Geography AS / A Level | Edexcel | 8GE0/9GE0

AS and A Level Edexcel Revision Booklet

Topic 5: The Water Cycle and Water Insecurity

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POD 9992

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Teacher's Introduction

The revision booklets in this series are designed to support your students as they study AS Edexcel Geography (8GE0) and A Level Edexcel Geography (9GE0). These revision summaries match the Edexcel specification perfectly. **This particular set supports Topic 5: The Water Cycle and Water Insecurity, examined in Paper 1.**

The concept is that *all* students need a clearly explained, concise yet comprehensive body of notes to revise from, both as they progress through the course and when preparing for the end-of-course examination. For this reason, th manageable chunks and are provided in both A4 and A5 formats for easy photoco carrying and reference for students, right up to the moment they walk into the ex revision time.

Since revision should be ongoing throughout one's study, it is recommended that issue students with the relevant revision booklet as they progress through the cou issued as a complete revision pack in the run-up to the examinations.

By use of bullet points, text boxes and grids, these revision booklets provide succi relatively detailed coverage of the specification content – probably far more than revision summary.

Each topic follows a clear structure of:

- **Key words:** lots of key words are clearly defined, and by covering up the defi students can easily self-test their memory of these all-important terms.
- **Key points:** these form the main body of the summaries for each topic. Conci they provide a solid bank of notes to support students' knowledge, understa
- **Core content:** the main content of the specification in bullet points, boxes an suggested examples allow students to name-drop examples in their exam, o
- **If you only remember these three things…:** the three most important takea
- **Consolidation questions:** several quick questions on the core content – desi points have been retained.
- **Take it further:** offers suggestions to support the option of extending learni
- **Student checks:** useful checklist to help students monitor their own learning.

Each pack also contains a **students' introduction** which introduces the topic and s structure; introduces command words, AOs and level marking, along with exam ti how to use the booklet. At the end tips are included on time management, and p along with an introduction to synopticity.

By using this resource, teachers will know that all students have the key points for al written format. It saves time in class for teachers and decreases the amount of prepa

This resource also helps achieve greater equality among students of differing abi students make the least helpful notes from which to study and revise outside clas revision summary notes help to overcome this problem and promote greater equ

And remember, these revision booklets are also perfect to refer back to as end-of examination – especially useful nowadays with linear examinations.

I trust that you and your students will enjoy using these revision summaries as m them for you.

Free Updates!

Register your email address to receive any future free upd made to this resource or other Geography resources your s has purchased, and details of any promotions for your su

** resulting from minor specification changes, suggestions from teachers and peer reviews, or occasional errors reported by customers*

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Students' Introduc

What's the topic?

This revision booklet is for Topic 5: The Water Cycle and Water Insecurity. You w
Paper 1, Section C.

Here's a quick overview of the things you might find in the exam. However, exp
sometimes exam boards can throw in a curve ball – a different type of question
but don't be too alarmed. Just read the questions carefully and be ready to ada

You'll be presented with a range of questions – remember that they ramp up in

- Firstly, you might be presented with a short factual recall question.
- Then you might be given a couple of figures – maps, charts and data. You p before. They're designed to see how you cope with unfamiliar sources – ho analyse them. You might have heard the term 'AO2'. AO2 marks require yo that you understand what it means.
  - You may be asked to use the figure(s) and your knowledge to answer t
  - These might be medium-length questions, worth around 6 marks.
- Finally, you'll get a longer, essay-based question – maybe worth 20 marks. You'll probably be asked for your viewpoints or to weigh up two sides of an argument. You may also be able to use a case study to support your answer. Justify your opinion(s), and support it with facts and balanced arguments if you are reaching for the higher marks. You'll need to draw on your knowledge and offer a supported opinion. PEE or, even better, PEEL here! And no, we don't recommend you get out a satsum evidence.

How to use this guide

You may be given this at the start or at the end of teaching on the topic. Don't w
being stuffed in your pocket (although don't take it into the exam itself!). Reme
you want to. Scribble all over it, or highlight bits you need to look at again.

Here are some brief suggestions:

- Work through it as you go through the course.
- Give it a glance after the lessons.
- Give it a read before an upcoming test.
- Use it when you revise, of course – perhaps even outside the exam hall if y

Now write down the date of the exam. You can use this to plan your revision tim

Date of my exam:	

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Checklist

It can be a useful idea to make a note of when you've read through something. I
confident that you know a topic, or you last looked at this six months ago, then i
another look!

Topic	When did I read this? *Write the date in here – preferably today's*	I kn
What is the Hydrological Cycle, and Why is It Important?		
The Drainage Basin as an Open System		
Influences on the Hydrological Cycle at the Local Scale		
The Causes and Effects of Drought		
The Causes and Effects of Floods		
Climate Change – Changes and Effects to the Hydrological Cycle		
Physical and Human Causes of Water Insecurity		
The Problems of Water Insecurity		
Managing a Sustainable Water Supply		

Exam tips

Now that you've thoroughly revised and hopefully answered a few sample exa
good idea of what to expect in your exam.

Command words
In each question there are 'command words'. These are essentially the instructi
to answer the question, and give you a clue on the type of response the examin

Command words are not a secret, and they're nothing to worry about. You've p
throughout your year(s) studying the course.

Edexcel has created a list of command words for you to refer to. They have also
of them will occur and given the number of marks for each. They might not alw
be concerned if questions are slightly different in your exam. **zzed.uk/9992-co**

Here's our quick run-down of the different command words and what you need
balanced answer.

- ✓ **SUGGEST:** Give a reason or cause, explaining if asked.
- ✓ **COMPLETE, DRAW or PLOT:** Use data provided to complete missing value
- ✓ **CALCULATE:** E.g. statistical analysis. You will be given marks for showing y
- ✓ **ANALYSE:** Identify the pros and cons or processes of EVERY view or opinio
  arguments or processes in a logical order, showing the relationships betwe
- ✓ **EXPLAIN:** Set out causes of the issue, event and/or factors influencing its f
  understanding and discussion of processes, may also require a graphical re
- ✓ **Assess:** Set out for and against or a relationship, and come to a conclusion
  between sides but pick out which is the most significant factor.

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✓ **EVALUATE:** Consider several options or arguments and come to a conclus… success or worth.

Assessment objectives

You may come across the words 'assessment objectives', or 'AOs' for short. The… command words. They are set by the government and vary by subject. As you'… get, and AO3s are the hardest.

Here's a quick summary:

	What you need to do	R…
AO1	Show your knowledge and understanding of geographical concepts and issues.	✓ Collecting ev… together
AO2	Manipulate and draw conclusions from geographical information, both familiar and new.	✓ Use of maps, … ✓ ICT skills: usi… ✓ Analysis, pre…
AO3	Investigate questions and reach conclusions through many geographical skills and techniques.	✓ Concluding a… ✓ Use of maps, … ✓ Statistics ✓ ICT skills: usi… ✓ Analysis, pre…

In your Paper 1 exam, you'll mostly be assessed on AO1 and AO2. There will be … most of those in the NEA (fieldwork investigation).

For every question, Edexcel will have decided which AOs they are targeting. Be… answer. If it's clear that an answer is looking for some AO2 or AO3 marks, don't … through.

You might find it useful to have a look at a couple of mark schemes for the topi… examiner wants you to answer the questions.

Level marking

Now that you've got a handle on how the command words work and what the … you need to be aware of how they will mark your answers.

For anything but the shortest of questions, you will be level marked. Each level … L1 = 1–3 marks, L2 = 4–6 marks. The essay-based questions will have four levels… for, the more marks you'll get.

An example of level marking criteria can be found overleaf.
Up to 3 marks can be awarded for AO1. A further 9 marks can be awarded for A…
If only AO1 content is provided, allow 1 mark for Level 1 answers, 2 marks for Le… Level 3 answers.

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Mark	Descriptor
1–4 marks	AO1: • The student shows basic comprehension and only limited facts. Some details may be incorrect and not in line with the context of the question.
	AO2: • The student addresses a narrow range of ideas, and details are limited, with few inferences and links made. • Limited explanation is present. • Ideas are poorly supported, and may be one-sided. Discussion may be difficult to follow. • No judgement and/or concluding remarks.
5–8 marks	AO1: • The student shows comprehension and some factual recall. Details are often correct and generally in line with the context of the question.
	AO2: • The student addresses a range of ideas, to a reasonable level of detail, with inferences and links made. • Some explanation is present. • Ideas are supported, but may still be one-sided. Discussion may be easier to follow. • Some judgement and/or concluding remarks.
9–12 marks	AO1: • The student shows good comprehension and factual recall. Details are mostly correct and tailored to the context of the question.
	AO2: • The student addresses a wide range of detailed ideas, with well-reasoned inferences and links made. • Good explanation is present. • Ideas are often supported, with both sides supported. Discussion is easy to follow. • Good judgement and/or concluding remarks.

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What is the Hydrological (
Why is It Importar

Key words

- **System:** Simplified model of the real world, where a process occurs. There a and stores within the system.
- **Open system:** A cycle or process where inputs and outputs can add or remov
- **Closed system:** Linked processes where there are no inputs or outputs of ma out of the network.
- **Input:** Addition to a system.
- **Output:** Loss from a system.
- **Store:** A sink where water, for example, is retained for a period of time, e.g
- **Biosphere:** Areas which support living things upon Earth.
- **Atmosphere:** The gaseous layer above Earth.
- **Lithosphere:** Rock environments – can act as a store of water.
- **Hydrosphere:** The store of water on Earth's surface.
- **Cryosphere:** The ice which exists upon Earth.
- **Atmosphere:** Water is stored as gas (vapour) within the air, or is condensed
- **Precipitation:** Collective term for all forms of water which fall from the sky – snow, etc.
- **Fresh water:** All forms of water that do not contain dissolved salts (saline wa lakes, rivers, groundwater and stored as ice.
- **Saline water:** Water with dissolved salts – such as the oceans, and containe
- **Surface water:** Water located above ground, for example in lakes, streams
- **Soil water:** Liquid located just below Earth's surface in loose, unconsolidated
- **Groundwater:** Water located below Earth's surface, stored in the pores of p
- **Surface water:** Water located above ground; for example, in lakes, stream
- **Permafrost:** Ground which is permanently frozen for at least two years in a
- **Residence time:** The average period of time that water molecules stay in a specific lake) before they flow away, or evaporate.
- **Fossil water:** Water that has remained underground as groundwater for mo

Key points

- We simplify the world into systems. Energy and matter can flow in and out o
- Systems contain stores, have inputs and outputs and processes operate withi
- Systems can be open or closed.
- The hydrological cycle is driven by the Sun and gravity. Water is transferre includes each of the four spheres.
- Most of our water is in the oceans – 97%. Most of the fresh water is locked below the ground. There is very little surface water on Earth!
- Water is found in all four 'spheres' – the lithosphere, hydrosphere, cryosphe also found within plants and animals – biological water.
- Soil water is located in the soil, and groundwater within rock. Some of that i
- Most water in the atmosphere is invisible – water vapour.
- Water exists on Earth in all three states – liquid, solid and gas.
- Water is transferred between the three states.
- Inputs include energy and precipitation, and outputs include run-off and eva
- Stores and processes can occur naturally – such as through ice ages. Human result of human-caused climate change.

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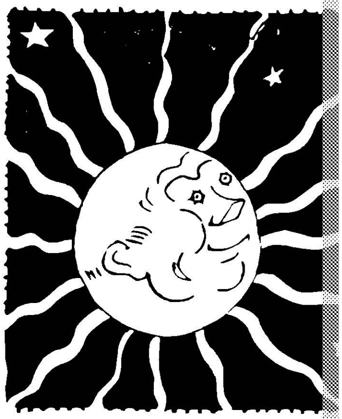
Key points (continued)

- Water is a very precious resource – very little of Earth's water is actually a accessible to us. Earth's water is also unevenly distributed.
- The length of time that water remains in a store is called its residence time.
- Some sources of water are non-renewable – for example, they have been s of years below the ground. We are exploiting some of these sources – whic drop, and the land's surface to subside.

An introduction to systems

The real world is incredibly complicated. This is why we break it down into **syst**

Systems include many different parts which are all related. They occur because t behind them.



The driver is usually the sun.

Sometimes, larger systems can be sub-divided into sub-systems.

The parts of a system include:

- Stores (components)
- Inputs and outputs
- Processes – mediums for change

Earth has four main interlinked **open** systems. They all affect each other.

They are:

- Atmosphere
- Hydrosphere
- Lithosphere
- Biosphere

There are two main types of system, based on whether energy and matter can b system.

Closed system

☑ Transfers energy

☒ No matter is transferred

- e.g. Earth

☑ T

☑ T

- e

The hydrological cycle as a closed system

- We're not gaining or losing any water – so there's no transfer of matter.
- But energy flows in and out.
- Therefore, globally, the hydrological cycle is a closed system.
- But on a local scale, drainage basins are open systems (because they have i

There are two drivers of the hydrological cycle:

❋ the Sun (solar energy)
❋ gravitational potential energy

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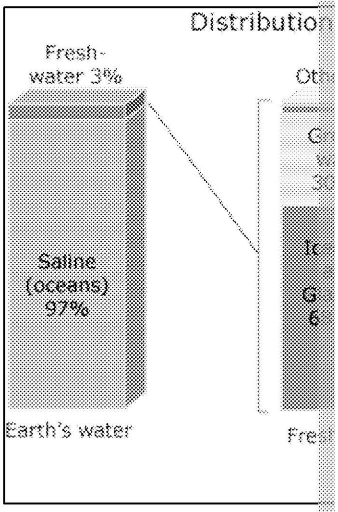
The distribution of Earth's water

Unsurprisingly, most of Earth's water is in the oceans – estimated at around 1,338,000,000 km^3.



! You'll see variations in all the sources you look at because the figures are estimates, or are rounded!

In fact, 71% of the surface is covered with water. This ocean water is salty (saline). We can't drink it, unless we spend energy and therefore money removing the salt.

The diagram on the right shows the stores.

We can divide Earth's water stores into the following 'spheres'.

The lithosphere:
Water within soil and rocks.

- **Soil water** within non-saturated soil and unconsolidated material – dependent on soil type, time of year and water budget.
- **Groundwater** – saturated rock below the water table – called aquifers.

E.g. Found throughout the world – Northwestern Sahara, Great Artesian Basin (Australia) and the Arabian Aquifer System.

The hydrosphe
This is the liquid wa
on the surface. The ma
is **oceanic** water – the
discussed above. Also
surface water on land
wetlands.

E.g. All of the w
rivers inclu
the Yangtz
include the
Victoria an

The cryosphere:
This is all of the frozen water on Earth, including:

- Ice caps, ice sheets, ice shelves, sea ice and glaciers.
- **Permafrost** – ground frozen for two or more years.

E.g. Greenland and Antarctica, winter sea ice, permafrost in Canada and Siberia, Alpine glaciers, etc.

