PHYSICAL GEOGRAPHY: Rivers, floods and management

THE HYDROLOGICAL CYCLE

- GLOBAL hydrological cycle is a closed system – no inputs/outputs
- LOCAL hydrological cycle is a "drainage basin hydrological cycle"
    - DRAINAGE BASIN = "area surrounding a river where the rain falling on the land flows into that river" a.k.a. catchment
    - WATERSHED marks boundary of a drainage basin. Precipitation beyond the watershed enters a different basin.
    - Drainage basins are open systems with inputs and outputs.

Terminology

INPUTS

- Precipitation – all the way sin which water comes out of the atmosphere.

STORAGE

- Interception – when some precipitations lands on vegetation or other structures. Creates a significant store in woodland. Temporary as water evaporates quickly.
- Vegetation storage – water taken up by plants. Includes all the water contained in plants at any one time
- Surface storage – water in puddles, ponds and lakes
- Groundwater – water stored in the ground (soil moisture or in rocks). The water table is the top of the saturated zone (zone of soil/rock where all pores are full of water). Very porous rocks are known as aquifers.
- Channel storage – water held in a river or stream channel

FLOWS AND PROCESSES

- Surface runoff a.k.a. overland flow is water flowing over the land. It can flow over a whole surface or in small channels
- Throughfall is water dripping off one leaf onto another
- Stemflow is water running along a stem or trunk
- Throughflow is water moving downhill through the soil. It is faster through 'pipes' such as cracks in the soil or animal burrows
- Infiltration – water soaking into the soil. Rate influenced by soil type, structure and level of saturation
- Percolation – water seeping down into the water table through the soil
- Groundwater flow - water flowing below the water table through permeable rock. Highly permeable rocks with lots of joints can have faster groundwater flow
- Baseflow – groundwater flow that feeds into rivers through the banks and bed
- Interflow – water flowing downhill through permeable rock above the water table
- Channel flow – water flowing in the river itself a.k.a. river discharge

OUTPUTS

- Evaporation
- Transpiration – evaporation from plant leaves
- Evapotranspiration – evaporation and transpiration together
- River discharge (or channel flow) is another output

The WATER BALANCE is the difference between inputs and outputs. It affects how much water is stored in the drainage basin.

- the general water balance in the UK shows seasonal patterns:
    - WET seasons: precipitation > evapotranspiration. Therefore water surplus. Ground stores fill with water so there is more surface runoff and higher discharge – so river levels rise.
    - DRIER seasons: precipitation < evapotranspiration. Ground stores are depleted as some water is used and some flows into the river channel but isn't replaced by precipitation. At the end of the dry season there's a deficit of water in the ground. The ground stores are recharged in the next wet season.

River Discharge = volume of water flowing in a river per second (cumecs)
It is affected by:

- precipitation (increases)
- hot weather (decreases)
- abstraction (decreases)

The STORM HYDROGRAPH is affected by PHYSICAL FACTORS

1. DRAINAGE BASIN CHARACTERISTICS
    a. larger drainage basins capture more precipitation therefore higher peak discharge
    b. smaller basins have shorter lag times because precipitation has a shorter distance to travel
    c. steep-sided basins have shorter lag times because water flows quickly downhill on steep slopes, which can also increase peak discharge
    d. circular basins are more likely to have a 'flashy' hydrograph than long, narrow basins. This is because all points on the watershed are roughly the same distance from the point of discharge measurement. Thus, lots of water reaches the measurement point simultaneously, increasing peak discharge.
    e. high drainage density basins drain quickly so have shorter lag times

2. ANTECEDENT MOISTURE
    a. (amount of water already present in the drainage basin)
    b. if ground already saturated then infiltration reduced & surface runoff increases. Surface runoff is much faster than throughflow or baseflow so rainwater reaches the river more quickly, reducing lag time

3. ROCK TYPE
    a. affects lag time and peak discharge
    b. impermeable rocks don't store water or let water through them. Reduces infiltration and increases surface runoff, reducing lag time. Peak discharge also increases as more water reaches the river in a shorter period.

