Geography A 'Level Summer Transition Work

You have two separate COMPULSORY tasks to complete for September; these are on the first two pages and include one for physical geography and one for human. The final pages include a range of different things for you to work on from reading to documentaries along with tasks. This work is advisable so that you are as ready as possible to start you're A 'Level learning in September.

PHYSICAL GEOGRAPHY:

In Physical Geography you will begin with the topic '**Water and Carbon Cycles**.

You need to complete the reading on the attached PDF (named 'The Water Cycle') and complete the questions below:

1. Using figure 1.5 describe the distribution of the water on planet Earth.
2. Describe the difference between terrestrial, atmospheric and cryospheric water.
3. What has happened to ocean pH in the last 250 years? Why has this happened?
4. Re-create the diagram on figure 1.6 – add more detail about the nature and location of the different cryospheric stores of water.
5. What is the difference between an ice sheet and an ice shelf?
6. How much are sea levels predicted to rise if both the Greenland and Antarctic ice sheets melt?
7. What is permafrost and how does it store water?
8. What are the characteristics of a wetland?
9. What is groundwater?
10. Why is groundwater decreasing globally? What impacts is this likely to have?
11. What is the difference between 'soil water' and 'biological water'?
12. Why is atmospheric water important for global climate?

Read the two articles (saved on the website):

- Bangladesh article
- Glasgow article

Both about how climate change is affecting the water cycle and the impacts that this is having on two contrasting places.

Based on your reading and own understanding, answer the following question:

Using examples, to what extent do human and physical factors affect the impacts of climate change.

It is recommended that you write approximately 500-1000 words.

Please have this work ready to hand to your Physical Geography teacher (Mrs Winterburn) during your first lesson in September.

HUMAN GEOGRAPHY:

In Human Geography you will begin with the topic **'Contemporary Urban Environments'.**

The first section of the specification states for you to cover:

Urbanisation and its importance in global affairs

To provide an introduction to this you should complete all of the reading, following the links below. You may want to do some extra research and reading on this topic.

They cover the themes of rapid urbanisation and the 21st century challenges that the process creates:

Growing Pains, Mark Rowe – attached as PDF

https://21stcenturychallenges.org/urbanisation-2/

https://geographical.co.uk/culture/rapid-population-growth

https://www.theguardian.com/cities/2018/mar/21/people-pouring-dhaka-bursting-sewers-overpopulation-bangladesh

https://www.theguardian.com/cities/2018/mar/19/urban-explosion-kinshasa-el-alto-growth-mexico-city-bangalore-lagos

https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

https://www.theguardian.com/global-development/2014/jul/10/urban-population-growth-africa-asia-united-nations

Once complete, please use the information and write an answer to the following question:

What is urbanisation? Why is it an important global issue?

It is recommended that you write approximately 500-1000 words.

Please have this work ready to hand to your Human Geography teacher (Miss Ship) during your first lesson in September.

Bridging the GCSE to A Level Geography Gap

The following tasks will help you be ready to study you're A 'Level in September:

Hoping to study Geography at A level? Or interested in just furthering your knowledge of Geography post the GCSEs?

There are a number of things you can do:

1. **Developing as a geographer** – through general reading around/ watching videos/listening to podcasts etc the geography subject to develop your geography knowledge and understanding.
2. **Become a News Buff-** Watch the news- BBC news between 6am-9am or at 6pm. Or get on the BBC news app? Other websites such as the Guardian, The Independent, The Times. Create a Geography in the News Diary of all things that are relevant to what you are studying?
3. **Preparing for the A Level Course-** Starting to explore the topics and their foundations in which they will be studied in the A Level Course.

To be a great geographer, you will need to develop the ability to think synoptically, being able to see the greater overview and how everything we study in Geography links together. Geography is not just about the studying people and landscapes, it is also the relationships that exist between people and their environment.

How can I develop as a Geographer before September?

Below are some links to podcasts, websites, books and even films which provide a great way of staying inspired and engaging with Geography:

PODCASTS:

- **Costing the Earth**- There are some great podcasts here to pick from on a wide variety of geographical issues. https://www.bbc.co.uk/programmes/b006r4wn/episodes/player (many topics including climate change, carbon, urban greening, deforestation, alternative powers, plastics (etc)
- **Royal Geographical Society – 'Ask the Geographer podcasts'**
- https://www.rgs.org/schools/teaching-resources/ask-the-expert-podcasts/ = a fantastic set of podcasts to keep A Level studies up to date with the latest geographical research = pick out some that interest you.
- **Links to general podcasts**
- https://eternalexploration.wordpress.com/2016/01/04/top-10-podcasts-for-geography-students/ - this has a number of different links to geography podcast, specifically targeted to Geography students. Definitely recommend the TED talks.

BOOKS:

If you are into reading both fiction and non-fictions, why not try some Geographically themed books/magazines:

- **Prisoners of Geography** by **Tim Marshall** – an insightful book which helps understanding how the physical geography impacts on political reality and really helps to understand how decisions of world leaders have been shaped by geography- a good introduction to Geopolitics
- **Geography Review Magazines**: Subscribe for £40 and you will get 4 up to date magazines with articles that will be really relevant to the topics that you are studying.
- **Six Degrees** by Mark Lynas – a scary walkthrough of the impacts of Climate Change as world temperatures increase by 1 degree through to 6 degrees.
- **Divided** by **Tim Marshall** – his follow-up to Prisoners of Geography – a great book which explains how & why the world is becoming more divided and how countries are putting up barriers. Very relevant to events in Europe (Brexit), the US (Trump) and the Coronavirus situation.

Geographical Documentaries:

There are some great geographical documentaries which will help develop your general geographical knowledge and understanding and help you see what an amazing world we live in.

The following are all available on IPLAYER:

- **David Attenborough Box Sets-** there are 9 amazing boxsets available on iplayer from David Attenborough exploring our amazing world. https://www.bbc.co.uk/iplayer/group/p06m42d9
- **The Americas with Simon Reeve** https://www.bbc.co.uk/iplayer/episodes/m00095p0/the-americas-with-simon-reeve The first episode in Alaska/Canada is particularly good for Resource Security looking at energy.
- **Simon Reeve around the World** https://www.bbc.co.uk/iplayer/group/p06rrnkm The Russia series is really interesting.
- **Britain Underwater:** Fighting the floods https://www.itv.com/hub/britain-underwater-fighting-the-floods/7a0157
- **Joanna Lumley's Hidden Caribbean: Havana to Haiti** https://www.itv.com/hub/joanna-lumleys-hidden-caribbean-havana-to-haiti/2a7578
- **Race across the World →** https://www.bbc.co.uk/iplayer/episode/m000g6nt/race-across-the-world-series-2-episode-1
- **Andrew Marrs Megacities →** https://www.bbc.co.uk/programmes/b011qmcl/episodes/guide
- **Trumps War on the Border →** https://www.channel4.com/programmes/trumps-war-on-the-border
- **Dispatches →** https://www.channel4.com/programmes/dispatches/on-demand/67256-001
- **Earth from Space – episode 4 The Changing Planet (BBC iPlayer) →** https://www.bbc.co.uk/iplayer/episode/p072n8m0/earth-from-space-series-1-4-changing-planet

Geography on NETFLIX, DVD or YOUTUBE:

- **Before the Flood-** A film presented by Leonardo DiCaprio- exploring climate change and looking at what needs to be done today to prevent catastrophic disruption
- **Our Planet Netflix Series**- Explores how climate change impacts all living creatures
- **Blood Diamond** – looks at the diamond trade in Sierre Leone
- **An Inconvenient Truth** – follows Al Gore on the lecture circuit as he seeks to raise awareness about Climate Change.
- **+ An Inconvenient Sequel**

What should I do with the News that I am watching?

You should be regularly watching the news to keep you up to date with what is happening in relations to the inter-relationship between people and the environment. You will be really surprised how many of the news bulletins relate to what you are studying.

- **BBC NEWS:** https://www.bbc.co.uk/news- an excellent source of up to date articles- explore the headings such as Science, UK, WORLD and other stores
- **THE GUARDIAN:** https://www.theguardian.com/uk - Again many useful articles and logically ordered – keep an eye on the Environment, Science, Society, Global Development Stories in particular.
- **THE CONVERSATION:** https://theconversation.com/uk - Really useful to support many of you're a Levels. Up to date articles from academics and specialists in the field written in a way that is accessible to all, summarising the key points in a short but insightful articles.

