

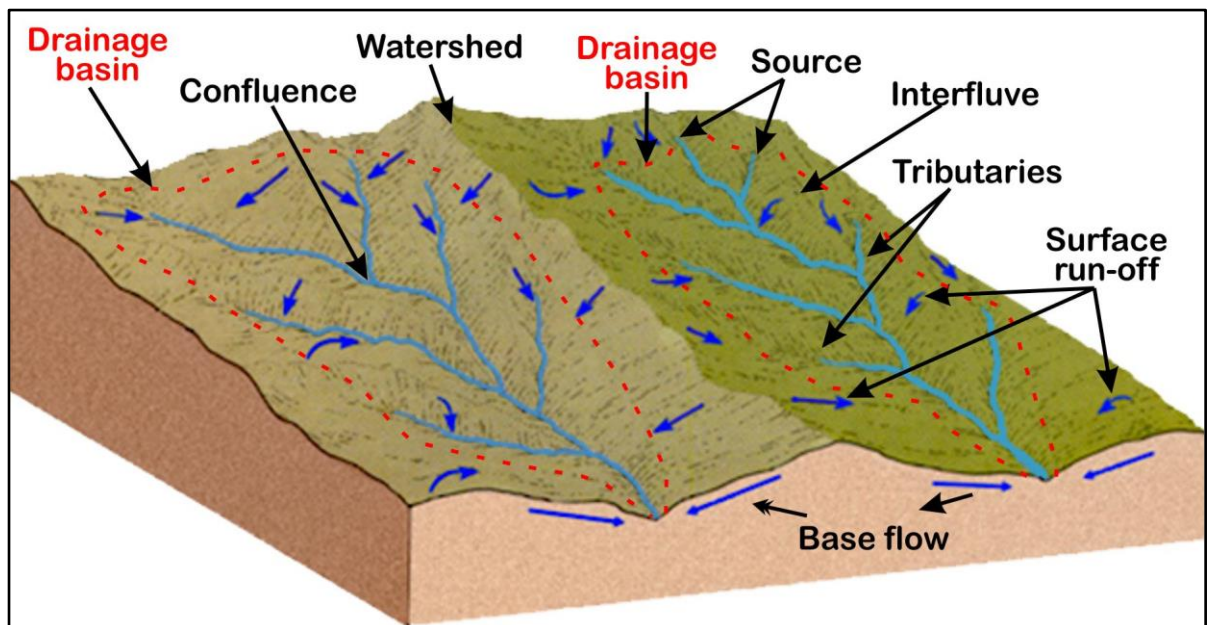
1. DRAINAGE SYSTEMS IN SOUTH AFRICA

1.1. Important concepts

- Drainage basins serve an important purpose on our earth.
- The rain that falls, the snow that melts and the groundwater that moves below the surface, move through drainage basins towards inland lakes and the sea.
- **Definition:** A **drainage basin** is an **AREA** that is drained by a river and its tributaries.

1.1.1. Features of a drainage basin

- The diagram below illustrates the main characteristics of a drainage basin.
 - A **watershed** is the high ground separating one drainage basin from another.
 - The **source** is the start of the streams that combine to form the river system.
 - Individual stream channels (**tributaries**) join to form the **stream network**.
 - **Interfluvies** are the ridges of high ground or spurs that are found between individual channels.
 - The **confluence** is where two tributaries or streams join.
 - **Base flow** is the movement of groundwater below the surface.
 - **Run-off** is the input into the drainage basin and the water flowing through all the components of the system.