The atmosphere:
Water within the atm

- Gaseous water vap
- Clouds (water drop

E.g. Everywhere!
around us, a
temperature
usually see it

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Note that technically, the hydrosphere is a term which encompasses all of Earth' term terrestrial water to mean all water on and below the surface.

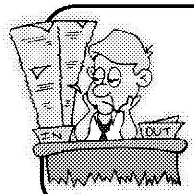
Biological water is found in living things, the sap of plants and trees, and in hum 60% water! Other organisms contain even more water – including some of the f about 96% water when it's fresh.

Here's the full breakdown in a table.

Water source	Volume (km^3)
Oceans, seas and bays	1,338,000,000
Ice caps, glaciers and permanent snow	24,064,000
Groundwater	23,400,000
Fresh	10,530,000
Saline	12,870,000
Soil moisture	16,500
Ground ice and permafrost	300,000
Lakes	176,400
Fresh	91,000
Saline	85,400
Atmosphere	12,900
Swamp water	11,470
Rivers	2,120
Biological water	1,120

Can you work out which 'spheres' each category falls into?

Note that water occurs in all states on Earth – solid, liquid and gas (vapour). Wit between all three states.



Inputs include:
- ➔ energy from the Sun
- ➔ precipitation

O

evapot

Inputs and outputs (drainage basin level)

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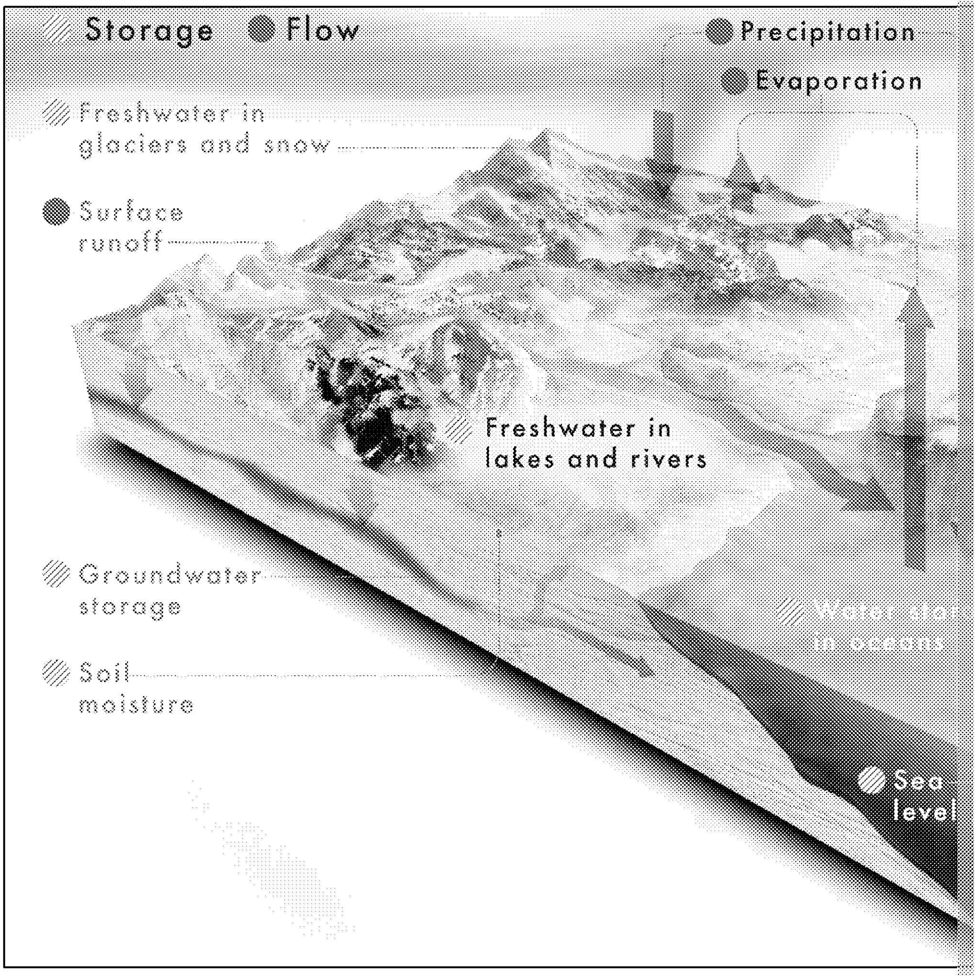
The stores and fluxes within the cycle

In the diagram below, we clearly see the stores and fluxes (flows) within the cyc



Stores

- Biological water
- Water vapour within the atmosphere

Fluxes

- Transpiration

Rivers are both a store and flow!

An introduction to the water budget and the conce times

- Later on, you'll read about the water budget – which is the difference betw water in a drainage basin.
- The water budget helps determine how much water is available to us.
- Water is a very precious resource because only 3% of global water is fresh is accessible.
- There is also great disparity in the distribution of Earth's water.

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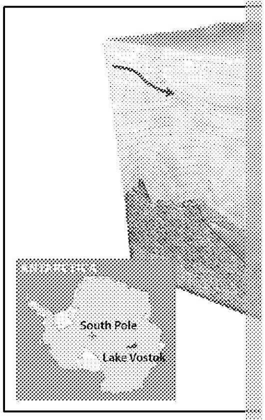
Storage length

The amount of time that water is stored is called the '**residence time**'. This is ca
within a store by the transfer rate (both in and out) of the store. Of course, thes

- Each store has a different timescale, varying from less than two weeks (the
  oceans).
- Deep underground water might last for 10,000 years.
- Ice caps have a residence time of around 800 years.
- Lakes might be several years, and soil water might be replaced within a ye

Non-renewable stores

- We call these stores 'fossil water'. They are stores of groundwater that are being replenished very slowly – they accumulated thousands or sometimes millions of years ago – for example, when the climate was different. This is why there are sometimes plentiful supplies of groundwater below deserts.
- They are not being replenished quickly – making them non-renewable resources.
- We are pumping fossil water from aquifers that can't be replaced, for example for irrigation water.
- Pumping leads to ground subsidence and a lowered water table.
- Fossil water can also be found in subglacial lakes (lakes of fresh water below an ice sheet), and some ice sheets themselves.
- Some ice sheets developed during past ice ages – they're currently meltin
  accumulating.



Lake Vostok in Antarctica
The lake may be 35 millio

E.g. The Nubian Sandstone Aquifer (below the Sahara Desert) and the O
United States

If you only remember these three th

❶ Systems include stores and components, and can b
whole is a closed system because there are no ou
smaller scale, drainage basins are open systems.

❷ 97% of Earth's water is saline sea water. Only a
remaining fresh water is actually located on the s
stores water, which exists in all three states. Wat
three states, as it flows between the stores within

❸ Water can remain in the stores for thousands of y
Others only have a few days or weeks. Sometim
thousands of years. If it's not being replenished, i
water.

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Activities

Consolidation questions

1. Which type of system is the overall hydrological cycle?

   ....

2. What are the drivers within the hydrological cycle?

   ....

   ....

3. How much of Earth's fresh water is locked up as ice?

   ....

4. Which is the largest component of atmospheric water?

   ....

5. Give two examples of stores in the hydrological cycle.

   ....

   ....

6. Which part of the cycle is both a store and a flow?

   ....

7. Which stores have the shortest and the longest residence time?

   ....

   ....

8. Why is fossil water a non-renewable resource?

   ....

   ....

Take it further

An introduction to the hydrological cycle from NASA:
zzed.uk/9992-nasa-earth

A news article about fossil water in northern Africa:
zzed.uk/9992-fossil-water

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
What is the Hydrological Cycle, and Why is It Important?	Systems / the hydrological cycle as a closed system				
	The distribution of Earth's water (including the four spheres)				
	Inputs and outputs				
	Stores and flows within the cycle				
	Residence times and storage length				
	Non-renewable stores (fossil water)				

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The Drainage Basin as a System

Key words

- ✓ **Precipitation**: Collective term for all forms of water which fall from the sky.
- ✓ **Transpiration**: The flow of water from the soil to the atmosphere via plants.
- ✓ **Interception**: Water is temporarily stored and delayed from entering chann on objects such as vegetation.
- ✓ **Infiltration**: The process where water enters the soil from the surface of the g
- ✓ **Percolation**: The movement of water from soil into the rock below.
- ✓ **Throughflow**: Flow of water through the soil.
- ✓ **Groundwater flow**: The movement of water through the bedrock, towards a
- ✓ **Stemflow**: Surface water movement through streams and rivers.
- ✓ **Infiltration excess overland flow**: Rainfall is too intense for the water to infi enough. Therefore, water will pool and run across the surface. **Saturated ov** travels over the land's surface because all pore spaces (voids) within the soi
- ✓ **Run-off**: Movement of water over the land's surface.
- ✓ **Channel flow**: Surface water movement through streams and rivers.
- ✓ **Evaporation**: State change of water from a liquid to a gas.
- ✓ **Condensation**: Change in state from a gas to a liquid – e.g. water vapour t
- ✓ **Sublimation**: A direct change in state from solid (ice) to gas (water vapour)
- ✓ **Ablation**: Melting of a glacier, which occurs especially during the warmer su
- ✓ **Drainage basin**: The area of land drained by a river and the river's tributa
- ✓ **Watershed**: The boundary between two drainage basins.
- ✓ **Monsoon rain**: Intense summer rainfall in areas such as India, East Asia and rainfall occurs in a very short time period.
- ✓ **Potential evaporation**: The amount of evaporation that could occur if there water available.
- ✓ **Antecedent conditions**: Precipitation that has already occurred – increasing soil is already saturated.

Key points

- There are many components and processes within the hydrological cycle incl and transpiration, condensation and precipitation. The water flows through – such as across the surface, within rivers, through the soil and even through
- Inputs into the hydrological cycle are energy from the sun and precipitation, evapotranspiration.
- Water can change states – such as from liquid to a gas (evaporation) – the and can go directly from solid to gas (sublimation). Solid to liquid is called
- There are several reasons why clouds form – such as at weather fronts, area convection. Different types of clouds and correspondingly different types of cause of formation.
- Land is divided up into drainage basins, which contain a river and its tributa
- We apply the well-known hydrological cycle to the drainage basins.
- There are various physical components of the drainage basin that affect the example the climate, soils, vegetation, geology and relief.
- Humans change the stores and flows within a drainage basin through farmin changing land use (cutting down trees and building cities), building dams, an environment.

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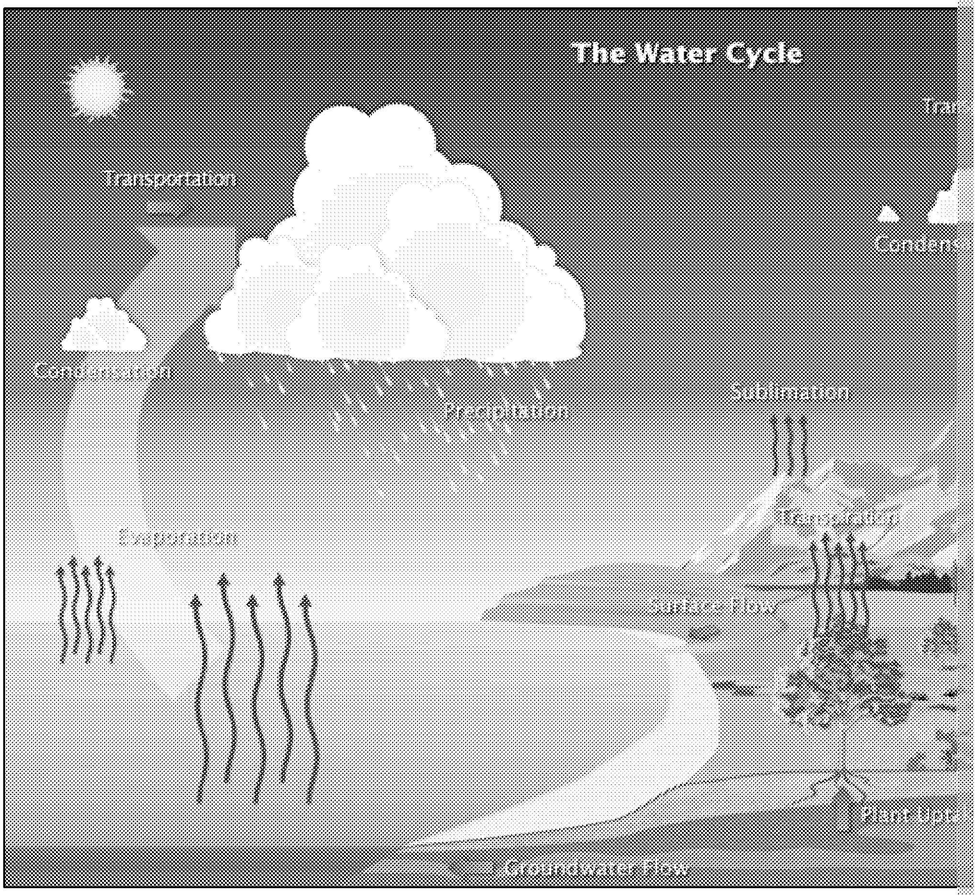
Inputs, outputs and processes within the hydrolog

Below is a common representation of the hydrological cycle. There are several f
Within the cycle, there are many different processes that are joined together to



Inputs

One of the inputs of the hydrological cycle is precipitation. Precipitation is a bro of water falling as ice and liquid water.

There are lots of reasons why clouds form, allowing for the precipitation.

Clouds form when warm air rises and cools to its dew point – often forming aro can occur due to heating of the ground, orographic uplift, at weather fronts, etc larger water drops.

- o The type of cloud varies depending on fronts, convection, etc.
- o There are several causes of rainfall – because there are different causes of w forced upwards by mountains (orographic or relief rainfall), and when 'fron At both warm and cold fronts, air is forced upwards. Air rises rapidly at cold precipitation. At warm fronts, the air rises slower, and precipitation is gentl
- o Sometimes warm air quickly rises (convection) such as on a hot summer's d develop – they can be thundery and can deposit large hailstones.

Flows

- At height, the water vapour **condenses** into clouds and falls back to Earth
- The water is stored and transmitted in several ways:
  - o Some of the water is **intercepted** by vegetation. It flows to the groun leaves and twigs. Some of the water will also evaporate from the vege interception as a temporary store with transport away through severa

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For water that reaches the ground:

- Some of the water **infiltrates** into the soil, where its flow is called **thro** (reaches) the water table, it moves as **groundwater flow**. Some of the the soil (soil water).
- If the precipitation is intense and/or there is little interception, or the s can't infiltrate and **overland flow (surface flow)** occurs. When the soi saturated overland flow, rather than infiltration excess overland flow. T **run-off**.
- Overland flow and groundwater (base flow) contribute to river flow. Ri Rivers generally flow into the oceans.
- Rivers may flow in and out of lakes.
- On high ground, or towards the poles, the water will fall as ice and cou ice cap.

