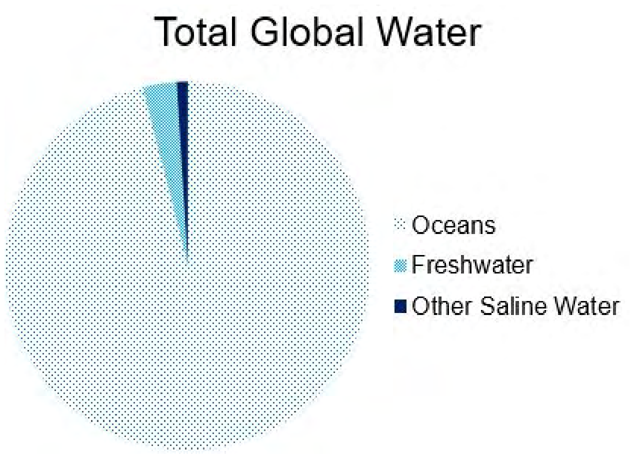
Edexcel Geography A-level

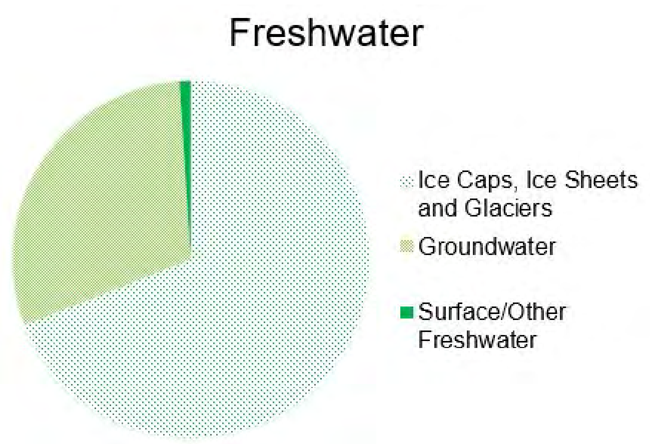
The Water Cycle and Water Insecurity

Detailed Notes

Global Water Budget

The global water cycle is comprised of many stores, the largest being oceans, which contain **97% of global water**. Only **2.5% of stores are freshwater** of which **69% is glaciers, ice caps and ice sheets** and **30% is groundwater**. Surface and other freshwater only accounts for around **1%** of global stores. Other surface and freshwater is made up of **permafrost, lakes, swamps, marshes, rivers and living organisms**.





Hydrology in Polar Regions

- 85% of solar radiation is reflected
- Permafrost creates impermeable surfaces
- Lakes and rivers freeze
- Rapid runoff in spring
- Seasonal release of biogenic gases into atmosphere
- Orographic and frontal precipitation

Hydrology in Tropical Rainforests

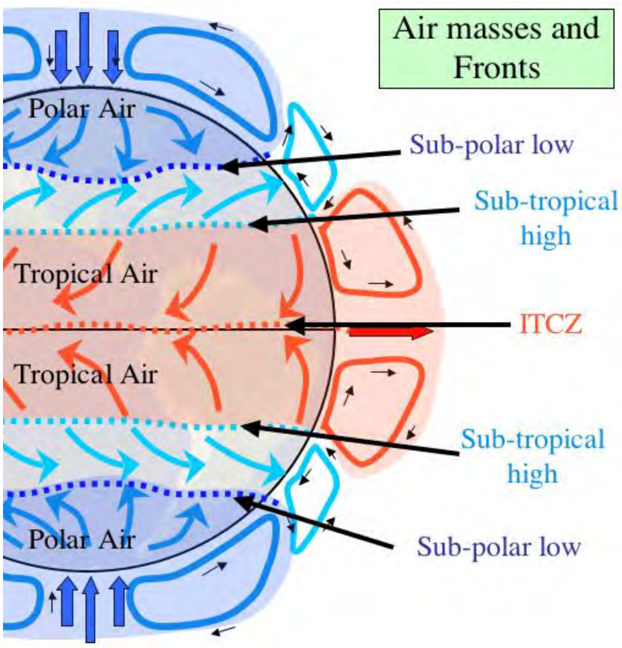
- Dense vegetation consuming 75% of precipitation
- There is limited infiltration
- Deforestation leads to less evapotranspiration and precipitation
- Very high temperatures
- Very humid
- Convectional rainfall

	% of total water	% of total freshwater	Residence time
Oceans	96.9	0	3600 years
Icecaps	1.9	68.7	15,000 years
Groundwater	1.1	30.1	10,00 years
Rivers and Lakes	0.01	1.2	2 weeks to 10 years
Soil moisture	0.01	0.05	2-50 weeks
Atmospheric Moisture	0.001	0.04	10 days

ITCZ (Inter-tropical Continental Zone)

The Earth consist of **six cells of circulating air,** which form the globe's climate control.

