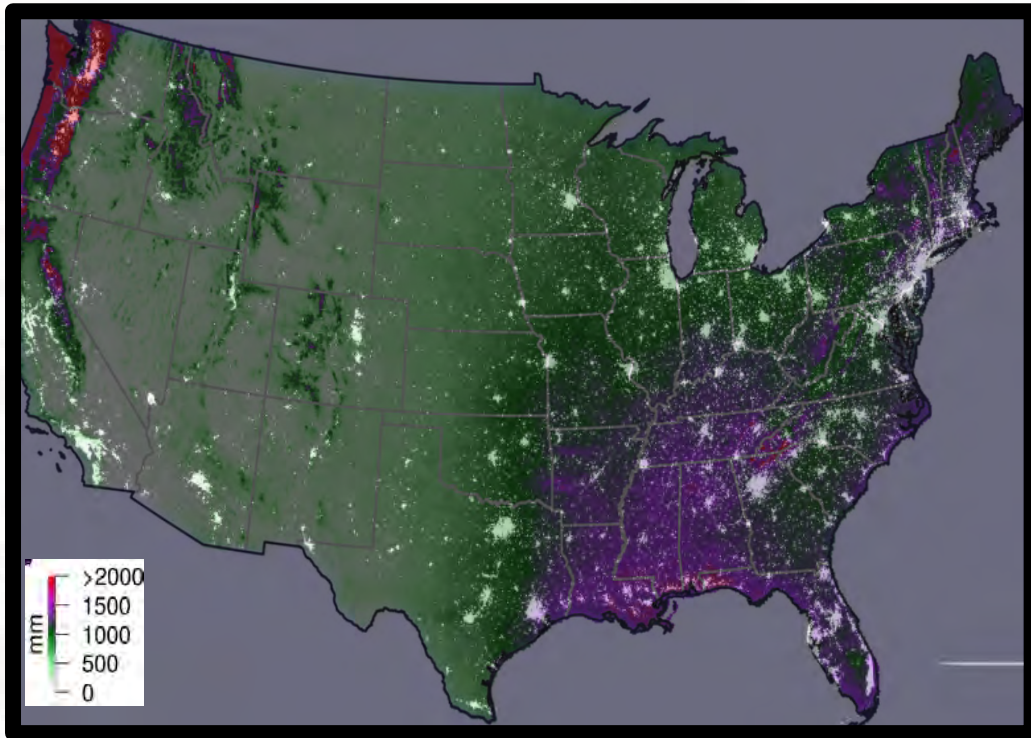
A previous module profiled the east/west divide in the United States. Similarly, an urban/rural divide also appears in the United States. Flowing water forms a constant connection between the two areas. Water collects along the often-rural headwaters of a watershed. Downstream, after these waters form into rivers and streams, humans gather in populations centers purposely positioned near these constant water supplies. Water will flow into a city or town and then flow out into the surrounding country traveling into sparsely populated localities again. Then, the sequence repeats, sometimes happening multiple times along a single watershed, city, country, city again. The cities use freshly arriving water and often soil the downstream water due to factors like urban storm water run-off laced with plastics, oils and tire particles. Rural areas pressure water supplies mainly in relation to agriculture. All the water contamination from both populations eventually arrives at the ocean or sinks into groundwater, making what happens in the city, important in the country and vice versa.

How Cities Stress Waters	How Rural Areas Stress Water
Sewer Discharge	Animal Waste Run-off
Strom Water Run-off	Fertilizer Run-Off
Chemical Spills	Silt Flows from De-Forested Areas
Fuel Spills	Mine Leach Fields

Cities themselves strangely interact when the outlet of one city’s sewer plant lays upstream of the inlet of another downstream city’s drinking water plant.

The map below depicts rainfall patterns (colors) of the U.S. projected over a dot map (white dots) of the U. S. population and reflects the interconnection between precipitation patterns where humans live.

Precipitation vs. Population



Urban centers that stand out as receiving little rain yet have substantial populations, include Phoenix, Las Vegas and southern California. Previous modules touched on the powerful infrastructure enabling SoCal life. Vegas similarly relies on infrastructure, especially the nearby Hoover Dam. Old maps list a wide swathe of land in the western U.S. as the “Great Desert.” Early Mormon settlers encamped to this area and founded another arid municipality, Salt Lake City, not by relying on the undrinkable lake, but instead on the mountain-fed rivers and creek that fed the lake.

**TRY TO TRACE THE ROUTE OF THE MISSISSIPPI ON THE
ABOVE MAP AND IDENTIFY MINNEAPOLIS, ST. LOUIS,
AND NEW ORLEANS**

The Water Within

ONE DROP SHOWS THE WAY

OH! THE PLACES THAT YOU CAN GO



A Waterism from HydroFathom states that, “one drop shows the way.” This means that if you know where a drop falls from the sky, then by examining elevation, you can determine the path that the water would naturally travel. Watershed maps reflect these routes. If rain or snow falls in a watershed, it will be directed to the mouth of the watershed. Though much water evaporates, and other water sinks into the ground, much of the water that lands in a watershed flows downstream to the mouth, making it possible for any particular drop to trace the path for all others.

The Water Within

A drop of water can fall in Wyoming and be drunk in Beverly Hills. Google Maps says the trip from Green River, WY to Los Angeles, CA would take 831 miles and over 12 hours by car. Here's the water drop directions.



Fall from the sky on the town of Green River, Wyoming, then head to the Green River. Go with the flow downstream to Lake Powell where the Yampa River joins. Proceed through the Glen Canyon Dam power turbines then continue down the Colorado and head towards the junction of the Little Colorado River where the main channel heads sharply west towards Las Vegas. Travel through Lake Mead and on past the turbines at Hoover Dam. Turn south towards Lake Havasu and then stop at Parker Dam. Divert into the MWD Aqueduct for a trip to L.A. Arrive at the first of five pump stations which lift the flow and send it over hills. About 240 miles after entering the aqueduct, travel down a short pipeline and emerge at Lake Matthews in Riverside County. There MWD handles logistics and provides gentle cleaning then transport to Beverly Hills. Join the Beverly Hills water supply and emerge from the tap and into a pitcher at a suitably ritzy restaurant. Wait for consumption by a random well-heeled citizen. Later, after leaving the consumer, take the sewers to a treatment plant near El Segundo which leads to the open ocean. Absorb some California sun and wait for another trip.

The above watery trip covers about 1,000 miles and when moving about 1 mph would take about 40 days, sky to ocean, Wyoming to the Pacific Ocean by natural routes and human intervention. Actual travel time may take longer. One factor to consider with water travel rate is slope, how many feet the watershed drops over distance. The steeper the route, the faster the travel. We can misjudge travel time by forgetting water travels constantly, even as we sleep. In a stream or creek, you can watch something floating by in the water. The speed of the floating item can be used to estimate the current speed of the water. Even water moving just one mile per hour covers 168 miles in a week.

