STATEWIDE WATER EDUCATION ACTION PLAN FOR COLORADO 2020-2025

CRITICAL WATER CONCEPTS

Revised May 8, 2020

The following concepts represent foundational understandings for water education throughout Colorado. Although this list was reviewed by the SWEAP Coalition during development of this plan, it will remain a working list of concepts. To have a credible, comprehensive list of academic concepts that helps achieve the impacts envisioned in SWEAP, this list will be subject to ongoing refinement. This Plan envisions discussions with the Colorado Department of Education and others to ensure maximum alignment with Colorado Academic Standards and applicable national standards. At this time, water educators are encouraged to use this list, but to be mindful of potential future refinements.

The physical and chemical properties of water are unique and constant[1].

Water is often taken for granted because it is so common, but water is a very unusual substance.

Its most spectacular property is that ice floats on water. Water is one of only a few substances whose solid form floats on its own liquid phase. This characteristic is responsible for the fact that oceans and lakes develop a layer of ice on top, rather than freezing solid from the bottom up.

Water is unusual in other ways as well. For example, the heat capacity of water is higher than just about any other substance. The heat capacity of a substance is the amount of heat it will absorb to raise its temperature by a given amount. The heat capacity of water is more than twice the heat capacity of natural mineral and rock materials. This tends to moderate temperature differences around the globe, from day to night and from summer to winter.

Water is also the best all-around natural solvent we know of. More substances dissolve in water than in any other liquid. This is due largely to water's unique "bipolar" structure, which allows water molecules to interact with many different substances – both polar and non-polar.

Water's molecular structure also generates strong inter-molecular attraction between the water molecules themselves. This gives rise to surface tension, which results in the spherical shape of raindrops and forms the "skin" that allows insects to walk on the surface of a lake or stream. Another effect of surface tension is the ability of water to rise, of its own accord, within a thin tube. This phenomenon is known as capillary action, and it is essential for the

[1] Why is Water Special? American Geosciences Institute. https://www.americangeosciences.org/education/k5geosource/content/water/why-is-water-special

survival of trees and other plants that rely on this property of water to bring life-giving water and nutrients into their root system.

Water is essential for life, our economy, and a key component of healthy ecosystems.

All living organisms need water to grow and survive. About 60 percent of the human body is made up of water and a person can only live three to five days without fluids[2]. For other animals and plants, including those people rely on for food, a reliable supply of clean water is just as critical.

Economically, the direct use of water is concentrated in major sectors around the world, including agriculture, forestry, mining, energy resource extraction, manufacturing, electric power production, and public water supply[3]. The output from these sectors supports activity elsewhere in the economy, creating a ripple effect as goods and services are produced and transferred through supply chains until they reach the final consumer.

In an ecosystem, water cycles through the atmosphere, soil, rivers, lakes, and oceans[4]. Some water is stored deep in the earth in groundwater aquifers. Surface water, on the other hand, is the source that sustains the majority of life on land. In many cases, water also structures the physical habitat of an ecosystem. Many small mammals, for example, rely on snow cover to forage and survive the winter out of view of predators. Rivers, lakes, and other bodies of water divide environments into different habitats, effectively creating unique systems where some organisms can live and others cannot. What's more, most of life on Earth actually lives completely submerged in the waters of the oceans. Water is truly a powerful factor in all ecosystems.

Water is a scarce resource, limited and variable.

Water covers 70 percent of the earth, and since it is often referred to as a "renewable resource," it is easy to think that it will always be plentiful. However, the freshwater used to drink, bathe in, and for irrigation is limited and finite. Only 3 percent of the world's water is

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[2] How Long You Can Live Without Water. Medical News Today, May 14, 2019. Medically reviewed by Elaine K. Luo, M.D., written by Jon Johnson. https://www.medicalnewstoday.com/articles/325174
[3] The Importance of Water to the U.S. Economy. U.S. Environmental Protection Agency, Office of Water Synthesis Report. November 2013. Pages i-ii. https://www.bafuture.org/sites/default/files/key-topics/attachments/Importance-of-water-synthesis-report.pdf.
[4] The Water Cycle. Schmoop Study Guides, Topics in Depth. https://www.shmoop.com/study-guides/biology/ecology/water-cycle

freshwater, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use[5].