For the Northern Hemisphere (the same is true for the south, just in opposite directions):



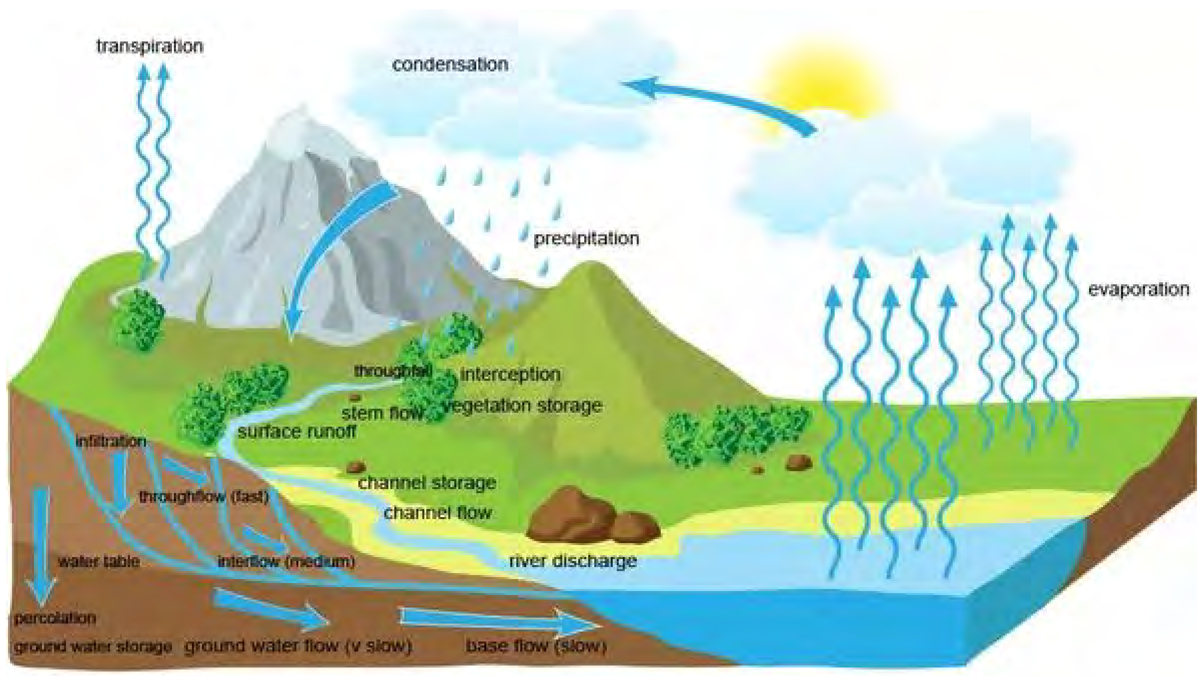
Hadley Cell - Air rises at The Doldrums, travels upwards, then sinks as it meets the cooler air of the Ferrel Cell. At this meeting point, precipitation tends to occur. The air then travels southwards, heating up as it does. It will then have heated sufficiently to rise up at the Doldrums, commencing the cycle again.

Polar Cell - Cold air sinks near the Arctic Circle, cooling and condensing to form precipitation over northern latitudes. The air then travels southwards, heating until it meets warm air from the Ferrel Cell. The air then rises, causing dry conditions for the land beneath, and then travels northwards, cooling as it does.

Ferrel Cell - The middle cell of the ITCZ (tends to be at a mid-latitude location). The air circulation is determined by the Hadley and Polar cells either side, similar to a cog system.

Drainage basins

A drainage basin is an **open subsystem** operating within the closed global hydrological cycle. It's defined as an area of **land drained by a river and its tributaries** with a boundary (known as the **watershed**), usually composing of hills and mountains. The basic flows, inputs and outputs are shown below:



On a **local scale,** the water cycle is an **open system** (a system of processes of water inputs, outputs and throughputs); on a **global scale**, the water cycle a **closed systems** (a system that has no inputs or outputs, only throughputs). The water cycle contains **flows/transfers, inputs, outputs and stores/components.**

Inputs to the Drainage Basin – Precipitation

Precipitation is caused by the **cooling and condensation** of water moisture in the atmosphere, forming clouds that release moisture in the form of rain, snow, hail, sleet, etc. Primary factors affecting volume or the condition of precipitation include:

- **Seasonality** – In some climates (such as monsoon and Mediterranean) there are strong seasonal patterns of rainfall. Therefore the time of year determines the precipitation input within the drainage basin
- **Variability** - sudden or long term changes to the climate can happen, which would affect precipitation levels and so the drainage basin as a whole.
  → **Secular Variability** – long term (for example as a result of climate change trends)
  → **Periodic Variability** – annual, seasonal or monthly context
  → **Stochastic Variability** – random factors like localisation of thunderstorm
- **Latitude** - The location of the drainage basin has a major impact on climate, and so the volume and type of precipitation falling. In most cases, the higher the latitude from the Equator, the colder the climate, and so snowfall occurs more often than rainfall. Also, at latitudes where air cells converge (**ITCZ**), the climate will be categorised by the rise or fall of air -