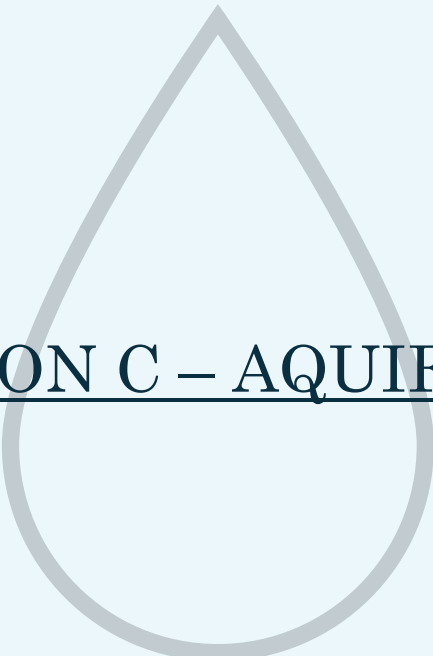
SECTION C

AQUIFERS



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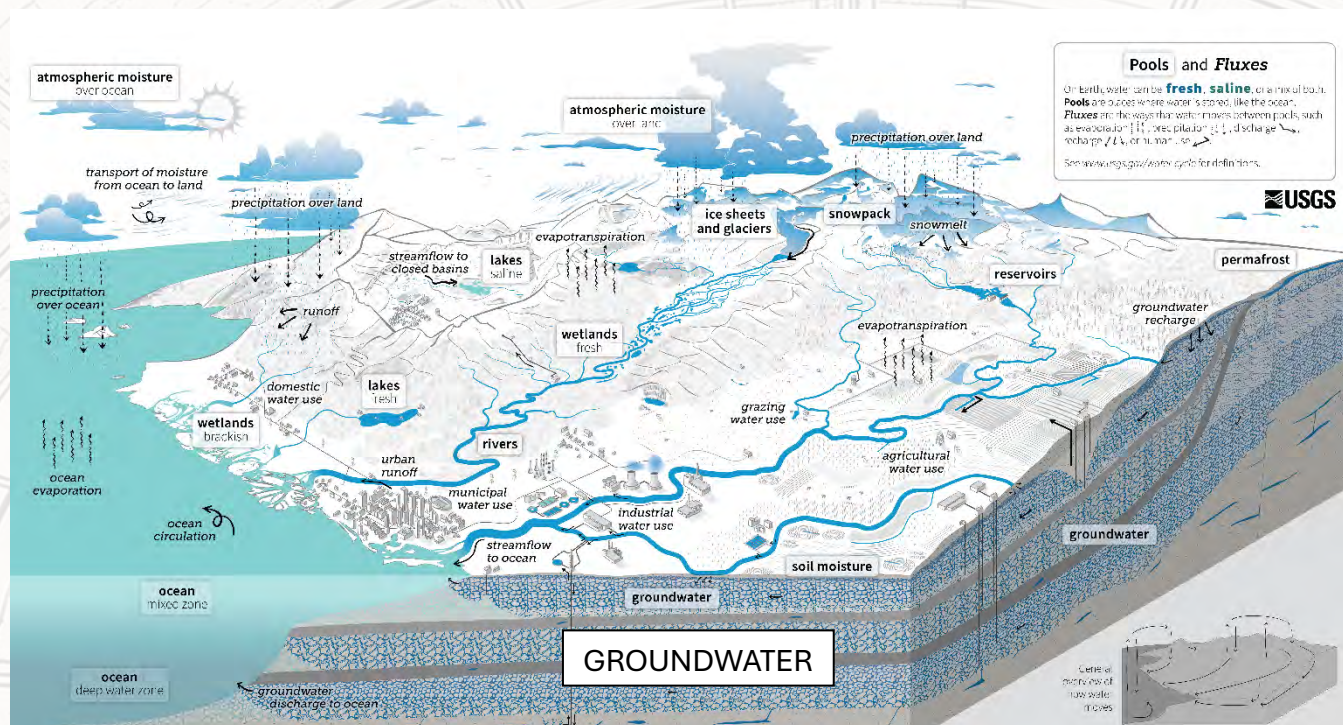
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SECTION C – AQUIFERS

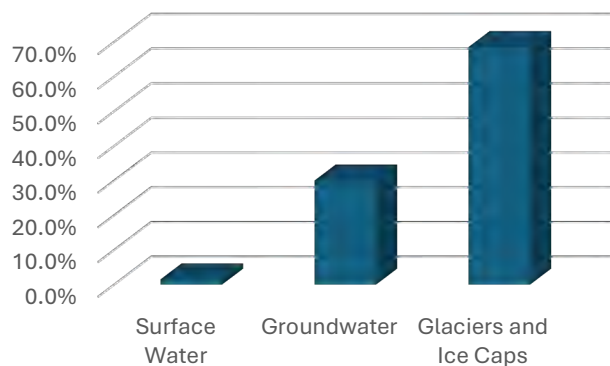
The Water Within

UNDERGROUND SEAS



AQUIFERS FORM WHEN WATER ACCUMULATES IN POUROUS SOIL BENEATH THE GROUND

Breakdown of Freshwater on Land

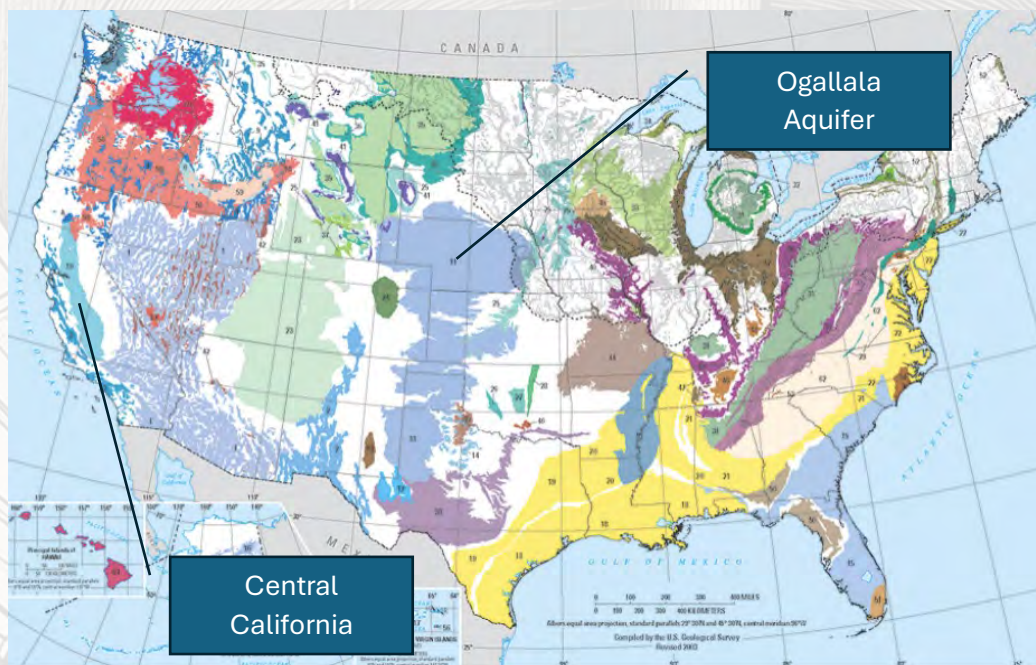


The ratio of saltwater to freshwater on Earth is about 50:1. So, a thin slice of the Earth's water nurtures all terrestrial life. Of this life-giving freshwater, thirty times more lies underground than above. In the last 150 years humans began heavily tapping these hidden aqueous stashes by using the power of mechanical pumps.

The Water Within



Substantial U.S. agricultural production relies on aquifers. The map below, supplied by the USGS, shows the major aquifers in the country. In the U.S., two notable aquifers face considerable peril because humans remove water from them faster than they can be recharged. The large aquifer underlying central California and the midwestern Ogallala Aquifer help feed not just the United States, but indeed much of the world, yet the water levels in both pools steadily drop every year.



The Water Within

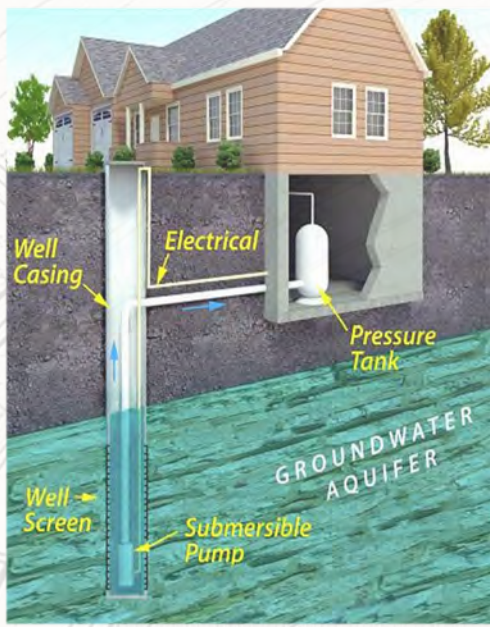


Over the last decades, aquifer depletion led to a rash of legislation sponsored by a swarm of government agencies hoping to eliminate over drafting of aquifers. California now requires overdraft mitigation plans from water users and Nevada is buying up water rights from farmers to reduce the number of farms using groundwater. Still, demand for perishable groundwater still mostly increases over time.

According to the National Ground Water Association,

As supplied by the Orange County Water District:

- The amount of available groundwater is 20 to 30 times larger than all U.S. lakes, streams, and rivers combined.
- 44% of the U.S. population depends on groundwater for its drinking water supply.
- 53.5 billion gallons (446 billion lbs.) of groundwater are used for agricultural irrigation each day. In 1990 that number was only 2.2 billion.
- The largest U.S. aquifer is called the Ogallala Aquifer, which underlies 250,000 square miles stretching from Texas to South Dakota.
- California water users pump 10.7 billion gallons of groundwater each day, a third more than the second-highest state, Texas.



A later module in this section explores the energy required to access groundwater. Once humans possessed the geological tools to deeply probe the Earth's crust, they realized the potential of this hidden fluid. Wells, originally hand operated, made life in select parched locations possible, expanding habitat options. Tapping aquifers and bringing the water to the surface could not only feed houses located far from natural water sources but could allow pump-driven agriculture. The coalescence of emerging ideas and farming techniques led to a new rural agrarian lifestyle amongst formally unwelcoming locales. This lifestyle depends on aquifers, energy, and mechanical pumps.

According to the USDA, the top five states ranked by acres under irrigation are: Nebraska, California, Arkansas, Texas, and Idaho.

Yearly, seventy percent of the water pumped from the ground goes to agriculture. In an earlier module, HydroFathom introduced our concept of, "manufactured life." Aquifer fueled agriculture demonstrates the interconnection between the intervention of humans in the natural water cycle and the explosion of human-favored life forms. According to the Groundwater Environment Facility, groundwater supplies 42% of the water for crops worldwide. Underground water extraction helps wet a worldwide agriculture machine that powers the daily slaughter of 900,000 cows, one million goats, and four million pigs. To analyze this production, imagine that every day, the 900,000 cows were led to the same slaughterhouse. A single-file bovine line containing almost a million cows would stretch from Kansas City to New York City. The beef line would need to march into the factory at 50 miles-per-hour to pass through in one day. If one theoretical factory could butcher all these cows daily, the beef products and byproducts would require one thousand trucks per hour to ship the food and remove the waste.



