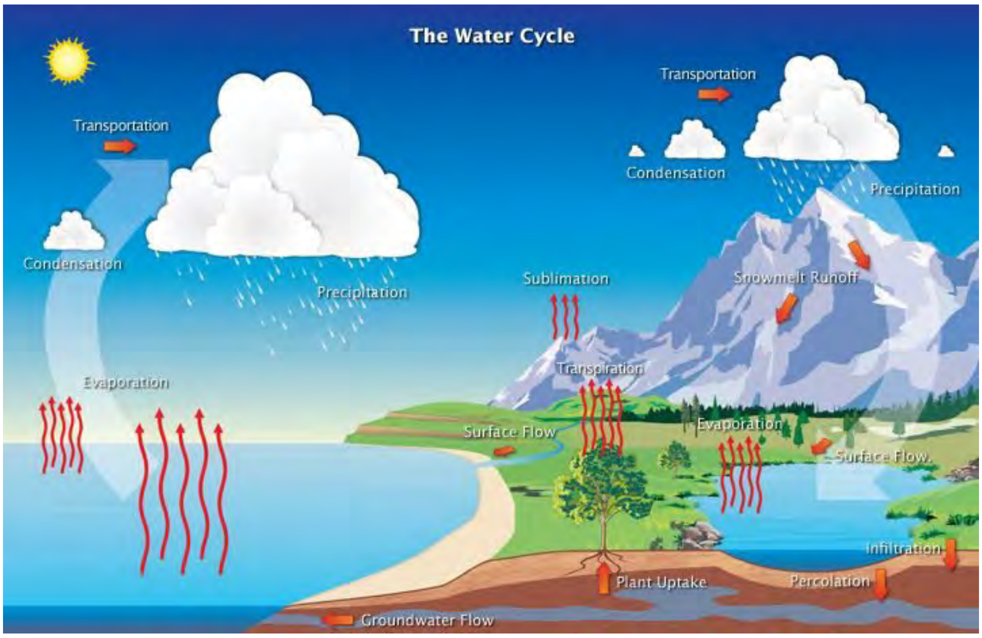
Edexcel Geography A-level

The Water Cycle and Water Security

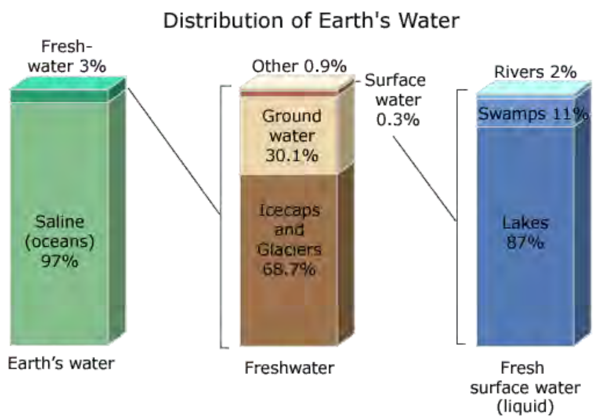
Essential Notes

The Hydrological Cycle - Global to Local Scale

- Water and the **hydrological cycle** are paramount in supporting life on earth. The cycle operates on a variety of spatial scales where physical processes control the circulation of water between stores on **land, oceans, the cryosphere and atmosphere.**
- The global hydrological cycle works as a closed system with inputs (rainwater), outputs, stores and flows within. These are driven by **solar energy and gravitational potential energy**.



- The hydrological cycle begins with **evaporation** where water vapour from the ocean is lifted and **condensed** in the atmosphere to form **clouds**.
- Moisture is then **transported** around the globe and returns to the surface as precipitation.
- When reaching the ground, some water will evaporate back into the atmosphere whilst some of the water may **percolate** the ground to form **groundwater**.
- The balance of water that remains on the surface of the earth is called **runoff** and is emptied into lakes, rivers and streams which carry it back to the oceans for the process to start again.



- As seen in the graphs to the left, the percentage contribution of water stores varies, with the majority of earth's water being in **saline oceans** and freshwater being largely **locked-up** within icecaps and glaciers.
- The **global water budget** limits water availability for human use and water stores have different residence times; some stores, such as those storing fossil water, are non-renewable. For instance the Ogalla aquifer in the USA High Plains has stored fossil water from the previous glacial melt so cannot recharge quickly.