Buy yourself a Scrapbook and either cut out the headline from a newspaper/print it off/ or just write it in your book and summarise the following:

- What are the key things that the article is telling you about- can you summarise in to 10 main points
- What part of Geography/what we study does this link to?
- Are there any keywords that you need to look into more or you feel would be useful for your studies.

Bring this with you for your first lesson in the September.

What does the A Level Course look like?

At A Level, we follow the AQA specification. You will have two exams; one physical exam and one human exam, and one Non-Examined Assessment- essentially a 3000-4000 word piece of coursework.

Physical Exam	Human Exam	NEA
This exam will be 2 hours and 30 minutes and is worth 120 marks	This exam will be 2 hours and 30 minutes and is worth 120 marks	This is an independent enquiry meaning that it is driven by you. You will be given a NEA mentor to support you but we will not be able to mark formally and give this back to you. It will be mentor meeting driven.
Water and Carbon (36 marks)	Global Governance (36 marks)	You will need to formulate a title and hypotheses from a topic that is studied on the AQA specification. You will then need to come up with methods to test your hypotheses, you will collect your own data and then present, analyse, conclude and evaluate your investigation.
Glacial systems and landscapes (36 marks)	Changing Places (36 marks)	
Hazards (48 marks)	Contemporary Urban Environments (48 marks)	You will be taken out on 3 days fieldwork work to prep you for this.

A-Level Course Pre Reading:

Water and Carbon:

- **Physics and Maths Tutor- Water and Carbon Revision** – A really good overview of what the course is about and some of the information you will learn next year.
- **Physics and Maths Tutor-** https://www.physicsandmathstutor.com/geography-revision/a-level-aqa/water-and-carbon-cycles/ - some good links to other reading for the subject.
- **An introduction in to the Water Cycle**
- **An introduction in to the Carbon Cycle**
- **An introduction into the Carbon Cycle** - a good geofile which introduces you to the carbon cycle.
- **Water and Carbon Overview** – a piece of work from the Royal Geographical Society that summarises the course
- **Documentary on Climate change:**
  - https://www.bbc.co.uk/iplayer/episode/m0009drg/panorama-climate-change-what-can-we-do
  - https://www.bbc.co.uk/iplayer/episode/m00049b1/climate-change-the-facts
- **News Articles on Climate Change**

Hazards:

- **Physics and Maths Tutor- Hazards Revision** – A really good overview of what the course is about and some of the information you will learn next year.
- **Physics and Maths Tutor-** https://www.physicsandmathstutor.com/geography-revision/a-level-aqa/hazards/ some good links to other reading for the subject.
- **Reading on Vulnerability and Hazards** – something that is different with the A Level is you need to be more aware of why people are vulnerable to Natural Hazards
- **Geofile on Hazard Hotspots and Response** – a A Level concept new to you on different ways to respond to Hazards
- **Haiti- A multi-hazard Environment**
- **Video:** Power of the Planet (Volcanoes) https://www.dailymotion.com/video/x5af4kg - a great introduction to the work on volcanoes we will be doing
- **Reading: Plate Tectonics (The Geological Society)** – This will be a good set up from your GCSE work to A Level and definitely worth navigating around the site https://www.geolsoc.org.uk/Plate-Tectonics

Glacial Systems and Landscapes

- **BBC GCSE Bitesize "Glacial Landscapes in the UK" -** https://www.bbc.co.uk/bitesize/topics/ztsx2p3
- **BBC GCSE Bitesize "Cold Environments" -** https://www.bbc.co.uk/bitesize/guides/zp37hv4/revision/1
- **Periglacial Processes and Landforms -** http://www.physicalgeography.net/fundamentals/10ag.html

- **Glacial and periglacial systems and environments -** http://thebritishgeographer.weebly.com/the-physical-characteristics-of-extreme-environments.html
- **Text book -** https://global.oup.com/education/product/9780198366515/?region=uk
- **Arctic Sea Ice Decline articles -** https://www.theguardian.com/world/2019/dec/10/arctic-sea-ice-cover-falls-to-alarming-low-as-temperatures-rise
  https://www.climate.gov/news-features/understanding-climate/climate-change-minimum-arctic-sea-ice-extent
- **Impact of Climate Change on the Arctic and Arctic Amplification articles -**
  https://arcticwwf.org/work/climate/
  https://nsidc.org/cryosphere/arctic-meteorology/climate_change.html
  https://en.wikipedia.org/wiki/Climate_change_in_the_Arctic

Global Governance

- **Physics and Maths Tutor- Global Governance** – A really good overview of what the course is about and some of the information you will learn next year.
- **Physics and Maths Tutor-** https://www.physicsandmathstutor.com/geography-revision/a-level-aqa/global-systems-and-governance/ some good links to other reading for the subject.
- **A RGS summary of Global Governance** – A good overview of the course
- **Antarctica Case Study**
- **The Effects of Globalisation on the movement of people**
- Really interesting **Antarctica Websites**: https://www.coolantarctica.com/index.php AND https://discoveringantarctica.org.uk/
- Tracking the **Coronavirus Pandemic**: https://www.worldometers.info/coronavirus/ and https://ourworldindata.org/ and https://www.who.int/
- Governing Climate Change – World Agreements: https://www.ipcc.ch/ and https://unfccc.int/

Changing Places

- **Physics and Maths Tutor- Changing Places** – A really good overview of what the course is about and some of the information you will learn next year.
- **Physics and Maths Tutor-** https://www.physicsandmathstutor.com/geography-revision/a-level-aqa/resource-security/ some good links to other reading for the subject.
- **A RGS summary of Changing Places** – A good overview of the course
- **Geofile on the Occupy Movement**
- **Interesting article by Doreen Massey**- A human geography looking at The Sense of Place
- **Changing Spaces –Making Places** = A good powerpoint going through some of the content of the topic.

Contemporary Urban Environments

- **The RGS. 21st Century Challenges** - https://21stcenturychallenges.org/urbanisation-2/
- **Growing Pains by Mark Rowe,** a really good insight into some of the issues that many cities are facing **-** http://geographical.co.uk/places/cities/item/1170-growing-pains
- **Megacities use mega-resources** - http://geographical.co.uk/places/cities/item/1004-megacities-use-megaresources
- **Dire Dhaka** – a real-life place example of some of the problems cities face - http://geographical.co.uk/places/cities/item/1171-dire-dhaka
- **The 100 million city**: is 21st century urbanisation out of control? https://www.theguardian.com/cities/2018/mar/19/urban-explosion-kinshasa-el-alto-growth-mexico-city-bangalore-lagos
- **7.7 Billion and counting by Chris Packham**, focuses on some of the problems cities are facing today due to increasing population growth - https://www.bbc.co.uk/programmes/m000dl6q
- **Sign up to/follow Guardian Cities on twitter -** https://www.theguardian.com/cities

Complete three of the tasks from the grid below based on the reading you have done.

Create a personal geography map of your own area- include photographs, personal reflections and places of importance (Changing Places)	Watch one documentary on Climate Change- Create 20 questions that people could answer if they were to watch the documentary. (Water and Carbon)	Read the Antarctica Case Study. Write a letter to the prime minister explaining three threats faced by Antarctica- which do you think is the most important one? (Global Governance)
Read 'Changing Cities'- produce a case study summary on one of the cities. (Changing Places)	In 300 words, explain what 'geography' means to you Give three ways in which the World Health Organisation (WHO) are helping to control the spread of Coronavirus	Produce a mind map of the multi-hazard area of Haiti (Hazards)

INEQUITY AT THE BOILING POINT

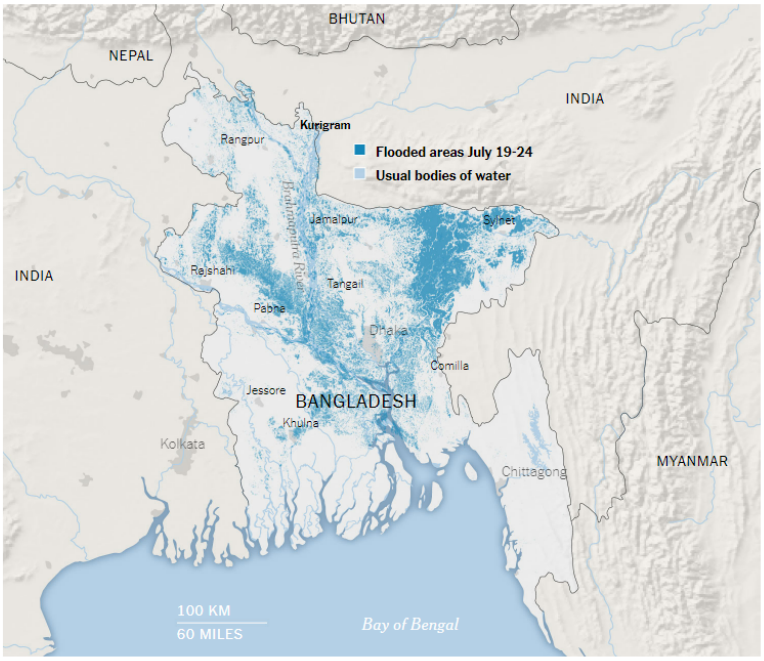
A Quarter of Bangladesh Is Flooded. Millions Have Lost Everything.

