Water Resources Engineering

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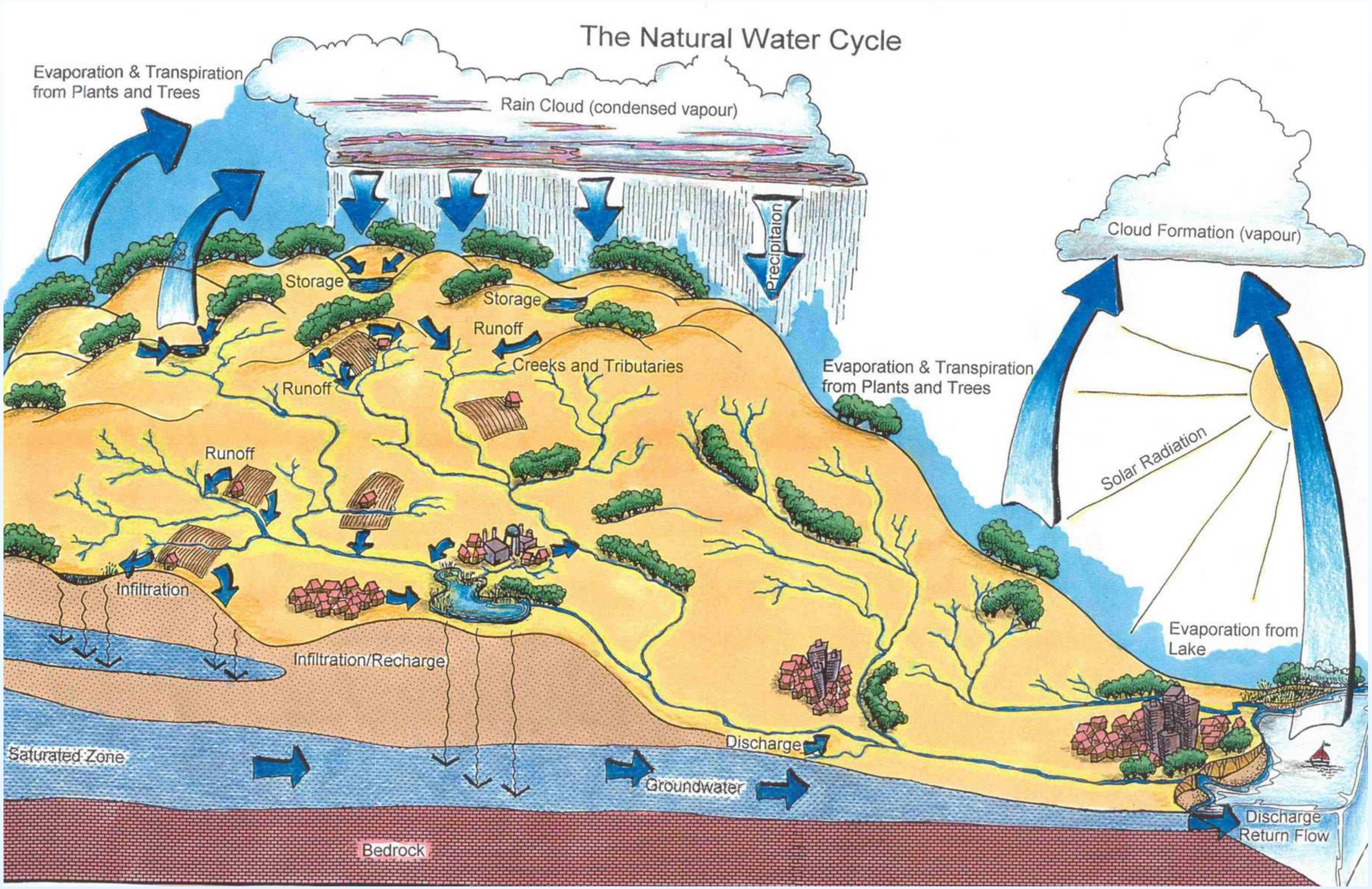
Hydrologic Cycle

Introduction

From a raging stream during monsoon, to a gentle summer rain, to the slow movement of water through the ground, water is in constant motion. The movement and endless recycling of water between the atmosphere, the land surface, and underground is called the hydrologic cycle. This movement, driven by the energy of the sun and the force of gravity, supplies the water needed to support life. Understanding the hydrologic cycle is basic to understanding all water and is a key to the proper management of water resources.

The Hydrologic Cycle recycles the earth's valuable water supply. In other words, the water keeps getting reused over and over. Just think, the next glass of water you drink could have been part of a dinosaur's bath in the Mesozoic Era one hundred million years ago. Water in that glass of water could have been a liquid, a solid, and a gas countless times over thanks to the water cycle.