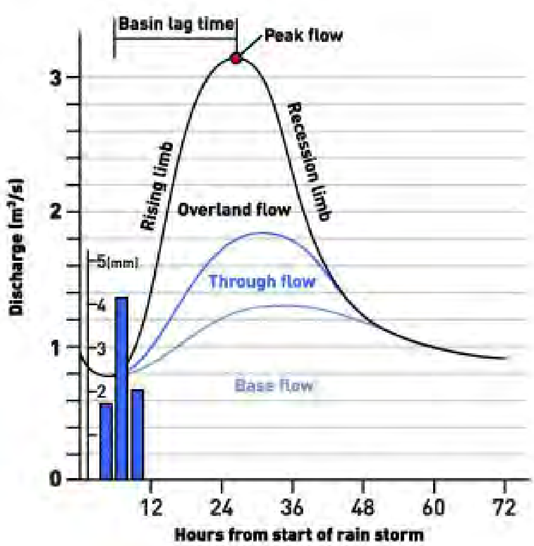
Drainage Basins

- ➔ The **drainage basin** is the area of land drained by a river (as shown in the image on the right). Water always travels downstream due to gravity.
- ➔ The hydrological cycle is a system of linked processes with flows involving:
  - **Interception**: Precipitation that does not reach the soil as it is intercepted by vegetation and the forest floor.
  - **Infiltration**: Water on the ground soaking into the soils and porous rocks.
  - **Throughflow**: The flowing of water within the soil, moving towards the river.
  - **Percolation**: The movement of water through the soil or underlying porous rock, being stored as groundwater.
- ➔ Outputs occur in the form of **evaporation, transpiration and channel flow**. Physical factors within the drainage basin determine the importance of flows, inputs and outputs. These physical factors involve:
  - **Climate**:
    - Temperature and precipitation patterns determine availability and vary according to latitude.
    - Seasonality determines patterns – Vancouver is wettest between October and March.
    - Summer temperatures increase evaporation rates but plant growth increases transpiration rates. Soils stores water in winter for summer use.
    - Equatorial areas receive the most rainfall. Mountain snow can be released as water in warmer temperatures, increasing the amount of easily accessible water.
  - **River Systems**:
    - Drainage basins collect precipitation and channel it towards the coast.
    - Availability depends on land use, basin size and shape and precipitation type.
    - Flow increases downstream but climate creates variation in discharge and water loss.
    - Climate can also produce river regimes where water is supplied through glacial and snow melt.
  - **Geology:**
    - Determines underground storage according to permeability. Porous rock stores water.
    - Metamorphic rocks such as granites are aquicludes, cause runoff but do not store water.
    - Gravel store the most water if unconsolidated and bounded by impermeable rocks.

- → Humans disrupt the drainage basin by accelerating processes such as **deforestation** and **changing land use**. By digging deep wells, there is a **high risk of salinisation** which contaminates water sources and therefore reduces the available water supply.
- → **Urbanisation** increases the proportion of impermeable surfaces which prevents precipitation penetrating the ground, meaning less groundwater is stored and thus water availability declines.

Water budgets and River Systems at Local Scales

- → **Water budgets** show the annual balance between inputs, being precipitation, and outputs, through evapotranspiration, and their impact on soil water availability.
- → Water budgets are influenced by **climate types**:
  - Temperate - Faces mild temperatures and steady climate.
  - Tropical - Can be tropical wet, tropical monsoon or tropical wet and dry seasons.
  - Polar - Tundra and ice caps climates. Tundra summers are short and in ice cap seasons, temperatures are seldom above freezing.
- → **River regimes** indicate the annual variation of discharge of a river and give an indication of the climate, geology and soils. As global temperatures increase, due to climate change, river discharge is likely to increase as glacier meltwater increases river input.
- → **Storm hydrographs'** shape depends on human factors such as land use and urbanisation as well as physical features of the drainage basin, including:



Shape: For rapid drainage, the shape will be circular. A long, narrow basin will mean it takes water longer to reach the river.
Size: Smaller the basin, the less time it takes for water to drain to the river so shorter the lag time.
Drainage Density: The higher the density, the greater the risk of flooding.
Rock Type: Impermeable rocks encourage greater surface runoff and a more rapid increase in discharge than permeable rocks.
Soil and Vegetation: Roots of plants take up water, reducing throughflow. Vegetation reduces the amount of discharge.
Relief: Steeper the basin, the quicker it drains.

Deficits with the Hydrological Cycle

- **Droughts** are long periods of time with below average precipitation. Meteorological causes involve **short-term precipitation deficit, ENSO cycles** (the onset of El Niño and La Niña), **anticyclones** (when air does not rise so condensation and cloud formation does not occur) and **changes in the ITCZ**.
- **El Niño** is a reverse of Walker's cells where high pressure accumulates above Australia, causing drought like conditions, whilst South America becomes a low pressure centre, at high risk of flooding and intense rainfall.
- **La Niña** is an intensification of Walker's cell where Australia has a low pressure system whilst South America experiences drought like conditions due to high pressure formation.
- In 2006, southern Australia had an extremely low rainfall season, the lowest since 1990. This caused the River Murray to dry up in places, reducing food production, social wellbeing and water supply for locals. The drought is said to be triggered by the El Niño and exacerbated by poor human management over water sources. Six million sheep died as result of the drought whilst thousands migrated away from the Murray Darling Basin.
- Human activity increases drought risks due to the **over-abstraction** of surface water resources and ground water aquifers, reducing water supply.
- Additionally, **deforestation** reduces the soil's ability to store water, causing the land to dry out. **Construction of dams** on a large river, albeit producing hydroelectric power and water for farmland, can cause drought by reducing water flow downstream.
- Droughts have impacts on ecosystems functioning as wetlands and the natural environment are unable to get the materials they require for adequate growth. Drought can cause a loss of wetlands and forest stress, highlighting the resilience of ecosystems.