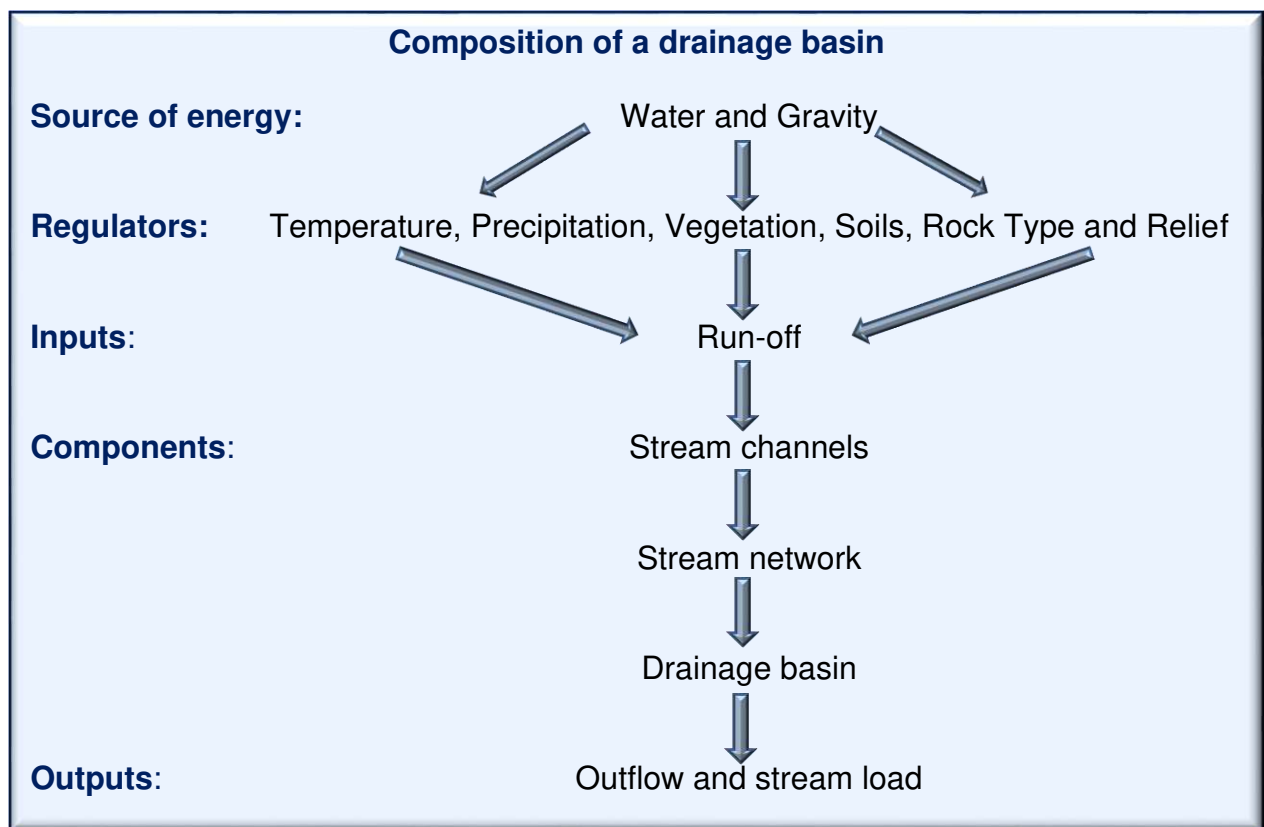


unamaha.edu adapted by Marilda van Niekerk

- **Groundwater:** Rainwater infiltrates (seeps) into the soil and permeable rocks and becomes **groundwater** which flows as **base flow**.
- The upper level of the saturated rock underground is called the **water table**.
- **River mouth:** The water of the main river leaves the drainage basin when it is discharged into an inland lake or the sea.

1.1.2. Characteristics of a drainage basin

- The function of the drainage basin is to collect water and sediment that is available in a specific area and to transport it to the estuary.
- Surface **run-off** is the input into the system and the element that flows through all the components of the system.



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- All the characteristics of a drainage basin can be seen in the Amazon River drainage basin (photograph below).

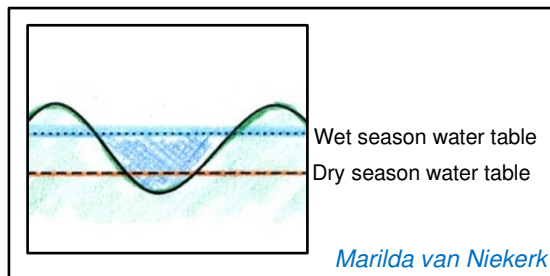


rainforests.mongabay.com

1.2. Types of rivers

1.2.1. Permanent (Perennial) Rivers

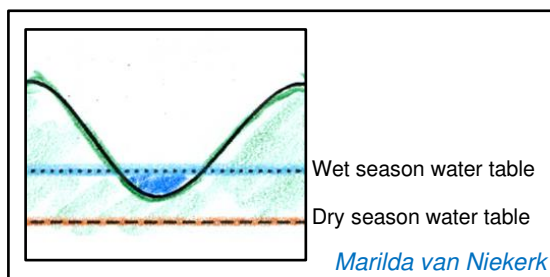
- Permanent streams are to be found in humid areas with a high rainfall.
- The rainfall exceeds the evaporation rate.
- Therefore, they flow throughout the year.
- There is more surface runoff in the rainy season than in the dry season.
- In the dry season base flow (ground water flow) supplies most of the run-off.
- Example: The rivers on the south and east coasts of SA.



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1.2.2. Periodic (seasonal) Rivers

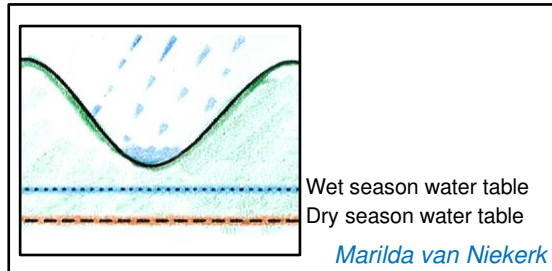
- Seasonal rivers are found in arid areas.
- These streams only maintain continuous flow during the rainy season.
- During the dry season, the ground water table drops below the average level of the stream bed therefore continuous flow is not possible.
- Most of South Africa's rivers are periodic/ seasonal rivers.



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1.2.3. Episodic Rivers

- If the base of the valley does not intercept the groundwater table during the dry season or the rainy season the river will only flow after rain.
- All flow is flood runoff with no base flow to ensure continuity.
- Example: Many of the rivers on the western side of Southern Africa like the Hartebeest, Auob and Nossob Rivers.



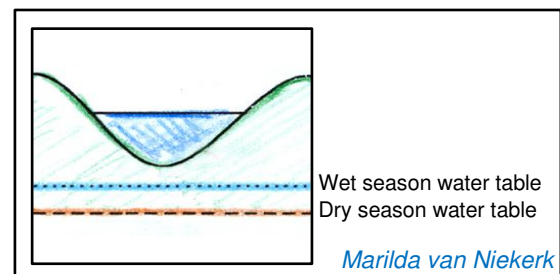
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1.2.4. Exotic Streams

- Exotic streams have their origin in an area with a high rainfall.
- The lower course of the river flows through an arid region with extremely low rainfall.
- The **Gariiep River (Orange)** and the Nile River.