As a result, at least 1.1 billion people worldwide lack access to fresh water, and a total of 2.7 billion find water scarce for at least one month of the year. Inadequate sanitation is also a problem for 2.4 billion people—they are exposed to diseases, such as cholera and typhoid fever, and other water-borne illnesses. Two million people, mostly children, die each year from diarrheal diseases alone[6].

Colorado has a semi-arid climate, with statewide annual precipitation averaging 17 inches and wide variations across different parts of the state and from year to year. Precipitation ranges from an average of just 7 inches in the middle of the San Luis Valley to over 60 inches in some mountain locations.[7] Native vegetation intercepts and uses approximately 85 percent of this annual precipitation, while the remainder feeds the state's rivers and replenishes groundwater. [8]

Colorado's population is increasing rapidly, increasing the demand on the state's scarce water resources. According to the Colorado Demography Office[9], the 2019 statewide population is 5.6 million people and is projected to grow to 8.1 million by the year 2050. At the same time, supplies of available fresh water are predicted to decrease due to the effects of climate change, which include more droughts and hotter temperatures[10].

By 2050, statewide water supply gaps may vary substantially, depending on future climate conditions and population increases considered in the 2019 Analysis and Technical Update to Colorado's Water Plan. In critically dry years, Colorado is predicted to have a municipal

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[5] Sustainable Earth: Water. National Geographic. Brian Handwerk. https://www.nationalgeographic.com/environment/sustainable-earth/water/#close

[6] World Water Day Report. World Health Organization. https://www.who.int/water_sanitation_health/takingcharge.html

[7] NOAA National Centers for Environmental Information, *State Climate Summaries Colorado*. Accessed March 31, 2020. https://statesummaries.ncics.org/chapter/co/

[8] Citizen's Guide to Where Your Water Comes From. Second Edition. 2019. Colorado's Geography and Natural Water Sources, page 4. Water Education Colorado. ISBN 978-0-9857071-5-6, www.wateredco.org/publications-and-radio/citizen-guides/citizens-guide-to-where-your-water-comes-from/

[9] Colorado State Demography Office, Department of Local Affairs. https://demography.dola.colorado.gov/

[10] Climate Impacts on Water Resources. U.S. Environmental Protection Agency. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources_.html#Supply

and industrial water supply gap of between 250,000 to 750,000 acre-feet annually[11]. For reference, 250,000 acre-feet is almost enough water to fill Dillon Reservoir, or 80 Mile High Stadiums[12]. Agricultural users are predicted to experience an incremental gap of between 23,000 acre-feet and 1,053,000 acre-feet[13]. Currently, on average, approximately 20 percent of the overall agricultural diversion demand is unmet on a statewide basis, though this varies in each of Colorado's major river basins[14].

Many of the natural water systems that maintain Colorado's unique ecosystems have become stressed. Rivers, lakes and aquifers are threatened by pollution or subject to large depletions that affect the water cycle, both upstream and down. Since becoming a state in the late 1800s, Colorado has lost approximately 50 percent of the state's original wetlands through drainage, fill, and excavation[15]. With each instance of degraded water quality and each acre of lost wetland, Colorado also loses associated wildlife habitat, usable water supply, and water storage functions.

Water cycles naturally through Colorado's watersheds, often intercepted and manipulated through an extensive infrastructure system built by people.