4. SOIL TYPE
    a. lag time and peak discharge
    b. sandy soils allow lots of infiltration but clay soils have very low infiltration rates
    c. low infiltration rates increase surface runoff, reducing lag time and increasing peak discharge

5. VEGETATION
    a. intercepts precipitation, slowing its movement into the channel, increasing lag time. Interception highest when lots of vegetation and deciduous trees have their leaves
    b. more vegetation = more water lost through evapotranspiration, reducing peak discharge

6. PRECIPITATION
    a. intense storms = more precipitation therefore greater peak discharge
    b. type of precipitation affects lag time e.g. snow can fall in winter but melt in sprint, giving a long lag time

7. TEMPERATURE
    a. hot dry conditions and cold freezing conditions both result in hard ground, reducing infiltration and increasing surface runoff – reducing lag time and increasing peak discharge
    b. high temperatures can also increase evapotranspiration, so less water reaches the river channel, reducing peak discharge

HUMAN ACTIVITY

- Urbanisation: concrete is impermeable so water cannot infiltrate into the soil, increasing surface runoff. Therefore lag time reduced & peak discharge increased.
- Man-made drainage systems have a similar effect. Water flows down drains into the river before it can evaporate or infiltrate into the soil, causing a shorter lag time and increased peak discharge.

RIVER PROCESSES

EROSION

- Headward erosion – makes river longer. happens near source as throughflow and surface runoff cause erosion at the point the water enters the river (valley head)
- Vertical erosion deepens river channels, upper stages of river
- Lateral erosion widens river channels, occurs in middle & lower stages

What are the erosive processes?

- hydraulic action
- abrasion a.k.a. corrosion
- attrition
- cavitation (air bubbles implode, causing shockwaves that break pieces of rock off the banks and bed)
- corrosion a.k.a. solution

TRANSPORTATION

- solution
- suspension
- saltation
- traction (material transported this way is the “bed load”)

DEPOSITION happens when a river loses energy and slows down. Speed and energy can be reduced in many ways:

- reduced rainfall -> lower discharge therefore slows down and less energy
- increased evaporation or abstraction -> lower discharge
- friction (eg shallow area / close to banks) -> reduced speed -> reduced energy
- when forced to slow down e.g. before narrow channel. Loses energy
- lots of energy lost when river meets sea

Some definitions:

- CAPACITY of a river = total load that a river can transport at a given point
    - load of a river can be divided into different categories by PARTICLE SIZE. Fine, silt, clay… boulders
- COMPETENCE of a river = maximum particle size river can transport at a given point

THE HJULSTROM CURVE

- Shows relationship between river velocity and competence, also how erosion, deposition and transportation vary with velocity
  - critical erosion velocity curve shows minimum velocity needed for river to entrain and transport particles of different sizes
    - takes higher velocity to entrain material than just to transport it
  - mean settling velocity curve shows velocities where particles of different sizes are deposited i.e. competence of river at different velocities
- Particles of sand can be eroded at lower velocities than finer particles such as silt and clay. This is because silt and clay flocculate more than sand, making them hard to dislodge and so requiring more energy to entrain them.

THE LONG PROFILE

- Shows how gradient of river channel changes from river's source to its mouth – shows height of river bed above base level for whole length.
  - base level = lowest point river can erode to (sea level or lake)
- Total amount of erosion vs deposition along the full course are balanced – but rates of erosion and deposition change along the course. This can result in landforms such as waterfalls which make the profile uneven.
- Because total erosion = total deposition, rate of erosion = rate of deposition. This means that over time the long profile will become graded – a smooth curve. This is seen rarely.