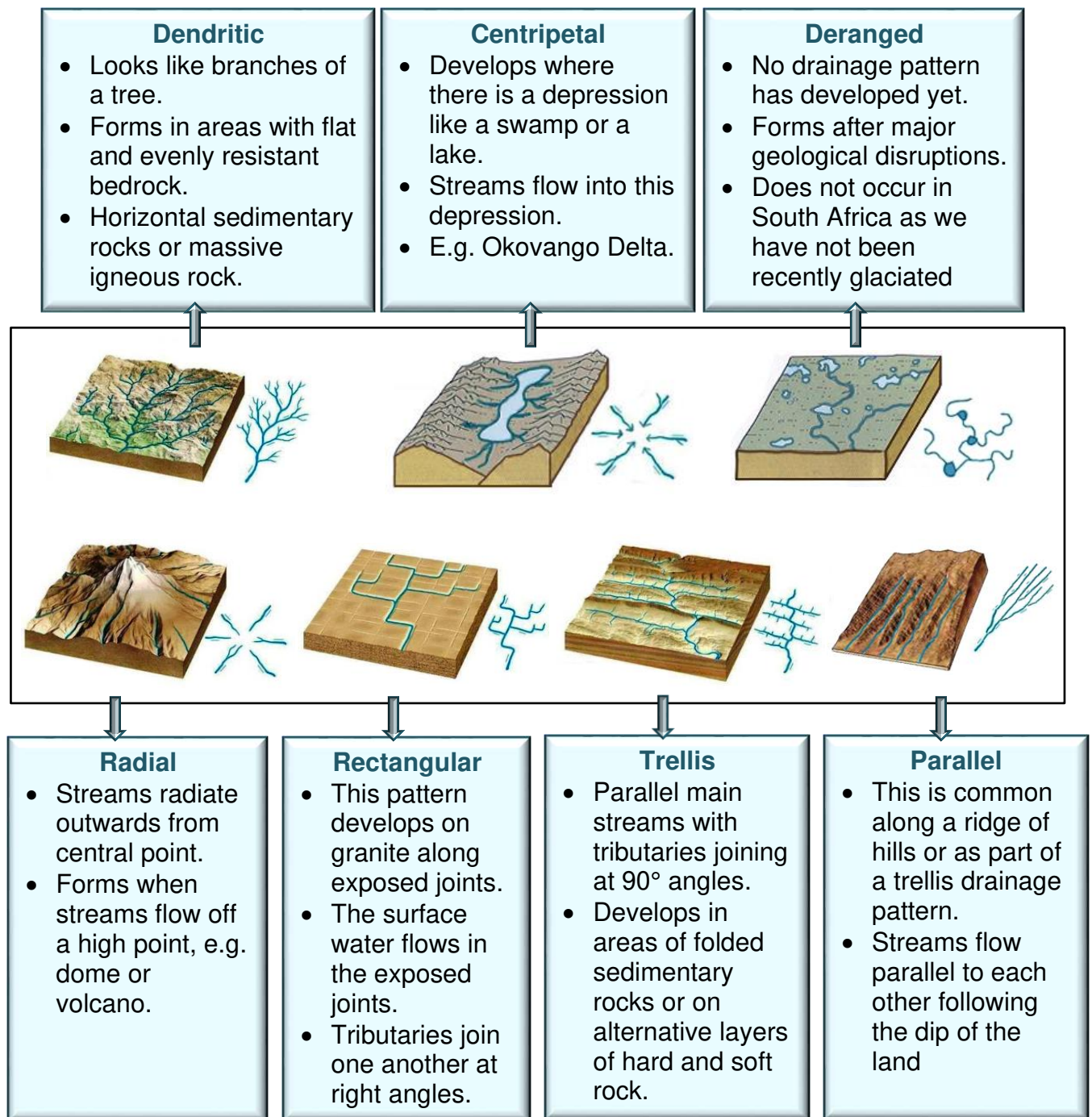
gettyimages.com



roamfarandwide.com

1.3. Drainage patterns

- Drainage patterns are formed by rivers and lakes in a drainage basin.
- They are determined by the shape of the land and the resistance (hard or soft) of the underlying rock to erosion.



geologyin.com and researchgate.net Diagrams adapted by Marilda van Niekerk

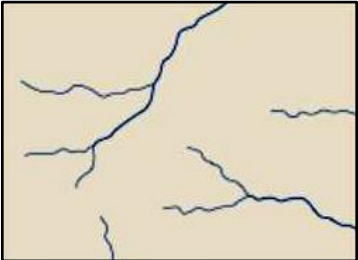
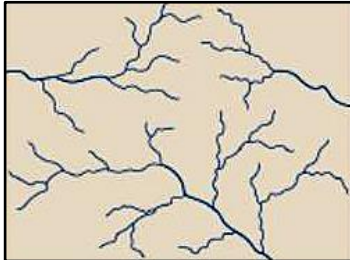
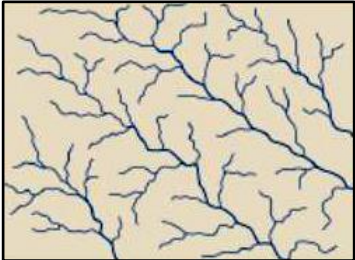
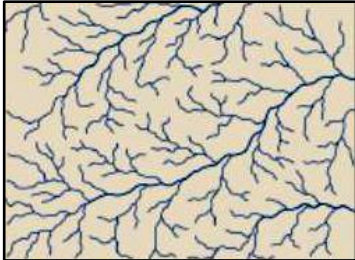
1.4. Drainage Density (stream density)

- Drainage density is the ratio between the total length of all the stream channels in the **drainage basin** and the **area** of the **drainage basin**.
- The drainage density (how many streams in a river basin) determines the drainage texture.