Outputs

- Water **evaporates** from the oceans and the land surface (driven by the Sun via vegetation, to become part of the atmosphere.
- Plants take in water from the soil using their roots. Some of the water is use used to transport minerals. To keep the water flowing through the plant, h evaporate. This is called **transpiration**.
- We call the flow in rivers '**channel flow**'.

Processes

The processes within the cycle include:

- **Evaporation** of liquid water (liquid → water vapour gas) because of heat f
- There are various determinates such as temperature (the warmer the air, th hold – the relative humidity), the availability of water, and the amount of w (is it already saturated? – if so, it can't hold any more).
  - Evaporation is fast in windy conditions.
- **Condensation** – water vapour back into liquid water (cloud formation).
  - Dew forms in the evening as the ground surface temperature drops a dew point. Radiation fog forms when the ground cools at night, mean closest to the ground cools to its dew point.
- **Sublimation** (below freezing).
  - Glacier ice directly to water vapour.
  - Frost direct from water vapour to ice.
  - Melting and freezing.
  - On cold winter nights, puddles and lakes freeze, and the surface soil a
  - When the weather warms up, or the sun comes up in the morning, the
- **Ablation** (above freezing).
  - Glacier ice melts to liquid water. Snow may settle in winter, and melt a of glacier-fed streams varies by month, and time of day – melting duri highest flow is in the late afternoon.
  - Sudden warming (melt events) can cause flooding.
  - Glacial processes also involve calving of icebergs (from glaciers and ic and into oceans).

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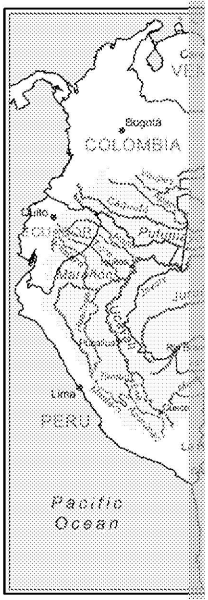
Physical determinants within drainage basins

The overall hydrological cycle can be represented in the smaller scale **drainage basins**. This is the area drained by a river and its tributaries, and they are open systems.



Drainage basins can be small, separated by ridges of high ground called **watersheds**. Some drainage basins, such as the Amazon, span several countries.

Note that water doesn't have to reach the oceans every time – it can evaporate from the land and then fall as rain over the land surface once again.

There are physical determinants that affect the inputs and outputs, processes, flows and stores covered above.

Climate

- Determines the amount, type and seasonality of rainfall, e.g. deserts vs rainforests, heavy convectional rainfall vs light rainfall at wa fronts, winter snowfall vs heavy **monsoon rain** or intense and (flash)flooding vs year-round precipitation.
- Determines the temperature, and therefore **potential evaporation**.
- Determines vegetation type and therefore processes such as interception, surface run-off and transpiration rates.
- Determines the saturation of the soil and influences **antecedent** events.

Soils

Soil type and texture (e.g. particle size and porosity) influence infiltration rate (a throughflow, etc.

Vegetation

Type of vegetation and the percentage coverage of the land affect interceptior flow, evapotranspiration, etc. Bare earth obviously has the greatest run-off pote forests have much greater interception ability than grasslands. And these chan throughout the year – a deciduous forest in summer (with leaves) has much gre interception capacity than when the trees are bare in winter.

Geology

The type of geology affects the storage and transmission of water. Porous rocks transmit water are called aquifers. However, rocks that can't store water will no and flooding is more likely.

Relief

Relief is the steepness of the land – steeper slopes mean that water runs off qui meaning there is less infiltration, more overland flow, and greater flood risk.

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Human changes within the drainage basin

Changes to the land

Local-scale hill-slope basins can be affected by natural and human factors.

Weather phenomena can temporarily affect a drainage basin – such as extreme r

Flooding in Cumbria in December 2015 (Storm Desmond), flood
February 2009 as the result of snowmelt, and drought in the sum
low river flows.

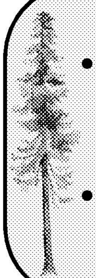
Population growth and urbanisation

- Urbanisation seals the land, meaning that water cannot infiltrate.
- Storm drains quickly channel water into local rivers.
- This increases the local flood risk, making rivers more responsive to rainfall events.
- Flood risk can be reduced by installing new drainage systems which allow the water to soak away.
- Settlements are often located on floodplains – river engineering works are often used for protection.

Land-us

- Deforest
  reduces
  scale, de
  overall p
  of rivers.
- Water fl
  faster af
  been fell

Forestry



- Planting trees (especially conifers) means that much of the precipitation is intercepted, of which much is evaporated straight back to the atmosphere.
- Trees also transpire large quantities of water, releasing soil water to the atmosphere.

- Harvesting c
  protected by
  interception.
  can occur, an
  decreasing in
  soil.
- Ploughing co
  downslope p
  towards stre
- Soil and wet
  runs into ditc
- Irrigation wa
  abstracted f
  underground

We can reduce the flashiness of a hydrograph – for example, by planting trees (
employing different farming practices, and through sustainable urban drainage

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Reservoir construction

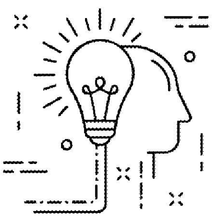
We create artificial lakes called reservoirs by either building a dam across a valle building a raised bank and pumping water in.

Building dams creates a store of water in the cycle, reducing overall channel flo downstream. We release water from the dam to keep rivers flowing, but the rap changes in flow from rainfall events are no longer seen. Dams can reduce flood

Water abstraction

We abstract water from surface supplies (lake and rivers) and from the ground. Removing water from surface supplies reduces run-off, and concentrates pollut Removing groundwater can lower the water table, reduce the base flow of stre vegetation die-off, and in coastal areas can cause saline seawater to intrude int the aquifer.

If you only remember these three th



1. There are lots of different processes operating w which cause the movement of water between the s and outputs.
2. Within the drainage basin, there are many physi inputs, outputs and flows, such as the climate, soils, they all affect the run-off and interception, etc.
3. Humans are constantly increasing their impacts or through land-use change, deforestation, urbanisa abstracting more water from the environment – b groundwater stores.

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Activities

Consolidation questions

1. When air rises and cools, the water vapour condenses. Give two reasons wh

   ....

   ....

2. Why doesn't all rainfall reach the ground?

   ....

   ....

3. What is the difference between groundwater flow and throughflow?

   ....

   ....

4. Why might water flow across the surface (that is, not in rivers)?

   ....

   ....

5. What are the outputs of a drainage basin?

   ....

   ....

6. On what scales are drainage basins?

   ....

   ....

7. Name the processes where water enters the soil and rock.

   ....

   ....

8. How does climate affect the processes within a drainage basin?

   ....

   ....

9. Give two consequences of human population growth on the drainage basi

   ....

   ....

10. Give an example of how humans modify the drainage basin by abstracting

   ....

   ....

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Take it further

A quick recap on the hydrological cycle:
zzed.uk/9992-water-cycles

Why does it rain? This short web page and video from the Met Office exp
zzed.uk/9992-met-office-rain

Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	sure ☺	
The Drainage Basin as an Open System	The water cycle: Inputs				
	The water cycle: Flows				
	The water cycle: Outputs				
	The water cycle: Processes				
	Physical determinants within drainage basins				
	Human changes within the drainage basin – land				
	Human changes within the drainage basin – reservoir construction and water abstraction				

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Influences on the Hydr Cycle at the Local S

(Water Budgets, River Regimes and Storr

Key words

- ✓ **Water budget (balance):** Equation relating to the inputs and outputs of wate as precipitation, flows and stores.
- ✓ **Potential evaporation:** The maximum evaporation that could occur with an c
- ✓ **River regime:** The trends in flow throughout the year, based on climate, and drainage basin.
- ✓ **Storm hydrograph:** Graphical representation of a river's response following
- ✓ **Rising limb:** The line on the hydrograph which represents the increasing disc precipitation event, until peak flow is reached.
- ✓ **Receding limb:** The line on the hydrograph which represents the decreasing discharge has been reached.
- ✓ **Lag time:** The period displayed on a hydrograph between peak precipitati
- ✓ **Peak precipitation:** The highest precipitation intensity during a storm.
- ✓ **Peak discharge:** The maximum channel flow which occurs after a precipitatio
- ✓ **Base flow:** Channel flow derived from the soil water and groundwater that precipitation events.

Key points

- We can model the inputs and outputs of a drainage basin using the water b (although we generally use this model for soil). The inputs and outputs chang year due to the seasons – precipitation and temperature, and therefore the Groundwater is therefore recharged or used.
- Budgets are most affected by the climate – the budget can be calculated b
- Positive budgets are when the precipitation is greater than the evaporation. equator, but negative in deserts.
- A river's flow at a set point is called the **regime** – we record how the flow
- The regime is affected by the climate and other physical factors of the catc
- The regime is also affected by factors such as spring snowmelt, summer glac
- We represent how a river responds to precipitation by plotting the data on
- If the lag time is short, and the peak flow is high, then we call it a flashy hyd
- There are natural and human factors which make the hydrograph flashy.

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Water budgets (balance)

The water budget (balance)

The water budget is the balance between the inputs and o

We can apply the budget across larger areas, regions and l

We use the equation:

$$Precipitation = discharge + evapotranspira$$

It can be written as $P = Q + E \pm \Delta S$

The water balance is often used to measure soil water.

In the UK, for example:

- Precipitation is greatest in the winter – it rises in the autumn and falls over t
- Potential evaporation is very low in the winter, and rises to a peak in the su
- During the autumn, when precipitation exceeds evaporation, groundwate
- There is a groundwater surplus in the spring, utilisation in the early summer, a

If there is more precipitation than evaporation, then the balance is positive (sto
If there is more evaporation than precipitation, then the balance is negative (sto

Examples

The water budget and therefore water availability are determined by climate.

Areas at and close to the equator have the highest rainfall and run-off. They hav
is very humid. Precipitation exceeds evaporation and the balance is positive.

This is the opposite for desert regions – hot, dry air means that there is very high
little rainfall means that the budget is strongly negative.

At the poles, there is very little precipitation, but it still exceeds the evaporation
positive, meaning that water stores are possible – e.g. within permafrost and ice

River regimes

The flow in a river changes throughout the year as the seasons change. Cli
factor, to include temperature (**potential evaporation**) and weather patte
of the catchment, and other physical factors such as geology, as well as hu
flow and response to precipitation events.

This is called the **regime**.

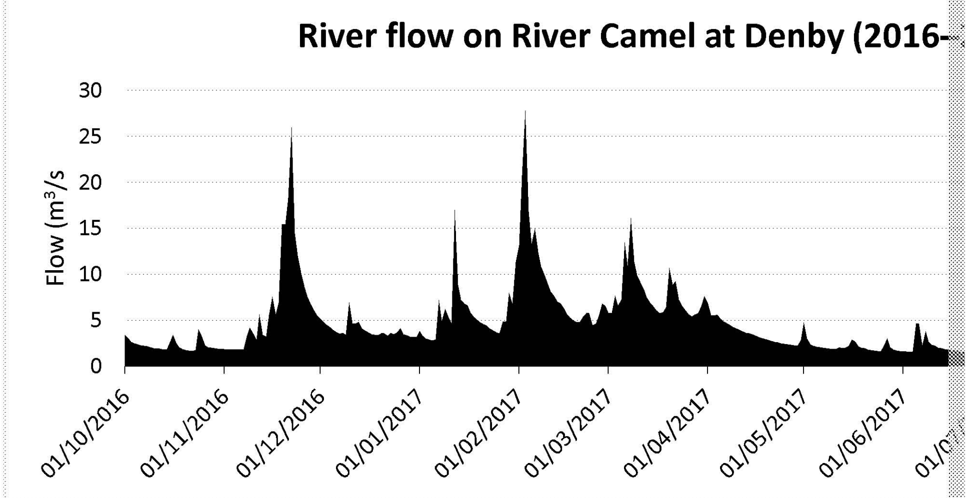
Some rivers may dry up completely in the summer – that's why some village
'Bourne' in their name.

Other rivers may have their highest flow during the summer if they are fed
peak in the spring as a snowpack melts, or have a sudden peak if they are

The river regime can be measured at set points along a river at gauging stations. T
and thaw events can be seen, but most rivers flow throughout the year – this is th

Example

Below is a river regime on the River Camel in Cornwall based on daily flow data



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? Why not start the graph in January? The water year starts on October 1st a

This is because recharge of stores usually begins in the autumn.

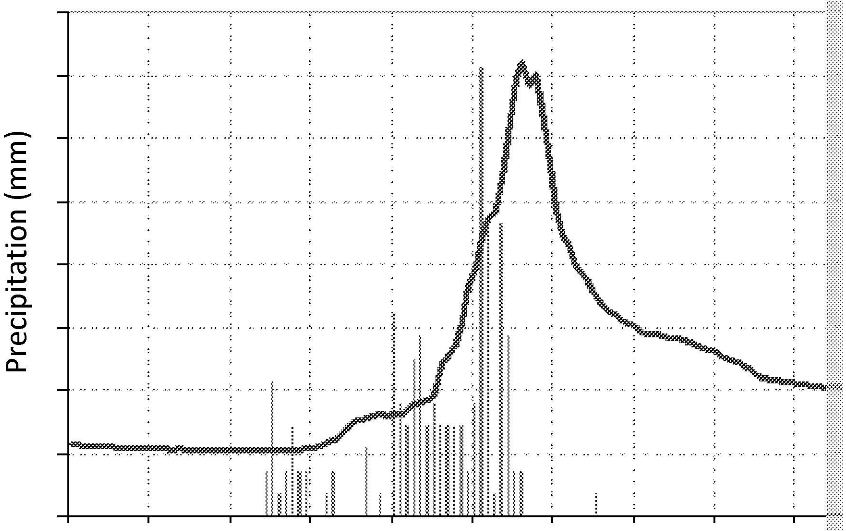
This catchment includes Bodmin Moor. The land use is moorland and agricultur geology includes granite (an impermeable rock). Human influences include a re (abstraction and controlled release of water) and release of treated sewage wat

So what does this graph show us?

- There were several periods of very high flow in November and January, wh storm events.
- Storms during the summer and early autumn can be seen from the short-te
- The peaks from storms are high because of the impermeable geology and l
- Average flow was high in February and March. This was probably due to an of soil/groundwater, increasing the chance of saturated overland flow.
- The downward curves after each peak show the river returning towards its

The storm hydrograph

We can represent precipitation and river flow on a graph. This allows us to see h precipitation. Planners can use these to plan river engineering projects.



This is a classic **hydrograph**.

The precipitation is shown by the vertical bars and measured on the left axis. The discharge – usually measured in cumecs (m^3/s) – is shown by the continu the right axis.
They are usually applied to an individual storm, and measure several days of fl

The graph clearly shows the **rising** and **receding limbs** as the water rises and The **lag time** is the duration between peak precipitation and peak discharge. Before the precipitation is the **base flow** (from ground and soil water).