The country's latest calamity illustrates a striking inequity of our time: The people least responsible for climate change are among those most hurt by its consequences.

By Somini Sengupta and Julfikar Ali Manik
Published July 30, 2020Updated May 19, 2021

Torrential rains have submerged at least a quarter of Bangladesh, washing away the few things that count as assets for some of the world's poorest people — their goats and chickens, houses of mud and tin, sacks of rice stored for the lean season.

It is the latest calamity to strike the delta nation of 165 million people. Only two months ago, a cyclone pummeled the country's southwest. Along the coast, a rising sea has swallowed entire villages. And while it's too soon to ascertain what role climate change has played in these latest floods, Bangladesh is already witnessing a pattern of more severe and more frequent river flooding than in the past along the mighty Brahmaputra River, scientists say, and that is projected to worsen in the years ahead as climate change intensifies the rains.



By Blacki Migliozzi - Source: Institute of Water and Flood Management, Bangladesh University of Engineering and Technology

"The suffering will go up," said Sajedul Hasan, the humanitarian director of BRAC, an international development organization based in Bangladesh that is distributing food, cash and liquid soap to displaced people.

This is one of the most striking inequities of the modern era. Those who are least responsible for polluting Earth's atmosphere are among those most hurt by its consequences. The average American is responsible for 33 times more planet-warming carbon dioxide than the average Bangladeshi.

This chasm has bedeviled diplomacy for a generation, and it is once again in stark relief as the coronavirus pandemic upends the global economy and threatens to push the world's most vulnerable people deeper into ruin.

An estimated 24 to 37 percent of the country's landmass is submerged, according to government estimates and satellite data By Tuesday, according to the most recent figures available, nearly a million homes were inundated and 4.7 million people were affected. At least 54 have died, most of them children.

The current floods, which are a result of intense rains upstream on the Brahmaputra, could last through the middle of August. Until then, Taijul Islam, a 30-year-old sharecropper whose house has washed away, will have to camp out in a makeshift bamboo shelter on slightly higher ground. At least he was able to salvage the tin sheet that was once the roof of his house. Without it, he said, his extended family of nine would be exposed to the elements.
Mr. Islam's predicament is multiplied by the millions among those on the front lines of climate change. Vanuatu is literally sinking into the Pacific. Pastoralists in the Horn of Africa are being pushed to the edge of survival by back-to-back droughts. In the megacity of Mumbai, the rains come in terrifying cloudbursts.

The inequity is striking, no matter which way you slice it. One recent analysis found that the world's richest 10 percent are responsible for up to 40 percent of global environmental damage, including climate change, while the poorest 10 percent account for less than 5 percent. Another estimated that warming had reduced incomes in the world's poorest countries by between 17 percent and 30 percent.

Poor countries have long sought a kind of reparations for what they call loss and damage from climate change. Rich countries, led by the United States and European Union, have resisted, mainly out of concern that they could be saddled with liability claims for climate damage.

It doesn't help that the rich world has failed to deliver on a $100 billion aid package to help poor countries cope, promised as part of the 2015 Paris accord.

Coronavirus recovery plans have lately begun to open the door to new discussions about debt relief linked to climate resilience.

In June, the Alliance of Small Island Developing States, led by Belize, pressed for what it called a new compact with private and bilateral creditors "to deliver debt relief and increase resilience financing."

Caribbean countries, with their economies ravaged by hurricanes in recent years, now find themselves falling deeper into debt as the pandemic dries up tourism revenues. A study commissioned by the United Nations found that the 20 most climate-vulnerable countries have paid more than $40 billion in additional interest payments because of losses stemming from extreme weather events.

In Bangladesh, the flooding of the Brahmaputra reflects the unequal pain of extreme weather.

The floods began in June. In most cases, heavy rains upstream in neighboring India swelled the river basins that flow through Bangladesh before draining into the Bay of Bengal. Those who live along the Brahmaputra are no strangers to flooding. When the river swells, work stops, land erodes, people move to higher ground and wait for the waters to recede. They rely on their savings or aid to feed themselves.

This year was different, though. By the time the river flooded, in June, people were already running out of food, said Mr. Hasan of BRAC.

Because of the lockdown, working people had all but stopped working. Remittances from relatives abroad, many of them newly unemployed, had dried up. In the countryside, people had begun to sell their goats and cattle at bargain prices. They had no food to eat.

When the river first swelled, Taijul Islam, the sharecropper from the Kurigram district in the country's north, rushed to save his livestock — cattle, goats, chickens, ducks. A few, he rescued. Many, he lost. The river took away the small vegetable garden next to his house, then his house, where he had stashed roughly 1,300 pounds of rice. Then it washed away a small shop that he ran when he wasn't working on other people's land. Also the school that his 6-year-old son attended in the village.

All he can think of now is where he can go to earn a living. He is the sole breadwinner of his extended family. All nine of them had been living on rice, boiled potato and lentils. Vegetables are unaffordable, let alone fish or meat, which, he said, "are now unimaginable."

Akkas Ali, 48, had already been through a bad flood. He moved to Mr. Islam's village six years ago, when his old village washed into the Brahmaputra. Two weeks ago, as the river rose, breaking through its embankments, his four acres of farmland went underwater. The village mosque and market washed away. So, too, a secondary school where more than 250 children were enrolled. Mr. Ali worried where they would go to school now, if at all.

His house still stood this week, but the river, which had been a quarter mile away, had rushed dangerously close. He was sure it, too, would wash away soon.

The Brahmaputra is a fearsome, shape-shifting 2,400-mile river that erupts from the Tibetan Himalayas and spills into northeastern India before merging with the Ganges in Bangladesh and emptying into the Bay of Bengal. It irrigates vast areas of farmland but it's also unpredictable, often swallowing the islands that form within it, like the one where Mr. Ali's village once stood.

Climate change, too, is altering its fate — and that of the people who live along its banks. The rains are more unpredictable and the river is rising above dangerous levels far more frequently than it did before, according to 35 years of flooding data analyzed by A.K.M. Saiful Islam, a water management expert at the Bangladesh University of Engineering and Technology in Dhaka.

The last five years alone have brought four major floods, eroding people's capacity to adapt, Dr. Islam said.

More and worse floods loom.

Even if average global temperature increase modestly — by 2 degrees Celsius over the average for preindustrial times — flooding along the Brahmaputra in Bangladesh is projected to increase by 24 percent. With an increase of 4 degrees Celsius, flooding is projected to increase by over 60 percent.
No matter what, Dr. Islam said, the country will have to adapt. That requires money to dredge rivers, maintain embankments, improve drainage and offer aid to those who are repeatedly displaced and impoverished.

Advocates for the poor say Bangladesh's predicament with disasters illustrates exactly why climate negotiations, postponed until 2021, need to deliver compensation for people who have not caused the problem.

"People are losing whatever little they have," said Farah Kabir, the Bangladesh country director for ActionAid International. "When and how are they going to be supported? When is the global community going to take responsibility?"