- Drainage density is calculated using the formula:

$$\text{Drainage density} = \frac{\text{Total length of the streams in the basin (km)}}{\text{Total area of the drainage basin (km}^2\text{)}}$$

Example: $1\,200\text{ km} \div 100\text{ km}^2$
 $= 12$

Low density  • Area with low rainfall. • The texture is coarse. • Less than 8km/km²	Medium density  • Area with seasonal rainfall. • The texture is medium. • 8-17km/km²
High density  • Area with high rainfall. • The texture is fine. • 18-24km/km²	Extremely high density  • Area with very high rainfall. • The texture is very fine. • Greater than 24km/km²

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Low drainage density



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High drainage density



alchetron.com

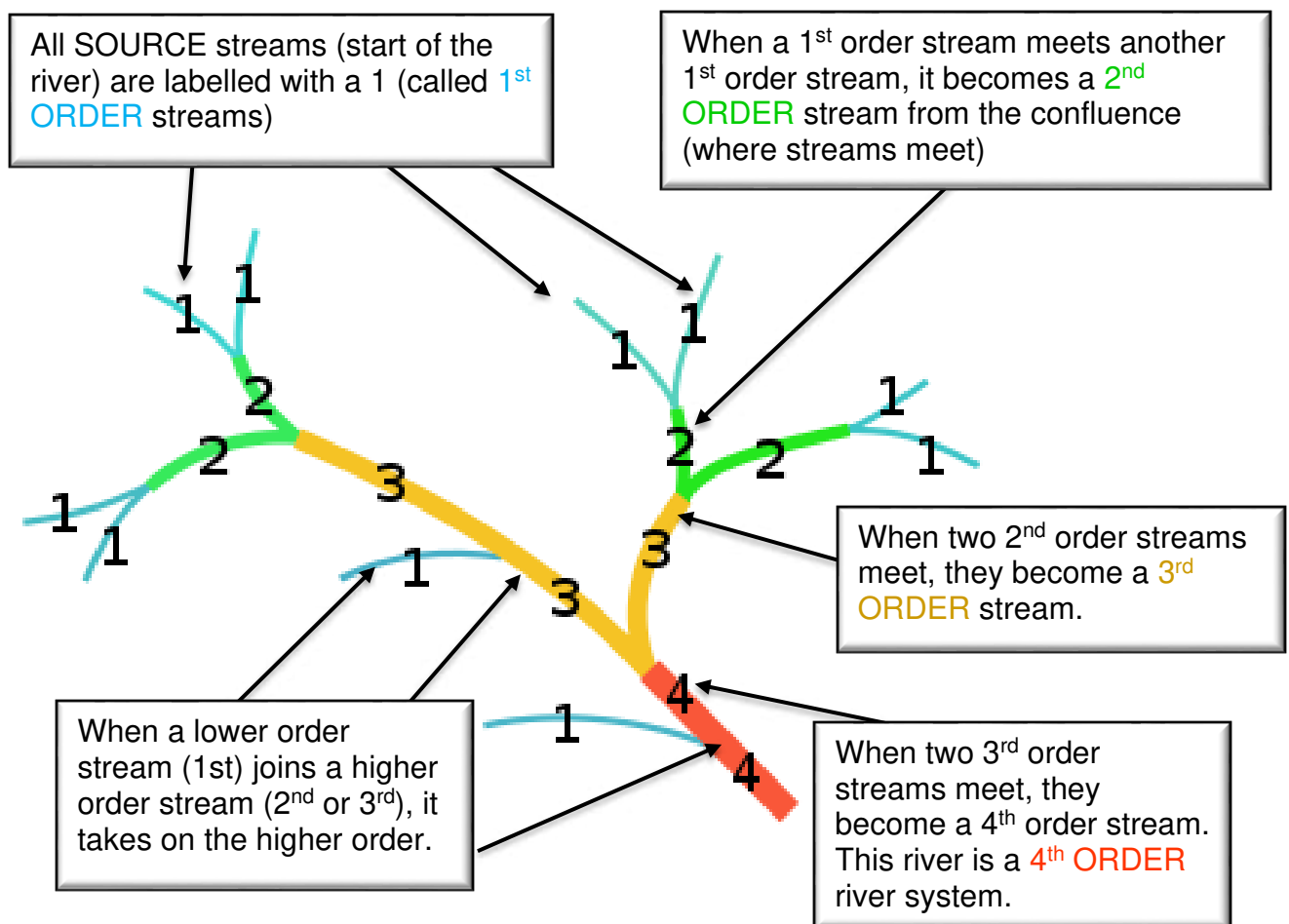
- Factors affecting drainage density:

	High Density	Low Density
Rock type	Rock that does not allow water to flow through like granite leads to more runoff and more streams.	Rock that allow water to flow through like sandstone leads to less runoff and less streams.
Vegetation cover	Where vegetation is removed nothing will hold the soil and more runoff will occur.	Lots of vegetation allows infiltration to take place and less water will runoff.

1.5. Stream order

1.5.1. Stream Order

- Stream order is the category of streams in a system.
- The higher the order of the river, the denser the drainage basin will be.



en.wikipedia.org adapted by Marilda van Niekerk

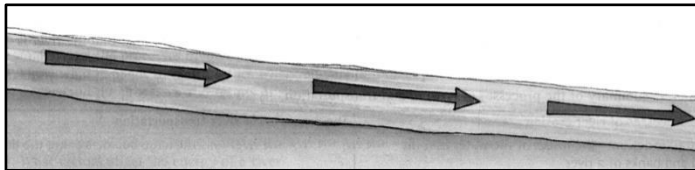
- Laws of stream order:
 - There are more streams of a lower order than of higher order.
 - The lower the stream order the steeper the gradient.
 - The lower the stream order the shorter the length of the stream.
 - The lower the stream order the smaller the drainage basin.

1.6. River discharge

- River discharge refers to the volume of water that flows down a river.
- Various flow characteristics can be observed.

1.6.1. Laminar flow:

- Laminar flow looks slow, smooth and calm.
- It flows in layers and has a greater velocity (moves faster) than turbulent flow.
- Fastest point of flow is just below the surface in the middle of the river.
- The air, sides and bottom of the river provide friction, making the middle section of the river very quick.
- There are no obstructions (rocks or branches) that will slow the water down.