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Influences on the storm hydrograph

Flashy?

If there is a very short lag time with high discharge, it means that the river respo to precipitation. We call this a flashy hydrograph.

There are many factors – both natural and human – which cause a flashy hydro them are outlined below.

Impermeable rock or soil
Overland flow occurs as water cannot infiltrate soil or percolate into bedrock easily.

Deforestation
Reduced interception and transpiration – especially if downslope.

Agriculture
Compacted soil, bare soil in winter fields, downslope ploughing all increase overland flow.

Lots of streams
Water reaches the river from many tributaries.

Sudden temperature change in winter (melting snow)
Rapid snowmelt will quickly increase river flow.

Urbanisation
Most urban surfaces don't absorb water and storm drains quickly transport the water into rivers.

River engineering can also increase downstream flood risk.

Lack of vegetation
Reduced interception and transpiration cause overland flow.

Circular basin
Water flows to the river from all parts of the basin quickly.

Human influences are in the black boxes – we looked at those in detail in the pr

Because we build on floodplains, planners need to ensure that flood risk is miti techniques they can employ to reduce risk, such as changing the land cover, bu floodplain based on risk.

If you only remember these three th

1. We can model the inputs and outputs of a drainag using the water balance equation – the stores chan because of the seasons.
2. A river's flow throughout the year is called the re controlling factor, physical and human factors aff
3. We measure the flow of water in a river on a hy human factors combine to affect the shape of the increase or decrease the peak flow.

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Activities

Consolidation questions

1. What is the equation for the water budget?

   ....

2. At what time of year is potential evaporation the greatest?

   ....

3. Which area(s) have a negative water budget?

   ....

4. What is a river's regime?

   ....

   ....

5. Give two seasonal factors that affect a river's regime.

   ....

   ....

6. What does a hydrograph show?

   ....

   ....

7. What is the lag time?

   ....

   ....

8. Why does deforestation result in a 'flashy' hydrograph?

   ....

   ....

9. How does deforestation change the catchment?

   ....

   ....

10. Does urbanisation increase or decrease the lag time?

    ....

Take it further

Use this website to make a regime graph for your nearest river.
zzed.uk/9992-river-data-search

Can you explain the annual variation?

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
Influences on the Hydrological Cycle at the Local Scale	Water budgets				
	River regimes				
	Storm hydrographs				
	Human influences on storm hydrographs				

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The Causes and Effects o

Key words

- ✓ **Drought:** Below-average precipitation in an area, can cause water deficits a consequences if prolonged.
- ✓ **Meteorological drought:** Drought associated with decreased precipitation in
- ✓ **Hydrological drought:** Drought associated with a reduction of water in the h surface and ground supplies.
- ✓ **ENSO cycles:** Changes in the sea temperature (surface) and wind patterns i which have large-scale effects on weather.
- ✓ **El Niño:** Part of the ENSO cycle with a weakening or reversal of trade winds ocean water and changes to global weather.
- ✓ **La Niña:** The other part of the ENSO cycle, increasing upwelling of cold wa increasing drought risk elsewhere.
- ✓ **Teleconnections:** Disruption to weather because of ENSO cycles up to thous Pacific.
- ✓ **Desertification:** The long-term process of creating new desert land, leading reducing or destroying the biological potential of an area.
- ✓ **Resilience:** The ability of an ecosystem to resist change.
- ✓ **Ecosystem goods and services:** Materials and services provided by natura (good) and water and climate regulation (services).

Key points

- Droughts occur when rainfall is significantly reduced for a period of time.
- Meteorological droughts are reductions in precipitation and occur because o weather – such as high pressure anticyclonic weather conditions, and ENSO c
- Hydrological droughts are a lack of water within the hydrological cycle – th streamflow and surface supplies, and reduced groundwater.
- Agricultural droughts occur when crop growth is impacted, and socio-economi types.
- ENSO cycles occur in the equatorial Pacific Ocean. They consist of two parts are driven by changes to the trade winds and the upwelling of cold ocean w of the sea surface.
- Both cause droughts and floods in different parts of the world – but can aff through teleconnections.
- Humans can also affect the risk of drought, by abstracting water from the en land use (e.g. deforestation), and decreasing the resilience of ecosystems.
- Droughts affect the functioning of natural ecosystems, which are often adapt in the environment. Droughts can cause deaths of the ecosystems and differe function to provide ecosystem goods and services.
- Ecosystems that are particularly affected are wetlands – which are major sto similarly some forests.

What is drought?

- Drought is difficult to define, and the definition varies from place to place.
- The broadest definition is a period with less precipitation than the average – lasting from a few weeks to several years or even decades.
- Droughts can have severe socio-economic and environmental impacts – including major famine events.
- They can also occur slowly over many years, and are influenced by climate change.

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- There are two basic classifications:
  - meteorological drought – reduced precipitation (e.g. rainfall and snov
  - hydrological drought – reduced river flow and groundwater
  - There are further definitions, such as agricultural drought – a decrease socio-economic drought – which is a consequence of all three types a

The physical causes of drought

Meteorological – short-term and long-term

In the UK, we sometimes experience meteorological droughts in the summer. T and are associated with hot, dry, sunny weather. They are caused by blocking h called summer anticyclones. The hot conditions mean that evaporation potenti

You might associate droughts with yellow grass, news stories about low water l occasionally hosepipe bans.

E.g. The UK – summer 2018 (short-term)

There are also longer-term trends such as the Californian drought which started unlikely to be playing a role – instead, internal variation such as ENSO cycles is a

ENSO cycles

ENSO cycles occur in the Pacific Ocean – but their effects are wide-reaching, ch around the world, such as floods and droughts, and extremes in temperature (w

ENSO stands for El Niño Southern Oscillation. There are two parts – **El Niño** and

They are caused by changes in the temperature of the sea surface, caused by th trade winds.

We are focusing on the area around the equator between South America, espec **Pacific** – Australia and Indonesia.

El Niño years happen on a regular basis (every 2–7 years). They are often follow

El Niño can increase global temperature!

ENSO cycles are tricky to learn. The easiest way is to watch videos. There are ple these two from the Met Office.
El Niño **zzed.uk/9992-el-nino-video**
La Niña **zzed.uk/9992-la-nina-video**

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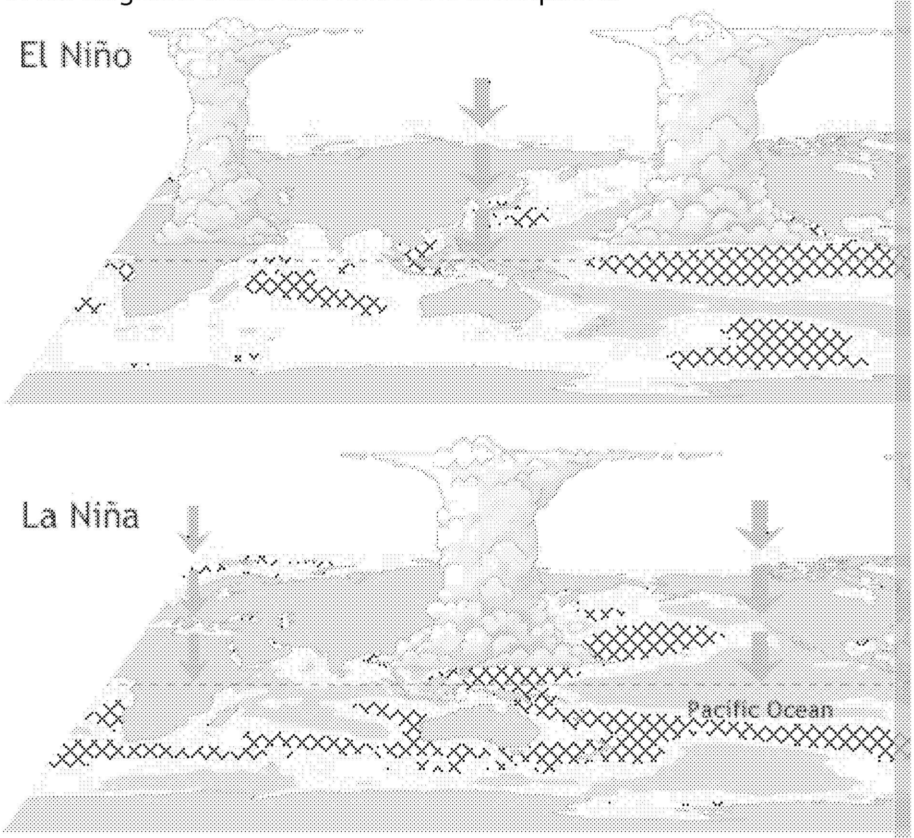
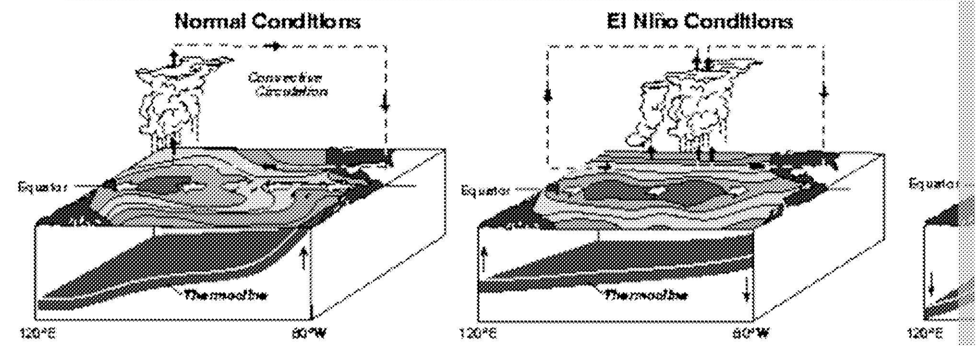
Look at the diagrams below and follow the descriptions.





Normal year:

- Trade winds at the surface blow from east to west (from Peru towards Wes
- Warm surface ocean water is pushed to the west.
- This warm water heats the air above the Western Pacific causing it to rise (c
- In the east, cold water from the deep ocean upwells to the surface, replacin been blown westwards.
- This creates a temperature difference across the ocean.
- At altitude, air travels back east and sinks – atmospheric circulation.

El Niño (WARM) year:

Changes in the atmosphere or surrounding ocean change the normal circulatio east-to-west trade winds.

- The weakened trade winds mean that less warm ocean surface water is pu upwells in the east.
- The water in the east is warmer than normal, and the temperature differen
- Rising air and clouds are now over the centre of the ocean, rather than in t
- The air therefore sinks over both Peru AND now over the Western Pacific.
- This changes weather patterns, locally and around the world.
  - e.g. droughts in Indonesia and India (seen by the sinking cold air in th

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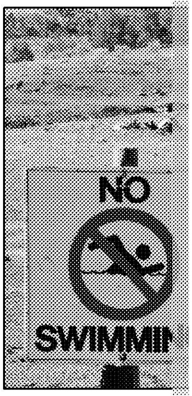
La Niña (COLD) year:

- Trade winds are stronger than normal, so the warm surface water is pushe water upwells in the east and towards the centre of the ocean.
- There is more rainfall and flooding in Indonesia because the rainclouds are more flooding in South America. The southern United States may experien cold air, and warmer air than normal increases the risk of hurricanes in the

Hydrological causes



After periods of low rainfall, hydrological drought becomes an issue. This is when streamflow decreases because of reduced run-off; lakes, ponds and wetlands all begin to dry up. Groundwater supplies are diminished, lowering the water table – so base flow is also reduced.

These droughts have implications to the environment, e.g. habitat loss in wetlands, vegetation shrivels, food and water for animals become scarce, and the risk of forest fires increases.

Our water supplies are also reduced – meaning that we have to change our life domestic water use. Some industries that use lots of water are also affected, inc and electricity production.

Human influences on drought risk

- Humans are increasing the risk of drought through:
  - abstracting groundwater (e.g. for irrigation) (lowered water table and
  - abstracting surface supplies (from rivers and lakes, building reservoirs
  - deforestation (e.g. decreased transpiration and rapid run-off in defore
- This means that the environment is more stressed before there is a change increasing the drought's impacts.
- Deforestation and overgrazing, in addition to natural cycles, can cause **des** don't mistake desertification for drought – they are very different.
- Climate change will inevitably play more of a future role in shifting weathe

E.g. Sahelian drought – exacerbated by human activity which causes lead to famine, with further health conditions caused by high ten

E.g. Australian drought – caused by El Niño – concern for future chan irrigation supplies requiring major infrastructure and water trans

The effects of drought on natural ecosystems

The distribution of the world's ecosystems has been formed because of climate living in the ecosystem are adapted to the climatic conditions. In ecosystems p plants and animals have developed coping mechanisms.

However, in areas where droughts are rare, or plentiful water is required for the have serious impacts such as mass die-offs of trees. The ecosystem's **resilience** change) is also reduced, along with the ability to provide its range of **ecosyste**

Wetlands

Water is important to wetlands, as the name suggests! There are many differen and swamps, some with ponds and open water. They are usually at or near wat

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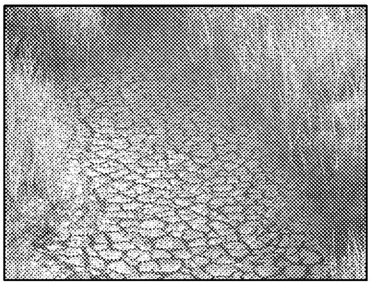
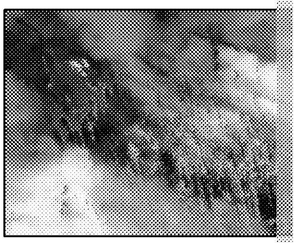


When they dry out, the ecosystem is significant moves away. They lose their ability to recycle, p They are also vast stores and sinks of carbon (th doesn't decompose because of the water) – but be released into the atmosphere. This means th climate change. Dried-out wetlands can also ca

Forests

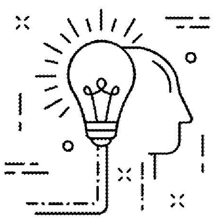
Forests are vital to both the hydrological and carbon cycles. In hot and dry cond drought, and become far more vulnerable to pests and diseases. Forest fires, ca strikes, and also through human activity, are more likely to occur – and can be m



Large, hot fires release more CO_2 into the environment, and affect the local hydrological cycle – increasing run-off into streams.

However, remember that some forests are adapted to fire, and even need fire for their survival – to remove undergrowth and open cones for seed germination.

If you only remember these three th



❶ Drought is the reduction of precipitation in an are overall water, and serious effects on people and t

❷ Drought can be naturally caused by weather syst and La Niña). Humans are increasing the risk of d abstraction and land-use change.

❸ Droughts can significantly affect ecosystems – the has wide-reaching consequences to weather and c

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Activities

Consolidation questions

1. Why is drought hard to define?

....

....

2. What's the difference between meteorological and hydrological drought?

....

....

3. Where do ENSO cycles occur?

....

....

4. Why do ENSO cycles affect precipitation?

....