SIZE AND DEPTH



Aquifers form when water trickles through soil and sinks deep into the ground. The deepest aquifers reach up to several miles underground. However, humans mainly tap the underground water that lies less than 1000 feet below ground. The largest aquifer in the world, The Great Artesian Basin in Australia, stretches across 650,000 square miles, lurking below the surface of about 20% of the country. Several factors influence the collection of water below ground and the holding capacity of an aquifer. Porous soils containing small rock and clay provide a perfect combination for aquifer formation. Sand, gravel, clay and silt form most of the soil in the largest aquifer in the U.S., the Ogallala. The depth of this subterranean pool averages ninety-five feet but can reach 800 feet.

To Explore the Ogallala, Google images of:
Depth Map of the Ogallala Aquifer

Note: The areas with great depth can most sustain agriculture

Surprisingly, an enormous aquifer, the Nubian Sandstone Aquifer System, lurks beneath sections of the dry Saharan desert. Here is a sampling of some large aquifers, one from each continent:

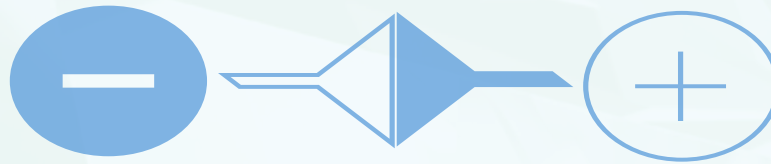
- o The Guarani Aquifer - South America
- o Northern Great Plains Aquifer, - North America
- o Lake Chad Basin – Africa
- o Canning Basin – Australia
- o Tungus Basin – Asia
- o Paris Basin – Europe



The Water Within

PRECIOUS/RENEWABLE/EXHAUSTABLE

An outstanding video series made through a collaboration involving USA Today, The Desert Sun, and The Pulitzer Center on Crisis Reporting details the hazards of overtaxing aquifers. The 2015 video series titled, Pumped Dry: The Global Crisis of Vanishing Groundwater, explores locations throughout the world experiencing groundwater depletion.



One video, detailing the stresses on the midwestern Ogallala aquifer, sports a byline titled, “Race to the Bottom.” Yes, like a soup bowl, an aquifer contains a bottom which can be reached. Every aquifer receives some recharge each year from rain or snow falling on the land above. Yet the amount of yearly precipitation limits the rate of aquifer replenishment. Like a checking account, if the withdrawals exceed the deposits, then an overdraft occurs. Ancient water, fossil water, stored for centuries, helps to balance the yearly extractions and recharges. However, eventually the primeval water bank may run dry.



PUNJAB

The organization Saving Punjab details that this precious aquifer, which feeds millions, faces severe depletion within the next twenty-five years. The organization lists the following factors that influence over-extraction of aquifers:

- Human Developed High-Yield Grains
- Introduction of Chemical Fertilizers
- Development of Infrastructure to move Groundwater

Names of California Aquifers: Pajaro Valley, Delta-Mendota, Santa Cruz, Mid-County, 180/400 Foor, Westside, Tulare Lake, Paso Robles, Los Osos, Cuyama Valley, Oxnard, Pleasant Valley, Borrego Springs, Indian Wells, Kern County, Tule, Kaweah, King, Madera, Chowchilla, Merced, Easter Sierra.

The Water Within

The Jet Propulsion Laboratory in 2015, referencing studies by UC Irvine using NASA GRACE data stated that a third of the largest groundwater basins on Earth are being rapidly depleted by human use.

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Education purposes only: HydroFathom maintains no position on the consumption of carrots

In 2015, the state of California requested that the state Department of Water Resources evaluate the state's aquifers for over drafting. The legislature mandated specific evaluations by passing the Sustainable Groundwater Management Act. Essentially the government wished to know which of their aquifers risked being emptied by over pumping. Certain activities extract groundwater faster than it can naturally replenish from precipitation and this threatens future water supplies. Major water users in each groundwater basin in California needed to form an organization to manage pumping from individual aquifers and develop a plan to conserve the water in the basin while assuring their long-term viability. HydroFathom recently visited one of the basins declared "critically over drafted" by the Department of Water Resources. A mitigation plan for this basin required that current water users slow the rate of yearly aquifer depletion. The plan development led to local squabbles over water rights. The sign shown above came from the Cuyama Valley where various farm interests, citizens, and corporate interests struggle to reach a water usage plan consensus that protect disparate interests.

The Water Within

LIFTING REQUIRES ENERGY

Imagine going to the top of the Empire State Building. Sorry, the elevator's out, too bad, you need to take a case of water to the top floor by the stairs. This would require considerable exertion. Toting a case of half liter bottles 1250 feet up from street level takes energy. The water in the case of bottles weighs about 50lbs. A physicist would say, lifting 50 lbs. 1,250 feet high means 62,500 foot-pounds of work occurred. Using a converter on the internet calculates the energy for this water lift to 24 watt-hours. Examine another perspective:



Delivering a case of water
to the top of the Empire
State Building

=

The energy to burn a 100-
watt light bulb for 14.4
minutes



A small bathtub holds 40 gallons,
or over 300 lbs. of water

A previous module explained that sometimes water weight matters more than volume, especially when calculating the energy to pump water. In short, lifting anything heavy, like water, requires energy. Often professional water engineers refer to pumping plants as lift stations. These lift stations specifically boost water over hills while transporting water past higher elevations. Transporting water often simultaneously intermixes together waters of untold watersheds. The Water Chain needs energy to move water from where it fell to where humans desire. Well pumps move water from below ground to the surface. Fathom the half billion pounds of water lifted daily from aquifers to the surface. These water lifts require massive energy.

According to the National Groundwater Association, water is the most extracted raw material on earth. Also, the two largest groundwater extractors in the world are India and China, by far.

The Water Within

DRILLS AND WELLS

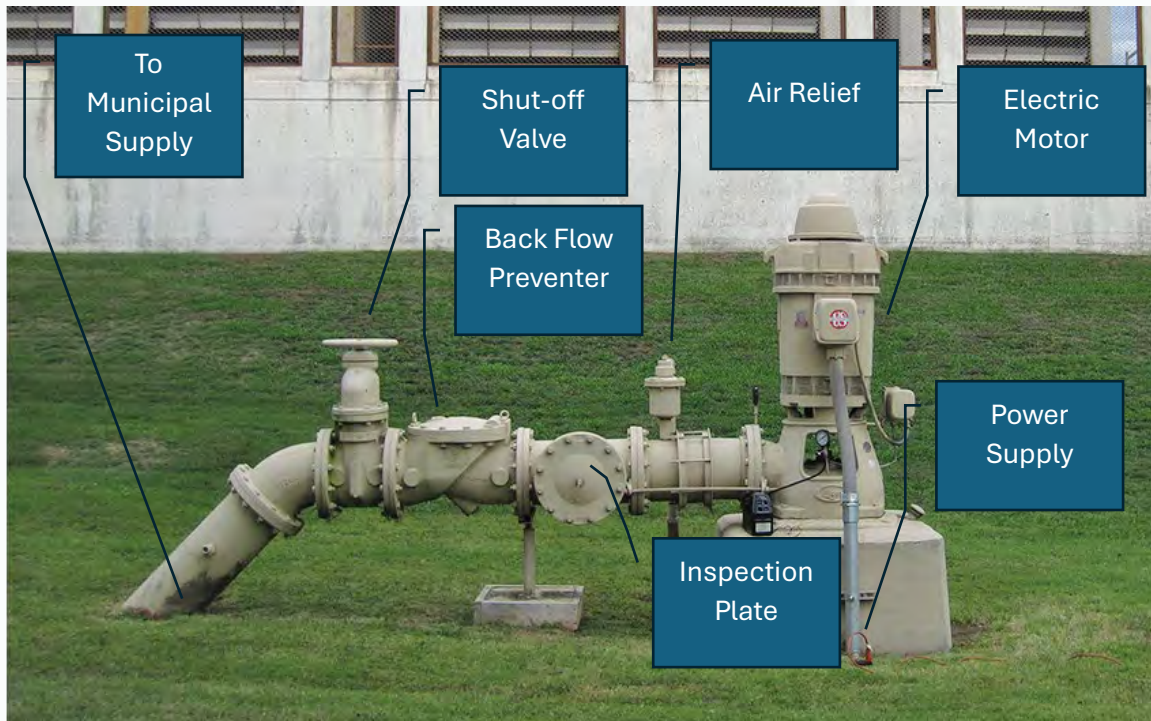


According to the National Groundwater Association, there are 15.9 million water wells in the United States. Over the last 100 years, drill rigs sank most of these wells.

The state of Michigan hosts the most domestic wells. Over 2.5 million residents of the state depend on a well for their daily water needs. The California Water Commission estimates between 7,000 and 15,000 rigs are drilled yearly in the state.



U.S. wells average about 100 to 200 feet deep. The holes drilled usually range from four to eight inches in diameter. After a drill rig bores this long cylindrical hole in the ground, a mechanical pump is placed atop the finished hole and connected to an electrical or engine-driven pump. After completion, many people barely notice these benign structures that dot the landscape and silently fill their drinking cups. Most pump systems mimic the system shown below.



Water wells freckle the rural U.S. landscape powering farming in areas that have the two elements of agriculture, land and warm weather, but lack rainfall. Wells and pumps tap aquifers to mechanically thrust the water to the surface and onto human-cultivated plants and to the lips of domesticated animals. In the picture below, an electrical line feeds each pump. Other pumps consume petroleum.