The continuous movement of water on, above and below the surface of the Earth is referred to as the water cycle, or hydrologic cycle. Up to 85 percent of Colorado's water accumulates west of the Continental Divide. Wind carries moisture into Colorado from the gulfs of Mexico and California, Pacific Ocean, Mississippi Valley, and localized sources. As the prevailing winds blow west to east, the state's mountain ranges force moisture-rich air to rise and condense—the main dynamic behind precipitation. For the most part, the eastern side of the Rocky Mountains is in a rain shadow as moisture is mostly wrung out of the atmosphere by the time it passes Colorado's Western Slope. Snow falls and snow accumulates on high peaks

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[11] Analysis and Technical Update to Colorado's Water Plan: Technical Memorandum - *Current and 2050 Planning Scenario Water Supply and Gap Results*. Section 6.2, page 201. https://www.colorado.gov/pacific/cowaterplan/analysis-and-technical-update

[12] Fillin' Dillon: Reservoir hits 84-billion-gallon mark. Denver Water. June 22, 2017. https://denverwatertap.org/2017/06/22/fillin-dillon-reservoir-hits-84-billion-gallon-mark/

[13] Analysis and Technical Update to Colorado's Water Plan: Executive Summary. Colorado Water Conservation Board. September 2019. Page XXi. https://www.colorado.gov/pacific/cowaterplan/analysis-and-technical-update

[14] Analysis and Technical Update to Colorado's Water Plan: Executive Summary. Colorado Water Conservation Board. September 2019. Page XXV. https://www.colorado.gov/pacific/cowaterplan/analysis-and-technical-update

[15] Wetlands Loss Since the Revolution. Thomas Dahl. National Wetlands Newsletter, U.S. Fish and Wildlife Service. Nov/Dec 1990. https://www.fws.gov/wetlands/Documents%5CWetlands-Loss-Since-the-Revolution.pdf

during the winter months, creating a natural reservoir that stores moisture throughout the winter. As the warmth of spring and early summer strikes, that snow begins to melt. Some returns to the atmosphere via sublimation, evaporation, or transpiration. Water runs off the slopes and flows down the terrain-divided by topography into distinct drainage basins[16].

As a headwaters state, the waters flowing through and leaving Colorado are part of extensive river basins and aquifers of nationwide significance: the Colorado, the Rio Grande, and the Mississippi Rivers and the High Plains, or Ogallala, Aquifer. These waters eventually cross many state lines and join with more tributaries as they flow toward their historic outlets in the Gulf of California and the Gulf of Mexico.

Along this journey, waters within Colorado are intercepted and manipulated by a complex system of dams, diversions and conveyance structures that store and redirect native flows to serve agriculture, municipal, industrial, and ecological needs. In order to make sure water is available when needed and to control deluges that might otherwise cause damaging floods, Coloradans, with the help of federal agencies like the U.S. Bureau of Reclamation, have built nearly 2,000 storage reservoirs and dams, altering the natural system[17].

The quality and quantity of water, and the timing of its availability, are all directly impacted by human actions and natural events.

Human actions have a measurable effect on the water cycle at every geographic scale, altering the amount, distribution, timing, and quality of both surface water and groundwater. Although Colorado's snowpack provides an excellent natural reservoir, the majority of runoff occurs over just a few short months, typically peaking in late May or early June. Irrigators, municipalities, and rivers themselves are drier and have higher water demands in the heat of late summer. Storage in reservoirs helps ensure that water is available all year, even when natural runoff has ceased. Storage can also occur underground, both through natural aquifer recharge, as well as through planned intervention and infrastructure. For example, in 1995, the state passed the first rules governing aquifer storage and recovery (ASR) for the Denver Basin aquifers. ASR is the practice of pumping treated water into groundwater aquifers for

[16] Citizen's Guide to Where Your Water Comes From. Second Edition. 2019. Colorado's Geography and Natural Water Sources, page 4. Water Education Colorado. ISBN 978-0-9857071-5-6, www.wateredco.org/publications-and-radio/citizen-guides/citizens-guide-to-where-your-water-comes-from/

[17] Citizen's Guide to Where Your Water Comes From. Second Edition. 2019. Colorado's Built Hydrology and Administration, page 4. Water Education Colorado. ISBN 978-0-9857071-5-6, www.wateredco.org/publications-and-radio/citizen-guides/citizens-guide-to-where-your-water-comes-from/

later extraction during dry times[18].