....

5. How do humans increase the risk of drought?

....

....

6. Name an area which is currently in drought conditions.

....

....

7. How can drought in wetlands release stored carbon into the atmosphere?

....

....

8. What are the effects of droughts in forests?

....

....

Take it further

How bad is Australia's drought?
zzed.uk/9992-drought-australia

For a much longer video (from a farming view):
zzed.uk/9992-drought-aus-long

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
The Causes and Effects of Drought	What is drought?				
	Meteorological drought				
	ENSO cycles				
	Hydrological drought				
	Human influences on drought risk				
	The effects on wetlands and forests				

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The Causes and Effects

Key words

- ✓ **Flooding**: Inundation of water on to the land as a channel overtops its bank high flow.
- ✓ **Flash flood**: Rapid onset inundation of the land, for example a storm after
- ✓ **Depressions (cyclones)**: Low-pressure weather system associated with stron
- ✓ **Jet stream**: Narrow band of high winds, 5 to 7 miles above the surface, whi each hemisphere.
- ✓ **Storm surge**: An offshore rise in sea level – low-pressure weather systems a flooding, e.g. from hurricanes or funnelling.
- ✓ **Monsoon**: Intense summer rainfall in areas such as India, East Asia and Afri rainfall occurs in just a few months.
- ✓ **Hard engineering**: Physical modification of a river channel, for example to speed of flow.
- ✓ **Soil erosion**: Degradation or removal of Earth's surface layer, for example
- ✓ **Socio-economic impact**: Monetary losses and effects on people following

Key points

- Flooding is a surplus of water in the hydrological cycle. Either the soil can't fast enough, or rivers burst their banks.
- There are many causes of floods – such as intense or prolonged rainfall fro tropical storms) and cyclones, annual monsoons and rapid snowmelt. Storm s
- Physical and human activity increase the flood risk – these are the same fa hydrograph.
- Changing land use such as deforestation, farming and urbanisation increase infiltration. Water is channelled quickly into sewers and storm drains.
- We have built settlements on many floodplains across the world – we try to engineering schemes – but these can make the issue worse elsewhere. This is
- Natural environments have adapted to flooding – some ecosystems rely on However, humans have changed the risk to the natural environment, for exa from storm drains.
- Social impacts include the loss of property, deaths and injuries.
- Economic effects include damage to commercial buildings and infrastructure
- Combined, these are the socio-economic effects.
- Some of these effects are harder to detect and quantify in monetary terms.
- The effects of flooding vary throughout the world and from flood to flood, level of development and the characteristics of the flood, such as the area

Meteorological causes of flooding

- **Flooding** is a surplus of water within the hydrological cycle, meaning that the land's surface is submerged.
- Sometimes rivers burst their banks on to their floodplains. At other times, heavy rainfall is the cause.
- Humans can increase flood risk through urbanisation and land-use change.
- Natural factors also increase the risk of flooding. Remember the hydrograph from one of the previous chapters? The natural factors that cause a flashy hydrograph also increase flooding – the faster water can flow to a river, the greater the flood risk.
- There are several causes of flooding, including:

Ex-hurricane St
2017. You migh
red from dust i

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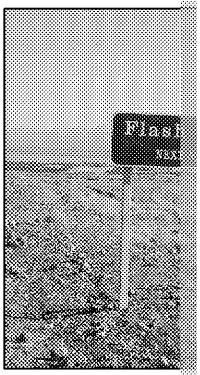
Storms and flash flooding

In the UK, we experience storms – they are periods of wet and windy weather t **cyclones**.

They often occur in the autumn and start of the winter, but we still see a few in because of the **jet stream**.

Very intense precipitation can cause sudden floods called **flash flooding** – these often occur in arid environments where the soil is very dry. Other physical factors can cause flash flooding, such as steep catchments where the water is channelled through a stream.

- In coastal areas, strong onshore winds and low pressure, coinciding with high tides, can lead to inundation of the coast with seawater (a **storm surge**).
- In the tropics, tropical revolving storms (e.g. hurricanes) lead to flooding and also cause storm surges at the coast.



A sign i

E.g. Boscastle, summer 2004; UK, summer 2007

Heavy and prolonged rainfall

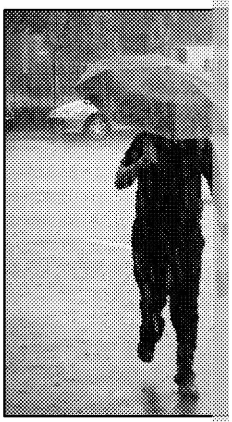
The ability of the soil to absorb water is affected by the intensity of the rainfall a

- Intense rainfall can't infiltrate the soil fast enough (infiltration excess overla
- If it's rained a lot recently, such as a succession of storms where the jet stre is little air space left in the soil for new water (saturated overland flow).

E.g. Somerset Levels, 2014; Cumbria, December 2015; Lincolnshire, Ju

Monsoon rains

Monsoons occur every year in some parts of the world including regions of Asia and Africa. They are caused when winds change direction and blow moist air from the oceans over the land. Intense rainfall for around three months drops most of the year's rainfall on the region. While the monsoon floods are expected and local people are prepared for their arrival, they can be particularly severe in some years. This is when monsoons negatively affect people.



E.g. South Asia (India, Bangladesh and Nepal), 2017

Snowmelt

In regions where winter precipitation falls as snow, a thaw begins each spring. I quickly, a large surge of water reaches the rivers, causing them to burst their ba

E.g. Ohio, 2015

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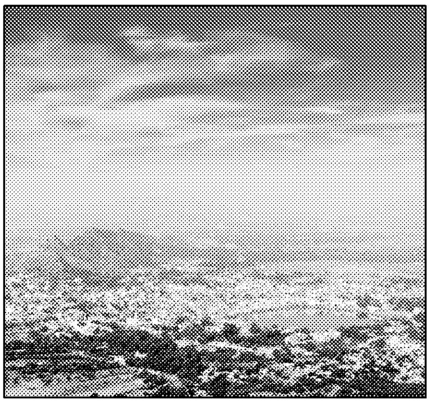
Human causes of flooding

- Again, we looked at human factors that cause a flashy hydrograph – these
  catchment also increase the flood risk.



Changing land use

Urbanisation means that natural land uses impermeable surfaces such as concrete an been designed to direct rainfall into surrou possible – every roof, road, pavement, and into the sewer network where the water is which lead directly to rivers.

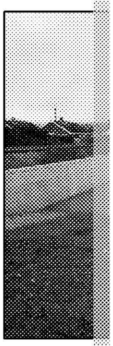
Deforestation and conversion of land to a interception, speeding up the flow of wate create channels for water flow, and heavy increasing overland flow.

As population grows, so does our demand for housing and food.

Mismanagement (and hard engineering)

We have built many of our towns and cities on floodplains because of the flat, rivers for navigation and water supplies.

But there's a problem with building on a floodplain. Hint, it's in the name! In or areas are managed. Natural meandering channels have been straightened – in Some rivers flow through concrete channels, others have been dredged, and so These are examples of **hard engineering**.



These measures are all designed to speed up the flow of water downstream. Downstream flooding may result. Conversely, the pillars of bridges in the water hold up the flow.

In order to mitigate this, management can help restore natural meanders and build stores for the extra water. There are also ways of managing the catchment in order to increase interception (e.g. afforestation), and slow down entry of water into the rivers.

Environmental effects of flooding

- Floods occur naturally. They are important to the functioning of some eco
  fertility by transporting nutrients downstream and on to the surrounding
- However, heavy rainfall and increased streamflow can cause **soil erosion**
  chance of mass-movement events such as landslides.
- Human activity has increased the damage of flooding to the environment,
  drains can contain high levels of pollutants.

Socio-economic effects of flooding

- There are many effects of floods on people (social) and on the economy.
- Factors such as the amount of land flooded and the length of the flood aff
- Some of the effects are obvious – such as the direct physical damage to pr
  obvious, and harder to quantify – e.g. indirect health issues and disruption
- Some floods (such as the monsoons) occur annually, while some areas floo
- The level of development plays a role – floods in developed countries may
  developing world; however, the economic costs tend to be much higher.
- Age is also a factor – the young and elderly are most likely to be affected.

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So what are the main socio-economic effects of flooding?

Direct effects include:

- loss of homes and property
- deaths and injuries
- loss of buildings and infrastru
- damage to farmland, loss of c

Indirect effects include:

- stress and mental health issu displacement
- financial difficulties and loss o

If you only remember these three th

❶ Flooding is a surplus in the water cycle – water fl burst their banks. There are many different cause monsoons and snowmelt.

❷ Floods occur naturally, but humans are increasing urbanisation and land-use change, and through h mismanagement of catchments.

❸ The effects of flooding on the environment are of ecosystems have adapted to it – however, human economically through the loss of life and property

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Activities

Consolidation questions

1. Why do storms cause flooding?

   ....

   ....

2. Name an area that is affected by monsoons.

   ....

   ....

3. Why does urbanisation increase flood risk?

   ....

   ....

4. Give an example of river mismanagement.

   ....

   ....

5. Why are some of the effects of flooding difficult to quantify?

   ....

   ....

Take it further

Here are several news articles about flooding in the UK.

An example of summer flash flooding (2014) **zzed.uk/9992-summer-flooding**

An example of a winter storm (Storm Desmond) **zzed.uk/9992-storm-desmond** and its socio-economic costs **zzed.uk/9992-desmond-costs**

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
The Causes and Effects of Floods	Meteorological causes of flooding (including storms, flash flooding, heavy and prolonged rainfall, monsoons and snowmelt)				
	Human causes of flooding (including changing land use, mismanagement / hard engineering)				
	Environmental effects of flooding				
	Socio-economic effects of flooding				

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Climate Change – Chan
Effects to the Hydrologi

Key words

- ✓ **Little Ice Age:** Cooler climate between 1300 and 1850 resulted in crop fail abandonment and glacial advance.
- ✓ **Permafrost:** Ground which is permanently frozen for at least two years in a
- ✓ **Desalination:** The removal of salt from saline or brackish water to provide through thermal processes or filtering (reverse osmosis).
- ✓ **Water security:** Maintenance of a constant and sufficient supply of water, fo scale, could be difficult in the future.

Key points

- Climate change is causing Earth's atmosphere and oceans to warm, increasi evapotranspiration.
- There will be changes to the water cycle – changes to the stores and flows, rainfall, increasing extreme events, floods and droughts, storm and hurrican change will affect areas differently.
- Climate change could also affect the severity of La Niña effects.
- Snow cover, sea ice, glacier ice and permafrost will all decrease across the
- In some areas, surface and groundwater stores will decrease, except in the
- There is still some uncertainty over how climate change will alter weather a humans. Models are still imperfect, as is the data that they use. There may b there may be feedback cycles which nullify positive feedback.
- Water suppliers have a difficult task in supplying our future water demands coping with decreases in rainfall, variation and extreme events in order to m

Changes to precipitation and evaporation

Precipitation and evaporation are the inputs and outputs in the hydrological cy change these.

- Climate change will cause warming of Earth's atmosphere and oceans.
- Higher temperature means that potential evapotranspiration rates increas increase the evaporation.
- A warmer atmosphere can hold more water vapour. A warmer, unstable at could lead to more intense precipitation events, stronger tropical storms (greater number of extreme events.
- In other areas, droughts, coupled with heatwaves, may become more com could occur due to changes in ENSO cycles and increased evapotranspirat surface temperature and associated weather patterns.
- However, the amount of warming and the effects of climate change differ will get wetter, others will get drier. The timing and intensity of precipitati

Changes to stores and flows

Climate change could affect each of the stores and flows in the following ways. climate change could speed up or strengthen parts of the hydrological cycle – increasing the fluxes between the stores.

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Snow and glacier mass

- Decreased snowfall, shorter snow seasons (less snow storage).
- Reduced sea ice (e.g. thinner, smaller area, later formation and early thaw) and increased winter navigation of the Northwest Passage.
- Most glaciers currently have a negative mass balance – ice stores are decreasing (after they expanded during the **Little Ice Age**), glaciers retreat and thin.

Permafrost

Permafrost is ground that is frozen for at least two years. As the Arctic warms (a the world), the permafrost is melting. While the active layer forms each year, th run-off in the area.

Reservoirs and lakes

In areas where streamflow decreases, surface water supplies will decrease. The o become wetter.

Soil moisture

Decreased precipitation and increased potential evaporation are likely to dry ou Groundwater is also likely to fall.
This is especially true where forests transpire large amounts of water.
Forest die-off and fires will cause positive feedback loops.

Run-off and streamflow

With drier soils (reduced infiltration rate) and intense rainfall events, surface run flood risk.

Reduced precipitation, coupled with decreased groundwater and soil water leve reduced river flow in some areas.

Increased streamflow in ice-fed rivers.

Short-term climate change (ENSO)

- The links between climate change and an intensification of El Niño are not fully understood, but some models suggest that over the next century, the chance of 'extreme El Niño' events could double in frequency, occurring every decade (e.g. causing large-scale droughts).
- Other models suggest that El Niño events could be weaker, having less effect.
- We don't have long, detailed records of El Niño events, and their effects vary – each El Niño is unique.
- Changes to La Niña may also be affecting the ocean temperature.

Climate change uncertainty

We are uncertain about the exact changes to the hydrological cycle from climate change because:

- We may not fully understand the complex interactions between parts of the cycle.
- Unknown unknowns – our models may miss out key components that we don't know about.
- Imperfect or incomplete data and weather observations to input into mode with short-term observed data.

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- Human impacts on the climate can be difficult to distinguish from natural v ENSO cycles and their teleconnections, or natural changes to the climate s other natural factors.
- Negative feedback cycles could occur – such as increased plant growth red warming, or an increase in cloudiness reducing evaporation rate.

Future water supply projections and uncertainty

- As a result of climate change, some areas will become drier, rains will beco certain seasons, and affect inputs from snowmelt. This is combined with ri places, fuelled by rising population, demand for food, and rising standards
- This is causing issues for water planners, who have to forecast demand, must attempt to meet that demand, and build additional storage capacity in the face of climate change uncertainty. This helps increase **water security**.
- Other challenges include the depletion of aquifers (use of fossil water), and the increase in evaporation (including from reservoirs).
- As a result, water suppliers may need to build extra storage (reservoirs), or **desalinate** sea water.

This Ke
riverbe

If you only remember these three th

❶ Climate change will change the stores and flows o hydrological cycle. Some areas will become wett be more extreme events.

❷ Within ENSO cycles, there could be more extrem ENSO cycles and teleconnections (internal variati distinguish between climate change and the effec

❸ Climate change uncertainty and predicting future challenge for water planners in order to maintain

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Activities

Consolidation questions

1. Will climate change affect the whole planet in the same way?

   ....

   ....

2. How will water stores change?

   ....

   ....

3. How might ENSO cycles / El Niño change?

   ....

   ....

4. Give a reason why El Niño might make the effects of climate change difficu

   ....