Billions needed to protect Glasgow from climate effects, report says

Exclusive – Study says 2m in Clyde area – due to host Cop26 – face severe disruption without urgent investment

Nearly 2 million people living in the greater Glasgow area face severe disruption from climate heating unless billions of pounds are invested in protecting homes, businesses and transport links, a report says.

A study on the impacts of climate change on the Clyde area estimates about 140,000 of its poorest residents will be the worst affected by increased heatwaves, flash floods and droughts, as they are the least equipped to cope.

The report from Climate Ready Clyde, a coalition of 15 councils, universities, the NHS and infrastructure bodies, has been published as Glasgow prepares to host the Cop26 global climate talks in November.

It estimates there is already a funding shortfall of at least £184m a year to begin retrofitting homes and offices for heatwaves, defending roads and rail links against flooding and storms, and planting 18m trees to absorb higher temperatures and rainfall over coming decades.

"Urgent mobilisation of additional finance is crucial," the report says, adding that failing to do so will cost the region billions in lost income and emergency spending.

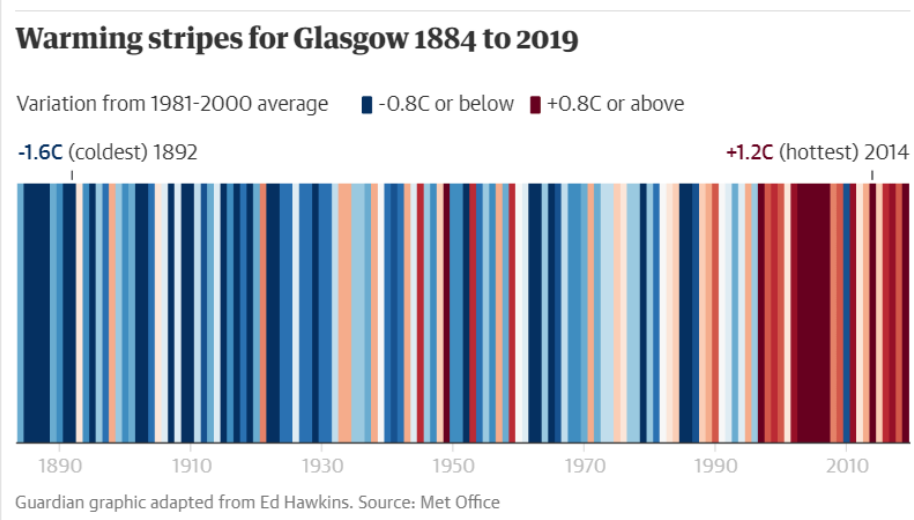
James Curran, the coalition's chair and a former chief executive of the Scottish Environment Protection Agency, said a "transformational approach" was needed. Playing host to Cop26 added to the sense of urgency in the region.

"Climate change exacerbates existing inequalities and if we don't respond in a coherent and urgent way then the inequalities that already exist in society will be worsened," he said.

"Some of the people who can least afford it and are least culpable in creating climate change are the ones that are going to suffer more with poor housing; they will be suffering damp in the winter; they'll be suffering excessive heat in the summer; public transport will be disrupted."

The region, which has a population of 1.8 million across an area of 1,292 sq miles (3,346 sq km) straddling the River Clyde, including towns such as Hamilton, Paisley, Lanark and Dumbarton, is already one of the UK's wettest city regions.

Met Office climate forecasts estimate that without radical action to halt global carbon emissions, Glasgow's maximum summer temperatures will rise by at least 1.1C by 2030 and by 2.6C by 2080.



By 2050 there is a 50% chance that every year Glasgow will experience summers as hot as the record reached in June 2018, when the city baked in temperatures of nearly 32C, buckling rail lines and melting material in the roof of the Glasgow Science Centre.

Average rainfall in summers will fall by about 5% under the conservative scenario, but the area will experience flash floods. Winter rainfall will increase by at least 5%, with a far greater rate of intense storms.

Glasgow is expected to experience warmer, wetter winters and drier, hotter summers

Average change compared to 1981-2000 base	2030	2050	2080
Summer air temperature, C	+0.9 to +1.8	+1.4 to +3.2	+2.5 to +4.3
Summer maximum air temperature, C	+1.1 to +2.2	+1.6 to +3.8	+2.6 to +6.9
Winter air temperature, C	+0.8 to +1.9	+1.2 to +2.8	+1.8 to +4.8
Winter maximum air temperature, C	+0.8 to +1.9	+1.1 to +2.9	+1.8 to +5.0
Annual mean air temperature, C	+0.9 to +1.6	+1.2 to +2.0	+2.0 to +4.8
Summer precipitation daily change, %	-5 to -21	-12 to -27	-14 to -40
Winter precipitation daily change, %	+5 to +15	+6 to +20	+10 to +23
Sea level change, cm	+7 to +12	+13 to +25	+25 to +55

Source: Met Office

Those figures assume the world limits climate heating to 2.9C above pre-industrial levels by 2080. In a worst-case scenario where they rise by 4.6C by 2080, the city's peak summer air temperatures could rise by 7C.

The report, the Glasgow city region adaptation strategy and action plan, says those general changes and an increase in extreme weather events mean up to 100,000 homes and 18,700 businesses in the region would be put at risk of flooding by 2080.

Viewed by climate policy experts as one of the most significant to emerge in the UK, the report identifies 11 priority issues, including some where there is already inadequate investment and planning. They include:

- An early warning system of public climate alerts covering many more hazards, including surface flooding, heatwaves, droughts, wildfires and landslips.

- Setting aside vacant land to use as flood plains, and blocking new developments on flood-prone areas.
- Paying to adapt people's homes and workplaces to cope with heatwaves, flooding and subsidence, particularly for residents in the poorest areas and in high-density housing.
- Investing in habitat restoration, tree-planting and wetlands to strengthen natural protection against flooding and heatwaves.
- A significant increase in spending to protect roads, rail lines and bridges from flooding, erosion and landslips.
- Ensuring social justice is embedded in the region's climate strategies, so the poorest and most vulnerable are helped the most.

Chris Stark, the chief executive of the Climate Change Committee, which advises the UK's governments on climate strategy, said the Clyde plan should be replicated by other city regions.

"It's a meaningful and pleasant plan. You can imagine what a well-adapted city ready for climate change would look like. And it would be a profoundly positive thing for the region and all the people living in it," Stark said.

There are criticisms that it avoids challenging the region's heavy reliance on motorways and private car use, and does not propose far greater investment in public transport. CRC argues their new report focuses on adapting to the impacts of climate heating rather than transport systems.

Dr Richard Dixon, the chief executive of Friends of the Earth Scotland, said failing to tackle car use was a "missing piece" in the strategy. But he added: "Agreeing such an ambitious plan with a wide range of bodies can have been no mean feat. It is particularly important for concentrating minds of decision-makers that there is a clear and specific price tag put on the necessary work."

Growing pains

- Written by Mark Rowe

Population levels are rising and nowhere is this felt more keenly than in the world's megacities – urban sprawls that each house over ten million people. But such growth brings with it a host of problems

Humans, it seems, are increasingly becoming urban creatures. Barely 60 years ago, only two cities – Tokyo and New York – had the ten million plus inhabitants required to fit the UN's definition of a megacity.

Even by 1970, just 39 million people lived in megacities. By 1990, the number of megacities had risen to ten, collectively home to more than 153 million people or slightly less than seven per cent of the global urban population at that time.

As of 2014, the Earth has 28 megacities worldwide – 16 in Asia, four in Latin America, three each in Africa and Europe, and two in North America. They are home to 453 million people, about 12 per cent of the world's urban dwellers. Shenzhen, described by the Asian Development Bank (ADB) as 'a small village in the mid-1980s', is now home to more than ten million people.

And the forecasters say that this momentum is far from slowing. According to the UN, by 2025 there will be 37 megacities – with all but one of the new ones in Asia – home to 630 million people, 13.6 per cent of the world's projected urban population. By 2030, the total will have reached 41.

URBAN EXPANSION

The extraordinary compaction of humanity into megacities is having profound repercussions for the world's resources. Megacities, according to the UN Population Division of the Department of Economic and Social Affairs (DESA), 'are where the pressures of migration, globalization, economic development, social inequality, environmental pollution and climate change are most directly felt'.

