

The Hydrological Cycle - overview

WHERE IS ALL THE EARTH'S WATER?

Water Cycle:

The Earth's total water supply is estimated to be over 1.3 billion cubic kilometres. It is constantly redistributed by a variety of processes. Water evaporates from the ocean and may fall as precipitation over land. Water re-enters the atmosphere from land by evaporation and transpiration (water loss by plants).

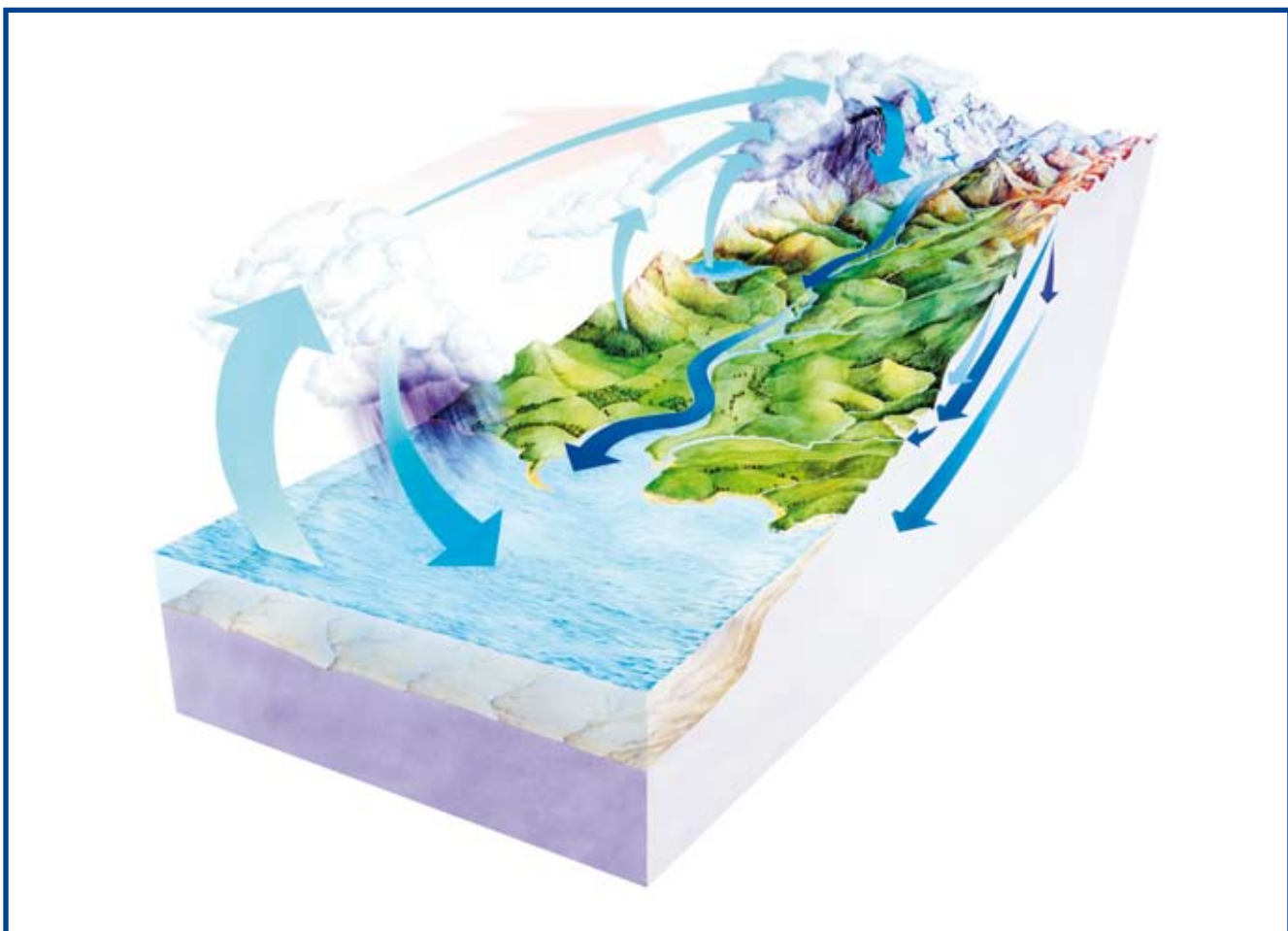
Water flows from land to ocean in surface rivers and streams. It also travels through soil and rock as groundwater. There is 30 times as much fresh water below ground than in lakes, rivers and inland seas.

*Photographer: Gary Hincks
(Science Photo Library)*

Water is the most widespread substance to be found in the natural environment and it is the source of all life on earth. Water covers 70% of the earth's surface but it is difficult to comprehend the total amount of water when we only see a small portion of it. The distribution of water throughout the earth is not uniform. Some places have far more rainfall than others.