   ....

5. Suggest why water planners face a difficult job in the future.

   ....

   ....

Take it further

Take a look at some of the articles about climate change linked here: **zzed.uk/9992-climate-articles**

NASA has a page dedicated to the water cycle, including predicted alterations b climate: **zzed.uk/9992-nasa-water-cycle**

Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
Climate Change – Changes and Effects to the Hydrological Cycle	Changes to precipitation and evaporation				
	Changes to stores and flows				
	Short-term change (ENSO)				
	Climate change uncertainty				
	Future water supply projections and uncertainty				

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Physical and Human Ca
Water Insecurit

Key words

- ✓ **Per capita:** by each person – e.g. the amount of water used by each person
- ✓ **Virtual (embedded) water:** Water associated with the growing or manufac product but isn't contained within the end product. When goods are transpo world, so too is the virtual water.
- ✓ **Water stress:** Water availability in a defined area is less than 1,700 m³ pe
- ✓ **Water scarcity:** Water availability in a defined area is less than 1,000 m³ p
- ✓ **Water abstraction:** The removal of water from a source, such as a stream, l us with a water supply.
- ✓ **Surface water:** Water located above ground, for example in lakes, streams
- ✓ **Groundwater:** Water located below Earth's surface, stored in the pores of
- ✓ **Water security:** Maintenance of a constant and sufficient supply of water, f scale, could be difficult in the future.
- ✓ **Physical insecurity:** Water supply is limited and cannot meet demand beca with (e.g. arid regions), or there is too much abstracted.
- ✓ **Climate variability:** Periods of drought may occur because of temporary cli
- ✓ **Salt water encroachment:** Due to groundwater abstraction in coastal areas, seeps into aquifers, polluting drinking water.
- ✓ **Water contamination:** Agriculture can pollute water supplies through nutrien from pesticides.
- ✓ **Increasing population:** As birth rates rise, and death rates fall, there are m supply.
- ✓ **Improving living standards:** As a person or country develops, water use in domestic goods are sought after, and lifestyles become water intensive.

Key points

- The distribution of Earth's water is not equal around the world – down to cli belts), past climate (fossil water), geology (determines aquifers and surface
- Human population (and therefore demand) is not equal either – and the hig availability and high population don't always tally. There is a mismatch bet
- We classify having limited water as water stress and water scarcity depend region is available per person.
- Physical insecurity is when there isn't enough water, or supplies are degrad geology play a role.
- Climate change, internal climate variation, floods and droughts all affect w aquifers can become polluted with salt water.
- Humans also abstract water from surface and groundwater supplies – affec hydrological cycle, and the quality of water in rivers. Some of the abstracti flood risk.
- Humans diminish supply through pollution from agricultural run-off, and from mines.
- We're increasing demand for water, putting pressure on finite resources thr and increasing per-capita and virtual consumption through industrialisation

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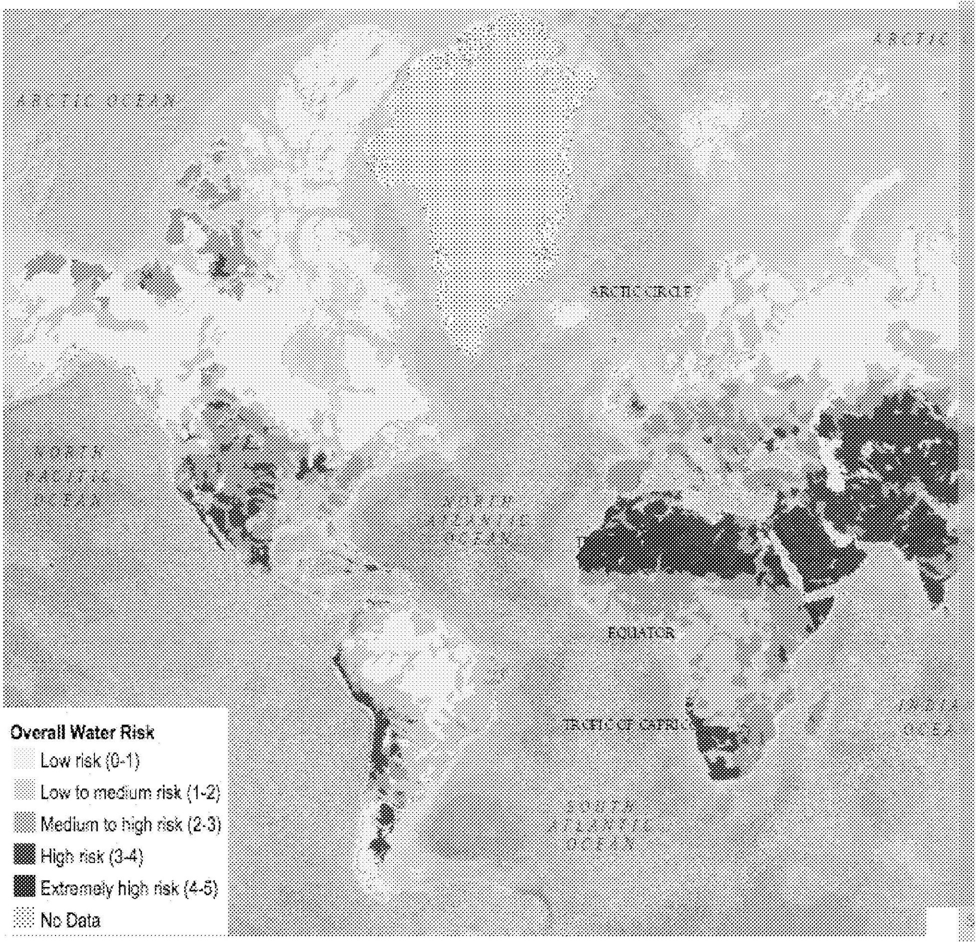
Supply vs demand – water stress and water scarcit

- The distribution of the world's water is not equal. Precipitation is linked to the equator (low pressure) and lowest in the deserts and at the poles (high
- There are also regional differences of precipitation within countries – e.g. the west is wetter than the east.
- In some places, there are groundwater deposits from when the climate wa
- Population is not evenly distributed around the world, or even within coun not equal throughout the world. Population is concentrated into small are There are also differences in demand for water based on economic develo more water **per capita** (per person)).
- Water availability and demand don't always match up!
- When there is not enough water for sustainable use, the supply is said to b
- Remember that the goods that we buy include **virtual (embedded) wate** your jeans, or the food that you ate for dinner needed lots of water to be g world (e.g. cotton) where water is scarce. That water is essentially importe
- There are two definitions that are important, based on the amount of wate

Water stress	**W**
Less than 1,700 m^3 of water available per person each year.	Less than 1,000 m^3

Below is a map of water security.

Water security is having a sufficiently clean and safe, sustainable water supply, demands of the population.



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Physical causes of water insecurity

Physical water insecurity is where there's not enough water for both people an

- Covers both surface and ground supplies.
- Causes include factors such as climate (arid regions), and depleted and de
- Annual distribution of rainfall is also a factor (e.g. areas affected by a mons parts of the year where water availability is limited.
- Relief alters water supply through orographic (relief) rainfall, but run-off is
- Geology determines run-off and water storage – e.g. impermeable geology stored in aquifers, while surface supplies are more likely.

Climate variability

- Long-term effects of climate change (decreased precipitation in some area
- Internal variation (ENSO cycles).
- Droughts and floods (remember floods can pollute water supplies with se

Coastal aquifer saline intrusion

- In coastal areas, groundwater can be polluted by the salty ocean water ent water unsuitable for drinking, unless the salt is removed.

Human causes of water insecurity

- Last time you turned on the tap, your water might have come from a river ground. If you live in London, some of that water might have been desalin our homes, in industry and for irrigating crops.
- We're abstracting water from many sources around the world. As you kno water, notably groundwater.
- Below are several ways in which we're reducing water supply through use

Overabstraction (surface supplies)

- Abstracting river water reduces streamflow, and reduces the water quality
- Building dams and reservoirs floods land and streamflow below the dam is
- Reduced flow also affects aquatic life – lower dissolved oxygen and polluta dispersion).
- Lower flooding risk.

Overabstraction (groundwater supplies)

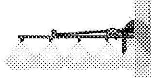
- Pumping out groundwater lowers the water table. In coastal areas, saline s aquifer.
- Base flow of rivers is also reduced.
- Reduced water table also causes ecosystem damage such as vegetation de

Therefore, the Environment Agency regulates water abstraction in the UK to en

Agricultural contamination

As the biggest user of global water, agriculture can also cause contamination t

- run-off of pesticide and fertiliser use
- **eutrophication** and therefore low oxygen dissolved in the water
- intrusion into groundwater – nitrate pollution is a growing problem in the UK, especially since 1945 when agricultural intensification occurred. The material can have a long residence time, and causes health effects – therefore we have to stop using the most contaminated boreholes, and increase the cost of water purification.



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Water pollution (industrial)

- Affects surface water (e.g. rivers where sewage is discharged) and can contaminate groundwater with heavy metals.
- Poorly regulated release of sewage in some parts of the world (e.g. China) – e.g. heavy metals from factories.
- Heavy metals from mining (including acid mine drainage).
- Causes health conditions, and even poisoning cases.

Increasing pressure on finite resources

- As you have already seen, only a fraction of a percent of Earth's water is fres AND available to us!
- Many of the groundwater supplies that we have are fossil water that is bein is being recharged.
- There are many reasons for increased demand, including:

Population growth

- More people to directly consume water for basic sanitation, including drink the toilet, for cooking with, doing the laundry and dishes, etc. There may be That's over 2 billion people more than we currently have.
- But a larger population also requires more water for:
  - agriculture
  - manufacturing goods
  - generating electricity

Better living standards and industrialisation

As a country develops, its population uses more water per person. Reasons inclu

- Greater access to piped water in the home – and more water using goods – toilets, washing machines and dishwashers.
- If you spend hours a day collecting and carrying water (which is heavy!), you treat it a lot more carefully than if it's available by just turning on a tap. We lot of water without even getting our hands wet – think of a dishwasher – th plates and dishes go in and come out dry. And if you've got a washer–dryer combo, so do your clothes!
- Greater consumption and import of goods (and therefore virtual water).

Increased agriculture

Greater demand for food (both from rising population and increased affluence) irrigation water.
As countries develop, their meat consumption also increases. Meat production water than growing crops.

Their impact on water insecurity risk

Increased demand and decreased supply increase water scarcity, and increase th cannot be met.

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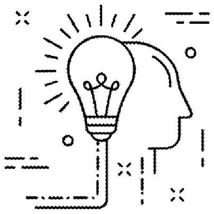
If you only remember these three th



1. The supply of water and the demand for water d physical and human reasons. Depending on the av either water stress, or water scarcity.
2. **Physical** factors lead to water insecurity – basec and factors, geology, climate variability (includin droughts), and coastal aquifer intrusion of saline the overabstraction of water and contamination o agriculture and improper disposal of industrial w
3. The world's demand for water is growing as the p needed for personal use, for growing food), comb standards, increasing the per-capita demand.

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Activities

Consolidation questions

1. What is the main factor that determines water availability?

   ....

2. What's the difference between water stress and water scarcity?

   ....

   ....

3. How does human abstraction affect water supply?

   ....

   ....

4. Explain how humans are decreasing the available water through pollution

   ....

   ....

5. Why does development increase the demand for water?

   ....

   ....

Take it further

Water shortages – 5 billion affected by 2050?
zzed.uk/9992-water-shortages

For a longer read, you can have a look at the executive summary of this UK repo
zzed.uk/9992-unesco-report

Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
Physical and Human Causes of Water Insecurity	Supply and demand – water stress and scarcity				
	Physical causes of water insecurity				
	Human causes of water insecurity				
	Increasing the pressure on finite resources (population growth and rising living standards)				

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The Problems of Water I

Key words

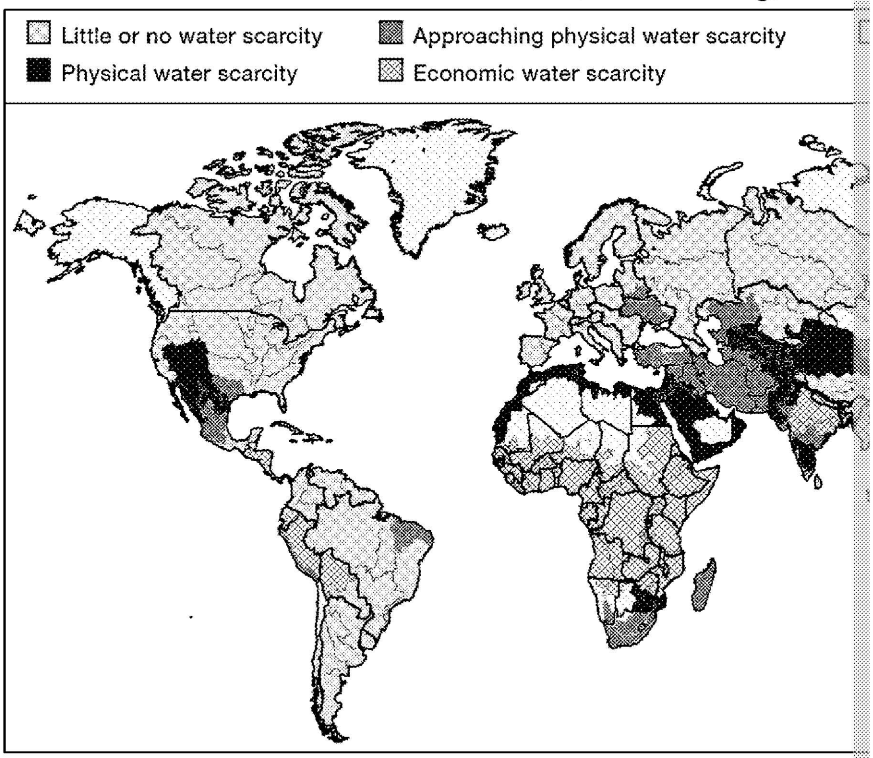
- ✓ **Economic scarcity**: People cannot afford to purchase water, or investment i lacking due to financial constraints on suppliers.
- ✓ **Conflict**: Disputes, for example over water supplies where one country is fa sometimes caused by upstream abstraction in neighbouring countries.
- ✓ **Geopolitics**: A branch of politics looking specifically at how geographical is relations.
- ✓ **Transboundary**: Conflicts (or sometimes cooperation) over water supplies w involved.
- ✓ **Local-boundary**: Pressures over water within a country, for example, where different regions.

Key points

- There are areas of the world where water is plentiful – but people can't af the infrastructure is not in place. This is economic water scarcity. This tends to developing and emerging countries.
- The price of water varies around the world, based on ease of abstraction, p affordability.
- Water is essential to economic development, for agriculture, industry and e
- We also need water every day for sanitation, preventing the spread of dis
- Limited supplies and continued abstraction affect the environment through lo output and economic development.
- Building water resources can cause tension both within a country, and betwe is shared.
- While wars over water might be rare, shared supplies may be one of many can be used to control another country.