The phenomenon of megacities is increasingly concentrated in the global south, a reversal of how things unfolded during the late 20th century. Tokyo remains the world's largest city, with over 38 million inhabitants, but it's now followed by Delhi (25 million), Shanghai (23 million), and then Mexico City, Mumbai and São Paulo, each of which have around 21 million inhabitants. Osaka has just over 20 million, as does Beijing. The New York–Newark area and Cairo complete the top ten most populous urban areas with around 18.5 million inhabitants each.

Yet by 2030, New York–Newark will have been pushed down to 14th on the list. Four more Indian cities – Chennai, Hyderabad, Bangalore and Ahmadabad – are projected to become megacities by that time. Meanwhile, Africa's three megacities – Cairo, Kinshasa and Lagos – are expected to be joined by Dar es Salaam, Johannesburg and Luanda, while in Latin America, Bogota and Lima appear on schedule to join this increasingly less-exclusive-by-the-decade club.

By 2025, Delhi's population is expected to rise swiftly to 36 million people, while China, which already has six megacities, will have three more, according to DESA. The ADB reckons that matters are unlikely to rest there: Asian urbanisation still has a long way to go, with the number and size of cities growing ever larger.

In 2010, the urban share of Asia's population was 43 per cent, compared with the worldwide share of 52 per cent. By 2050, the urban share in Asia is projected to reach 63 per cent. Guanghua Wan, principal economist at the ADB, says that globalisation and heightened economic competition will

almost certainly cause megacities to proliferate. 'Megacities in Asia are inevitable, due to the large populations, particularly in China, India, Indonesia and Bangladesh,' he says.

MASS MIGRATION

To gauge just where megacities may be going, and what that means for the planet, it's probably worth asking how a megacity evolves. How does
it coalesce and balloon in size, seemingly exponentially, from a smaller city?

Several drivers are at play according to Erik Swyngedouw, professor of geography at the School of Environment and Development at Manchester University. Among the key factors is mass migration from the countryside, which is accelerating as globalisation increasingly frames 21st century life. 'The only thing that rural people can do is to move somewhere where they hope to have some chance of survival, and cities are historically the place to which people mass migrate,' he says. 'This is happening as a result of the disintegration of the social conditions in which they've lived, making it difficult for them to continue to survive in the ways they traditionally have.'

Swyngedouw cites China as a key example of why megacities emerge. 'You have this extraordinary transformation of agricultural practice and an equally extraordinary expansion of demand for unskilled labour in cities,' he says. 'Increasingly, food and agriculture are organised globally, and we've seen an accelerating process that takes away traditional livelihoods.'

As Swyngedouw points out, that by itself doesn't explain why megacities bloom out of large cities. 'Megacities are indeed mega. It's precisely in places such as this that people who don't know what to do can find a way of surviving,' he says. 'There's a variety of activities. What makes megacities so attractive to people is that they're integrated into the global system. The accelerated growth of megacities is tightly linked to the increase of global infrastructures.'

FLOOD RISKS

The way in which megacities grow – often without an overarching controlling vision – only adds to the issues that they bring with them. This is largely due, says DESA, 'to the challenges of providing urban jobs, housing, energy and infrastructure to mitigate urban poverty, expansion of slums and a deterioration of the urban environment'.

Infrastructure supply lags behind demand, basic public services – such as water connections and solid waste disposal – don't reach the majority, and many residents live on marginal land where, says the ADB's Wan, 'they face risks from flooding, disease, and other shocks'.

A 2012 ADB report concluded that 'crowded cities whose growth in numbers is not matched by a growth in infrastructure are vulnerable: susceptible to crime, pollution and, among other risks, flooding'. More than 550 million urban Asians were considered to be at risk of coastal and inland flooding in 2010. This is projected to rise to 760 million by 2025. 'The pace of urbanisation has not only led to traffic snarls and massive pressure on resources such as water and sanitation, it has also created slums – 61 per cent of the world's slum dwellers are in Asia – and contributes to rising crime levels.'

If current trends continue, by 2030, urban land will have expanded by as much as 3.3 million square kilometres, up to five times as much as in 2000, according to the Cities and Biodiversity Outlook (CBO) project, the world's first global analysis of how projected patterns of urban land expansion will affect biodiversity and ecosystems. This, says the CBO, will result in 'a considerable loss of habitat in

key biodiversity hotspots' in cities that are located in biodiversity-rich areas such as floodplains, estuaries and coastlines.

UNSUSTAINABLE GROWTH

UN Habitat, a body that looks at urban futures, says that 'car-centred urban models are still the widespread norm, with strict zoning policies dividing urban space into residential, commercial, and industrial areas. These horizontally sprawling cities find it gradually harder to deal with an ever-increasing urban population.' They aren't sustainable over the long term, according to a UN Habitat report, 'owing to overwhelming negative externalities, such as congestion, infrastructure issues, pollution, and social [break-up]'.

'Water and air pollution have local impacts, while the climate and energy impacts of these cities are of a global scale,' says Barbara Evaeus, global communications manager for WWF International's Earth Hour City Challenge. 'Water, and what will happen with fresh water, is a major issue. It will throw natural ecosystems out of kilter and will have impacts on agricultural areas nearby that feed cities. These risks and factors will be compounded by climate change, with changes to the frequency of flooding and drought, and the availability of food, as well as sea-level rises that infiltrate freshwater systems.'

Beijing has the lowest per capita water availability in China – just 100 cubic metres a year, which is less than five per cent of the national average and far below the internationally defined scarcity of less than 1,000 cubic metres per person per year. Yet, there may be hope that Beijing can unpick some of the problems it faces, and offer a template to other megacities on how to use resources more sustainably (see Water Logged box, overleaf).

LEGAL ISSUES

Many observers identify another issue as more important than access to, and the use of, resources: the rule of law. Just how on Earth do you – or can you – govern a city of 20 million, or even 30 million people?

'The difficulties with gaining access to water, health or fuel are structured through the absence of a coherent government,' says Swyngedouw. 'The megacities of the global south aren't governed or governable in the way that Tokyo or London or New York are governed. The things we're familiar with – housing, infrastructure, policing, allocation of land – are only possible in a highly truncated and uneven way.

'You find some well-organised government in the small, middle class and hermetically-sealed off elite areas,' he continues. 'But most people live in megacities where there is no state. They live in organisations of self-management and self-help, completely out of reach of standard state government. The social polarisation is extraordinary, leading to tension, riots and conflicts.'

Dhaka, the capital of Bangladesh, has been cited as one of the worst examples of how to construct a megacity (see Dire Dhaka box, previous page). 'Everyone has recognised the problems with Dhaka,' says Dr Bruno Parolin, who formerly worked at the faculty of the Built Environment, the University of New South Wales in Sydney. 'The master plans for the city since 1945 have recognised the issue of rapid growth, the deficiencies around high-density populations, the need to disperse this population and jobs. But these plans have generally been given lip service; most of them have been failures. You end up with reactive rather than proactive planning.

‘There has been little understanding of the evolution of urban space – and that has been a problem with most of the megacities of Asia,’ he continues. ‘The plans also have little political clout. What we learn from Dhaka is the need for solid institutions, a solid planning process.’

This point is echoed by the ADB’s Wan. ‘The single most pressing issue is the shortage of, and lag in, the supply of urban-development expertise to plan, design and govern megacities,’ he says. ‘Most governments in Asia aren’t prepared or equipped to effectively manage the rapid wave of urbanisation that’s sweeping Asia. This is particularly serious at the megacity level. Failed megacities will face rising crime levels, social unrest and an increasingly unbearable, unsustainable living environment.’

In such a context, the negative impacts of megacities appear formidable. ‘The dynamic consequence of megacities is that every day, the incoherent functioning of these cities is predicated on the extraordinary use of the world’s resources,’ says Swyngedouw. ‘The sociological implications of megacities are devastating in the long run for the world’s natural base. The extraordinary challenge is how to make these places tick.’

More positively, Wan says that models for running a megacity are at hand. ‘There are good examples where megacities are well-governed, such as Tokyo and, more recently, Seoul,’ he says. ‘Within China, Shanghai is managed better than other megacities. Two major factors are essential to ensure good governance: expertise and adequate financing. The latter is closely related to the level of economic development.’