Surpluses within the Hydrological Cycle

- Surpluses within the hydrological cycle can lead to **flooding** which can have disastrous impacts for people, destroying **social wellbeing and economic security**.
- Meteorological causes of flooding include **intense storms** (causing flash flooding), **heavy and prolonged rainfall, a series of depressions** (low pressure systems), **extreme monsoonal rainfall** and **snowmelt**.
- Human actions such as urbanisation and deforestation increase flood risk. Urbanisation results in an increase in impermeable surfaces, allowing for surface runoff, whilst deforestation reduces the amount of water being intercepted, likewise causing an increase in surface runoff.
- As well as changing land use, **mismanagement of rivers** and **inadequate hard engineering systems** also exacerbate flood risk. The Carlisle flooding in 2005 saw two months' worth of rainfall drop in 24 hours, killing three people and leaving 2700 homes flooded. The cost of flooding was over £400 million, losing business and employment opportunities for the destroyed McVitie's Biscuit factory.
- Flood damage strains economic activity whilst ruining infrastructure and settlements. Environmental impacts involve damage to soils and ecosystems as roots are inundated.

The Role of Climate Change on the Hydrological Cycle

- **Climate change** effects the inputs and outputs of the hydrological cycle by altering precipitation and evaporation rates. Some areas are likely to face flooding, such as Bangladesh since it's on low lying land, whilst other regions will face prolonged drought, such as the Sahel region in Africa.
- Climate change has an impact on stores, flows, size of snow and glacier mass, reservoir, lakes, permafrost, soil moisture levels and runoff rates. The entirety of the hydrological cycle is thus at risk of change.
- Climate change's impacts are uncertain, causing concern over water supplies and efficiency of management.

Water Insecurity & Global Implications

Physical and Human Causes of Water Insecurity

- In some areas of the world there is a growing mismatch between water supply and demand as demand, due to a **growing population** outstrips the finite supply of available freshwater.
- This has led to a global pattern of **water stress**, which involves the deterioration of water quantity and quality.
- Water stress is when each person has below **1700 m^3 of water** whilst water scarcity is when freshwater shortages threaten food production and ecosystem wellbeing; there being below **1000 m^3 of water** per person.
- Physical causes of water insecurity include **climate variability** and **saltwater encroachment** at the coast where drinking water becomes contaminated as salinity increases.
- Human causes exacerbate these physical issues due to factors such as:
  - **Over-abstraction from rivers, lakes and groundwater**: During the Green Revolution in Punjab within the 1960s, over abstraction of ground water caused salinization as wells were dug too deep to extract water, some being greater than 110 ft. deep. This reduced food production and caused water and food insecurity.
  - **Water contamination from agriculture**: Use of fertilisers and pesticides can wash into lakes/rivers, polluting water sources.
  - **Industrial water pollution**: Chemicals used in industry can contaminate water sources. Additionally there is a conflict between whether water should be use by industry, who can afford it, or used by locals for food production/living. In Kerala there was conflict between locals and Coca-Cola after allegations were made claiming the Coca-Cola company 'stole' local water sources for Coke production.

- Finite water sources face pressure from rising demands, due to increased population, improving standards of living, industrialisation and agriculture. In some locations, such increases are already threatening water security, such as in Delhi, Egypt, Jordan and Israel.

<u>Consequences and Risks of Water Insecurity</u>

- The price of water varies globally according to wealth. The process of cleaning water is expensive and so water price matches production costs. Additionally, in densely populated areas, water prices increase as supply cannot meet demand. In some places, such as Mexico and Kenya, a bottle of Coca-Cola is cheaper than a bottle of water, having significant impacts on water scarcity and health.
- Water supply is vital for economic development, needed for activities in industry, energy supply and agriculture. It is also important for human wellbeing such as **sanitation, health and food preparation**. A lack of water thus has detrimental impacts on the economy and environment.
- Water insecurity problems is likely to cause **transboundary and international conflicts**. One example is The Euphrates River which is predominantly controlled by Turkey, limiting supplies for downstream states such as Syria.

Managing Water Supply Sustainably

- Hard engineering schemes, including **water transfers** (The Australian Snowy Mountains Scheme brings water to South Australian communities) **desalination plants** and **mega dams** are effective but expensive and unsustainable.
- Water conservation, such as **rainwater catchment** in Singapore and Bermuda, is small scale but sustainable and cheaply done. **Recycling water** is environmentally friendly but some may reject the idea of using grey water (e.g. reusing water to flush).
- **Integrated management** can involve international treaties, such as the Helsinki Rules, but are difficult to run.