In the previous chapter, we mainly looked at **physical water scarcity**, which is water largely related to the climate. In this chapter, we'll look at the **economic**

The map below shows areas of the world where water is, or is becoming, scarce



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The map is broken down as follows:
Little or no water scarcity – our use is sustainable. We use less than 25% of riv
Physical water scarcity – our use is not sustainable. We use 75% or more of riv
Approaching physical water scarcity – will soon become scarce, 60% or more
Economic water scarcity – less than 25% of flow is used, but people can't affor investment in supply. People are malnourished.

The cause and pattern of physical water scarcity

- Looking at the map, the areas where there is physical water scarcity includ
  - parts of the United States and Mexico – arid regions, affected by drou
  - Northern Africa and the Middle East – arid regions
  - Central Asia – arid regions
- Overall, scarcity is when demand for water can't be supplied.

The cause and pattern of economic water scarcity

- Again, looking at the map, we see economic scarcity in Peru and Bolivia, m countries such as India, Bangladesh, Myanmar, Cambodia and Vietnam.
- Economic scarcity occurs when people can't afford the water, or there is la water. The physical supply is not a problem!
- This explains why the countries affected by economic scarcity are all devel

Why does the cost of water vary throughout the world?

There are many reasons why the price of water varies around the world. Howev production costs, and the price at which the water is sold to the consumer.

Here are several factors that determine the price:

- The cost of production – the difficulty in abstracting water, the need to bui pumping stations, and the cost of purifying and distributing the water. The polluted the water, the higher the purifying costs, and the further the dista travelled, the more expensive the pipeline, etc.
- How much the end user can pay – if the price is too high, the water in unaf
- Whether the water is provided by a private company (including investmen developing world), and how much local authorities or governments agree
- Whether the company intends to make a profit (traditional), or grants are u the user only pays for the maintenance and purification costs. Sometimes schemes are developed by Chinese companies.
- Development of water in rural vs urban areas (may be cheaper in rural area from a well or carried by bucket is much cheaper than piped water.
- The way that water is metered – e.g. flat fee per day plus based on use, just

Water is important for economic development

Water is vital to countries' economies. The amount of water used in industry va except Europe and Central Asia, water for agriculture dominates the withdrawa around 20%.

Not only is water important for industry, it affects those in the developing worl their day collecting and carrying water, i.e. if water was available on tap, then th would have more opportunity for paid employment.

Industry

Water is used in primary and secondary industry (mining and manufacturing). I used in some forms of mining, and in the production of materials, including paper, steel and chemical production. Water is used for dying clothes, and even in making electronics.

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Therefore, water is necessary to power the economies of emerging countries su
to develop.

Energy production

As countries develop, their energy demand increases.

Water is used in primary energy production – such as in fracking fluid to release
production of oil.

Water is used in many types of electricity production, including:

- hydroelectric power
- to generate steam in thermal and nuclear power stations
- for cooling (either in cooling towers, or water is pumped from rivers or the s
  the waterbody (but it is warmer than before, so can't hold as much oxygen)

Agriculture

Many countries rely on agriculture to feed themselves, and for the exports of ca
know, most of the world's water is used for agricultural irrigation.

Water is important for human wellbeing

- We couldn't live without water on a daily basis. Not only do we need to dri
  in our daily lives to wash, for cooking and to remove waste (sewage). Witho
  such as cholera can quickly spread.
- Even in the twenty-first century, up to 780 million people around the world
  source, which impacts on their health daily.
- People in rural areas are less likely to have access to clean water.
- Some deaths caused by poor sanitation are easily avoided, including by ba
  chlorination and filtration of supplies.

Sanitation

- Up to 2.5 billion people worldwide don't have access to improved sanitation.
- Sanitation includes removal of sewage from homes.
- Rural areas are likely to have latrines which, rather than flushing the waste, deposits it into the ground. Groundwater, and therefore drinking water, are polluted.
- There may not be a reliable water source for washing hands, further spreading disease.

Health

- Poor sanitation, untreated sewage and waste, and open sewers lead to the
- Diarrhoea is a major killer worldwide, including in young children – mostly
  supply and sanitation.
- Open and/or polluted water also spreads disease – such as malaria, dengu
  and schistosomiasis (snails).

Food preparation

- Water is essential in the cooking of foods if they are boiled.
- Water is essential to washing up utensils, crockery and cutlery, stopping th
- Water is also vital for washing hands after touching raw foods, especially m

Environmental and economic problems caused by li

- We've already covered the environmental problems caused by overabstrac
  reduction of groundwater, lakes and rivers drying up and pollutants becom

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- The economic consequences are also obvious, as are the limitations on economic growth – given that many industries rely on water, and water pl major role in energy production, especially electricity. Droughts significan affect the production of power, and can cause famine in countries where c are largely rain-fed.
- Lack of water also hinders development because women spend so much ti collecting it. In some parts of the world, women are more likely to miss sch or workdays because of periods.

The potential for conflict

- Often, water resources span international borders – both rivers and aquife
- Each country might be allocated a share of the water under an agreement. take more than their allocation, build new dams or pump more groundwa supply.
- Some people suggest that, in the light of climate change and increased po tensions over water may lead to armed conflict.
- This may be the case, but others suggest that rising tension over water mig a conflict, such as in areas where there has been a long history of conflict o
- Conflicts could occur during droughts, including those caused by El Niño e

Within a country

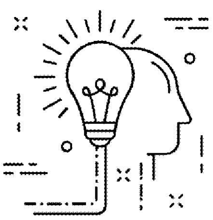
- Within countries, some parts are naturally wetter, or have greater supply. W distances to the drier areas. In the UK, we've dammed valleys in Wales and cities including Birmingham, Manchester and Liverpool. We've also built a Northumberland called Kielder Water. Such schemes cause tension becaus people and businesses are forced to move.

International conflict (shared resources between countries)

- Countries upstream can control water downstream, reducing or stopping t countries. In this way, water can be used as a weapon. Limiting water supp health and sanitation, as well as reducing industrial and agricultural outpu
- The effects of surface water abstraction (e.g. rivers) are easy to measure be easily measurable at stages along the river.
- The result of building dams can be measured, and the effects are immedia
- The effects of shared aquifers are difficult to measure. We don't fully know amount of water stored, or the amount of water abstracted by each countr might take a long time to show.
- There are many different players in each country, such as governments and residents, energy suppliers and conservationists.

Rivers Nile (Africa) and Mekong (Asia); aquifers include Palestine a

If you only remember these three th



1. Economic water scarcity occurs when there is wate cannot afford to use it, or there are limited wate developing and emerging countries.
2. Water is essential to economic growth because it generation. It's also vital for human development everyday life, and is important for sanitation and
3. When water resources are shared, e.g. rivers and boundaries, there is the potential for conflict or te abstracts more water than agreed, reducing the

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Activities

Consolidation questions

1. Which parts of the world are likely to experience economic water scarcity?

   ....

   ....

2. Is water more likely to be cheaper in rural or urban areas?

   ....

3. Why is water important to energy production?

   ....

   ....

4. Why is water for sanitation so important in reducing mortality rates?

   ....

   ....

5. How likely is water to cause armed conflict?

   ....

   ....

Take it further

Take a look at the water resources shared between Israel and Palestine.
zzed.uk/9992-israel-control-water

Water as a weapon?
zzed.uk/9992-water-weapon

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
The Problems of Water Insecurity	Cause and pattern of water scarcity				
	The cost of water around the world				
	Importance of water for economic development				
	Importance of water for human well-being				
	Environmental and economic problems caused by limited water				
	The potential for conflict				

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Managing a Sustainabl Supply

Key words

- **Players:** Another name for 'stakeholders' – people with differing opinions a the use of a resource.
- **Techno-fix:** Form of hard engineering with emphasis on scientific advanceme problems faced by predicted future water supply deficiencies.
- **Hard engineering:** Built, physical structures used to increase the water suppl
- **Water transfer:** The movement of water from areas of surplus to areas of de north scheme.
- **Megadams:** Large-scale construction projects to store water for use during d
- **Desalination plant:** Building where saline or brackish water is turned into fr and condensation, or through reverse osmosis.
- **Brackish water:** Seawater mixed with fresh water, such as at the mouth of a than out to sea.
- **Sustainable schemes:** Water projects that meet current needs and will mee won't be depleted.
- **Restoration:** Process of undoing problems caused in the past, which diminish
- **Water conservation:** Reducing the demand for water through efficiency mea and dishwashers.
- **Smart irrigation:** Equipment that only waters plants and crops when needed sensors determine when the soil is dry enough to recommence watering.
- **Water recycling:** Reuse of water when clean water isn't needed; for exampl your garden.
- **Hydroponics:** Way of growing plants without soil, by spraying water on to t
- **Grey water:** Waste water from sinks, baths and domestic appliances that d
- **Integrated drainage basin management:** Holistic approach to a catchment, collaborations, including those between countries.
- **Water allocation:** Users in each section of a river are allowed to abstract a allowing for fair use of the resource.
- **Drainage basin planning:** Overarching control and strategies which overse flooding, ensure that abstractions are sustainable, and to ensure a variety c
- **Water Sharing Treaty:** Written agreement between countries that use water abstraction limits/quotas, or allowing/permitting developments.
- **UNECE Water Convention:** Agreement between countries with shared wate and cooperative use.
- **Helsinki Treaty:** International (unenforceable) guidelines discussed in Finlan guidelines were pioneering in their transboundary nature.
- **Berlin Treaty:** 2004 replacement of the Helsinki Rules, to ensure no shortage resources occur, or that supply is not sabotaged.
- **Water Framework Directive:** European legislation signed in 2000 to improv surface water by 2015.

Key points

- The techno-fix uses technology such as dams, water transfers from wet to dr desalination of seawater in coastal areas to solve global water shortages. T additional benefits, including reducing flooding.
- There are negative impacts on both people and the environment resulting fr schemes because the extra use can reduce water availability in downstrean from the natural environment. People are displaced from their homes, and f are constructed.
- Water sustainability is about ensuring that everyone has access to affordab important in the light of rising demand through industrialisation, population with a backdrop of climate change.

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Key points (continued)

- There are many ways of conserving and recycling water – such as improving techniques – more smart irrigation rather than flood irrigation.
- Because there are so many different water users within a drainage basin, a also needs considering, water use must be sustainable. Large-scale plans mu cover the effects on the whole drainage basin. This is integrated drainage b implemented where water resources are shared between countries.
- Where water resources are shared, agreements between the different coun These can be formed using the principles of international guidelines, initially Helsinki, and later updated in Berlin in 2004. Such agreements consider all u countries and the environmental needs of the ecosystems within the drainage
- Other water agreements and directives in Europe include the UNECE Water Framework Directive.
- There are many different players involved in creating and implementing ea governments, planners, environmentalists and the companies that supply the farmers and businesses) also play a part through water conservation.

The techno-fix (technological fix)

- The **techno-fix** is a way of solving water shortages around the world.
- These fixes often require large-scale engineering projects and advanced te pipelines, and **desalination** plants.
- These are **hard engineering** projects – they are expensive to build, and ca environmental implications.
- They involve many players, including political players and national govern charities and NGOs, local residents, farmers and business owners, and also lobbyists.

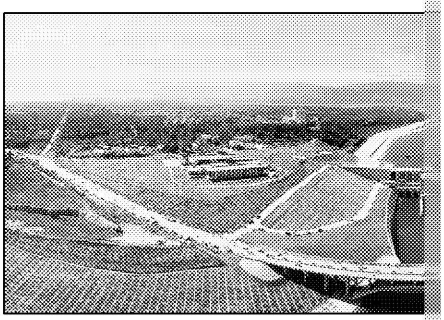
Water transfers (pros and cons)

- Transfer water from areas of surplus to areas of water deficit.
- Schemes can cost millions (and sometimes billions) to build. They have hu
- While they can be very successful in increasing supply, the social and envir very high.

E.g.

The world's largest transfer scheme is the Chinese South–No consists of three major water transfers to meet demand in th 44.8 billion m^3 of water will be transferred annually from the Y purpose-built canals, and also through existing rivers.

The project won't be completed for several decades to come. Economic costs of this project have been and will be very high (much higher than anticipated). Social issues include the relocation of over 300,000 people from their homes, and could allow the spread of schistosomiasis to the north.



Part of China's South–N

Environmental issues include changes to river flow, water quality and increased pollution. Issues could also occur in the receiving area, such as salinisation of the soil through increased irrigation.

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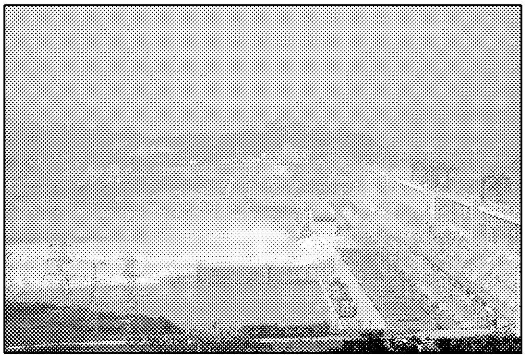
Megadams (pros and cons)

The term 'megadam' is difficult to define. There's no universal definition. Do we height, volume of material, the size of the lake, the amount of hydroelectric pow combination?



The Three Gorges Dam

The larger the dam, the fewer there dams than we used to. There are m the world.

You're probably familiar with dams Aswan (India) and the Hoover Dam the Hirakud Dam in India? The lake a volume of 5,896,000,000 m^3!

China has the most dams per count Gorges Dam, and is also building da through FDI.

Benefits of large dams include:

- water for irrigation (once the primary purpose)
- water for domestic and industrial use
- flood control
- hydroelectric power, often as a secondary function, reduces the amount of production

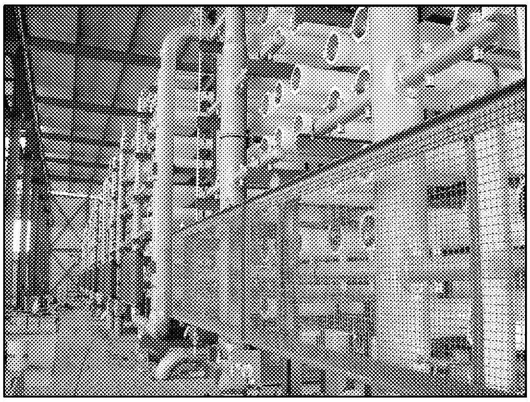
However, there are many social and environmental issues, such as:

- displacement of thousands of citizens, and agricultural land
- flooding of important cultural and archaeological sites (unless artefacts are
- flooding of valuable habitats, some with endangered or threatened species
- decrease in river flow and regime, water quality (dissolved oxygen), silt dep life such as fish migration can be stopped unless fish-passes are installed

Desalination (pros and cons)

Desalination is where the salt is removed from saline or **brackish** water. The earl by boiling the water to produce steam. This was highly energy-intensive and the fuels and generating CO_2). More modern plants use a process called reverse osm and uses less energy.