Types of Rainfall

- **Convectional** – Often a **daily** occurance. The morning heat warms the ground, which in turn heats low-level moisture (from plant dew or surface stores). This moisture evaporates and rises. As the air rises, it cools and the moisture within will condense, to form rain and in turn (as more moisture accumulates) rainfall. In **tropical climates**, convectional rainfall is most common; within tropical rainforests, rainfall occurs mid-morning before the temperature rises too high for condensation to occur.
- **Frontal/Cyclonic** – Where **two air masses meet**, a wedge can occur of hot air within cold air - this is called a **depression**. At the front (were the two air masses meet), warm moist air is forced to rise above the cold air mass, causing the water moisture within to cool and condense, to form **cyclonic precipitation.** Depressions are very common to the UK - approx 100 depressions hit the UK each year.
- **Relief/Orographic** – When warm, moist air (often travelling onto land from sea) meets land of **high relief** (e.g. hills), the air mass is forced to rise above the hill to continue travelling. As it rises, the air mass cools and the moisture within condenses, to form clouds and rainfall. **Orographic rainfall** depends on the relief and location of the land immediate after the sea - many coastal landscapes are too cold, low lying or hills are set too far inland for relief rainfall to occur.

Fluxes and Flows within the Drainage Basin

There are many flows within the drainage basin, many due to **gravity** and so depend on the **relief** of the land. These flows occur at **different speeds** which can influence many things including water balance and the likelihood of flooding

Interception

Interception is the direct intervention of plants' leaves in changing the direction or temporarily stopping precipitation as it falls to the surface. Any moisture retained by the surface of the leaf (**interception store)** is generally greatest at the start of storms. A plant's interception capacity varies depending on the type of vegetation.

Infiltration

The movement of water from the surface into the soil. The infiltration capacity is the maximum rate at which water can be absorbed by the soil, and can be affected by:

- **Soil Composition** – Sandy soils have higher infiltration rates compared to clay.
- **Previous precipitation** - The saturation of soils will reduce infiltration rates, hence surface runoff increases after long, intense periods of rainfall.
- **Type and amount of vegetation** - dense root growth can inhibit the infiltration of water, and interception of plants' leaves will delay infiltration (never stopped, as water will never permanently remain on the leaf).
- Compaction of soils will reduce the infiltration rate.
- **Relief of land** – sloped land will encourage more runoff, therefore less infiltration as a direct result.

Surface Runoff - Water flows overland, rather than permeating deeper levels of the ground. Overland flow occurs faster where the gradient of land is greater. Surface runoff if the primary transfer of water to river channels, hence heavily influencing their discharge - **Moderate/Fast**

Throughflow - Water moves **through the soil** and into streams or rivers. Speed of flow is dependent on the **type of soil**. **Clay soils** with a **high field capacity** and **smaller pore spaces** have a **slower flow rate**. **Sandy soils drain quickly** because they have a **lower field capacity**, **larger pore spaces** and **natural channels** from animals such as worms. Some sports fields have sandy soils, to reduce the chance of waterlogged pitches, but this may also increase the flood risk elsewhere - **Moderate/Fast**

Percolation - Water moves from the ground or soil into **porous rock or rock fractures** (deeper bedrock and **aquifers**). The **percolation rate** is dependent on the **fractures** that may be present in the rock and the **permeability** of the rock - **Slow**

Groundwater Flow - The gradual transfer of water through porous rock, under the influence of gravity. Water can sometimes become trapped within these deeper layers of bedrock, creating aquifers and long water stores for the drainage basin - **Slow**

Outputs of the Drainage Basin

There are three main outputs to a drainage basin; since the basin is an open system, often water and moisture are transferred across the watershed.

Evaporation

This is the direct loss of water moisture from the surface of a body of water, the soil and interception storage (on top of leaves) to the atmosphere. Evaporation rates increase when the weather is warmer, windier and dryer. Alternative factors also influence evaporation rates:

- **Volume and surface area of the water body** - the larger the surface area (more spread out), the faster the rate of evaporation.
- **Vegetation cover** or **built environment surrounding the water** - anything that reduces direct sunlight to the water body will reduce evaporation.
- **The colour of the surface beneath the water** - black tarmac will absorb heat faster than white snow, and so evaporation will occur faster on the tarmac.

Transpiration

This is a biological process where water is lost to the atmosphere through the pores of plants (**stomata**). Transpiration rates are affected by seasonality, the type of vegetation, moisture content of the air and the time of day (morning dew is the release of moisture through transpiration in temperate climates).