ENGINES OF THE WORLD

The resoundingly bleak picture of the polluted, overcrowded, crime-ridden megacity is strongly countered by those who believe that megacities, if judiciously governed, can be a force for good. DESA’s World Urbanization Prospects report describes them as ‘the engines of the world economy and centres of innovation, where many solutions to global problems are being piloted’. The report points out that urban living is often associated with higher levels of literacy and education, better health, greater access to social services, and enhanced opportunities for cultural and political participation.

‘Megacities are a positive force, not a negative one,’ says Eduardo Moreno of UN Habitat. ‘They generate high densities of population, and that’s good for infrastructure such as housing. You also get the economics of agglomeration [where offices or companies cluster close to one another], which are fundamental for economic growth. Megacities are also conducive to economic development. The more people that live in these cities, the more opportunities there are for innovation, creativity and jobs.’

Moreno also argues that megacities aren’t as chaotic as some observers suggest. ‘It’s wrong to say that megacities are growing with a lack of control,’ he says. ‘Unlike how many people think, social capital comes when you have interaction between social and economic groups. In rural areas, the exchanges are between poor people and other poor people. In cities, they’re between rich, middle class and the poor. Megacities are very clear drivers of growth. On average, megacities produce two to three more times GDP than other cities. There are also more intangible benefits from all this interaction, such as the empowerment of women.’

Swyngedouw also identifies beneficial elements: ‘They can be positive; it’s extraordinary if you look at everyday life,’ he says. ‘It works. There’s creativity, inventiveness – it’s nothing short of remarkable. When I visit these places, I’m struck by how well life functions.’

Mexico City, with 21 million inhabitants, is the largest megacity in North America – ahead, even, of New York (Image: shipfactory)

DUMPING GROUND

The CBO also finds plenty to praise, highlighting Kolkata, Mexico City, Montreal, Nagoya, New York City and São Paulo as examples of megacities that boast high levels of biodiversity.

In Mumbai, Sanjay Gandhi National Park's dense semi-evergreen forests are home to 280 bird species, 150 species of butterfly, and 40 species of mammal – including a small population of leopards – and protects 104 square kilometres entirely within a megacity.

In São Paulo, 21 per cent of the city is covered by dense forest, with 1,909 plant species and 435 animal species – 73 of them endemic to the Brazilian Atlantic rainforest.

Mumbai has also moved to tackle the issue of the phenomenal amount of waste it produces – about 6,500 tonnes per day of municipal solid waste and about 2,400 tonnes per day of construction waste. For almost 40 years, all of this went to the Gorai Dump, a 20-hectare open site in Mumbai's western suburbs.

Situated next to a creek and close to residential areas, the dump caused significant environmental damage and was one of the unhealthiest places in Mumbai. In 2009, the site was closed and covered, and a power plant is now being built there that will run on methane gas from the decomposing waste.

Wan concurs that, given the right circumstances, megacities can work. 'Megacities, if managed well, can be positive as they allow Asia to profitably ride the globalisation wave by producing and exporting goods and commodities competitively.'

But he warns that policy makers need to be nimble. 'Asia's current urbanisation is different from historical experience in terms of speed and scale, and is generating and confronting unprecedented challenges,' he says. 'But it also comes with forces that, if properly managed, can help to address the challenges.'

SATELLITE CITIES

So is it possible to reconfigure existing megacities and make them better places to live? Wan believes that better transport planning and more mixing of housing and office space are needed. 'At the micro level, satellite cities must be developed to deflect burgeoning populations out of megacities,' he says. 'The key is to link the main and satellite cities by rail-based transport systems, not highways'.

'There's talk of US$350 trillion of investment in infrastructure in the next decade [in cities in the global south], so it's important to get it right and make sure the development is sustainable' says Evaeus. 'When you look at megacities, you look at them through two different lenses: one for the cities in the global south and another for those in the north. The big cities in the north have lots of technology that can mitigate their impact. It's important that technology gets transferred to cities in the global south.

'If city planners use projections for climate change impacts, they can plan a city by not developing coastal areas, leaving them as natural barriers,' he continues. 'If you build-in public transport rather than cars, and manage food sustainably, you'll greatly reduce the impacts. Living in a city, your footprint can be smaller than in the suburbs, where you may be car dependent.'

Swyngedouw believes that to succeed, megacities must avoid replicating the formats of cities in the developed world. 'A lot can be learned from these practices and how people manage to live more or

less decent lives,' he says. 'Historically, we've been used to having energy, water and health centrally organised. In megacities, that approach doesn't work. You see ingenious community efforts to support health and schools. The community transport systems that operate in Johannesburg and Cape Town are remarkable.

'We're seeing the rise of insurgent citizenship,' he continues. 'Those who seem to be excluded seem to be beginning to articulate their rights. What does it mean to be a citizen in a megacity of 25 million people? What will be the forms of governance? The election cycles we have in the West just don't work in megacities. My hope or pessimism is structured by the way in which local people begin to organise themselves to fight for a different trajectory for megacities.'

META-CITIES

The issues around megacities appear to be emerging just as rapidly as the cites are growing. The UN already distinguishes megacities from those that are even larger. Now, we have the term 'meta-city' to describe conurbations of more than 20 million people.

China plans to merge nine cities in the Pearl River Delta, including Shenzhen, Hong Kong and Guangzhou. This would create a 41,000-square-kilometre urban area (that's 26 times larger than Greater London), with integrated transport, energy and telecommunications systems. Moreno believes that this throbbing entity will be home to an almost unfathomable 120 million people with, he says, 'no urban discontinuity'.

Similar meta-cities are evolving in Japan – the Tokyo-Osaka-Nagoya region will soon be home to 60 million people – and in Brazil, where 43 million people are projected to coalesce around São Paulo. 'The new meta-city regions are better planned – they're not accidents. It's a conscious undertaking of national development,' says Moreno.

'We have to accept that we can't not have megacities,' says Swyngedouw. 'They will keep on expanding and it's unlikely that people will move en masse back to the countryside. The world we live in is an urbanised world.

'Cities have always been the laboratories of the future, but that doesn't answer the question of how that laboratory will turn out,' he continues. 'It may be quite nasty. These places are very explosive – that's what happens in a laboratory. The challenge is to decide which bits of the laboratory we want to support, and which bits we should avoid.'

Parolin admits to being temporarily lost for words when he tries to identify how megacities function. 'They still work,' he says. 'There's some amazing self-organisation that takes place, even though people have to put up with some quite horrid conditions. Despite the limitations, it always amazes me. It says something about the resilience of these kinds of places.'

Meanwhile, Evaeus wonders if megacities – and even meta-cities – will be just one part of the problem of urbanisation. '[The existing] megacities are meeting their natural restrictions and borders; it's the cities with one million plus people that will be taking real leaps,' he says. 'These issues will get even more magnified.

'I'm confident the solutions exist and with good governance they can be delivered,' he continues. 'The question is whether politicians will be courageous enough to do what's needed. It isn't a big sacrifice we're asking to be made, even though things such as cycling to work rather than driving the same distance are presented as hardships. A different mindset is needed.

1.2 The water cycle

Key terms

Atmospheric water – Water found in the atmosphere; mainly water vapour with some liquid water (cloud and rain droplets) and ice crystals.

Cryospheric water – The water locked up on the Earth's surface as ice.

Hydrosphere – A discontinuous layer of water at or near the Earth's surface. It includes all liquid and frozen surface waters, groundwater held in soil and rock and atmospheric water vapour.

Oceanic water – The water contained in the Earth's oceans and seas but not including such inland seas as the Caspian Sea.

Terrestrial water – This consists of groundwater, soil moisture, lakes, wetlands and rivers.