There are many reasons for this, such as where the mountains are and where the prevailing winds blow. This rainfall distribution partly explains the differences in vegetation and why some areas are deserts and some are rainforests.

Water exists in three states: *liquid*, *solid* and invisible *vapour*. It forms the oceans, seas, lakes, rivers and the underground waters found in the top layers of the earth's crust and soil cover. In a solid state, it exists as ice and snow cover in polar and alpine regions. A certain amount of water is contained in the air as water vapour, water droplets and ice crystals, as well as in the biosphere. Huge amounts of water are bound up in the composition of the different minerals of the earth's crust and core.



WHAT IS THE HYDROLOGICAL CYCLE?

HOW DOES THE HYDROLOGICAL CYCLE WORK?

Evaporation

To assess the total water storage on the earth reliably is a complicated problem because water is so very dynamic. It is in permanent motion, constantly changing from liquid to solid or gaseous phase, and back again. The quantity of water found in the hydrosphere is the usual way of estimating the earth's water. This is all the free water existing in liquid, solid or gaseous state in the atmosphere, on the Earth's surface and in the crust down to a depth of 2000 metres. Current estimates are that the earth's *hydrosphere* contains a huge amount of water - about 1386 million cubic kilometres. However, 97.5% of this amount exists as saline waters and only 2.5% as fresh water.

The greatest portion of the fresh water (68.7%) is in the form of ice and permanent snow cover in the Antarctic, the Arctic and in the mountainous regions. 29.9% exists as fresh *groundwaters*. Only 0.26% of the total amount of fresh water on the earth is concentrated in lakes, reservoirs and river system, where it is most easily accessible for our economic needs and absolutely vital for water ecosystems.

The values for stored water given above are for natural, static, water storage in the hydrosphere. It is the amount of water contained simultaneously, on average, over a long period of time, - in water bodies, aquifers and the atmosphere. For shorter time intervals such as a single year, a couple of seasons or a few months, the volume of water stored in the hydrosphere will vary as water exchanges take place between the oceans, land and the atmosphere.

The total amount of water on the earth and in its atmosphere does not change but show that rain and flowing rivers must be a motion that transfers water in a never-ending cycle. Oceans, rivers, clouds and rain, all of which contain water, are in a frequent state of change. This circulation and conservation of earth's water as it circulates from the land to the sky and back again is called the 'hydrological cycle' or 'water cycle'.

The stages of the cycle are:

- Evaporation
- Transport
- Condensation
- Precipitation
- Groundwater
- Run-off

Water is transferred from the surface to the atmosphere through *evaporation*, the process by which water changes from a liquid to a gas. The sun's heat provides energy to evaporate water from the earth's surface. Land, lakes, rivers and oceans send up a steady stream of water vapour and plants also lose water to the air (transpiration).

Approximately 80% of all evaporation is from the oceans, with the remaining 20% coming from inland water and vegetation.

Transport

The movement of water through the atmosphere, specifically from over the oceans to over land, is called *transport*. Some of the earth's moisture transport is visible as clouds, which themselves consist of ice crystals and/or tiny water droplets.

Clouds are propelled from one place to another by either the jet stream, surface-based circulations like land and sea breezes or other mechanisms. However, a typical cloud 1 km thick contains only enough water for a millimetre of rainfall, whereas the amount of moisture in the atmosphere is usually 10-50 times greater than this.

Most water is transported in the form of water vapour, which is actually the third most abundant gas in the atmosphere. Water vapour may be invisible to us, but not to satellites which are capable of collecting data about the moisture content of the atmosphere.

Condensation

The transported water vapour eventually *condenses*, forming tiny droplets in clouds.

Precipitation

The primary mechanism for transporting water from the atmosphere to the surface of the earth is *precipitation*.

When the clouds meet cool air over land, precipitation, in the form of rain, sleet or snow, is triggered and water returns to the land (or sea). A proportion of atmospheric precipitation evaporates.

Groundwater

Some of the precipitation soaks into the ground and this is the main source of the formation of the waters found on land - rivers, lakes, groundwater and glaciers.

Some of the underground water is trapped between rock or clay layers - this is called *groundwater*. Water that infiltrates the soil flows downward until it encounters impermeable rock and then travels laterally. The locations where water moves laterally are called 'aquifers'. Groundwater returns to the surface through these *aquifers*, which empty into lakes, rivers and the oceans.

Under special circumstances, groundwater can even flow upward in artesian wells. The flow of groundwater is much slower than run-off with speeds usually measured in centimetres per day, metres per year or even centimetres per year.