Stores

Soil Water - Water stored in the soil which is **utilised by plants** - **Mid-term**
Groundwater - Water that is stored in the **pore spaces of rock** - **Long-term**
River Channel - Water that is stored in a river - **Short-term**
Interception - Water intercepted by plants on their branches and leaves before reaching the ground - **Short-term**
Surface Storage - Water stored in puddles, ponds, lakes etc. - **Variable**

The **water table** is the **upper level** at which the **pore spaces and fractures in the ground become saturated**. It is used by researchers to **assess drought conditions, health of wetland systems, success of forest restoration programmes** etc.

Factors influencing the Drainage Basin

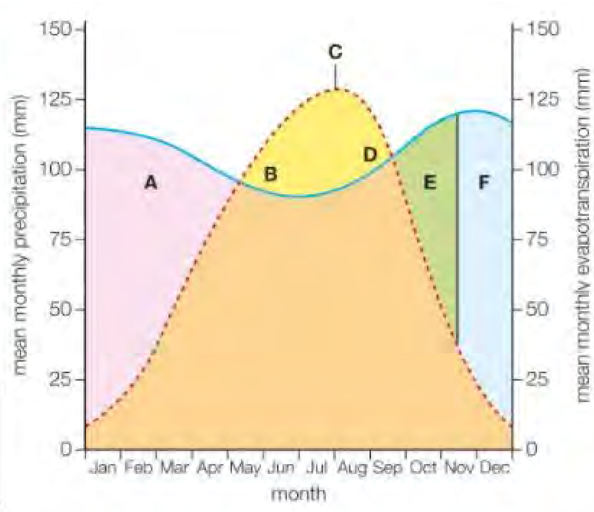
Physical Factors	Anthropogenic Factors (Human)
➢ **Climate** – influences amount of rainfall and vegetation growth. ➢ **Soil Composition** – influences rate of infiltration and throughflow. ➢ **Geology** – affects percolation and groundwater flow ➢ **Relief** – steeper gradients of land will encourage faster rates of surface runoff ➢ **Vegetation** – affects interception, overland flow ➢ **Size** – larger basins collect more precipitation generally	➢ **Cloud seeding** – substances dispersed into the air to provide something for condensation to occur on in example: Was used in China right before 2008 Beijing games to try and reduce pollution levels ➢ **Deforestation** – Less vegetation means less interception, less infiltration, more overland flow leading to more flooding, cycle speeds up ➢ **Afforestation** – More vegetation means interception, less overland flow, more evapotranspiration ➢ **Dam construction** – Dams reduce downstream river flow and discharge, increase surface stores so more evaporation Example: Lake Nasser behind Aswan dam in Egypt – 10-16 billion m^3 water loss from Nile ➢ **Change in land use** – Infiltration is 5 times faster under forests compared to grasslands. Converting land to farmland means less interception, increased soil compaction and more surface runoff ➢ **Ground water abstraction** – When water is taken out faster that the water is recharged, groundwater flow decreases and the water table drops Example: In China, groundwater irrigates 40% of farmland whilst 70% of drinking water comes from groundwater ➢ **Irrigation** – Drop in water tables due to high water usage. Example: Aral Sea in Kazakhstan shrank in 1960s due to farmers using the water to grow cotton ➢ **Urbanisation** – Impermeable surfaces reduce infiltration, increase surface runoff, river discharge increase. Cycle speeds up like

Water Balance and River Regimes

The Water Budget

In the short term, water availability varies between different days and months. Over long periods of time (annual) surpluses and deficits can cancel out.

Precipitation = Discharge + Evaporation ± changes in stores



A. Precipitation is greater than evaporation, therefore the soil's moisture increases creating a **soil moisture surplus**.

B. As temperature increases, the rate of evaporation will increase. The soil uses the moisture gained during its surplus, through **soil moisture utilisation**.

C. The point of maximum evaporation. This is the point of highest risk of drought.

D. Despite evaporation decreasing, there isn't enough precipitation to provide for vegetation use of water loss, therefore there is a **soil moisture deficit**.

E & F. As precipitation exceeds evaporation rates, the soil will regain moisture and reduce its deficit, through **soil moisture recharge**.

River Regimes

A regime is the **annual variation in discharge** of a river at a particular location. Most of this river flow isn't from immediate precipitation, but is supplied from **groundwater** between periods of rain, which slowly feeds water into the river system.

There can be **seasonal** variations in the regime - periods of high discharge followed by low discharge which are due to **glacial meltwater, snowmelt** or **monsoons** which cause sudden fluctuations in river input. **Complex regimes** tend to occur for larger rivers, that cross different reliefs and climatic zones (e.g. The Ganges, Mississippi).