River course can be split into three stages:

1. Upper – steep gradient, river high above seal level which means lots of potential energy
2. Middle – decreased gradient. Potential energy converted to kinetic energy so river gains velocity
3. Lower – little potential energy but lots of kinetic energy – so flows faster

CHANNEL CHARACTERISTICS

- Most of a river's kinetic energy is used to overcome friction: the rest erodes and transports
  - more energy available for erosion & transportation = more efficient
  - efficient river = high velocity, high discharge, little friction
- Efficiency also measured by hydraulic radius. Larger HR = more efficient
  - *hydraulic radius = cross-sectional area / length of wetted perimeter*
  - contact between the water and the wetted perimeter increases friction -> increases energy loss -> slows the river down
  - larger HR = smaller proportion of water in contact with WP therefore friction lower -> reduced energy loss -> increased velocity and discharge
  - smooth narrow and deep channels have larger HR and are more efficient than shallow broader channels
- Channel roughness affects efficiency. Protruding banks and large angular bedload increase WP and cause more friction, which reduces efficiency.
- as channel roughness increases so does turbulence. Turbulent flow is better at picking up particles from the river bed – hence turbulent flow causes greater erosion.
- In the lower stages the banks and river bed are smooth so there is less friction. Therefore less energy is lost so discharge and velocity are highest in this stage.

CHANGING RIVER PROCESSES U/S TO D/S

UPPER	MIDDLE	LOWER
Erosion Mainly vertical, by abrasion (some HA). Happens in high energy conditions (high velocity and discharge following heavy rain/snowmelt). Rough channel = turbulence, large angular bedload dragged along river bed. Intense downward erosion.	Erosion Mainly lateral and by abrasion. Attrition of larger particles means sediment particle size decreases from source to mouth.	Erosion Velocity and discharge are highest in this stage but there is less erosion because turbulence is lower and sediment particle size is reduced (which reduces abrasion). Some lateral erosion occurs in the formation of meanders.
Transportation Mainly larger particles carried by traction or saltation	Transportation More material carried in suspension as particle size decreases. Some larger particles transported by saltation	Transportation Mainly smaller particles such as silt and clay carried by suspension or substances carried in solution.
Deposition Little deposition – largest particles deposited in the bed as energy levels drop.	Deposition Sand and gravel are deposited across the floodplain as the river floods and friction reduces the river's energy.	Deposition Smaller particles (sand, clay) are deposited on the flood plain when the river floods and in the river mouth as the sea absorbs river energy.

CROSS PROFILE

- Upper stage – steep V-shaped valley. Vertical erosion creates narrow valley floors and steeply sloped sides
- Middle stage – valleys are wider, caused by lateral erosion. Deposition creates a flood plain on the valley floor.
- Lower stage – valleys are wide with gently sloping sides. There's a much wider flood plain caused by deposition.

RIVER LANDFORMS

Fluvial Erosion (water acting)

WATERFALLS

- Form where band of hard rock meets softer rock. Soft rock is eroded more than harder rock, causing a 'step' in the river bed.
- Water flowing over the step speeds up due to lack of friction as it drops over the step. Speed increase = greater erosive power -> further erosion of the soft rock and undercutting of the harder rock.
- As rock undercut it can collapse. Deep plunge pool carved out by abrasion at the floor of the waterfall as bits of collapsed rock move round due to turbulence
- Over time more undercutting causes more collapse. The waterfall retreats, leaving a steep sided gorge.

POTHOLES are small circular hollows in the river bed, formed by abrasion as turbulence swirls a river's bedload in a circular motion so it rubs and scrapes out holes.

RAPIDS are relatively steep sections of river with turbulent flow where there are several sections of hard rock.

MEANDERS (combined erosion and deposition)

- form where alternating pools and riffles develop at equally spaced intervals along a stretch of the river. Distance between pools is 5-6x the river bed width.
    - channel deeper in pools so more efficient -> greater energy -> greater erosive power. In riffles energy is lost because of increased friction.
- Spacing between riffles and pools causes the river's flow to become uneven and maximum flow to be concentrated on one side off the river.
- turbulence increases in and around pools as the water speeds up so the water flow begins to twist and coil. This causes corkscrew-like currents known as helicoidal flow, which spiral from bank to bank.
- causes more erosion and deepening of the pools. Eroded material is deposited on the inside of the next bend where the river loses energy.
- combination of erosion and deposition exaggerates the bends until large meanders are formed. The combined processes also create the meanders' swoosh-style distinctive asymmetric cross-section
- oxbow lakes are formed when the neck of the loop of the meander is broken through, often during flooding. Deposition dams off the loop, leaving an oxbow lake.