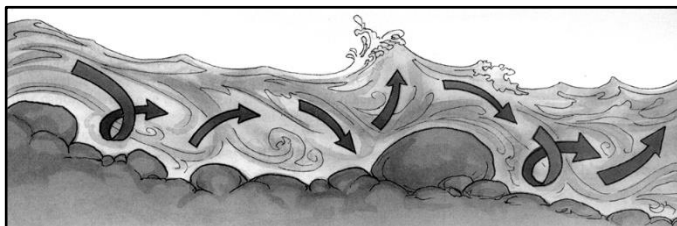
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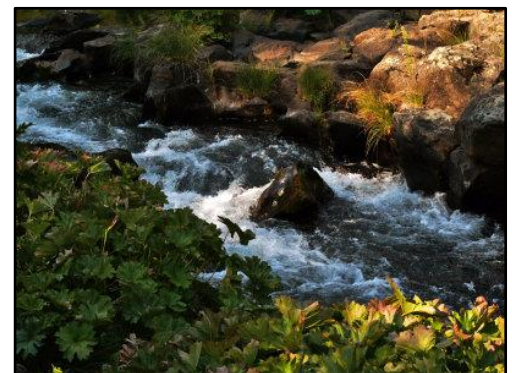
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1.6.2. Turbulent flow:

- The water flows with a bubbling motion.
- The riverbed is uneven, the water continuously changes levels and there is much internal friction.
- Turbulent flow looks fast as it bounces over rocks and other obstacles in its path, but it flows slower than laminar flow.
- A lot of the river's energy is used up getting around obstacles in its path.
- This results in lower flow speeds.
- The velocity (speed) of turbulent flow changes according to the obstacles in the water.



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2. FLUVIAL PROCESSES

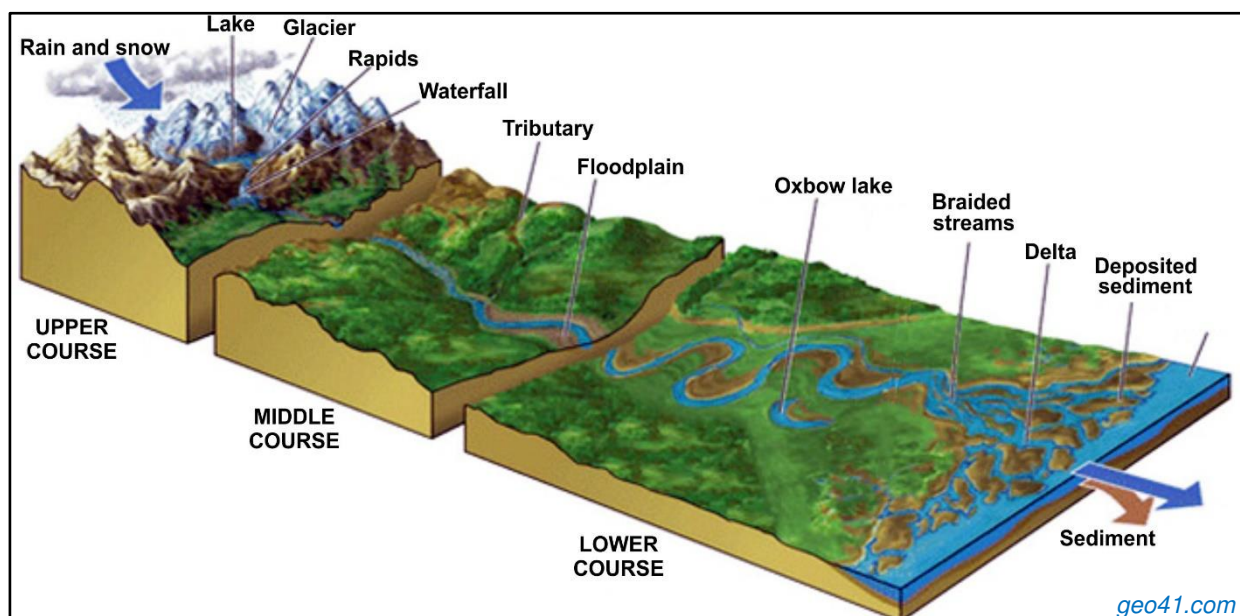
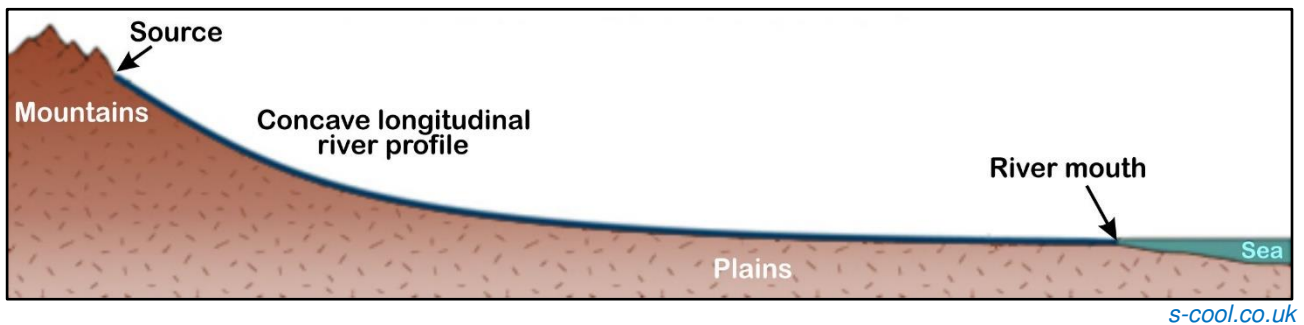
- On the way from a river's source to its mouth, a river is separated into three courses: **Upper Course**, **Middle Course** and **Lower Course**.
- Each course has its own particular characteristics determined by a number of factors, which will be studied under Fluvial Processes.
- A river uses **energy** to do its work of erosion, transportation and deposition.
- Energy moves the river's water and its sediment load from the source to the mouth.
- The total energy at a stream's disposal depends on:
 - the difference in height between the source and the mouth and
 - the volume of the stream.

2.1. River profiles

- Stream channels or valleys have been shaped by water running downstream.