Factors affecting the characteristic of a river's regime include:

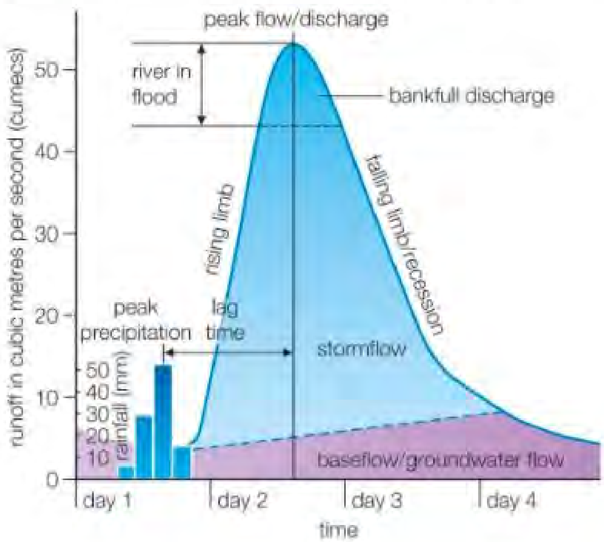
- Channel capacity of the river
- Area and relief of the drainage basin
- Volume, pattern and intensity of precipitation
- Climate
- Geology of the soil (affecting the input of groundwater)
- Anthropogenic (human) activities, such as building dams or terracing the land.

Storm Hydrographs

Storm hydrographs represent the variation in discharge within a short period of time (**days**, rather than years). Before a storm begins, the main supply of water to the river is through groundwater or base flow. However, as a storm develops, infiltration and surface runoff will increase which causes a greater **throughflow**.

Features of storm hydrographs include:

- **Rising limb** – The increase of river discharge, not necessarily instantaneously after precipitation.
- **Peak flow -** The maximum discharge, delayed after maximum precipitation has occurred.
- **Lag time** – The time delay between peak rainfall and peak discharge
- **Falling limb** – As the storm precipitation levels decrease, discharge will in turn decrease over time.
- **Base flow** – Eventually, the discharge returns to its normal level



Physical factors influencing Hydrographs

	Flashy Storm Hydrograph	Subdued Storm Hydrograph
Description of hydrograph	Short lag time High peak Steep rising limb	Long lag time Low peak Gently sloping rising limb
Weather/Climate	Intense storm which exceeds infiltration capacity of soil Rapid snow melt as temperatures rise above 0° suddenly Low evaporation rates due to low temperatures	Steady rainfall which is less than the infiltration capacity of soil Slow snow melt as temperatures rise very slowly High evaporation rates due to high temperatures
Rock type	Impermeable rocks like granite which encourage rapid surface runoff	Permeable rocks like limestone which allow for infiltration and reduce runoff
Soil	Low infiltration rate	High infiltration rate
Relief	High and steep slopes → More runoff	Low and gentle slopes → Less runoff
Basin size	Usually small basin	Usually large basin
Vegetation	Low density vegetation, less interception and more rapid movement of water	High density vegetation, more interception, more evapotranspiration
Pre-existing conditions (Antecedent conditions)	Basin already wet from previous rainfall	Basin dry Low water table

	High water table Soil saturated, less infiltration	Soil unsaturated, more infiltration
Human activity	Urbanisation, Deforestation Channelisation, Dams	Afforestation

Management of Drainage Basins

Attempting to manage a drainage basin **sustainably** can be challenging. Some river management schemes try to reduce runoff from precipitation, therefore reducing the risk of flash flooding or storm flow discharge, by:

- Growing **vegetation on roofs**, to increase interception and temporarily stores some water within plants.
- Create **permeable pavements** (gaps within paving blocks) to increase infiltration and reduce surface runoff .
- **Rainwater Harvesting** – collecting rainwater to use as domestic greywater
- Creating **wetlands** (areas with marsh and wetland vegetation) that will act as natural sponges and increase temporary water storage.

Alternatively, trying to manage the anthropogenic impacts on a drainage basin can also be challenging. Allowing human development on a basin can outweigh the need for sustainable management, due to population or housing pressures. Impacts can include:

- **Deforestation, tree felling and slash-and-burn** - Soil becomes exposed and roots are lost (which bind the soil together), which leads to more soil erosion and so more surface runoff.
- **Impermeable surfaces** – As more tarmac and concrete is laid, less infiltration into the topsoil can occur, and so more surface runoff occurs.
- Bridges can act as dams for rivers, restricting channel flow (especially storm flow) and increasing the pressure the river's water is under, therefore worsening flood impacts.
- Drainage and sewage systems will reduce lag time, and so a quick flow of water back to rivers, increasing the risk of flash flooding.