The Cycle



The Natural Water Cycle
Evaporation & Transpiration from Plants and Trees
Rain Cloud (condensed vapour)
Precipitaion
Cloud Formation (vapour)
Storage
Storage
Runoff
Runoff
Runoff
Creeks and Tributaries
Evaporation & Transpiration from Plants and Trees
Solar Radiation
Infiltration
Infiltration/Recharge
Evaporation from Lake
Discharge
Saturated Zone
Groundwater
Discharge Return Flow
Bedrock

Components

The U.S. Geological Survey (USGS) has identified 16 components of the water cycle:

- Water storage in oceans
- Evaporation
- Sublimation
- Evapotranspiration
- Water in the atmosphere
- Condensation
- Precipitation
- Water storage in ice and snow
- Snowmelt runoff to streams
- Surface runoff
- Streamflow
- Freshwater storage
- Infiltration
- Ground-water storage
- Ground-water discharge
- Springs

Oceans

The water cycle describes how water moves above, on, and through the Earth. But, in fact, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 1,386,000,000 cubic kilometers (km^3) of the world's water supply, about 1,338,000,000 km^3 is stored in oceans. That is about 96.5 percent. It is also estimated that the oceans supply about 90 percent of the evaporated water that goes into the water cycle.

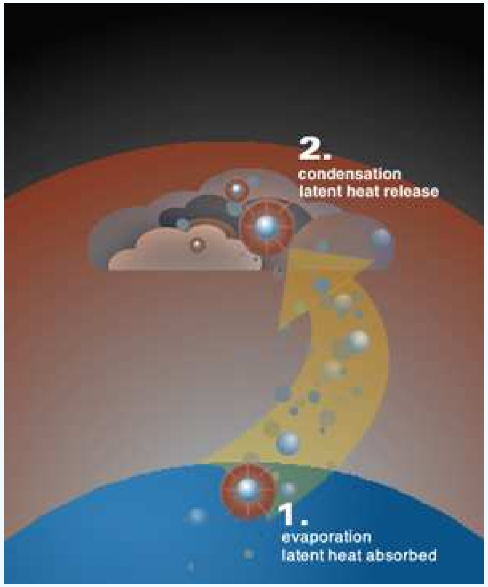
During colder climatic periods more ice caps and glaciers form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age glaciers covered almost one-third of Earth's land mass, with the result being that the oceans were about 122m lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 5.5m higher than they are now. About three million years ago the oceans could have been up to 50m higher.

Evaporation

Evaporation is the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as water vapor. Oceans, seas, lakes, and rivers provide nearly 90 % of the moisture in the atmosphere via evaporation, with the remaining 10 % contributed by plant transpiration.

Heat energy is necessary for evaporation. It is used to break the bonds that hold water molecules together. Net evaporation occurs when the rate of evaporation exceeds the rate of condensation. A state of saturation exists when these two process rates are equal, at which point, the relative humidity of the air is 100 percent.

Condensation



Condensation, the opposite of evaporation, occurs when saturated air is cooled below the dew point (the temperature to which air must be cooled at a constant pressure for it to become fully saturated with water), such as on the outside of a glass of ice water. In fact, the process of evaporation removes heat from the environment, which is why water evaporating from your skin cools you.

Condensation

Even though clouds are absent in a crystal clear blue sky, water is still present in the form of water vapor and droplets which are too small to be seen. Water molecules combine with tiny particles of dust, salt, and smoke in the air to form cloud droplets, which grow and develop into clouds, a form of water we can see. Cloud droplets can vary greatly in size, from 10 microns to 1 mm, and even as large as 5 mm. This process occurs higher in the sky where the air is cooler and more condensation occurs relative to evaporation. As water droplets combine (also known as coalescence) with each other, and grow in size, clouds not only develop, but precipitation may also occur.

Precipitation

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Most precipitation falls as rain.

Precipitation

The clouds floating overhead contain water vapor and cloud droplets, which are small drops of condensed water. These droplets are way too small to fall as precipitation, but they are large enough to form visible clouds. Water is continually evaporating and condensing in the sky. If you look closely at a cloud you can see some parts disappearing (evaporating) while other parts are growing (condensation).