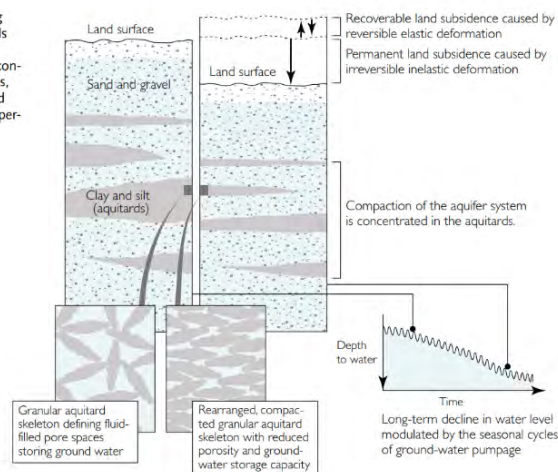
The Water Within

SUBSIDENCE

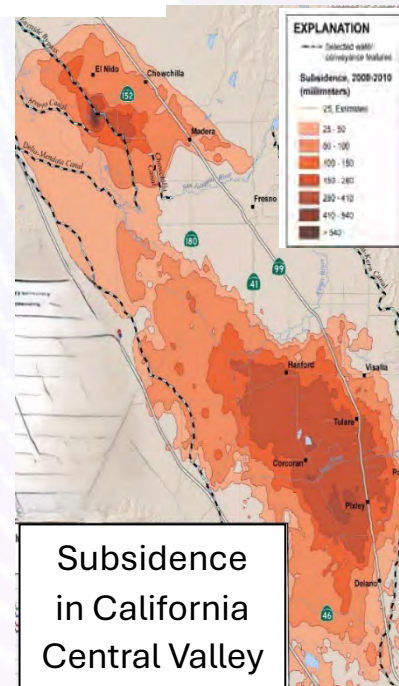


If you hold an apple in the palm of your hand and firmly push your thumb into the apple, then a slight dent forms. The surface deforms. Similarly, pumping water from below land dents the surface of the earth. Water underground helps to support the land above. Removing water from under the land allows the land to sag down into the ground.

When long-term pumping lowers ground-water levels and raises stresses on the aquitards beyond the preconsolidation-stress thresholds, the aquitards compact and the land surface subsides permanently.



In Arizona, the town of Wenden sank eighteen feet over the last eighty years according to local surveys. The local newspaper, The Copper Courier, reports that some Wenden residents blame the subsidence on water pumping at farms leased by an overseas group. Aquifer pumping in any region often leads to conflict with large users. Typical participants in the debate over water usage include government entities, large farms, small farms, urban areas, and individual homes. In California, one water usage collides with another as sinking land in the Central Valley damages aqueducts meant to run downhill to other users.



Views of Subsidence in the California Central Valley

Pictures from USGS



San Joaquin Valley subsidence causes buckling in an aqueduct as one type of water usage affects another

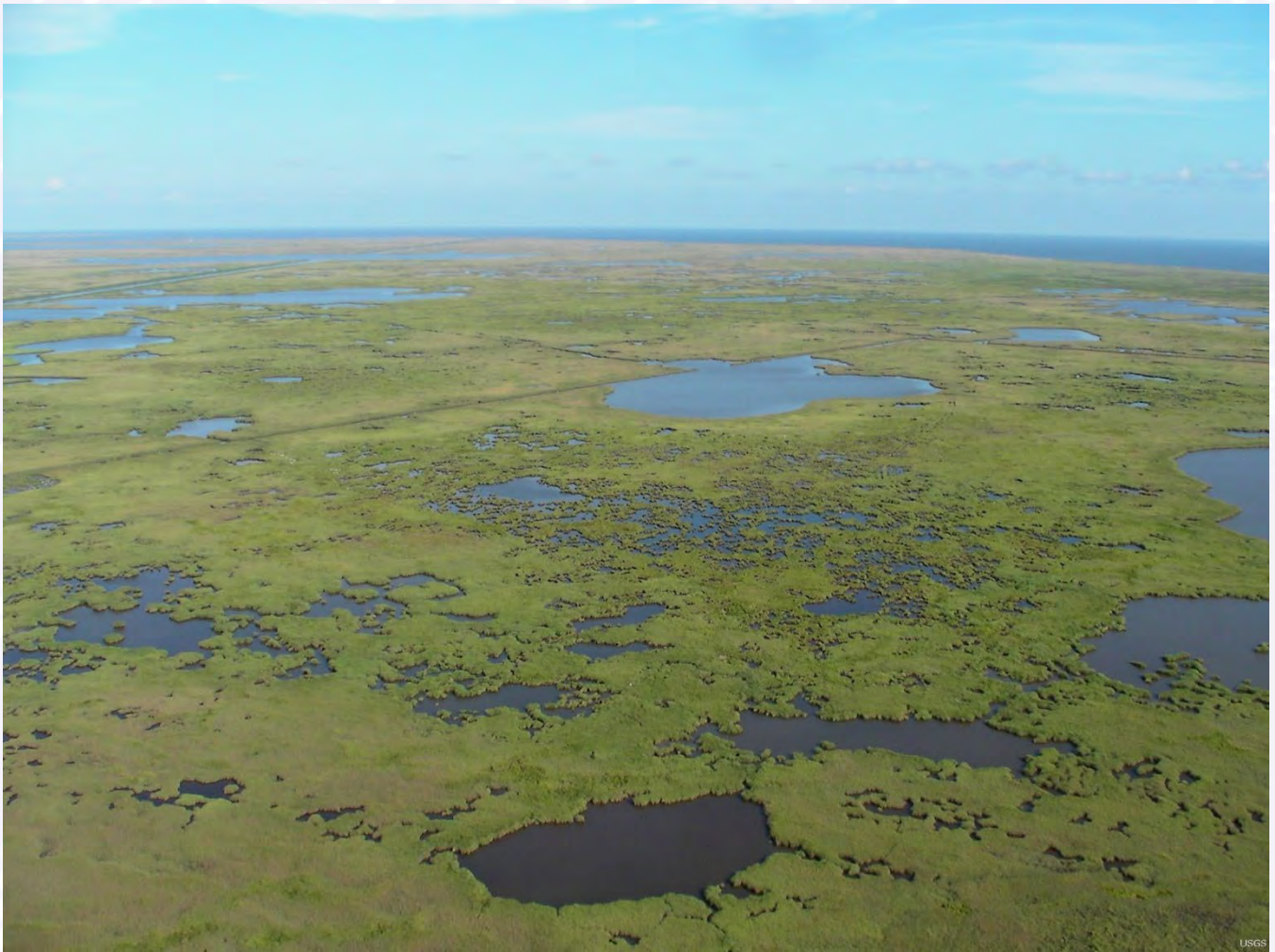


San Joaquin Valley subsidence from 1925 to 1977



More San Joaquin Valley subsidence, but from 1988 to 2016

The Water Within



A related type of subsidence affects river deltas across the Earth. The Delta Alliance recounts that delta subsidence occurs due to the reduction of alluvial flows that results from upstream water diversion. Without yearly land renewal, the ground slowly sinks. This leads to increased flood risk inland and saltwater incursion into once freshwater bays. Deltas also serve as an important food source, providing both fish species for consumption and areas favorable to rice production and other agriculture.

SUBSIDENCE = A SINKING FEELING

The Water Within

SECTION D

INFRASTRUCTURE



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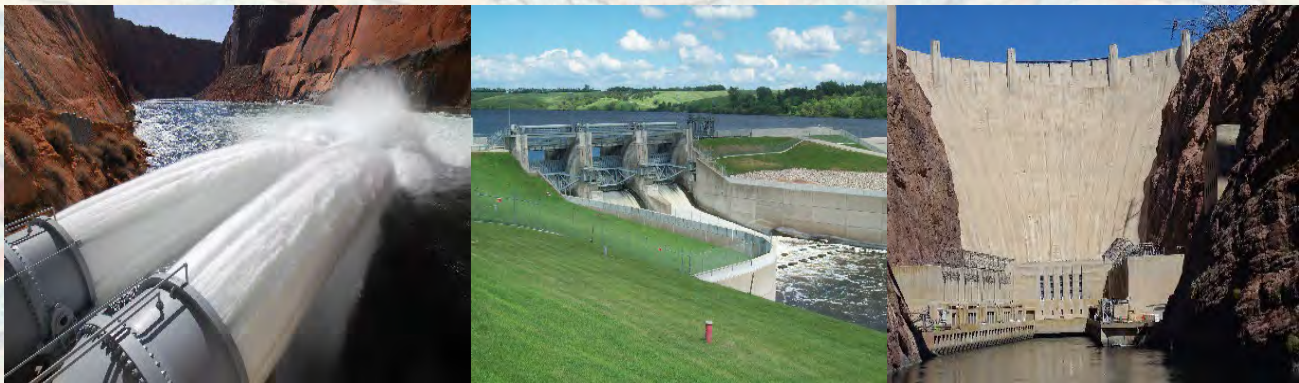
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SECTION D – INFRASTRUCTURE

The Water Within

DAMS AND RESERVOIRS



An elegant terrestrial interaction between sunlight and the ocean propels water onto “dry” land. Earth’s precipitation system, the water-cycle, starts when light ejects from the sun and barrels across space for eight minutes then strikes the earth. Immense solar gravity drives solar nuclear fusion which causes “natural” light to eject from the sun. The earth absorbs this energy. Since ocean water covers most of the earth’s surface, two-thirds of sunlight falling on earth plunges into the ocean somewhere. This happens constantly because a section of the earth always faces the sun. The comparatively diminutive earth heats slowly while circling about the much larger sun, simultaneously rotating about its axis, resembling a top spinning while relentlessly traveling round a circular track. The energy in sunlight warms the ocean and the air which causes water vapor to rise into the atmosphere. The earth’s rotation causes wind which forces humid air over “dry” land then atmospheric cooling produces rain and snowfall. When wind-driven moist air collides into mountains, it must climb up, towards frigid outer space which extracts heat and drastically cools the air. This cooling may result in sudden massive snowfall, and snow gathers at higher elevations, frozen water sitting in a natural fridge way up high.