Deficits in the Hydrological Cycle

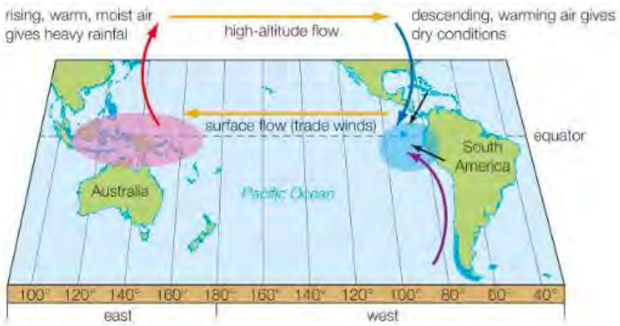
An **imbalance** in inputs and outputs of water can have serious implications for the hydrological cycle. A **deficit** (more commonly known as a **drought**) refers to when input is less than output. This deficit can be caused by natural and/or human factors.

Types of droughts and their characteristics		
Features		Impacts
Meteorological Drought	**Rainfall deficit** Low precipitation High temperatures Strong winds Increased solar radiation Reduced snow cover	Loss of soil moisture Irrigation supply drops Reduction in water available for consumption.
Hydrological Drought	**Stream flow deficit** Reduced infiltration Low soil moisture Little percolation and groundwater recharge	Reduced storage in lakes and reservoirs Less water for urban supply Poorer water quality Threats to wetlands and habitats
Agricultural Drought	**Soil moisture deficit** Low evapotranspiration Reduced biomass Fall in groundwater level	Poor yields from rainfed crops Failing irrigation systems Livestock productivity falls Rural industries affected Government aid may be required
Socio-Economic Drought	**Food deficit** Loss of vegetation Increased risk of wildfires Soil erosion Desertification	Widespread failure of agricultural systems Food shortages Rural economy collapses Rural to urban migration International aid required Humanitarian crisis

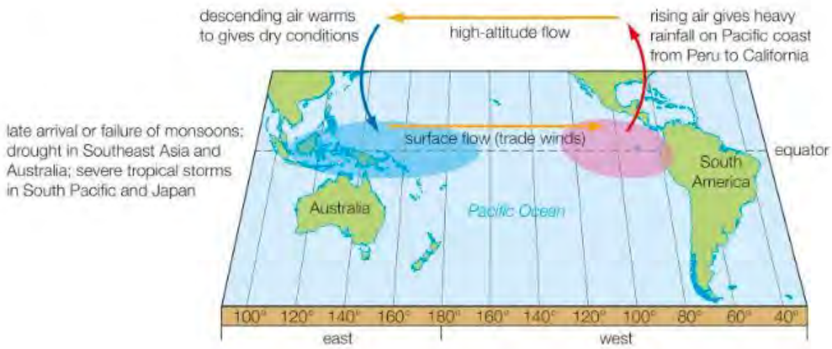
El Nino Southern Oscillation

El Nino is the **change** in water body patterns within the Southern hemisphere, leading to unusual weather conditions. The causes of El Nino aren't fully understood.

- Normally cool water is found along the Peruvian coast, and warm waters are found around Australia.
- ENSO causes this to switch (Peru gets warm waters, whereas Australia get cold water) and usually occurs every 3 to 7 years, generally lasting for 18 months.
- Peruvians can determine ENSOs occurrence based on their **anchovy** harvest - anchovies prefer cold waters, therefore as the water warms up (due to El Nino) the anchovies will migrate away, causing a reduction in Peruvian harvest.
  - ENSO can also trigger **extremely dry conditions** in areas South & South-East Asia, Eastern Australia and North-East Brazil. In South Asia, ENSO can **weaken the annual monsoon**.



The conditions before and during El Nino



Functioning Ecosystems

Wetlands

Wetlands act as **temporary water stores** within the hydrological cycle, which can help **mitigate** from river floods due to sudden storm discharge. Chemically, wetlands act like giant water filters by **trapping and recycling nutrients and pollutants**, which helps to maintain water quality of the river. Wetlands have very high **biological productivity** and support a very **diverse food web**, providing nursery areas for fish and refuges for migrating birds. All these functions contribute towards their natural importance as well as a value for human society (for example, providing fish for food or a clean water supply)

Value of Wetlands:

Supporting Life	Provision of Resources	Regulating Conditions	Cultural Value
- Stores and flows of carbon (through vegetation and soils/peat)	- Fuelwood	- Regular supply of groundwater and so base flow of river	- Aesthetic value
- Nutrient recycling	- Fisheries	- Water purification	- Recreational use
	- Mammals and bird for tourism	- Reduced flood risk	- Cultural heritage

Meteorological droughts have a major impact on wetlands; reduced interception due to less precipitation will cause vegetation to wilt and die, which in turn impacts **soil nutrients levels** and the rest of the complex food web.

Desertification

Physical Causes:

- **Reduced Precipitation** - As vegetation dies, the **protective layer** it provided for the soil will also be removed. As a result, the soil will be increasingly **exposed** to wind and rain, which will accelerate the rate of **soil erosion**, leading to worsening soil conditions. This may cause a **positive feedback loop** of worsening soil condition and vegetation death, leading to desertification.
- **Global Warming** - The rise in average climatic temperatures will increase the rate of evaporation of water moisture, especially in tropical and sub-saharan climates. If more moisture has evaporated, less will be available for convectional rainfall, and so plant growth will be stunted and vegetation dies (leading to desertification as described above).