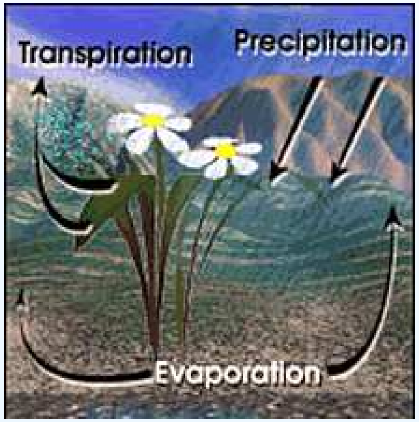
Most of the condensed water in clouds does not fall as precipitation because their fall speed is not large enough to overcome updrafts which support the clouds. For precipitation to happen, first tiny water droplets must condense on even tinier dust, salt, or smoke particles, which act as a nucleus. Water droplets may grow as a result of additional condensation of water vapor when the particles collide. If enough collisions occur to produce a droplet with a fall velocity which exceeds the cloud updraft speed, then it will fall out of the cloud as precipitation. This is not a trivial task since millions of cloud droplets are required to produce a single raindrop.

Evapotranspiration

Evapotranspiration is defined as the water lost to the atmosphere from the ground surface and the transpiration of groundwater by plants through their leaves.

Transpiration: The release of water from plant leaves

Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. Transpiration is essentially evaporation of water from plant leaves. It is estimated that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration.

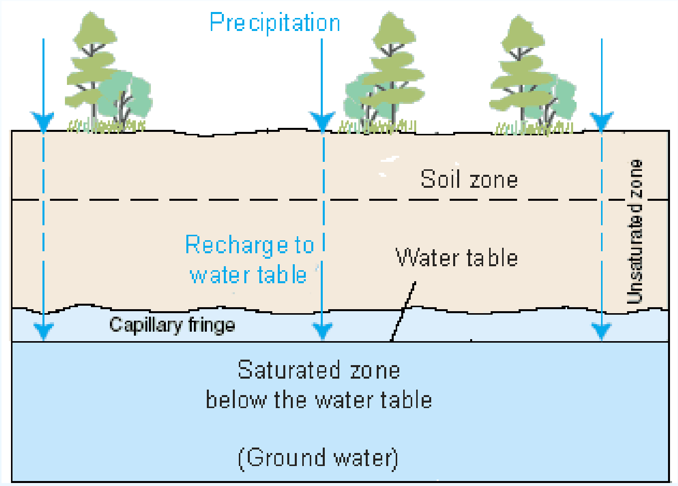


Plant transpiration is an invisible process—since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathing". During a growing season, a leaf will transpire many times more water than its own weight. A large oak tree can transpire 151,000 liters per year.

Infiltration

Anywhere in the world, a portion of the water that falls as rain and snow infiltrates into the subsurface soil and rock. How much infiltrates depends greatly on a number of factors.

Some water that infiltrates will remain in the shallow soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material. Eventually it might enter a stream by seepage into the stream bank. Some of the water may infiltrate deeper, recharging groundwater aquifers.



If the aquifers are shallow or porous enough to allow water to move freely through it, people can drill wells into the aquifer and use the water for their purposes. Water may travel long distances or remain in ground-water storage for long periods before returning to the surface or seeping into other water bodies, such as streams and the oceans.

Surface Runoff

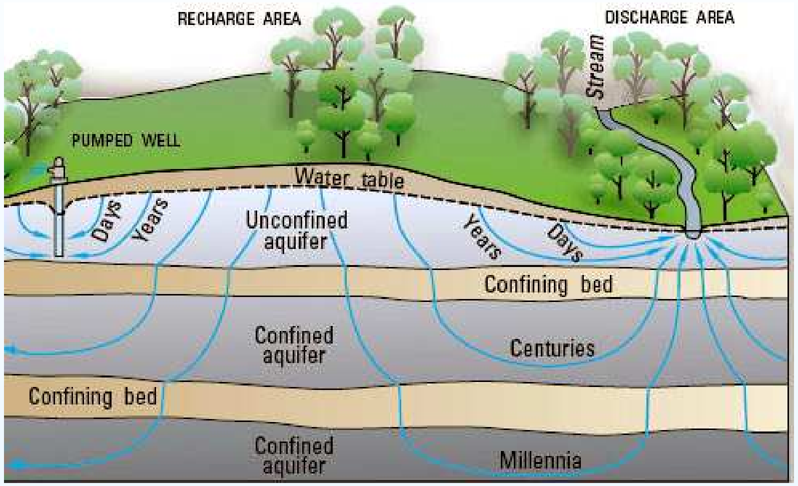
Surface runoff is a term used to describe the flow of water, from rain, snowmelt, or other sources, over the land and is a major component of the water cycle.

During precipitation, a part of it is lost due to initial loss, evaporation and infiltration. The remaining amount flows overland and ultimately discharges into local channels or streams. These streams in turn join a river and the water gets drained from the catchment. Both these two phases of flow, i.e., overland flow and channel flow are known together as surface runoff.