Snow makes up a significant portion of precipitation that provides “fresh” (salt-free) water. The water-cycle naturally provides two essential services, it de-salts the water, and moves this water to a higher elevation which imparts energy to the water. When rain falls it barrels down watersheds and eventually returns to the ocean. Rain hurries back to the ocean. Snow lingers at heights daring the earth to warm and melt it, nature’s natural water stash. Eventually, the snow melts and water seeps back into the ecosystem, meandering to the ocean.

Humans long ago, maybe by watching beavers, learned that damming streams and rivers improved their access to water and allowed them to harness the energy in water. Currently, water lingers behind human dams, helping people access their daily water needs. Dams mitigate natural dry periods that can stretch into droughts. Snow supplements dams by gradually melting into water that flows into reservoirs created by dams. Rain provides sudden bursts that dams also capture. The best dams lay at higher elevations since damming water up high also ensnares the energy of the water being propelled by the ceaseless force of gravity which slowly tugs the fluid back to the ocean. The higher the water the more energy that one can extract. Water drove ancient water wheels and turns modern hydropower turbines alike. Without intervention water that reaches land would return to the ocean significantly quicker than if humans delay the return. Dams are the piece of infrastructure which improves water access and harnesses green energy. With ninety-thousand dams in the U.S. and eight-hundred thousand dams worldwide, people everywhere know the utility and necessity of dams.

The Water Within

The major parts of a dam are shown at Lopez Lake, near the headquarters of HydroFathom. From the upper left, clockwise: barrier, penstock for releases, reservoir, overflow structure.



Largest California Dams

Reservoir	Capacity (Acre-Feet)	River Dammed	Name of Dam
Shasta Lake	4.55	Sacramento River	Shasta Dam
Lake Oroville	3.53	Feather River	Oroville Dam
Trinity Lake	2.45	Trinity River	Trinity Dam
New Melones Lake	2.40	Stanislaus River	New Melones Dam
San Luis Reservoir	2.04	Off-stream, Human made	San Luis Dam
Don Pedro Reservoir	2.03	Tuolumne River	New Don Pedro Dam
Lake Berryessa	1.60	Putah Creek	Monticello Dam
Lake Almanor	1.30	North Feather River	Canyon Dam
Folsom Lake	1.12	American River	Folsom Dam
Lake McClure	1.02	Merced River	New Exchequer Dam

The Water Within

DAM FAILURES



Dams can fail when not properly designed, improperly operated, or poorly maintained.

Select Dam Failures:

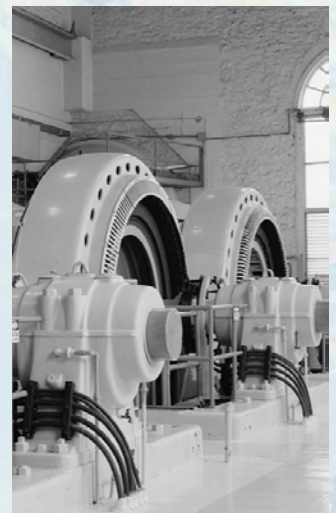
- S. Fork Dam – Johnston, PA – 2208 Perished – 1889
- St. Francis Dam – Los Angeles County – 431 Perished – 1928
- Teton Dam – Eastern Idaho – 11 Perished – 1976
- Banqiao Dam Disaster – Henan, China – at least 26,000 Perished – 1975



The Power of Water, One Example

Pacific Gas & Electric (PG&E) operates an extensive hydroelectric system in California, mainly focused on the upper reaches of Sierra Nevada. The system consists of more than 100 reservoirs that collect water behind dams. PG&E reports the following facts about their system:

- The system is built along 16 river basins which stretch nearly 500 miles along their service area
- The system uses water from more than 100 reservoirs, mostly located in the Sierra Nevada Mountains
- The system has 67 powerhouses
- The system produces roughly 3,900 megawatts (MW) of power
- The system can provide power for nearly four million homes
- PG&E holds 26 Federal Energy Regulatory Commission (FERC) licenses. FERC issues licenses for periods of 30 to 50 years



The Water Within

CANALS AND AQUEDUCTS



Humans so prodigiously store and move water that they have slightly altered the rotation of the earth by moving the immense weight of dammed water to higher elevations. Water stored in dams facilitates the movement of water from one place to another. Humans hold water higher and more dispersed than natural. This relocated water funnels primarily to agriculture, hydropower and drinking water. Canals and aqueducts



serve as superhighways that move water around the earth. Water running downhill, even slightly, can move in an open topped channel, a canal. Water running uphill needs to be enclosed. Early large “pipes” consisted of brick topped channels that held the water in the channel. Think about when water is left in a garden hose. If you hold one end up, then water will come out the other lower end. Pouring water in the high end of a hose assures water flowing out the far end. Downhill sloping channels have powered human water movement systems, like the Roman aqueducts, since antiquity.



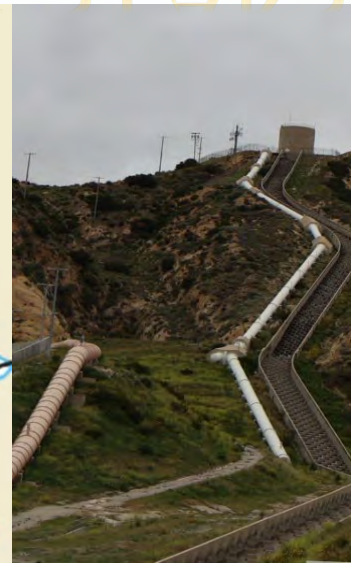
The California Aqueduct, part of the California State Water Project, moves water from the northern end of the state to the southern end, supplying water to millions.

The Water Within

WATER OF THE STARS



The original L.A. Aqueduct moved water from the Owens River watershed to arid Los Angeles, spurring the explosive growth of the city



The Cascades at the end of the L.A. Aqueduct, San Fernando Valley



Roman Aqueduct
Segovia Spain

On November 5, 1913, water from the Los Angeles Aqueduct first reached the San Fernando Valley, west of Los Angeles. This 233-mile pipeline and canal transported water from the far away Owens River Valley into the metropolis of Los Angeles County. This project foreshadowed the work that lay ahead for the state as California's water system grew to the largest in the country and the state's densely packed cities became dependent on imported water.



The original water intake to the L.A. Aqueduct



The naturally flowing Owens River before diversion

The Water Within

PUMPS AND PIPELINES

In the modern world, water and electric-powered pumps are married. Imagine standing on a large hill and looking at two other large hills nearby. The first hill you look down on the peak and the second hill you look up at the peak. If you stretch a garden hose between your hill and the first lower hill, then you can send water to the lower hill just by pouring water into the hose and letting it travel through the hose to the lower hill. This is not true for the second higher hill. If one wants to send water up to the higher hill, one must overcome gravity and pump it up there. Dam stored water and well water often need pumping to be relocated to an alternate human selected location. Water is heavy. The average U.S. citizen needs about two-hundred pounds of water daily for the drinking, bathing and irrigating needs, much more is required to grow each person's food and produce their goods. So, water pumps gobble energy, especially electricity. Water pumps operate continuously, daily while steadily lifting water to higher elevations and faraway places. Pipelines join pump stations and provide water transportation across miles. Manufacturers make long-haul piping systems mainly from steel and concrete. These rugged materials allow for high pressure and long durability.



Ira J. Chrisman Pumping Plant, Grapevine CA

The Water Within

Imagine taking a case of water to the tenth floor of a tall building, by the stairs. Imagine the work required. Similarly, a pump needs to do work to lift water to a higher elevation. Pumps serve as devices that lift water higher.



Large pipelines may stretch for miles underground mostly undetected. Here an air relief valve structure reveals the pipeline beneath.



Diesel also powers some pumps



This pipeline runs exposed along the ground feeding a nearby water treatment plant.