Coloradans have engineered the state's watersheds and heavily administered water right decrees in order to move water where it is needed.[19] Although 85 percent of Colorado's precipitation accumulates on its Western Slope, the state's urban centers and the bulk of the population lives along the Front Range, while rich soils and long growing seasons are also found in the more arid Eastern Plains. On the Eastern Slope, Coloradans have relied heavily on water imported from the Colorado River Basin, creating tunnels and intricate systems that transport water from the headwaters region near the Continental Divide to other parts of the state through transbasin diversions. Colorado's communities, industries, and ecosystems are consequently affected by these actions, because all human activities and functions depend, either directly or indirectly, on water.

With large-scale changes such as climate change, the water cycle is projected to undergo significant change[20]. According to many models, Colorado can expect less precipitation, especially in the warm months, and longer, more severe droughts as storm tracks shift northward leaving arid areas increasingly dry.

The form that Colorado's precipitation takes is also likely to change: projections for many regions of North America, including Colorado, suggest less snow overall and earlier spring runoff. In areas dependent on the gradual melting of snowpack to supply surface water through the warm months, this means lower flows and greater water stress in summer – a trend already in evidence in Colorado and other parts of the western U.S.[21] While the effects of climate change on groundwater are not fully understood, rising water competition and stress at the surface are likely to drive greater use – and potentially overuse – of groundwater.

Impacts to water quality are another consequence of human actions. Water temperature, for example, generally rises in streams, lakes, and reservoirs in urban areas or deforested areas. This tends to lead to lower levels of dissolved oxygen in water, hence more stress on the aquatic animals that rely on dissolved oxygen to live. As a consequence of untreated runoff in many areas, pollutants such as nutrients, sediment, and pathogens can be washed into

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[18] Citizen's Guide to Colorado Groundwater. Introduction, page 4. 2019. Water Education Colorado. ISBN: 978-0-9857071-7-0. https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-groundwater/

[19] Citizen's Guide to Where Your Water Comes From. Second Edition. 2019. Colorado's Built Hydrology and Administration, page 4. Water Education Colorado. ISBN 978-0-9857071-5-6, www.wateredco.org/publications-and-radio/citizen-guides/citizens-guide-to-where-your-water-comes-from/

[20] Water and Climate Change. Union of Concerned Scientists. June 24, 2010. https://www.ucsusa.org/resources/water-and-climate-change

[21] Colorado Climate Change Vulnerability Assessment. Western Water Assessment. 2015. Colorado's Climate: Past and Future History, page ii. https://wwa.colorado.edu/climate/co2015vulnerability/

waterways, resulting in degraded aquatic habitat, decreased reservoir storage, and higher treatment costs for potable water supplies.

Human actions are also responsible for many positive impacts on Colorado's water resources. Effective wastewater treatment, for example, is an essential feature of every municipality, and is largely responsible for protecting water quality throughout the state. Many farming practices, both ancient and modern, are also essential for minimizing negative water quality impacts due to irrigation. By consciously managing toward sustainable supplies and high-quality water, many of the potentially damaging effects of human actions can be mitigated.

Water is a public resource governed by water law. [22]

Colorado water law rests on a strong foundation of territorial and state law, which prove a basic proposition time and again: Water is a public resource and water law evolves with the customs and values of the people.

The Colorado Doctrine is a set of laws regarding water use and land ownership, adopted by the people of Colorado starting in the 1860s. It defines the essential principles of Colorado water law, which include that all surface and groundwater in the state is considered a public resource, and that water rights are the right to use a portion of that resource. It also states that water is subject to appropriation on a "first in time, first in right," basis, where those who were first to put water to a beneficial use have seniority during times of shortage, and junior water right holders are subject to being curtailed if needed to meet the needs of senior users.

Efficient water diversion and storage, beneficial use without waste, and recognition of all beneficial uses that Coloradans value—these have always been fundamental precepts of Colorado water law.

Over time, the types of uses considered "beneficial" have increased in response to the changing economic and community values of Colorado's people, such as the protection of streamflows for the environment and for recreation.

[22] Citizens Guide to Water Law. Water Education Colorado. Fourth Edition. 2015. ISBN 978-0-9857071-2-5. https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-water-law/