'Water is life's matter, mother and medium.'
Albert Szent-Gyorgyi, 1937 Nobel Prize acceptance speech

Water on planet Earth

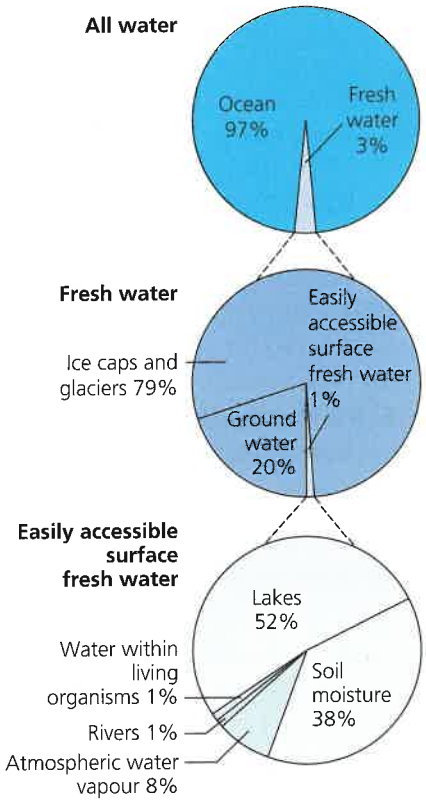


Figure 1.5 The distribution of the world's water

Water on or close to the Earth's surface is called the **hydrosphere**. Scientists have attempted many times to estimate the total amount of water in the hydrosphere. There is general agreement that it amounts to some 1.338×10^9 km^3. It is thought that approximately 97 per cent of this is **oceanic water**. Fresh water, which makes up the remaining 3 per cent, is locked up in land ice, glaciers and permafrost (**cryospheric water**), groundwater, lakes, soil, wetland, rivers, biomass (**terrestrial water**) and **atmospheric water**.

12,900 km^3 of water vapour are found in the atmosphere. This amounts to a global average of 26 kg/m^2 of water for each column of air on the surface of the Earth. There are large variations in this, however. Although atmospheric water only makes up 0.4 per cent of all water, it has a profound effect on our lives at present.

The amount of water in these stores is in a state of dynamic equilibrium with changes at a range of timescales from diurnal to geological. Changing amounts of atmospheric water in the future could be a major cause and/or important effect of climate change.

Oceanic water

The oceans dominate the amount of available water. Its exact amount is unknown with figures varying from 1,320,000,000 to 1,370,000,000 km^3 with an average depth of 3,682 m. That difference is greater than the sum of all the rest of the water put together. They cover approximately 72 per cent of the planet's surface (3.6×10^8 km^2). They are customarily divided into several principal oceans and smaller seas. Although the ocean contains 97 per cent of the Earth's water, oceanographers have stated that only 5 per cent has been explored.

Oceanic water tastes salty because it contains dissolved salts. These salts allow it to stay as liquid water below 0°C. They are alkaline with an average pH of about 8.14. The pH has fallen from about 8.25 in the last 250 years and it seems destined to continue falling. This change in the pH is linked to the increase in atmospheric carbon and may have a profound influence on marine ecosystems.

Cryospheric water

The cryosphere is those portions of the Earth's surface where water is in solid form. Figure 1.6 shows the five locations of cryospheric water.

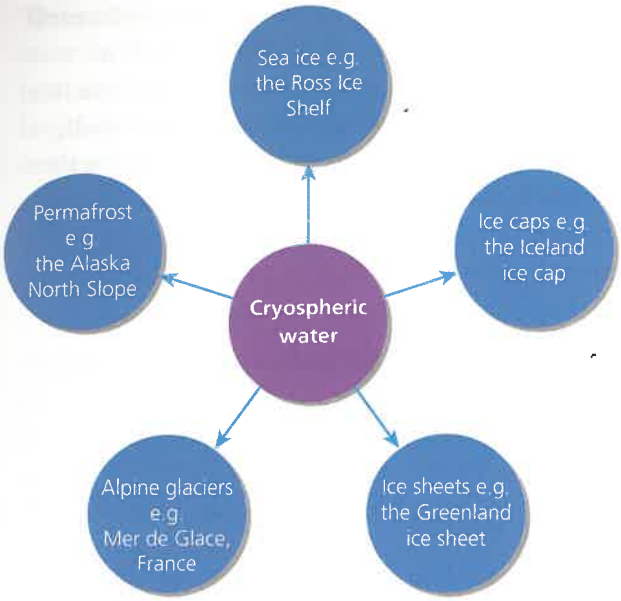


Figure 1.6 The locations of cryospheric water

Sea ice: Much of the Arctic Ocean is frozen; the amount of which grows in winter and shrinks in summer. The same is true of the waters surrounding Antarctica. Sea ice forms when water in the oceans is cooled to temperatures below freezing. Sea ice does not raise sea level when it melts, because it forms from ocean water. It is closely linked with our planet's climate, so scientists are concerned about its recent decline.

Figure 1.7 Chunks of broken sea ice in Yelverton Bay, Ellesmere Island, Canada

Ice shelves are platforms of ice that form where ice sheets and glaciers move out into the oceans. Ice shelves exist mostly in Antarctica and Greenland, as well as in the Arctic near Canada and Alaska. Icebergs are chunks of ice that break off glaciers and ice shelves and drift in the oceans. They raise sea level only when they first leave land and push into the water, but not when they melt in the water.

Ice sheets: An ice sheet is a mass of glacial land ice extending more than 50,000 km^2. The two major ice sheets on Earth today cover most of Greenland and Antarctica. During the last ice advance, ice sheets also covered much of North America, northern Europe and Argentina.

Figure 1.8 Mountains rising out of part of the Greenland ice sheet

Together, the Antarctic and Greenland ice sheets contain more than 99 per cent of the freshwater ice on Earth. The Antarctic Ice Sheet extends almost 14 million km^2, roughly the area of the United States and Mexico combined. It contains 30 million km^3 of ice. The Greenland Ice Sheet extends about 1.7 million km^2, covering most of the island of Greenland.

Ice sheets form in areas where snow that falls in winter does not melt entirely over the summer. Over thousands of years, the layers of snow pile up into thick masses of ice, growing thicker and denser as the weight of new snow and ice layers compresses the older layers. Ice sheets are constantly in motion, slowly flowing downhill under their own weight. Near the coast, most of the ice moves through relatively fast-moving outlets called ice streams. This type of glacier is significant in the Antarctic where they can be up to 50 km wide, 2 km thick and hundreds of kilometres long. As long as an ice sheet accumulates the same mass of snow as it loses to the sea, it remains stable.

Ice sheets contain enormous quantities of frozen water. If the Greenland Ice Sheet melted, scientists estimate that sea level would rise about six metres. If the Antarctic Ice Sheet melted, sea level would rise by about 60 m.

Ice caps are thick layers of ice on land that are smaller than 50,000 km². They are usually found in mountainous areas. Ice caps tend to be dome-shaped and are centred over the highest point of an upland area. They flow outwards, covering almost everything in their path and becoming the major source for many glaciers.

Ice caps occur all over the world, from the polar regions to mountainous areas such as the Himalayas, the Rockies, the Andes and the Southern Alps of New Zealand. The Furtwangler Glacier on Kilimanjaro, at 60,000 m², is Africa's only remaining ice cap. It is melting rapidly and may soon disappear.

Figure 1.9 The Furtwangler Ice Sheet. The last ice sheet in Africa

Alpine glaciers are thick masses of ice found in deep valleys or in upland hollows. Most valley glaciers are fed by ice from ice caps or smaller corrie glaciers. These glaciers are particularly important in the Himalayas where about 15,000 Himalayan glaciers form a unique reservoir which supports perennial rivers such as the Indus, Ganges and Brahmaputra which, in turn, are the lifeline of millions of people in South Asian countries (Pakistan, Nepal, Bhutan, India and Bangladesh). Frozen ground and permafrost ring the Arctic Ocean. Glaciers, snow and ice cover the nearby land, including a thick sheet of snow and ice covering Greenland.

Permafrost is defined as ground (soil or rock and included ice or organic material) that remains at or below 0°C for at least two consecutive years. The thickness of permafrost varies from less than one metre to more than 1,500 m. Most of the permafrost existing today formed during cold glacial periods and has persisted through warmer interglacial periods, including the Holocene (the last 10,000 years). Some relatively shallow permafrost (30 to 70 m) formed during the second part of the Holocene (the last 6,000 years) and some during the Little Ice Age (from 400 to 150 years ago). Subsea permafrost occurs at close to 0°C over large areas of the Arctic continental shelf, where it formed during the last glacial period on the exposed shelf landscapes when sea levels were lower. Permafrost is found beneath the ice-free regions of the Antarctic continent and also occurs beneath areas in which the ice sheet is frozen to its bed.

The permafrost has begun to melt as climate warms. This melting is releasing large amounts of carbon dioxide and methane, potentially affecting global climates.