2.1.1. Longitudinal profile

- A longitudinal profile is normally concave and shows us the river from its source to its mouth.
- The features carved by **fluvial processes** (erosion, transportation and deposition) on the river's journey are found in the three courses.



Upper course landforms:

- Steep sided, V-shaped valleys
- Interlocking spurs
- Waterfalls
- Gorges
- Rapids

Middle course landforms:

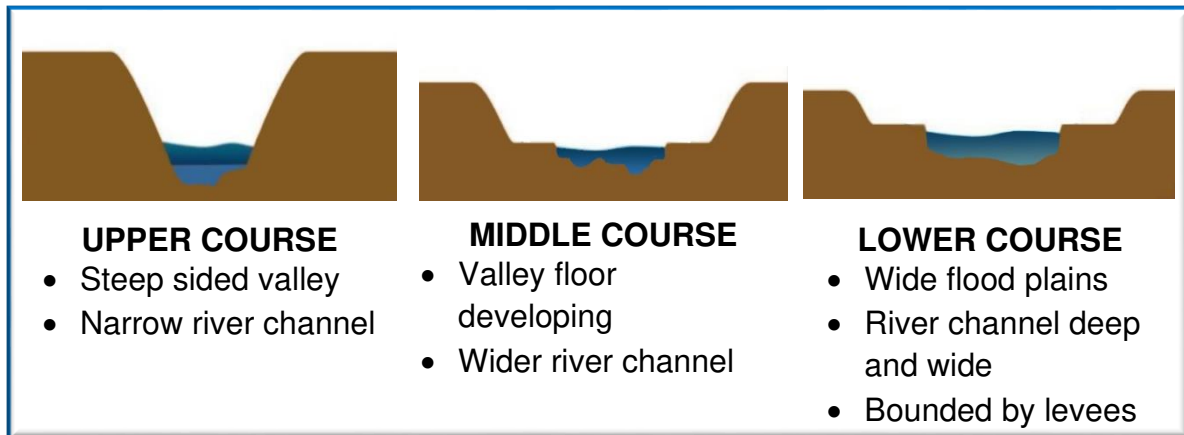
- Wider, shallower valleys
- Small floodplain
- Small meanders
- Rapids

Lower course landforms:

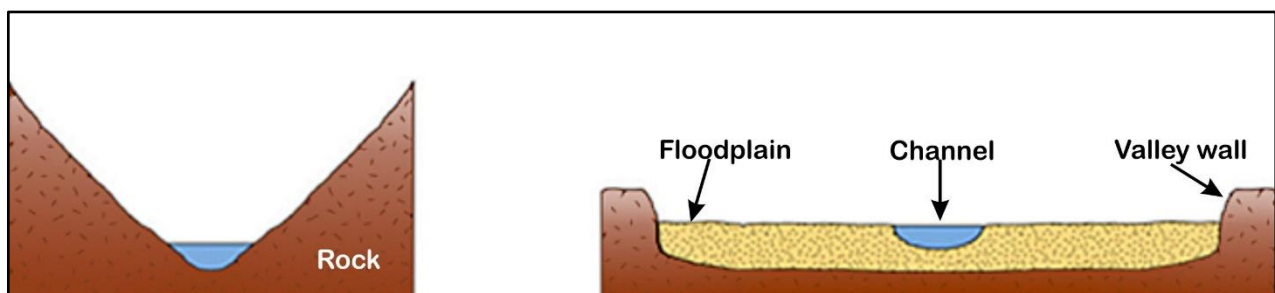
- Wide, flat-bottomed valleys
- Large floodplains
- Braided streams
- Natural levees
- Oxbow lakes
- Deltas

2.1.2. Cross or transverse profile.

- A transverse profile is a cross-section of a river's channel (view from the side)
- The profile changes as the river enters each course of the river.
- The changes in the profile are as a result of the river velocity (how fast the water is flowing) and if the river is eroding or depositing its load.