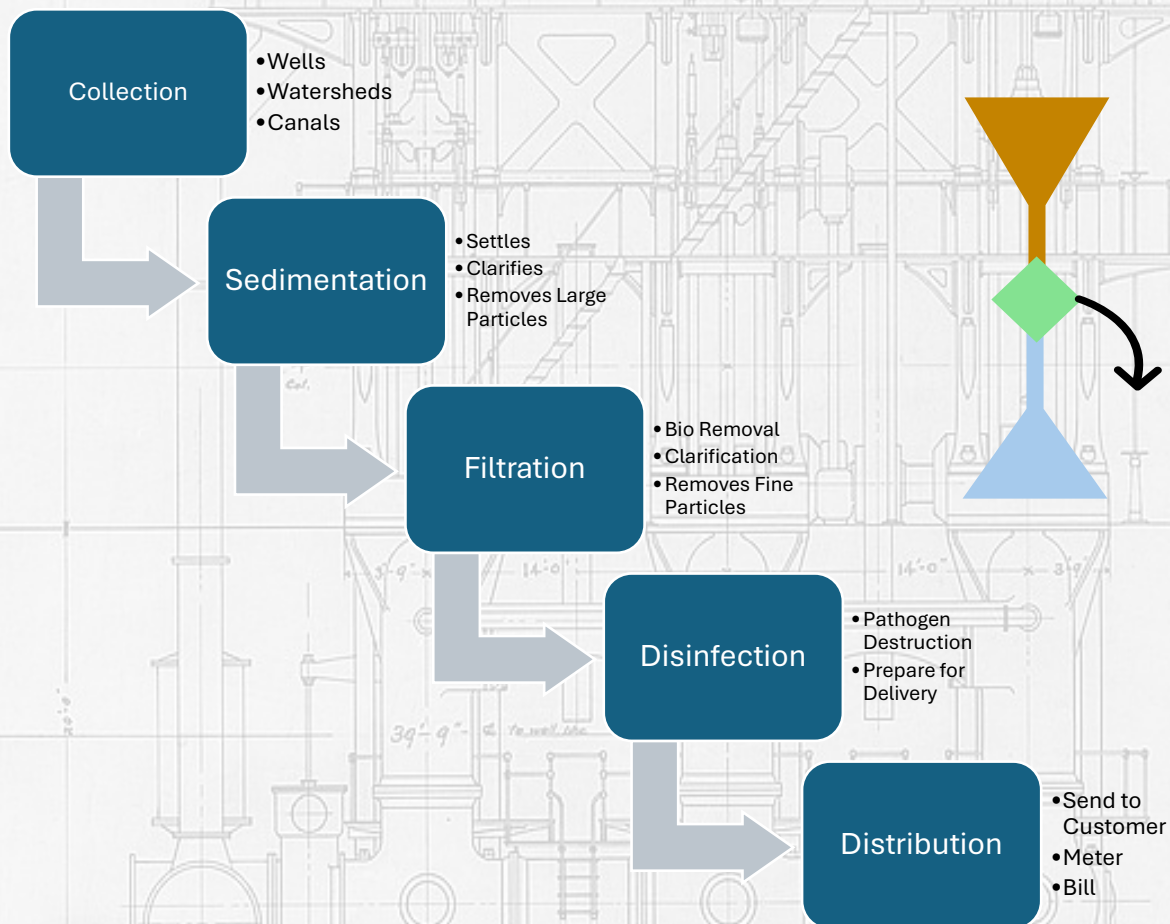
TREATMENT PLANTS

Famously, New York City drinks unfiltered drinking water. The local water company adds some chemicals, but mostly for clarity and disinfection. Yet, most drinking water requires treatment from a plant prior to public consumption. Over one-hundred-fifty thousand public water systems operate in



the U.S., and sixteen thousand sewer plants filter the returned soiled water prior to release to the ecosystem. Many drinking water plants receive water supplies from vast supply networks that reach out for hundreds of miles.

This flowchart lists the primary steps in a typical treatment plant process:



Chemical Consumption:

Water treatment plants in the United States consume about \$8 billion of chemicals each year. Most drinking water in the United States contains at least one treatment chemical, chlorine. Here are some chemicals used in treatment:

Chemical	Type	Use
Chlorine	Disinfectant	Chlorine serves as the primary disinfectant for most water systems in the U.S.
Ammonia	Disinfectant	Water providers add ammonia in combination with chlorine to prolong the effects of disinfectant
Aluminum Sulfate	Coagulant	Aluminum Sulfate or alum is added in treatment process to get particles to stick together for filtering
Ferric Chloride	Coagulant	Ferric Chloride is also a coagulant which causes particles to stick together for removal by filters
Lime	pH Adjustment	Adjustment of pH can speed some chemical reactions. Lime lowers pH
Sodium Hydroxide	pH Adjustment	Sodium Hydroxide has the opposite effect of lime and raises pH in water
Polyphosphates	Corrosion Inhibitor	Some types of water are especially corrosive to pipes and certain polyphosphates slow corrosion
Fluoride	Public Health	At times controversially, some water systems add fluoride to water to slow tooth decay

University of Michigan PDF Info Sheet on Treatment Plants

<https://css.umich.edu/sites/default/files/2025-09/CSS04-14.pdf>

Seventy-five percent of homes are served by sewage treatment plants. Daily about 34 billion gallons of water ejects into the ocean from sewage treatment plants. Due to spills and equipment failures, billions of gallons of untreated sewage are also discharged yearly. Mainly in the east, sewers and storm drains combine. During heavy rains, these combined sewers overwhelm sewage treatment plants with high-peak inflows preventing the plants from effectively treating the water.

Yearly, sewage treatment plants produce about 8 billion pounds of dry sludge (mainly fecal matter), about twenty-five pounds for each U.S. citizen. Farmers yearly spread over half of this amount on their fields.



The Water Within

DISTRIBUTION SYSTEMS AND COLLECTION SYSTEMS

One could compare a municipal water distribution system to a leaf with water entering the large stem and then flowing into the leaf through the veins which branch out in various sizes throughout the leaf. Another comparison would be a milk truck which gets milk from a dairy which is supported by a larger farm. In comparison, water in a municipal system

depends on the precursor treatment and the subsequent distribution to produce a useful and desirable product. A dairy makes milk. Treatment plants make water. However, a dairy needs a truck for delivery, and a water system needs a buried network of pipes. If the distribution system fails then all previous work yields no results, like a full milk truck running off the road.

In the last few miles of water's journey to your tap, it faces great peril, placing at risk a lot of previous effort. It's imperative that the water remain unspoiled. Remember parents mix tap water in their children's bottles. In fact, when a baby floats in water inside their mother's belly, that water is likely simple tap water supplied to the baby's mother. Water flattens society, the same distribution system leads to rich neighborhoods and poor alike. In the water industry one can hear the words, "we all touch at the tap." Yes, we do.



The Water Within

WATER AMERICANA



Distribution systems feature a piece of infrastructure familiar to most, a water tower. Many towers sport the name of the town served. Some older towers are merely tall slender buildings. Either way, the towers put pressure on the system when pumps are not running and store water in case of supply disruptions. In hilly areas, tanks at high elevations supply this function. Some tanks mimic local products like corn or peaches for their tower shapes and others incorporate whimsy like a coffee pot or a faux hot water tower.

Extra Credit:

Goggle “Images of water towers”



The Water Within

Distribution systems must remain clean and pathogen free. Here are some duties of the distribution system operators:

- **FIRST** – Fire Protection
- Monitoring Water Flow
- Quality Sampling
- Meter Reading and Billing
- Connections/Disconnections
- Repairs
- Emergency Response
- Control Taste and Odor



Old Vs. New Piping



Hydrant Under Construction



A Large Main Valve Awaiting Installation

A recent Underground Infrastructure magazine article referenced a recent Utah University study, finding the following:

- 2.3 million miles of water mains exist in the United States with 20% beyond their useful life
- The US and Canada experience 260,000 water main breaks annually, representing \$2.6 billion in annual repair costs
- Utilities reported the average failure age of water pipes is 53 years. Notably, 33% of water mains are over 50 years old, representing 770,000 miles of piping
- The estimated average yearly water loss to leakage is 11%

The Water Within

IRRIGATION

In the U.S. about 55 million acres of farmland depend on irrigation, about the same area covered by the state of Utah. As detailed in previous modules, groundwater supplies about half the water for U.S. irrigation with the remaining agricultural irrigation mostly dependent on human constructed infrastructure. Infrastructure moves water from where it fell as precipitation to other locations, crossing natural watersheds. This water mechanization allows large-scale farming in previously dry zones like the Imperial Valley in California. Additionally, U.S. citizens use a significant portion of their water supply to irrigate what could be classified as “ornamental” plants, landscaping. In about two-thirds of the U.S., rainfall will not naturally support a green grass lawn. Yet, in places like Las Vegas, where three inches of rain falls yearly, residents still insist on lush verdant lawns and golf courses populated by mostly non-native European grasses. Palm trees do not stand naturally in Los Angeles, nearly all of them transplanted and fed from a limited water supply. Americans love the hose and water can.



The City Farmer



Irrigated lawns in the U.S. cover about 40-50 million acres which means that turfgrass consume more irrigation water than any other "crop."

Key Figures & Details:

o **Total Turf Acreage:** In the United States, the area covered by irrigated lawn turf exceeds the size of Georgia.

o **Irrigated Acreage:** Lawns consume more plant dedicated irrigation water in the U.S. than any agricultural product.

o **Consumption:** Lawns greedily absorb water daily and contribute to significant waste since much of this water runs off and yields no identifiable good.

o **Agriculture vs. Urban:** Irrigated lawns and landscaping consume a significant portion of the U.S. water supply while contributing little but aesthetic appeal, this despite known methods to provide appealing landscaping without water consumption.