Human Cause:

Population growth is the root cause of the recent increase in rates of desertification. As populations increase, the **demand for food, water and other resources** also increases. As pressure for food increases, **agricultural** methods change to supply the demand. For example, cattle farming is becoming intensified resulting in large areas of forest being cut down to provide enough land for grazing. Intensification of crop farming means the fallow time between crop harvest and new planting will be reduced. These farming practices can cause **over-cultivation, trampling of vegetation and loss of soil nutrients** which reduces soil fertility. In addition, forests may be **felled or slashed-and-burned** to make room for new farms or housing, further worsening soil quality and exposing the topsoil to erosion. Over time, desertification will escalate in a **positive feedback loop**.

Surpluses in the Hydrological Cycle

All drainage basins are vulnerable to surpluses in water. However, some locations are more susceptible to flooding:

- **Low-lying land, the base of a river valley and estuaries** - River flooding can occur along with groundwater flooding as the ground become saturated, therefore any surface close to the water table is vulnerable to flooding.
- **Urbanised, built environments** – Impermeable surfaces increase surface runoff, reducing lag time and so increasing the risk of flash flooding.
- **Small basins,** especially in **semi-arid and arid regions** - These regions suffer from flash flooding due to very short lag times, which can be hazardous.

Mitigation & Adaptation to Flood Risk

- **Afforestation** of upland areas - increasing vegetation cover will reduce rapid surface runoff
- **Restricting construction on floodplains** - reducing potential economic and social loss for residents living on flood plain. Also, by reducing urbanisation, there will be maximised levels of interception.
- Establishing **temporary extra flood plains**, in the event of extreme weather - some UK councils have designated football pitches or parks next to the river, to channel some of the storm discharge and reduce the flood risk for towns living close to the flood banks.

Impacts of Climate Change on the Hydrological Cycle

Anthropogenic Global Warming is due to increased **greenhouse gases** in the atmosphere (see Carbon Cycle notes!). This could lead to several different impacts directly affecting the hydrological cycle:

- If land and sea surface temperatures continue to rise, the **period between ENSO cycles** (currently every 2-3 years) could **decrease**. This would lead to more periodic unusual climates for both South America and Australia.
- Increasing average global temperatures would increase rates of evaporation, which could lead to potential **droughts** and **increasing water scarcity**.
- However, for some locations, a rise in average temperatures will lead to more convectional rainfall and **enhanced tropical cyclone or depression intensity**. This in turn will cause more intense and periodic flooding.

Climate Change will **reduce inputs, reduce stores but may increase outputs** with the hydrological cycle:

- ➔ Less precipitation
- ➔ Less water available in stores
- ➔ Reduced size of snow and glacier mass
- ➔ Water Table drops (height/ capacity of groundwater store) and Aquifer stores deplete
- ➔ High rates of evaporation

- ➔ More frequent cyclones and monsoons

However, it is important to note that since the future of drainage basins and the hydrological cycle depends on Climate Change and ENSO cycles (both of which are **unpredictable** and not well understood), **managing future change is challenging** if not impossible!

Inequality and Insecurity over Water

Water is **spatially distributed unevenly** across the globe. 66% of the world's population live in areas which only have access to 25% of the world's annual rainfall. Conflict can further limit accessibility to water sources.

Demand has risen because of:

- Population growth - generally more people = more water needed.
- Growing middle class population as countries develop and industrialise, therefore increasing lifestyle and domestic demand.
- Economic growth means industrial demand may also increase.

However, **supply cannot meet demand** since:

- Aquifers and deep-water wells are being dug, especially for water-intensive agriculture.
- Water tables (groundwater storage) are dropping as a result.
- Water is being extracted at a faster rate than the soil is able to recharge.

Causes of Water Insecurity

- **Precipitation** varies across different climates: mid-latitude areas generally receive the most rainfall.
- **Topography** is also significant because areas with high relief generally get more precipitation and surface runoff is greater for more inclined planes, so channel flow tends to be larger and so water can be easily stored by **dams and reservoirs**.
- **Geology** also determines water security or insecurity; permeable rocks can be infiltrated, and water can be easily stored underground.

However, humans are also reducing supply through **pollution**. **Industrial activity** (especially in developing countries with slack environmental laws) and **population pressure** (lack of treatment of sewage, the "plastic tide") are reducing accessibility to clean freshwater.

In addition, **saltwater encroachment** due to **over extraction and rising sea levels** (Climate Change) is further reducing freshwater stores, hence increasing water insecurity.

Consequences of Water Insecurity

As a result of a limited supply, the **price of clean water has increased** in certain regions, and may increase globally in the future.