geo41.com and slideshare.net adapted by Marilda van Niekerk

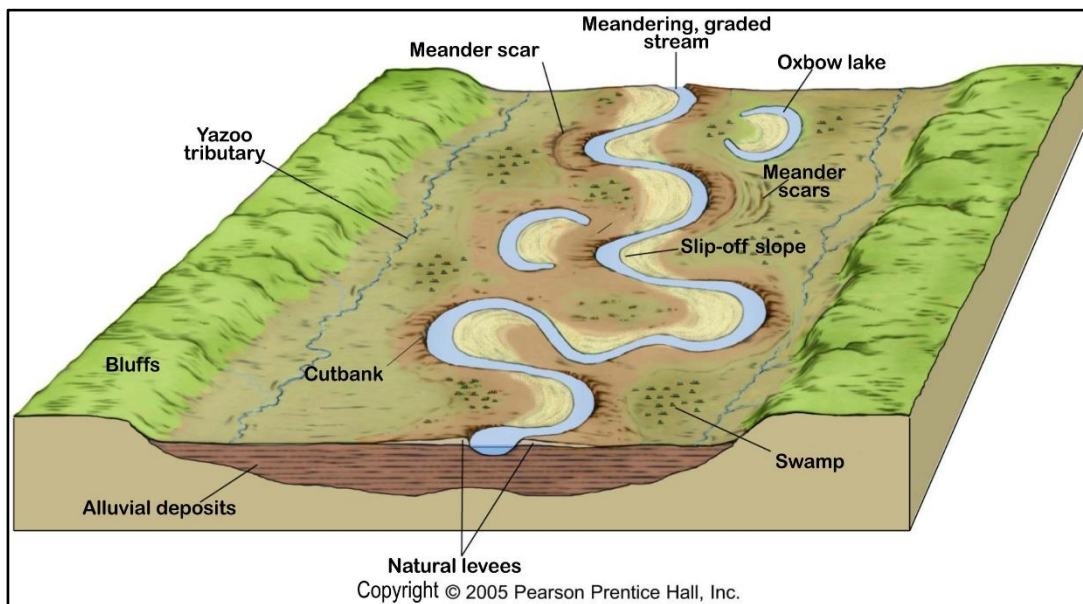


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2.2. Fluvial Landforms

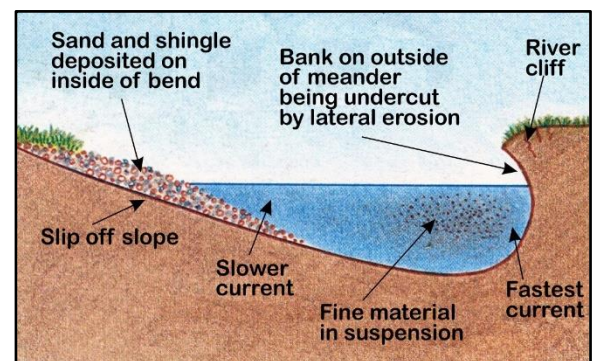
2.2.1. Floodplains

- A flood plain of a river absorbs the flood waters of a river after heavy rain or snow melt.
- Floodplains are found in the lower course of the river where the valley is widened by lateral erosion.
- During flooding the water spreads out across the floodplain and deposition occurs in the shallower water.
- Each time the river floods a layer of silt is added.
- This silt increases the fertility of the soil.

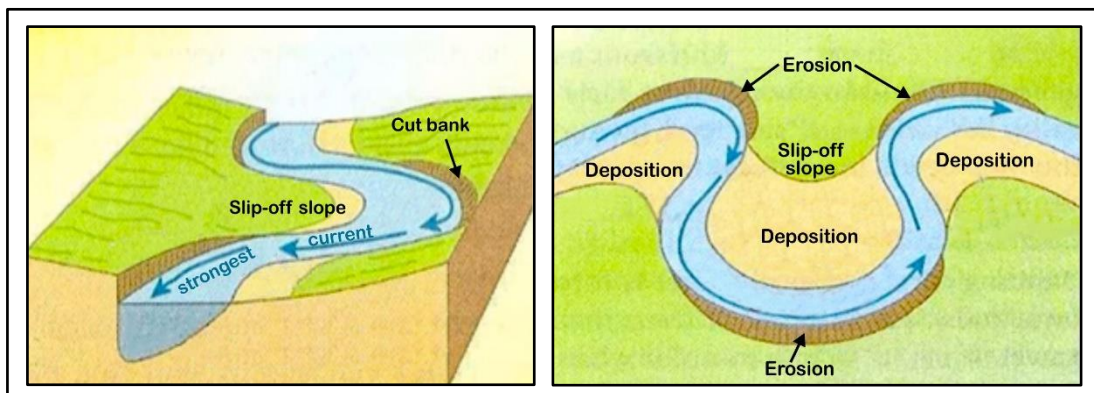


2.2.2. Meanders

- The water does not flow as fast and the river starts to curve/ meander as deposition occurs.
- The water flows fastest on the outer bend (cut bank) of the river, eroding (undercutting) it at this point.
- Deposition occurs on the inside bend (slip-off slope) as water is flowing slower here.
- The river changes from a straight channel to a channel that starts to curve, like a snake.
- This is called a meander.
- These are curves found along the course of a river, usually in the middle and lower course.
- They constantly change position and shape.