The Middle East is a major user of desalinated water because of the lack of surfa countries were also able to use their plentiful supply of oil as fuel.



A reverse osmosis plant

While there are many social and ec largely environmental. Concentrat the sea, disrupting ecosystems incl Gulf is an example – the outlet is re content could build up in the ocea

However, a cheap and efficient sup reduces overabstraction of aquifer increases the cost and environmen population is increasing.

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The value of sustainability

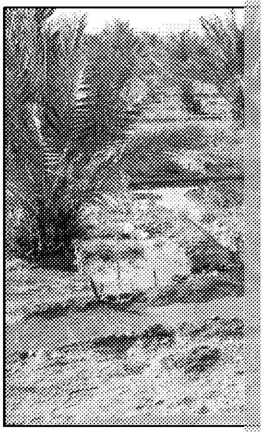
- Humans are using and diverting more and more water away from nature, m increasing.
- Use of fossil water, for example, is unsustainable – meaning that the resour
- Water use will continue to rise as population rises and countries industriali
- In order to allow a secure and affordable supply of clean water for future g be more **sustainable**.
- There are several ways to increase the sustainability, including:

Restoring supplies

Return catchments and rivers to their natural state – e.g. restoring wetlands and – increasing the natural storage in the system and creating natural land uses.

Conserving water

Globally, we waste a lot of water. There are many ways that water consumption can be decreased, including:



H

- Agriculture (the greatest use) – one of the worst forms of irrigation is flood irrigation where, as the name suggests, the land is flooded. Up to half of the water is wasted – it either runs away or evaporates. There are many ways that irrigation losses can be reduced – for example, **drip** or **smart irrigation**, and recycling of irrigation water. **Hydroponics** are another option, and mulching reduces evaporation from the soil surface.
- Recycling of water is possible on all scales, such as in gardens and by farmers, e.g. using **grey water**. Grey water can also be stored to flush toilets.
- Capturing rainwater and use of green roofs are practical ways to cut down on water in the garden.

E.g.

Singapore covers a tiny area at 721.5 km^2 and has a population of its own water resources, so has historically obtained its water from source its own water, so in addition to desalination, it's starting to recycles its own sewage, producing a third of its supply.

Reducing conflict through better management and

- As we saw in the last chapter, shared water resources can be a source of ten integrated drainage basin management are tools to help diffuse that tensio share of the water.

Integrated drainage basin management

- Back to the concept of sustainability.
- Relatively new concept, developed in the late twentieth century.
- Manages water resources in the whole drainage basin, including land use, t sufficient water without adversely affecting ecosystems.
- Manages the abstraction of groundwater and surface water supplies, includ recycling of water, which is monitored using sensors.
- Challenging when the drainage basins are very large and cross internationa manageable when the drainage basins are smaller.

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Water-sharing treaties

- Most countries that share water resources reach agreement without any form of armed conflict. Even countries at war for other reasons tend to adhere to agreements over water.
- Water-sharing agreements can be based on international guidelines, such as the **Helsinki Rules on the Uses of the Waters of International Rivers (1966)**, later succeeded by the **Berlin Rules on Water Resource (2004)**. Again, these focus on water supply to both people within each country and the environment, and where agreements are made, they factor in both natural and human characteristics within the catchment.
- **UNECE Water Convention** is another example, based in Europe with links t
- The EU also has its **Water Framework Directive**, aimed at improving the q the EU, based on pollution, oxygen and temperature, etc. In 2007, a worksh implementing legislation on hydropower which accounts for the effects on reduce the impact of the generation of a renewable electricity supply.

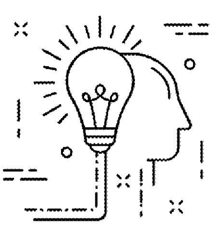
There are many different players within large catchments, spanning countries e water supply and land use.

The players include governments to set the guidelines, planners and environme methods and assess the environmental impact of the schemes, and the end use have the power to reduce their consumption. Water companies not only provid to help reduce demand, through leakage control, installing water meters to pro customers on how to conserve water.

E.g.

The Colorado River flows through the United States and into Mex abstraction quota of the river's water. Allocations of water were e River Compact of 1922 – but abstractions have been changed sin climate change. Population change is also increasing pressure on

If you only remember these three th



1. The techno-fix aims to solve global water shortag by large-scale engineering projects, including wa desalinating sea water. They can have major soc consequences.
2. We can reduce pressure on water resources by c – better irrigation practices and use of grey wat
3. There are various ways of reducing our impacts o environment through integrated drainage basin m water sharing treaties are signed between countr over shared resources.

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Activities

Consolidation questions

1. Give an advantage and disadvantage of increasing water supply through t

   ....

   ....

   ....

   ....

2. Why is the environmental effect of desalination smaller than in the past?

   ....

   ....

3. Give an example of how farmers could decrease their use of water.

   ....

   ....

4. Why does river basin planning need to occur on such a large scale?

   ....

   ....

5. Why do countries sign water-sharing treaties?

   ....

   ....

Take it further

Take a look at water recycling in Singapore:
zzed.uk/9992-singapore-water

Research 'Minute 319', which is an amendment to the Colorado River Compact o share resources in times of surplus and shortage. Here's a slightly older article fr anything changed since?
zzed.uk/9992-minute-319

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Student checks

Topic	What do I know?	No idea ☹	Nearly 😐	Sure ☺	
Managing a Sustainable Water Supply	The techno-fix				
	Water transfers				
	Megadams				
	Desalination				
	Restoring supplies and water conservation				
	Integrated drainage basin management				
	Water-sharing treaties				

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Exam Advice

Time management

If you open the paper and see a question you didn't expect: don't panic! Take a
follow the steps below. Whatever you do, don't just start writing down everythi

Before you rush headlong into the exam, take a moment to look at the question

Reading the whole paper

- Remember to take your time at the beginning, reading through all of the questions.
- You don't have to answer them in any particular order, but be aware that sometimes Edexcel order the questions for a reason, and earlier questions might help you answer later ones.

Reading th

- Too often stude and lose marks
- It might be use and command w what the questio

Planning

- After reading through the question, make sure you plan your answer.
- This stage is key to getting higher marks, so make sure you don't skip it. Planning can help you:
  - structure your answer
  - answer the question properly
  - save time
- You may do any rough work and planning in your exam paper, but make sure to ~~put a line through it~~ to indicate it is not to be marked.

- Remember to p spelling, gramm as content.
- You can use as need, but try to quantity when i be put off by h around you.
- Any mistakes yo don't use corre
- If you get stuck go on to anoth back to it at the
- Adopt a forma and concisely.
- Your introducti issue at hand, g information.
- The body of yo evidence for yo the points you For long-answe demonstrate yo recommendatio need to presen viewpoints.

Checking

- Leave some time after to go through your answers, correcting spelling, grammar and terminology errors and making sure you haven't left anything out.
- Finally, double-check that your candidate details are on any extra sheets you may have, and put them in the correct order with your answer book, using a treasury tag to attach them if you need to.
- Put a cross through any pages you don't want marked, e.g. planning pages.

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Geographical terms

One of the points you are being assessed on is the correct and appropriate use o geographical terms. You should have assembled a list of key terms that might b useful for this exam, so make sure you learn them and think about how you mig include them in your answers. If you are scared of forgetting these words when start writing your answers, you could try writing them all down as soon as you a permitted to start writing – remember to cross them out at the end though!

However, don't use geographical terms if they are unnecessary or you are unsu include them only when they are relevant and useful.

Getting the tone right

As well as using key geographical terms in your answers, your writing should st This helps your answers appear considered and professional.

Do ✓	Do
• Write out abbreviations in full the first time you use them. • Be clear when a statement is a personal opinion as opposed to fact. • Use linking words: thus, therefore, etc. • Try to include the source of a fact if you can, e.g. according to the WHO, the death toll from the tsunami was 1,200.	• Write in the first p • Use contractions • Use slang terms a language. • Use rhetorical qu

It might help to think of yourself talking to your examiner, or a geography teach don't know you, so you need to make sure you are clear, but they do know abo to explain every key term you use if it's not necessary.

Ask your teacher if you are unsure about your current 'tone', but don't worry ab are more focused on how you answer the question.

Spelling, punctuation, grammar and legibility

It can often be hard to think about these in the exam hall, but proper spelling, p and grammar really help keep your meaning clear. They also keep your senten getting too long, which aids with clarity and readability.

While examiners are used to reading all sorts of handwriting, it is good to try to answers as legible as possible. One way to do this is to slow down while writing letters are an appropriate size. The final read-through of your answers before fi any words which are especially tricky to read.

Quality over quantity: writing skills are only important in that they h meaning clear and communicate your geographical knowledge and u have a focused and clear answer than a waffled answer stuffed with c question.

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In the event of emergencies!

- All your planning and preparation means this isn't going to happen... But i the first rule is always to try to relax!
- Take a minute for some deep breaths, close your eyes and imagine a lush, g woodland... Clear your mind.
- Now read over the question, think over what you haven't said yet, and con

'Thinking like a geographer' and 'synopticity'

Learning to 'think like a geographer' is crucial for exam success and important f

As you are well aware, the world is a complicated place – cause and effect, and a pull information together, join up the dots, and work out why things happen in include space, place, environment and scale.

Don't be afraid to draw on your own knowledge and other modules to help illu creative, original and innovative, but use this skill wisely. Make sure you use tha question rather than going off on a tangent or writing down *everything* you kno called '*synopticity*'.

Here are a few tips on thinking like a geographer:

Consider the many aspects of the issue from many

- Think across the social/natural divide, using your knowledge of b geography.
- Involve many aspects of the issue: historical context, cultural pers
- SPEED can be a useful tool for thinking synoptically: social, politic environmental, and demographic. But don't forget to consider cu material factors when appropriate.
- Try to see the issue from many viewpoints: work on your empathy
- Don't be afraid to think outside the box!

Spatial concepts

- Geographical perspectives often focus on the importance of space, l issues at hand.
- Think about movements and flows of people, goods, ideas, etc.
- Think about the effects of 'scale': local, regional, global.

Be creative

As long as your approach is logical and well justified, you can think in

Exam preparation

My take-home tips:

✓ Before the exam (Eat a good BREAKFAST)
✓ During the exam (Read the question CAREFULLY)
✓ Planning (HIGHLIGHT key words and concepts)
✓ After the exam (Take some time to RELAX!!!)

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Answers to Consolidation

What is the Hydrological Cycle, and Why is It Importan

1. Closed.
2. Energy from the Sun, and gravitational potential energy.
3. 68.7%
4. Water vapour.
5. Any two – such as ocean, atmospheric, ice sheets, lakes, groundwater and
6. Rivers.
7. Shortest = atmosphere; longest = oceans.
8. Formed under different climate conditions than today – being used faster

The Drainage Basin as an Open System

1. Any two from: convection, relief (orographic) and fronts (warm and cold).
2. Intercepted by trees – either evaporated back into the air, or absorbed by
3. Groundwater is through rock, throughflow is through soil.
4. Intense precipitation can't infiltrate into the soil fast enough, or the soil is lot of water. No more water can infiltrate, or the rate is very low.
5. Run-off (channel flow), evaporation and transpiration (evapotranspiration)
6. It depends – some are small-scale, others are hundreds to thousands of sq
7. Soil = infiltration; rock = percolation.
8. Determines the amount, type and seasonality of precipitation, and the veg
9. Any two suitable answers, such as land-use change / urbanisation, change deforestation and afforestation.
10. Creation of reservoirs (changes to river flow, dampens the effect of precipi and alters water availability), abstraction of groundwater (reduces water ta rivers, saline intrusion in coastal areas).

Influences on the Hydrological Cycle at the Local Scale

1. $P = Q + E \pm \Delta S$.
2. During the summer.
3. Deserts.
4. The annual pattern of flow of a river at a gauging station.
5. Any two suitable suggestions, such as weather patterns such as rainfall, me groundwater recharge.
6. The response to how a river flow is temporarily changed by a precipitation
7. The duration between peak precipitation and peak discharge.
8. Reduced interception increases the overland flow, meaning that the water
9. Increased run-off / less interception and evapotranspiration, etc.
10. Decrease.

The Causes and Effects of Drought

1. The definition varies from place to place – such as the duration the decrea
2. Meteorological = reduction in precipitation; hydrological = reduction of w cycle.
3. In the Pacific Ocean, around the equator.
4. They affect where air rises (and forms rain) and cold air sinks (causing drou
5. Abstracting surface and ground supplies, changing land use, and deforest anthropogenic climate change is likely to have greater effect.
6. Allow any suitable suggestion, such as the Sahel, Australia, California.
7. Respiration of the carbon stored in peat, peat fires.
8. Direct tree die-off, increased susceptibility to pests and diseases, and incre

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The Causes and Effects of Floods

1. Heavy/intense rainfall / antecedent conditions result in both infiltration ex flow.
2. Regions in Asia (including India and Bangladesh) and Africa.
3. Sealing of the ground with impermeable surfaces, very rapid run-off from r drains.
4. Development of hard engineering features that increase the flood risk dow
5. They are indirect effects, and social effects are often difficult to assign mon

Climate Change – Changes and Effects to the Hydrolog

1. No – some areas will become wetter and others drier – however, there will
2. Less ice, in some areas less groundwater and soil water, and surface water. store more water vapour as it warms. Also, the ocean store will increase.
3. Possibly extreme El Niño years will become more frequent.
4. We may not be certain whether the changes are solely down to climate ch associated with El Niño years.
5. Uncertainty in the overall rainfall level, its variability, and future demand fo

Physical and Human Causes of Water Insecurity

1. Climate (determines rainfall and aquifer recharge).
2. The amount of water available per person per year – 700 m^3 less for water s
3. Depletes surface and ground stores and flows, capable of damaging the en
4. Diminish supply through pollution of surface and ground supplies – throu water may still be there, but it's too polluted to use or would cost too muc
5. Better living standards – more water use per person (water is available on t import of consumer goods, increased food consumption (irrigation water)

The Problems of Water Insecurity

1. Developing and emerging countries, allow specific examples from South A
2. Rural areas.
3. HEP and electrical generation, extraction of some fuels such as gas and oil.
4. Essential to stop the spread of diseases and diarrhoea.
5. There are areas where water is very scarce, and water resources are shared While unlikely to be the single cause, water could be one factor among ma as a weapon.

Managing a Sustainable Water Supply

1. Any suitable advantage, e.g. increased water security and other benefits su Disadvantages could include social (people forced to move) and environm disease, removal of water from natural ecosystems).
2. Advances in technology – reverse osmosis requires far less energy than re water.
3. Reduction of flood irrigation – replace with smart irrigation, use of hydrop use of grey water.
4. There are many users of water, all affect the wider drainage basin. Widespr occur for both humans and the environment.
5. To reduce the potential for conflict by allocating each country their fair sha considering the needs of the environment.

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