Subsurface Runoff

Some of the precipitation that falls onto the land infiltrates into the ground to become ground water. Once in the ground, some of this water travels close to the land surface and emerges very quickly as discharge into streambeds, but, because of gravity, much of it continues to sink deeper into the ground. If the water meets the water table (below which the soil is saturated), it can move both vertically and horizontally. Water moving downward can also meet more dense and water-resistant non-porous rock and soil, which causes it to flow in a more horizontal fashion, generally towards streams, the ocean, or deeper into the ground.

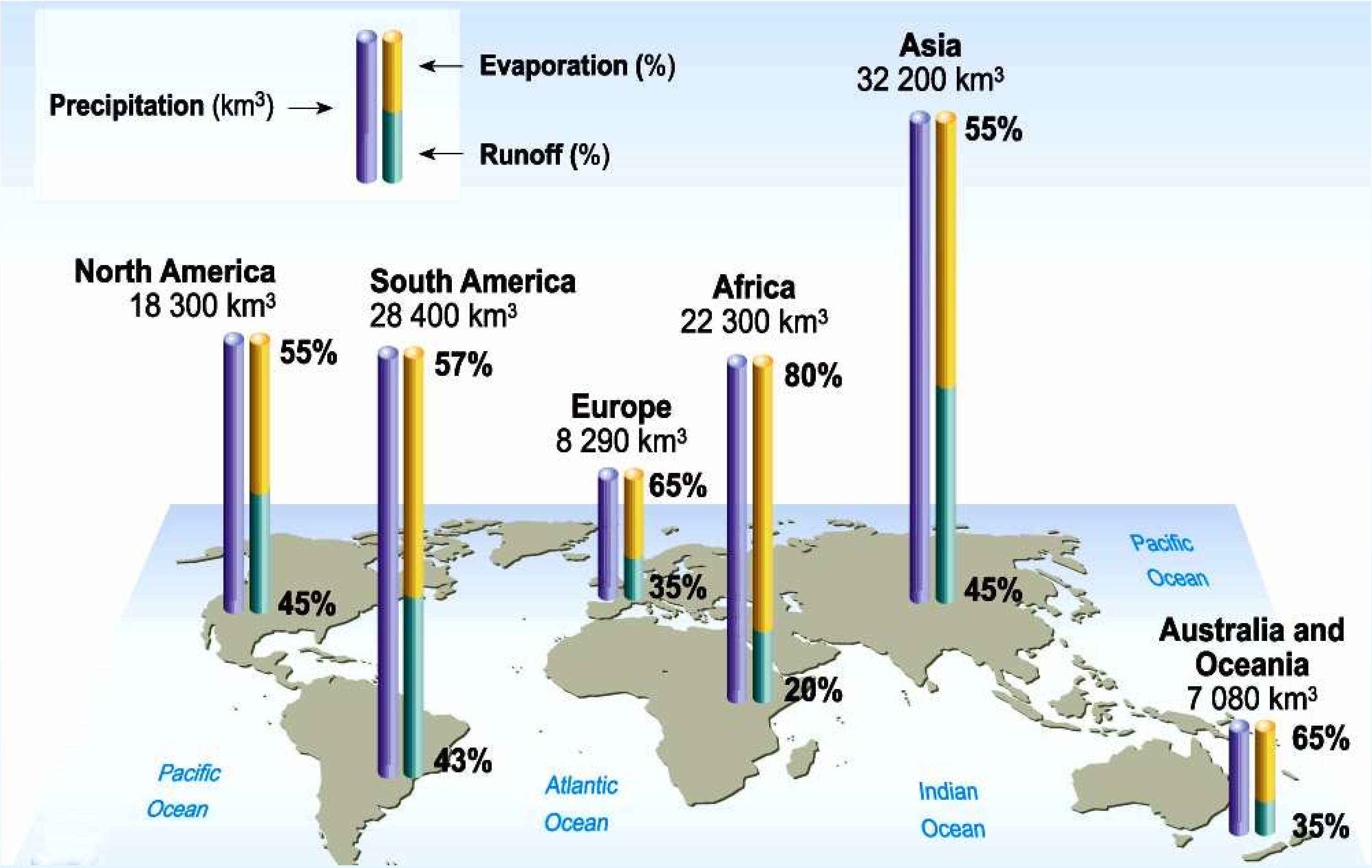
Subsurface Runoff



The direction and speed of ground-water movement is determined by the various characteristics of aquifers and confining layers (which water has a difficult time penetrating) in the ground. Water moving below ground depends on the permeability (how easy or difficult it is for water to move) and on the porosity (the amount of open space in the material) of the subsurface rock.

If the rock has characteristics that allow water to move relatively freely through it, then ground water can move significant distances in a number of days. But ground water can also sink into deep aquifers where it takes thousands of years to move back into the environment, or even go into deep ground-water storage, where it might stay for much longer periods.

Global Distribution



Available Water