Run-off

Most of the water which returns to land flows downhill as *run-off*. Some of it penetrates and charges groundwater while the rest, as river flow, returns to the oceans where it evaporates. As the amount of groundwater increases or decreases, the water table rises or falls accordingly. When the entire area below the ground is saturated, flooding occurs because all subsequent precipitation is forced to remain on the surface.

Different surfaces hold different amounts of water and absorb water at different rates. As a surface becomes less permeable, an increasing amount of water remains on the surface, creating a greater potential for flooding. Flooding is very common during winter and early spring because frozen ground has no permeability, causing most rainwater and meltwater to become run-off.

This entire process repeats as illustrated in Figure 1.

Figure 1.
The stages of
the hydrological
cycle.

(http://www-k12.atmos.washington.edu/k12/pilot/water_cycle/grabber2.html)

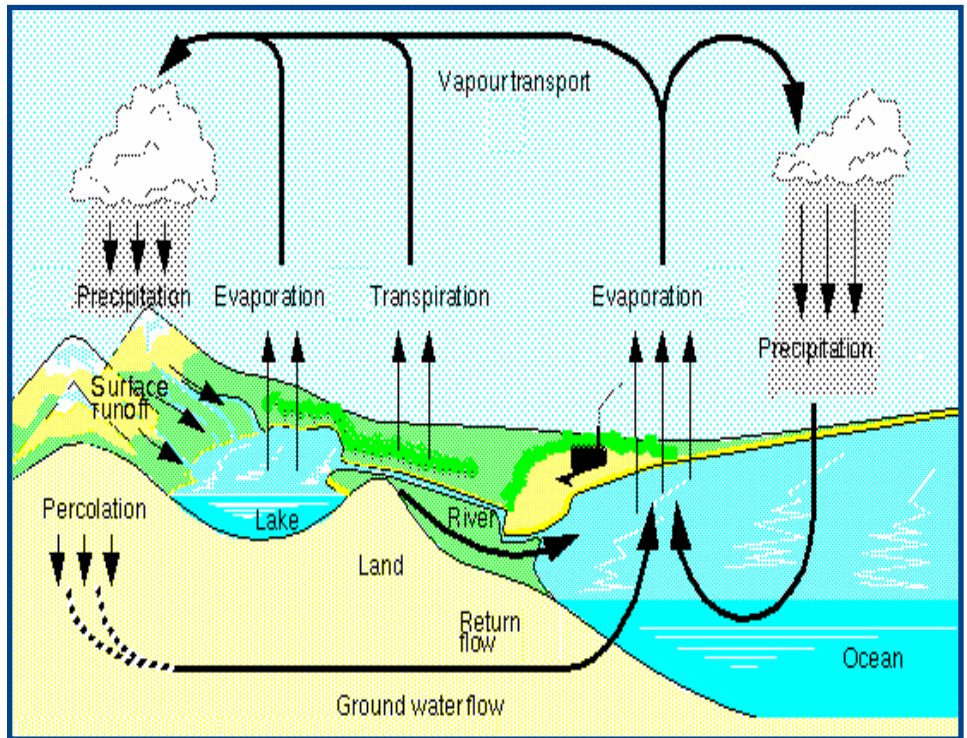


Diagram from Max Planck
Institute for Meteorology

A water balance

A considerable portion of river flow does not reach the ocean, having evaporated those areas with no natural surface run-off channels. On the other hand, some groundwater bypasses river systems altogether and goes directly to the ocean or evaporates.

Every year, the turnover of water on Earth involves 577,000 km³ of water. This is water that evaporates from the ocean surface (502,800 km³) and from land (74,200 km³). The same amount of water falls as atmospheric precipitation, 458,000 km³ on the ocean and 119,000 km³ on land. The difference between precipitation and evaporation from the land surface (119,000 – 74,200 = 44,800 km³/year) represents the total run-off of the Earth's rivers (42,700 km³/year) and direct groundwater run-off.

More information on the volumes of global water and freshwater can be found at:

(<http://www.unesco.org/science/waterday2000/Cycle.htm>)

HOW DOES WATER SUPPLY AND SEWAGE DISPOSAL FIT INTO THE HYDROLOGICAL CYCLE?