Water is very important in economic productivity, crop yield and manufacturing capacity. Agriculture consumes around 67% of all water extractions and industrial water consumption is on the rise especially in developing and industrialising countries. Fields and grazing lands are dependent on rainwater and aquaculture (fish farming) has been on the rise as wild fish supplies have diminished. Over 20% of all extracted water is used in industries and for energy production

Solutions to Water Insecurity:

Many solutions are dependant on reducing water consumption, such as:

- Many farmers focus on storing rainwater, to use for irrigation and greywater purposes.
- There has been an increase in HEP and the generation of energy without the consumption of freshwater
-

Other solutions include **hard-engineering schemes**:

	Advantages	**Disadvantages**
Mega Dams	Can provide a large volume of water Can generate HEP Reduces demand for groundwater	Floods land Expensive Countries/areas downstream suffer from lack of water Water is stored on surface so gets evaporated quickly
Desalination Plants	-Can provide a large volume of clean water -Reduces demand for groundwater	-Energy intensive -Releases lots of CO_2 -Expensive -Produces salt waste -Expensive to build and maintain
Water Transfer Schemes	-Can provide water for areas that lack water and arid areas -Water can become a valuable resource for countries otherwise poor and undeveloped	-Can dry up source areas -Expensive -Lots of water evaporated -People relocated to construct

The Water Poverty Index (WPI)

The WPI is an index used to measure localised water stress, for the use of national governments to improve provisions.

The WPI focuses on 5 components:

- **Water resources** – the availability and quality of water
- **Access to water** – the distance from safe water for drinking, cooking, cleaning and industries
- **Handling capacity** – management, infrastructure and income
- **Use of water** – for domestic, agricultural and industrial purposes
- **Environmental indicators** – ability to sustain nature and ecosystems

The WPI is scored similarly to The Human Development Index (*see Globalisation and Health & Human Rights*). Each component is scored out of 20, giving a total score between 0 and 100 (100 meaning no water stress, 0 meaning water stress and deficits constantly).

The highest scoring country on WPI is Finland (with a score of 78), whilst Haiti has the lowest score of 35.

Sustainable Water Management

- Sprinklers are by **automated spray technology** or **advanced irrigation systems** which are more efficient.
- **Recycling city wastewater** is a relatively cheap method of conserving freshwater supplies, especially in areas of extremely high demand. 'Grey water' doesn't need to be cleaned as much to meet drinking standards, therefore is less energy intensive.
- **GM crops** are being developed, many are tolerant of dry and saline conditions
- Domestic conservation includes:
  - installing **smart metres**
  - **charging** more for water during times where there is a lack of water supply
  - using **eco-kettles**
  - taking a **shower** instead of a bath
- Restoration of damaged **lakes, rivers and wetlands** to increase natural water storage
- **Restoring meanders & replanting vegetation**

Co-Operation on Water Security

Integrated Water Resource Management

The IWRM approach emphasises the river basin as the logical geographic unit for strategic planning. The basin is treated holistically to protect environment and ensure fair distribution:

- Freedom from **corruption**
- Environmental protection of all supplies and ecosystems
- **Food and water security** for poorer people
- Effective dialogue between people
- **Decentralised** approach
- Cash recovery of schemes through **effective pricing**
- Effective regulation and **planning use**

Groundwater Management -Aquifer storage and reuse -Groundwater quality and quantity modelling	**Waterway Management** -River rehabilitation -Sustainable water allocation -Environmental flows
Integrated Urban Water Management -Water treatment technology -Water sensitive urban design -Water harvesting and reuse	**Monitoring Technology** -Sensor technologies -Real time wireless monitoring and controlling

Water Sharing Treaties

Under the **Helsinki rules**, international treaties must contain concepts like equitable use and shares. The criteria could be based on:

- **Natural factors** → rainfall amounts, discharge, share of drainage basin
- **Social and economic needs** → population size, welfare of people, development plans
- **Downstream impacts** → restructuring flow, water tables, pollution
- **Dependency** → availability of alternative sources
- **Prior use** → the tricky question of existing historic rights and potential future use
- **Efficiency** → avoiding waste and mismanagement

Different organisations are involved in promoting effective water management schemes:

- The **UNECE Water Convention** promotes joint management and conservation of shared freshwater ecosystems in Europe and neighbouring areas.
- The **UN Water Courses Convention** offers guidelines on the protection and use of transboundary rivers.
- However, the **WWF** says that most agreements lack appropriate enforcement and monitoring.

Key players involved in water management include:

UN – UNECE (UN Economic Commission for Europe Water Convention) aims to protect and ensure the quality and sustainable use of transboundary water resources.
EU – Water Framework Directive agreed in Berlin 2000 – Targets to restore river, lakes, canals, coastal waters to suitable condition.
National Governments – e.g. the UK's environment agency which checks compliance with EU frameworks.