The Rural Farmer



Dry western states lead the USA in agriculture irrigation including: California, Arizona, Texas, Washington and Nebraska

In other previous modules, HydroFathom explored the connection between rural and urban communities, detailing how large cities need food from remote farms and thus, the cities indirectly depend on water delivery to farms. Industrial scale farms, factory farms, supply most of the nation's food and these operations need fuel, fertilizer, equipment, land, farmers, financing, pesticides, herbicides, and especially water to operate. Mass irrigation causes issues like excess fertilizer runoff, river depletion, nitrite groundwater pollution, and salt accumulation. Salt accumulation, due to irrigation, already fallowed over 1.5 million acres in the California Central Valley since the start of the irrigation age in the early 1900s

Dam Water Grows Food

In the California Central Valley, signs proliferate begging for access to more irrigation water to irrigate the naturally arid soil for farming. Two signs appear here to the right, and we list a common slogan above. The statement above ignores the fact that 1,300 major dams already stand in California. Some signs blame state politicians for water shortages, even though the federal government controls much of the state's water resources. Assuredly, nobody "dumps" water into the ocean. It flows there of its own volition as it has for eons. Currently, little water supply remains for further diversion to agriculture, since humans have already diverted all the readily available natural water in the state.



The Water Within

Caltrans the Gardener

It may surprise some that Caltrans, the state highway department, perhaps stands as the greatest landscaper in California. Few if any can rival their ability to raise non-native species like eucalyptus trees, palm trees and ice plants, all while using irrigation. So committed is this department to their craft that they operate personnel development programs focused on landscape architecture. Caltrans manages 30,000 acres of highway landscaping across the entire state about 50 square miles. They use 132,000 gallons of liquid herbicide each year and another 93,000 lbs. of dry. All this landscaping requires constant maintenance and indeed the department owns a vast array of landscaping equipment and pays millions of dollars yearly to landscaping companies that must operate petroleum powered equipment to conduct their massive cutting, planting, pruning, and trimming.

Somewhat, by chance, Caltrans became the poster child of reclaimed water, discussed below. The agency requires water for their massive gardens, oblivious to the necessity of these botanical oddities in the first place. After all, other dry states such as Utah devote little effort to raising ornamental speedway plants, instead preferring to use simple materials like rock and bark where needed. Little demand occurred for reclaimed water when first introduced, so local governments convinced the state government to consume this stigmatized product which allowed Caltrans to build, build, and build gardens in medians, islands, and lane dividers

Flush It, Then Spray It (or drink it)



Initially introduced in the late 1990s, reclaimed water, water made from filtered sewage, promised to, “reuse and replace.” In California, as the state population increased, new water resources simply did not exist. Thus, politicians and engineers decided that they had found a “new” undiscovered water source, right in there in their own toilets. Accordingly, they embarked on gargantuan building programs to construct reclaimed water plants. The reused water produced by these new reclamation plants would replace tap water being used for irrigation and harvest a precious resource, sewer water. Not surprisingly, few wanted this product and no pipelines initially existed to carry this separate water source. San Diego constructed plants with the capacity to churn out 45 million gallons of this “grey water” water daily, but thirty years on, these plans still operate at about 25% capacity, much of this reduced flow directed to Caltrans or city-owned parks and golf courses. Conveniently for California cities, the reclamation plants allowed them to claim new water resources which in turn allowed them to permit new housing developments. Yet still, little demand exists for reclaimed water, and it mainly flows between government agencies. Seemingly seldom considered, recycled water contains a myriad of pollutants including pharmaceuticals, personal care products (PCPs), hormones, nanoparticles, salts, pathogens (viruses, bacteria), industrial chemicals (heavy metals, PFAS), pesticides, and disinfection byproducts. Despite advanced treatment, some traces of these hazards will always remain. Meanwhile, we spray reclaimed water across the state, spreading the range of PFAs and other pollutants. Currently, California cities remain unsatisfied with merely recycling semi-polluted water for landscape. A few agricultural irrigation districts have begun using the product on crops and many cities plan to further clean up reclaimed water and ship it directly to the citizens faucets, toilet-to-tap. Some bright water marketers have decided on calling drinking water made from sewer water, “pure water.” No long-term studies exist of any system using this practice.



The Water Within

ENERGY

Due to gravity, if you take a rock up to the top of a building, you increase the energy in the rock. This additional energy considered potential energy releases when one tosses the rock off the roof. Anytime an object on earth travels to a higher elevation, the object gains energy. Warm water vapor rises in free air. Water has mass so when water rises to a higher elevation, it gains energy. Gravity constantly tugs at the water, pulling it closer to the center of the earth. Early Americans took advantage of this natural phenomenon to place water wheels on rivers. These wheels drove grain mills and sawmills, converting the energy in water to mechanical energy.



Water is heavy, so moving large amounts of water to higher elevations requires large amounts of energy. The sun floods the earth with energy constantly. HydroFathom stresses the natural interplay of water, sun, and terrain that powers the water-cycle. This natural cycle infuses earthly bound waters with energy. Humans drive the unnatural modern water-cycle which requires the movement of small seas across vast distances, over fluctuating terrain. Getting water where humans want depends on energy. In the United States, most Americans daily water needs depend on energy.

Southern California Edison operates 36 hydropower powerhouses while controlling 39 dams, 143 miles of waterways and 79 generating units. This system produces a maximum of 1176.2 megawatts of power.



In our modern world, water and electricity stand adjacent. Water produces electricity but also consumes electricity. Electricity cannot make water or consume water. Water lying on dry land, higher than sea level, contains energy due to gravity which can be harnessed as electricity by passing the water through a hydropower electric station. Natural rivers flowing through tall canyons that lead to steep drops make the best hydroelectric power stations sites, places where a lot of water flows lower quickly. Take Hoover Dam for example. Conversely, electric driven pumps can lift water and transport water, allowing water distributions across wide regions. Water drawn from a kitchen tap may have fallen to earth hundreds of miles afar.

Consider, the Department of Water Resources (DWR), California's state water provider, produces about 6 billion kilowatt-hours of power yearly, enough for 600-thousand homes. They do this by damming and storing water which they later slowly release through turbines to generate power. Meanwhile, while producing all this power, DWR also stands as the largest consumer of power in California. In fact, the power that DWR generates from hydropower only feeds about 70% of their own needs, demonstrating the limits of hydropower and ravenous appetite of electric driven pumps.



Google, “Dragon Spline Pump”

The Water Within

DISTRICTS



Governments in the U.S. spend between \$150 billion and \$600 billion on water depending how expenses are classified. Most of this spending comes from local and state sources. About 145,000 public water districts exist in the United States. Governments have established water districts as the organizations that control the operations of most of the water

supply systems. The criticality of water led many governments to monopolize the water systems to protect the public but also to control the inevitable clashes that erupt when human beings compete for a valuable, limited, natural resource. Accordingly, water districts often control those who ultimately benefit from earth's natural waters. Water districts control considerable sums of money. Water district customers pay over \$120 billion of bills yearly in the United States. These bill payments and taxing powers fund water districts. The factors of money and control naturally make water districts coveted political organizations while also giving the districts bureaucrats considerable regional political clout.



LOOK AT YOUR LATEST WATER BILL AND SEE WHO SENT IT

LOOK UP YOUR STATE WATER AGENCY THAT SET STANDARDS AND
ISSUES LICENSES

WATER DISTRICTS STARTED AS PRIVATE ENTITIES, SOME STILL ARE
GOVERNMENTS OFTEN CONTRACT COMPANIES TO PROVIDE WATER

The Water Within

JOBS WITHIN A WATER DISTRICT			
Board Member	Executive Director	Deputy Director	Controller
Accountant	HR Director	Administrator	Lead Operator
Chemist	Safety Officer	Maintenance Mechanic	Instrumentation Technician
Electrician	Meter Reader	Equipment Operator	Engineer

New York City receives high marks for their drinking water quality. A multi-agency structure provides their water with the Department of Environmental Protection, the lead agency on water, wastewater and storm water. Each day



over one billion gallons of water flow through the N.Y. system to nine million customers throughout the state, averaging 111 gallons per customer. On the wastewater side, their fourteen plants treat about 1.3 billion gallons of wastewater daily. The dense city structure prevents the land from absorbing stormwater which flows into a third system that prevents flooding. The overall operations generate about \$5.1 billion revenue annually against \$4.7 billion in expenses and in 2025 the operations generated a \$400 million surplus. The New York City Municipal Water Finance Authority controls these funds and in 2025 they predicted capital spending, mainly construction, would cost \$37 billion over the next decade.



\$\$-BONDS-\$\$ - Districts often fund their long-term construction projects with bonds. The New York system as of June 30, 2024, owes \$32.58 billion in total debt, much of this bonds.