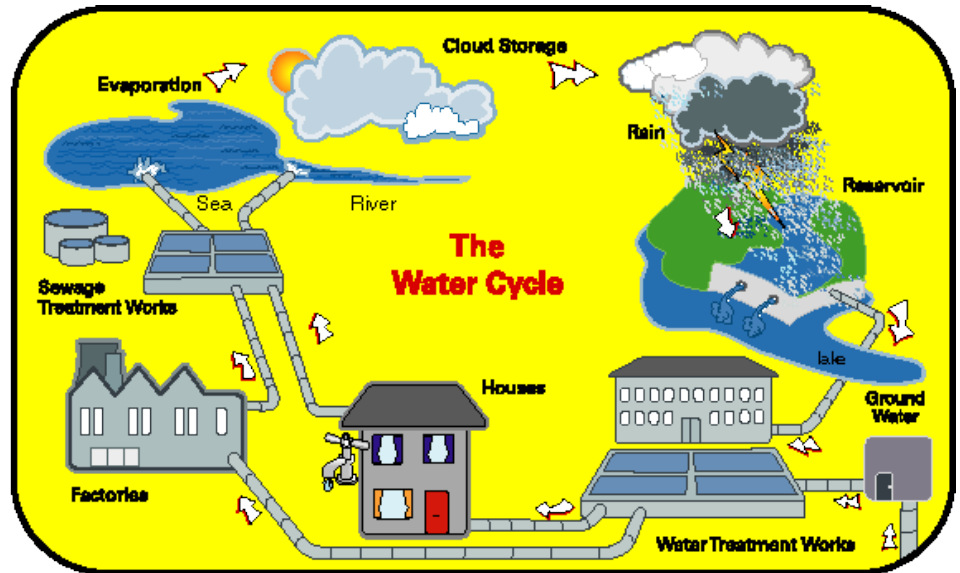
We have seen that water flows into rivers, lakes and into groundwater storage. Most importantly, for our daily water needs, it also flows into our homes and taps. A network of underground pipes, pumping stations and treatment works ensures that clean, fresh drinking water is delivered by our local water utility to our homes every day of the week. After water has been used, the water utility collects, transports and then cleans this dirty water and returns it safely back into rivers where it can continue its journey downstream to the sea.

The water utility's responsibility begins at the precipitation stage of the hydrological cycle. Utilities in some water-scarce countries encourage the collection of rainwater from rooftops (rainwater harvesting) but in most of Europe the hydrological cycle begins with surface waters.

Figure 2 illustrates the water utility's role in the hydrological cycle.

Figure 2.
The water utility's role in the hydrological (water) cycle.

Reference UK Drinking Water Inspectorate website
(<http://www.dwi.gov.uk/pubs/tap>)



Surface waters

Rain water searches for the quickest route to the sea and flows into rivers, streams, lakes and underground stores. The water in the surface waters is clean enough to support a variety of wildlife. Although it is clean, it is not safe to drink and needs to be treated in a water treatment works to remove any substances that may be harmful.

Water treatment works

see also Information Note FWR-WFD12 - Water Treatment and Supply.

Water is abstracted from underground sources via boreholes or alternatively is pumped from rivers and stored in reservoirs before being passed through sand filter beds which trap any dirt and organisms. It is then treated using the most up to date advanced water treatment (AWT) technology such as ozonation and carbon filtration (granular activated carbon) which remove the substances that we cannot see.

Water distribution

Clean, fresh drinking water is pumped into an underground network of pipes and storage reservoirs and is not seen again until it reaches your tap. This guarantees that the water you drink remains clean and fresh.

Water use

On average, in European countries, each person uses around 55,000 litres of water every year. Baths, showers, washing up, washing clothes and toilet flushing all use large amounts of water. These activities transform clean tap water into dirty wastewater. The water utility not only supplies clean drinking water but also collects, transports and disposes of the dirty water after it has been used.

Sewerage

Dirty water or sewage is collected firstly in drains and then in underground sewers and is transported via a sewerage system (a network of pipes and tunnels) to a sewage treatment works.

Sewage treatment works

see also Information Note FWR-WFD15 - Sewage Treatment.

These works use natural micro-organisms to remove harmful substances from dirty water. The solid material (sludge) is separated from the liquid (effluent) and both are treated to produce clean effluent that can be released back to the river and bio-solids that can be used in agriculture as a fertiliser or incinerated to produce energy.

Completing the cycle

The river continues its journey back to the sea where the cycle starts again. Water evaporates to form clouds, condenses to droplets and eventually falls as rain on to the ground.

ACTIVITIES FOR SCHOOLS

This section is adapted from Thames Water's 'Water in Schools' website:

<http://www.waterinschools.com/challenge/index2.html>

There are a number of other websites which are of interest to students and teachers and which contain animated diagrams or slide shows for each stage of the hydrological cycle:

The University of Illinois

[http://ww2010.atmos.uiuc.edu/\(Go\)/guides/mtr/hyd/smry.rxml](http://ww2010.atmos.uiuc.edu/(Go)/guides/mtr/hyd/smry.rxml)

National Curriculum Educational Resources and Materials

<http://www.water-cycle.info/>

http://www.bbc.co.uk/schools/riversandcoasts/water_cycle/rivers/index.shtml

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