    - Cross section:
      lateral erosion by abrasion and hydraulic action forms river cliffs on the outside of the meander.
      deposition creates a slip-off slope on the inside of the bend

Fluvial Deposition

BRAIDING occurs when rivers are carrying vast amounts of eroded sediment e.g. in snowmelt

- if the river's velocity drops or the sediment load becomes too much for the river to carry, sediment is deposited in the channel
- this causes the river to divide into multiple small winding channels that eventually re-join to form a single channel.

FLOOD PLAINS

- when a river bursts its banks and floods the flat land either side of the river, there's an increase in the wetted perimeter and reduction in hydraulic radius
- this increases friction and reduces the velocity of the river, causing silt and sand to be deposited on the flood plain.

LEVÉES are natural raised embankments formed as a river overflows its banks.

- during a flood, material is deposited across the whole flood plain as the river loses velocity and energy due to increased friction
- the heaviest material is dropped first, closest to the river channel
- over time this material builds up on the river bank to create a levee.

DELTAS

- when a river reaches the sea its energy is absorbed by the slower-moving seawater
- causes the river to deposit its load. These deposits build up on the seabed until the alluvium rises up above sea level, partially blocking the mouth of the river
- the river then has to 'braid' into several 'distributaries' in order to reach the sea, forming a delta.

Rejuvenation allows a river to resume vertical erosion.

- river is rejuvenated if its base level is lowered – caused either by ground level rising or a drop in sea level
- drop in base level = greater potential energy -> more potential vertical erosion
- long profile extended and a KNICK POINT (sharp change in gradient, often a waterfall) forms at the junction between the original long profile and the new one.

Rejuvenation brings with it several landforms:

- <u>RIVER TERRACES</u> – former floodplains that have been left above the level of present-day flooding following increased vertical erosion
- <u>INCISED MEANDERS</u> – formed when a river keeps its meandering course as vertical erosion increases. Results in a deep winding valley with sleep sides. The river is left far below the original level of the former floodplain.

-FLOODING-

CAUSES

Flooding occurs when the discharge of the river is so high that the river spills over its banks on to the floodplain.

- a major cause of flooding is *PROLONGED RAINFALL* – after a long period of rain the ground becomes saturated so any further rainfall can't infiltrate, which increases surface runoff & thus discharge
- *HEAVY RAINFALL* can lead to rapid surface runoff if it's too intense for infiltration to occur. Can lead to a sharp rise in river discharge called a flash flood
- *MELTING SNOW/ICE* can also lead to a large increase in the river's discharge

<u>PHYSICAL FACTORS</u>

- *SPARSE VEGETATION* means little interception therefore more rain reaches the ground and volume of water reaching river increases -> as does discharge

- *DECIDUOUS TREES* have no leaves in winter so little interception

- *IMPERMEABLE GROUND* increases surface runoff therefore discharge
  - *e.g. clay soils and some rocks like granite and shale, or if ground baked hard by heat, or frozen*

- *CIRCULAR DRAINAGE BASINS* – water draining into the channel will all arrive in a short space of time as all points in the basin are of similar distance from the river. This thus increases discharge.

- *HIGH DRAINAGE DENSITY* – these basins drain quickly so have short lag times. Lots of water flows from the streams into the main river quickly, increasing discharge.

- *STEEP RELIEF* – water will reach the channel faster, increasing discharge

<u>HUMAN FACTORS</u>

- *URBANISATION* – large areas of impermeable tarmac/concrete so rapid surface runoff, + gutters & drains quickly take runoff to rivers. Reduces lag time & so increases discharge.