Terrestrial water

Terrestrial water may be considered as falling into four broad classes:

- surface water
- groundwater
- soil water
- biological water.

Surface water is the free-flowing water of rivers as well as the water of ponds and lakes.

- **Rivers** act as both a store and a transfer of water; they are streams of water within a defined channel. They transfer water from the ground, from soils and from the atmosphere to a store. That store may be wetlands, lakes or the oceans. Rivers make up only a small percentage (0.0002 per cent) of all water, covering just 1,000,000 km² with a volume of 2,120 km³. One river alone, the Amazon in South America, is the largest river by discharge of water in the world, averaging a discharge of about 209,000 m³/s, greater than the next seven largest independent rivers combined. It drains an area of about 7,050,000 km² and accounts for approximately one fifth of the world's total river flow. The portion of the river's drainage basin in Brazil alone is larger than any other river's basin. The Amazon enters Brazil with only one fifth of the flow it finally discharges into the Atlantic Ocean, yet already has a greater flow at this point than the discharge of any other river.
- **Lakes** are collections of fresh water found in hollows on the land surface. They are generally deemed a lake if they are greater than two hectares in area. Any standing body of water smaller than this is termed a pond.

The majority of lakes on Earth are freshwater, and most lie in the Northern Hemisphere at higher latitudes. Canada has an estimated 31,752 lakes larger than 3 km² and an estimated total number of at least 2 million. Finland has 187,888 lakes 500 m² or larger, of which 56,000 are large (10,000 m²).

The largest lake is the Caspian Sea at 78,200 km³. It is a remnant of an ancient ocean and is about 5.5 million years old. It is generally fresh water, though becomes more saline in the south where there are few rivers flowing into it. The deepest lake in the world is Lake Baikal in Siberia with a mean depth of 749 m and a deepest point at 1,637 m.

- **Wetlands:** The **Ramsar Convention** defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing where there is a dominance by vegetation'.

  They are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season. Water saturation determines how the soil develops and the types of plant and animal communities living in and on the soil. Wetlands may support both aquatic and terrestrial species. The prolonged presence of water creates conditions that favour the growth of specially adapted plants and promotes the development of characteristic wetland soils.

  Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors, including human disturbance. They are found from the polar regions to the tropics and on every continent except Antarctica.

Figure 1.10 The location of the Pantanal wetlands (shown in dark green)

The Pantanal of South America is often referred to as the world's largest freshwater wetland system. It extends through millions of hectares of central-western Brazil, eastern Bolivia and eastern Paraguay. It is a complex system of marshlands, flood plains, lagoons and interconnected drainage lines. It also provides economic benefits by being a huge area for water purification and groundwater discharge and recharge, climate stabilization, water supply, flood abatement, and an extensive, transport system, among numerous other important functions.

Wetlands are the main ecosystem in the Arctic. These peatlands, rivers, lakes, and shallow bays cover nearly 60 per cent of the total surface area. Arctic wetlands store enormous amounts of greenhouse gases and are critical for global biodiversity.

Groundwater is water that collects underground in the pore spaces of rock. Scientists have set a lower level for groundwater at a depth of 4,000 m but it is known that there are large quantities of water below that. A very deep borehole in the Kola Peninsula in Northern Russia found huge quantities of hot mineralised water at a depth of 13 km.

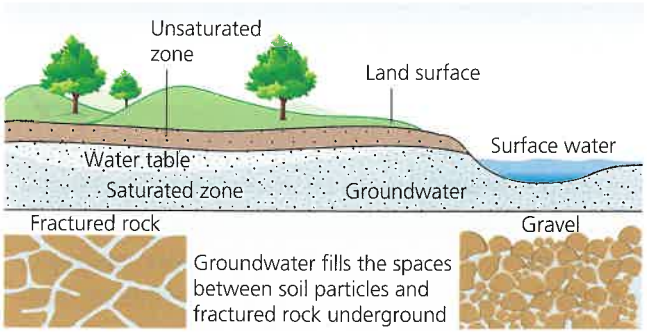


Figure 1.11 Groundwater

The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface. Natural discharge often occurs at springs and seeps, and can form oases or wetlands. The amount of groundwater is reducing rapidly due to extensive extraction for use in irrigating agricultural land in dry areas.

Soil water is that which is held together with air in unsaturated upper weathered layers of the Earth. It is of fundamental importance to many hydrological, biological and biogeochemical processes. It affects

weather and climate, run-off potential and flood control, soil erosion and slope failure, reservoir management, geotechnical engineering and water quality. Soil moisture is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays an important role in the development of weather patterns and the production of precipitation.

Biological water constitutes the water stored in all the biomass. It varies widely around the globe depending on the vegetation cover and type. Areas of dense rainforest store much more water than deserts. The role of animals as a water store is minimal.

Trees take in water via their roots. This is either transported or stored in the trunk and branches of the tree. The water is lost by the process of transpiration through stomata in the leaves. This storage provides a reservoir of water that helps maintain some climatic environments. If the vegetation is destroyed, this store is lost to the atmosphere and the climate can become more desert-like. Many plants are adapted to store water in large quantities. Cacti are able to gather water via their extensive root system and then very slowly use it until the next rainstorm. The baobab tree stores water, but it is thought that this is to strengthen the structure of the tree rather than to be used in tree growth.

Atmospheric water

Atmospheric water exists in all three states. The most common atmospheric water exists as a gas: water vapour. This is clear, colourless and odourless and so we take its presence for granted. This atmospheric water vapour is important as it absorbs, reflects and scatters incoming solar radiation, keeping the atmosphere at a temperature that can maintain life. The amount of water vapour that can be held by air depends upon its temperature. Cold air cannot hold as much water vapour as warm air. This results in air over the poles being quite dry, whereas air over the tropics is very humid.

A small increase in water vapour will lead to an increase in atmospheric temperatures. This becomes positive feedback as a small increase in global temperature would lead to a rise in global water vapour levels, thus further enhancing the atmospheric warming.

Cloud is a visible mass of water droplets or ice crystals suspended in the atmosphere. Cloud formation is the result of air in the lower layers of Earth's atmosphere becoming saturated due to either or both of two processes: cooling of the air and an increase in water vapour. When the cloud droplets grow they can eventually fall as rain.

Factors driving the change in magnitude of water stores

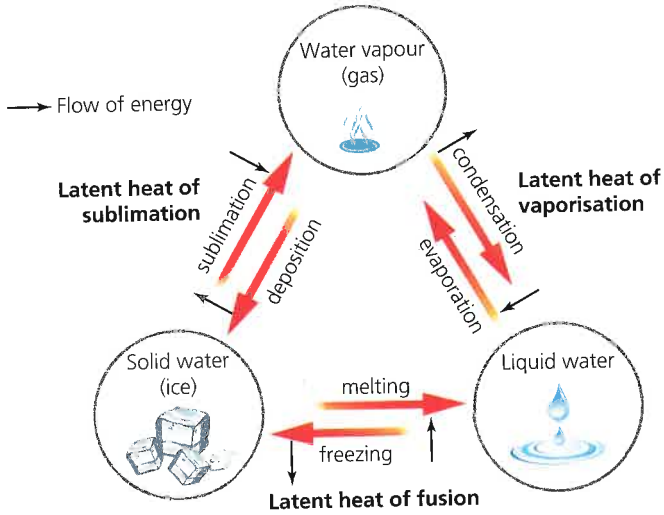


Figure 1.12 The phases of water and the phase changes

Water exists on Earth in three forms: liquid water, solid ice and gaseous water vapour. Figure 1.12 shows the processes that occur as water changes from one state to another. Energy, in the form of latent heat, is either absorbed or released depending on the process. This is particularly important in atmospheric processes such as cloud or precipitation formation.

Evaporation

Evaporation occurs when energy from solar radiation hits the surface of water or land and causes liquid water to change state from a liquid to a gas (water vapour). The rate of evaporation depends upon several factors:

- the amount of solar energy
- the availability of water (for example there is more evaporation from a pond than from a grassy field).
- the humidity of the air; the closer the air is to saturation point, the slower the rate of evaporation
- the temperature of the air; warmer air can hold more water vapour than cold air.

Linked to this is the fact that all terrestrial plants lose water through **transpiration**. This is where water is transported from the roots of a plant to its leaves and