GOOGLE: YEARLY U.S. WATER BOND MARKET

The Water Within

WATER PROFESSIONALS



When HydroFathom films videos of watersheds, the videos seldom show people, allowing the natural watersheds to take center stage while focusing on the natural water cycle. With infrastructure humans interdict the natural water cycle. Our infrastructure videos feature human-made works and humans themselves. A hidden army of professionals provide water to most individuals. They labor mostly anonymously in the background. Yet, the modern leviathan water infrastructure system needs workers. Operators and maintenance personnel man the front lines of the contemporary water complexes. The Environmental Protection Agency through the Safe Drinking Water Act mandates that states regulate and license the workers of water providers. In the United States, about 150,000 people hold a license to operate water plants, wastewater plants or distribution systems. In a land of over 300 million, for every two thousand people, one licensed operator holds a job. A few people can supply water to so many people because of infrastructure. Machines, knowledge, energy, and human work allow the daily movement and treatment of small seas of water. These operators are supplemented by the workers that operate the powerhouses described previously and by engineers, constructors, administrators, and others as described in the next sections. A water main break or water shut off pushes these workers to the forefront but daily most Americans need not consider how their water reaches their tap.



WANT TO BECOME A WATER PROFESSIONAL?

HYDROFATHOM HAS A PDF DOCUMENT THAT EXPLAINS THE PROCESS

VISIT OUR WEBSITE:

WWW.HYDROFATHOM.ORG

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CONSTRUCTION COMPANIES



The American Water Works Association (AWWA) predicts that an additional \$2.1 to \$2.4 trillion in funding is required over the next 25 years to sustain safe, reliable drinking water in the U.S., nearly \$100 billion per year.

Private Entities provide most of the resources required to perform this construction

According to Engineering News-Record the following companies had over \$250 million dollars of revenue associated with water work in 2023:

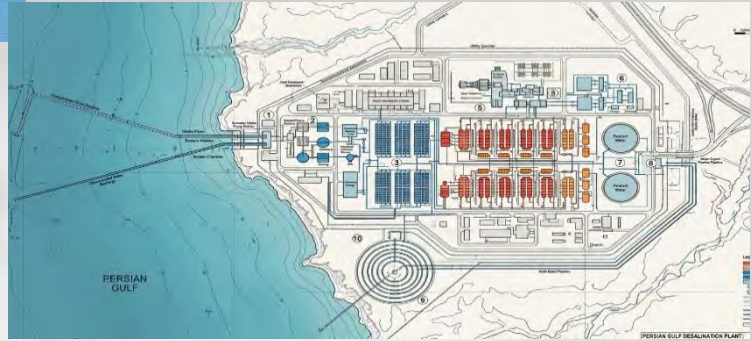
-  Kiewit - \$631 Million
-  Walsh - \$626 Million
-  Sundt Construction - \$536 Million
-  Garney Holdings- \$373 Million
-  Wharton-Smith- \$350 Million
-  MWH - \$321 Million

The Water Within



Humans build water projects throughout the world. The China's South-to-North Water Transfer Project cost tens of billions of dollars and likely serves more people than any other water project.

Governments in the Middle East, like Qatar and Saudia Arabia, have invested additional billions in desalination plants.



These companies and districts are supported by a variety of manufacturers and suppliers. Here are some of the largest:



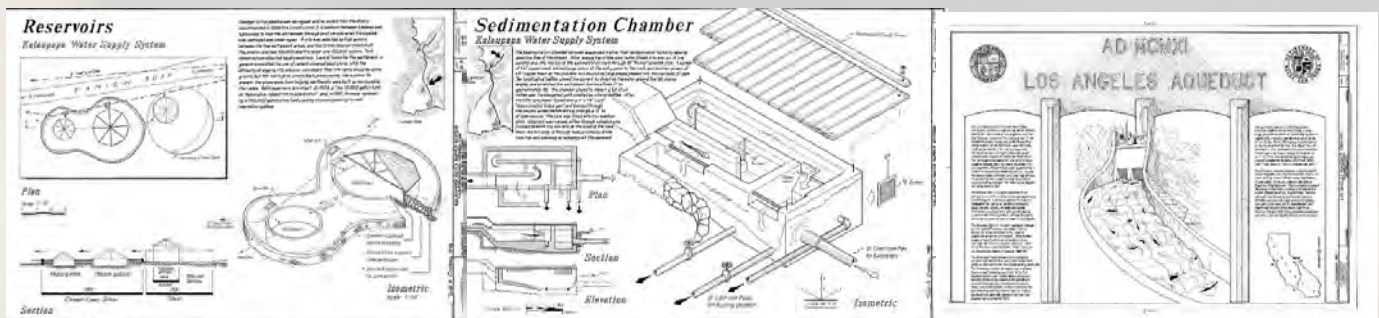
The largest private water provider in the world, Veolia, provides water to 110 million people globally. The largest in the United States, American Water, provides water to 14 million people.



ENGINEERS



Water engineering goes back to the edge of history. Five thousand years ago, the bronze age Minoan people had settlements with flushing toilets, water distribution systems, rainwater collection systems, and piping. 2,500 years ago, Chinese engineer Shi Lu designed the Lingqu Canal, a 22-mile-long waterway, which linked the Yellow and Yangtze rivers. Around the same time, the Romans constructed aqueducts to convey water to their major cities.



According to Engineering News-Record, in 2024, engineering firms brought in \$11 billion of Engineering/Design revenue and another \$19 billion of Consulting/Studies work associated with the water industry.

Some of the largest Environmental engineering firms in the U.S. include:

AECOM, Dallas, Texas

JACOBS SOLUTIONS INC., Dallas, Texas

TETRA TECH INC., Pasadena, Calif.

FLUOR, Irving, Texas

BECHTEL, Reston, Va.

BLACK & VEATCH, Overland Park, Kan.

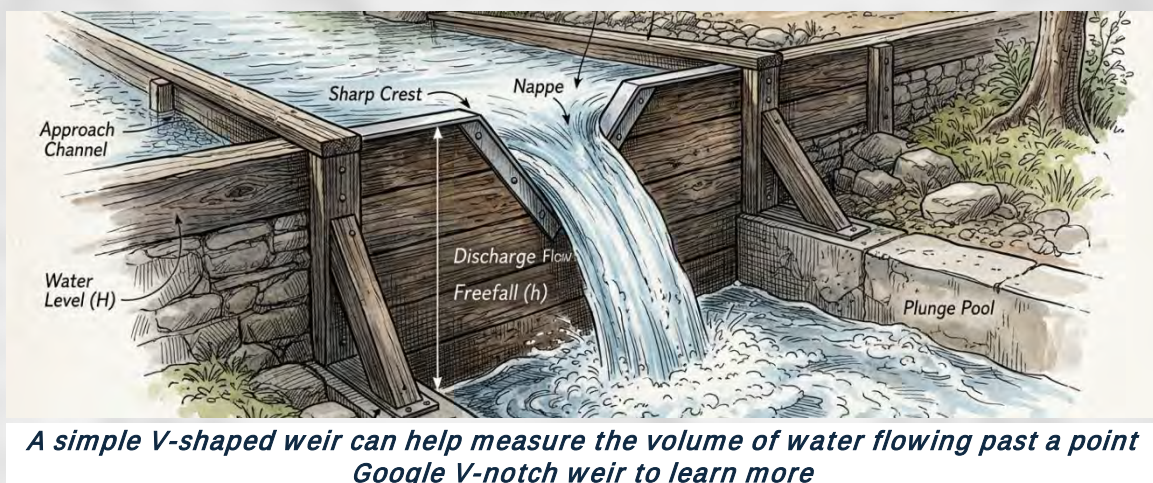
STANTEC INC., Edmonton, Alberta, Canada

The Water Within

INSTRUMENTATION



Many subspecialties service the districts, engineers, and contractors operating in the water industry including pipeline, mechanical, electrical, concrete, steel, and excavation specialists. Another subspecialty, instrumentation, enables a handful of people to control large water systems which capture, treat, and transport water. To measure the flow pace of a stream, a person may watch flotsam drifting along atop the flowing water. The faster the floating debris travels, the faster the flow of the stream, the wider and deeper the stream, the greater the total flow volume. Using various techniques, water professionals can measure flow quite accurately. Instrumentation technicians measure flow versus time and express the flow in units that compare how much flow crosses a certain point over a certain time, gallons-per-minute for example.



Flow likely served as the first data point measured by humans, but humans currently monitor a multitude of additional points. Overall, professionals call the devices associated with measuring water variables instrumentation and instrumentation measures a wide range of water parameters including:



Many Americans perhaps have not heard the term, Supervisory Control and Data Acquisition, which abbreviates as SCADA. This seldom noticed computer-based technology controls industrial processes throughout the world.

Accordingly, SCADA controls most modern water supply systems. SCADA integrates with another obscure technology, programmable logic controllers (PLCs). In industrial plants, PLCs and SCADA systems receive input from field sensors (instruments) while coordinating and controlling the movement of pumps, motors, valves, chemical injectors, and other end devices allowing just a few people to supervise and control water being delivered to millions of people. To provide an analogy, pipes may serve as the body of a water system, treatment plants the heart maybe, pumps might be viewed as the muscle but instruments, PLCs, and SCADA systems, compromise the senses, nerves, and brains of modern water systems.



The totalizing flow meter, water meter, is an instrument known to most people. This instrument totals the amount of flow that passes a certain point over time. A water meter often totals how many gallons of water that flows through a pipe to a residence each month.

\$\$ - The annual water quality instrument, the sensors, market exceeds \$5 billion and includes several large companies such as:

Hach

Emerson

Endress-Hauser

ABB

Xylem

Did you know??? – A Swiss mathematician revealed a fundamental flow equation, **Bernoulli's equation**, in 1738, in his book, *Hydrodynamica*.

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LET IT FLOW

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