- *DEFORESTATION* – reduces interception and evapotranspiration. Increases volume of water reaching channel therefore discharge. Also leaves soil loose – it is eroded by rainwater and carried to the river, raising the riverbed and reducing channel capacity.

- *FLOOD MANAGEMENT STRATEGIES* can sometimes make flooding worse e.g. if dams fail there is a huge increase in discharge

- *AGRICULTURE* – overgrazing leaves areas with less vegetation, has same effect as deforestation. This and ploughing also increase soil erosion.

- *CLIMATE CHANGE* – could cause increase in rainfall and more storms in some areas.

IMPACTS OF FLOODING

SOCIAL

- people/animals killed
- floodwater spreads contaminated sewage – lack of potable water
- contaminated water spreads diseases
- possessions damaged or lost
- people made homeless as properties inundated and damaged

ECONOMIC

- businesses shut down as premises inundated and power supplies down
- rescue and repair are costly. Insurance premiums go up
- unemployment rises as businesses shut down
- transport links destroyed/out of action
- crops destroyed – rise in food prices

ENVIRONMENTAL

- contaminated floodwater pollutes rivers
- river banks eroded

- but some POSITIVE ENVIRONMENTAL IMPACTS:
  - sediment deposited on floodplain = more fertile
  - wetlands can be created – habitats for many species

- Social impact of flooding usually higher in poorer countries as flood defences poorer, people less able to evacuate, sanitation is poor and buildings are not good quality.
- Absolute economic impact higher in MEDCs as more high value infrastructure/buildings
- Relative economic impact higher in LEDCs as stuff that's damaged is worth less but has greater impact as they have less money to use to recover from it.

FLOOD MANAGEMENT STRATEGIES

HARD ENGINEERING

DAMS

- Floodwater caught by the dam, prevents flooding downstream. Released as steady flow through year
- Benefits: turbines often built in so can get H.E.P.; steady water release allows irrigation of land throughout year; resultant reservoir can be used for recreation
- Disadvantages: expensive; land flooded – often farmland, people forced to move; affects wildlife; traps sediment, can cause dam to fail or increased erosion downstream

CHANNEL STRAIGHTENING

- meanders removed by building artificial cut-throughs. Makes water flow faster, reduces flooding as water drains downstream more quickly and doesn't build up to a point where the river channel can't contain it anymore.
- Disadvantages: flooding may happen downstream instead; more erosion downstream because river flows faster; disturbs wildlife habitats

LEVÉES

- embankments built along rivers – can hold more water without overflowing so floods less often.
- Benefits: floodplain can be built on
- Disadvantages: expensive, risk of severe flooding if breached

DIVERSION SPILLWAYS

- channels that take water elsewhere if the water level in the river is too high. Water normally diverted around an important area or to another river. Prevent flooding because discharge reduced. Often have gates that can be opened so release of water can be controlled.
- Disadvantages: increase in discharge when diverted water joins another river could cause flooding d/s of that point. If spillways overwhelmed, water floods areas not used to flooding – could cause even bigger problems.

SOFT ENGINEERING

LAND USE MANAGEMENT (FLOODPLAIN ZONING)

- planning restrictions prevent buildings or roads being constructed on the floodplain. Floodplain use restricted to playing fields/allotments/parks. Allows water infiltration so less surface runoff – reduces discharge and flooding.
- Benefits: impact of flooding reduced; provides recreational opportunities
- Disadvantages: development restricted – problematic where a shortage of housing exists; can't be used in areas already urbanised.

WETLAND AND RIVER BANK CONSERVATION

- wetlands store floodwater and slow it down. Reduces flooding d/s. Conserving / re-establishing wetlands gives natural protection. Planting trees/shrubs along the bank increases interception and lag time, reducing discharge too. Decreases flooding.
- Benefits: little maintenance; better habitat for wildlife.
- Disadvantage: less land available for farming

RIVER RESTORATION

- making river more natural e.g. removal of manmade levees. Can then flood naturally. As water spreads out over floodplain the river's discharge is reduced, reducing d/s flooding.
- Benefits: little maintenance; wildlife
- Disadvantages: local flood risk can increase

ALTERATION OF URBAN SURFACES

- building porous pavements / soakaways increases infiltration, reducing rapid runoff. Increase lag time -> reduce discharge and chance of flooding
- Benefits: pollutants filtered out by soil before water reaches channel
- Disadvantages: expensive

Soft engineering is more sustainable than hard engineering. Tends to be cheaper and requires less time/money to maintain. Designed to integrate with natural environment, and creates wetlands etc with are important for wildlife. Lower economic cost and environmental impact.

FLOODING IN AN MEDC: 2004 BOSCASTLE

1 in 400 year flash flood hit ~3pm in August 2004.

Causes

- remnants of *HURRICANE ALEX* and convectional rainfall due to intense summer heating of the ground led to heavy rainfall over south of England. 60mm over 2hrs in Bostcastle. 200mm by end of flood
- Rain fell on Bodmin Moor – area of *IMPERMEABLE SHALE* with sparse vegetation.
- River Valency's valley has high relief and steep sides
- ground saturated by previous rainfall
- Floodplain urbanised
- Confluence Valency-Jordan in Boscastle = large volumes of water flowing through town when both river's discharge increased.
- Valency's channel through Boscastle had been walled off – prevented it from adjusting to the increased discharge and limiting its efficiency.

Effects

- ECONOMIC
  - Insurance claims £15k-£30k per property. Potential for premiums to rise but unlikely due to rarity of flood
  - businesses badly damaged
  - tourism income reduced
  - 76 cars washed out to sea
- SOCIAL
  - no deaths, some broken bones and hypothermia cases
  - homes flooded and damaged
  - water and power supplies taken out
- ENVIRONMENTAL
  - raw sewage washed out to sea
  - 76 cars and 6 buildings washed out to sea

Short-term responses

- flood warning at 1530, Boscastle not specifically
- SAR operation started lasting to 0230 next day. 150 people saved.
- 11 days after flood people were able to salvage belongings
- Prince Charles visited, donated money to victims
- 100 people used leisure centre as a refuge, council gave 11 tourists accommodation

Long-term responses

- reconstruction in 2005 as council waited on hydrologist report to determine RI of flood
- money invested in flood defences. Channel widened and deepened to increase its capacity. Tested in 2007 and a much smaller controlled flood occurs
- new bridge built with higher arches
- town won 5 awards for eco-friendliness

FLOODING IN AN LEDC: 2004 BANGLADESH

Causes

- sources of rivers in Himalayas so spring snowmelt adds to discharge
- S.Asia has monsoon climate – wet season May to September
- Bangladesh suffers from cyclones – high winds, heavy rainfall and storm surges
- Urbanisation, esp. in Dhaka
- Rapid deforestation in Himalayas
- River management difficult in LEDCs – no money!
- In 2004 the monsoon season brought more rain than usual.

Effects

- ECONOMIC
    - £4Bn cost to Bangladeshi economy
    - Dhaka airport out of use
    - Loss of income from jute plant export = loss of foreign currency
    - after floods, govt had to use money for rebuilding – couldn't plan/expand for the future
- SOCIAL
    - 21% population left homeless
    - 100 000 diarrhoea cases in Dhaka
    - 750 dead
    - starvation as crops destroyed
- ENVIRONMENTAL
    - 60% of Bangladesh submerged

Short-term responses

- govt provided food, water, medical supplies & temporary shelter
- citizens rebuilt their homes and infrastructure
- UN issued appeal for emergency aid – 20% of the requested amount was received
- WaterAid distributed water purification kits

Long-term responses

- flood shelters built on high land, containing puritabs, food, fodder for animals. When flood warning received, residents are instructed to go to shelters and stay there
- artificial levees built along rivers in some places – can overflow slightly w/o flood