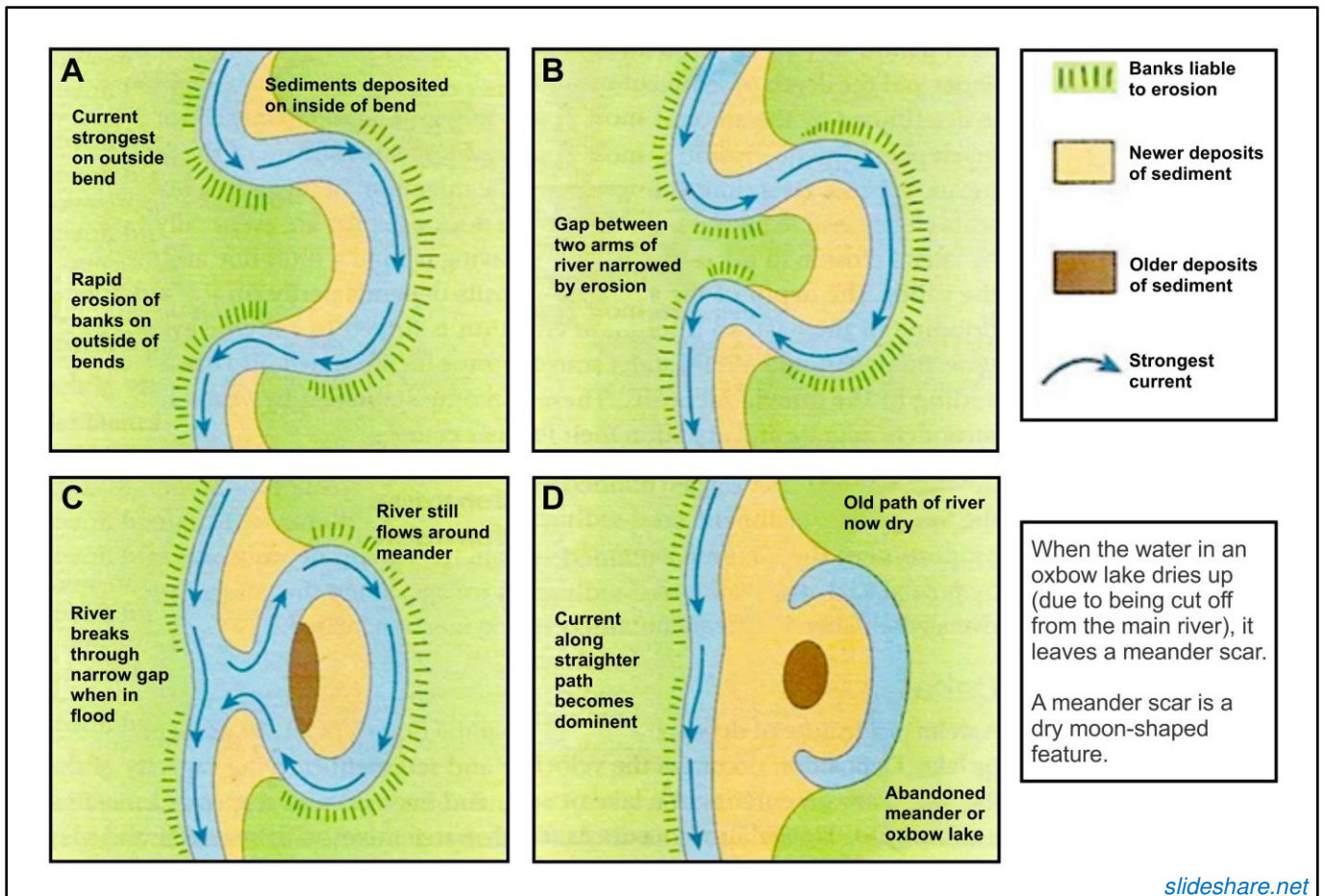
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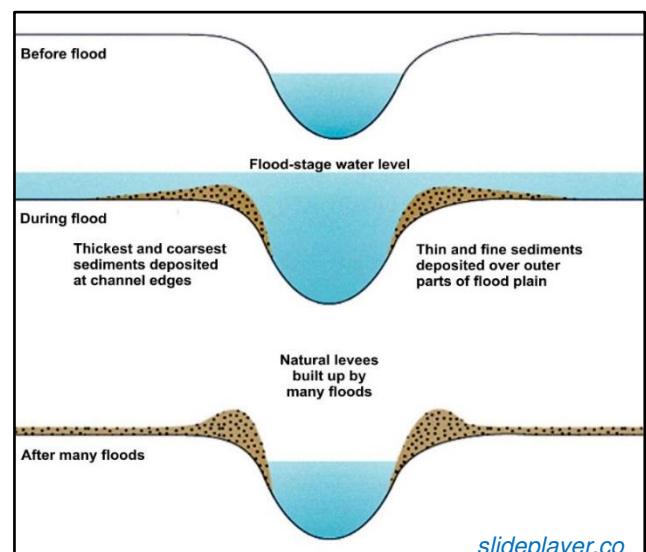
2.2.3. Oxbow lakes

- Meanders get wider and during a flood the narrow section can be bridged.
- The abandoned meander loop becomes an **oxbow lake**.
- Such lakes do not exist for long because they are silted up during successive floods and only **meander scars** remain.



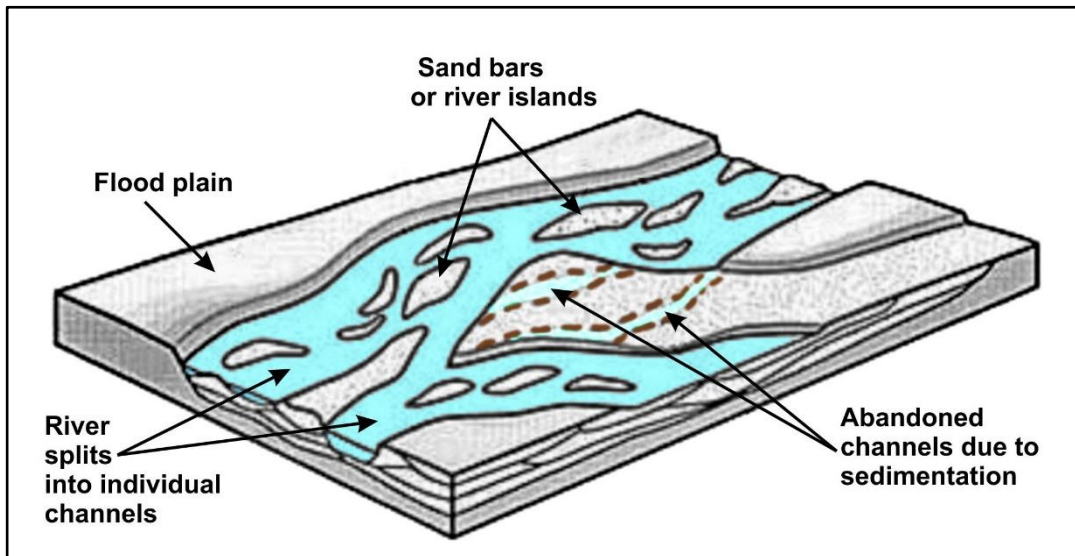
2.2.4. Natural levees

- During flooding the coarsest material is deposited first.
- Deposition starts to build up natural walls on the banks of the river, called a natural levee.
- Levees can be artificially strengthened to act as flood banks.
- If the river breaks through its levees, widespread flooding occurs.



2.2.5. Braided streams

- This type of stream channel occurs where the channel floor is flat and wide.
- When in flood, the river covers the sandbars and islands.
- After the flood, deposition occurs in the riverbed to form sand banks.
- The stream then divides into several different inter-connected channels separated by sandbars.
- In arid regions there is often so much deposition that the river blocks its own course.

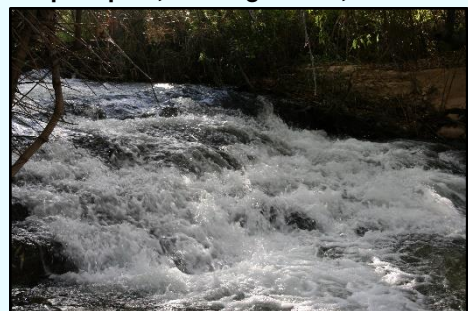


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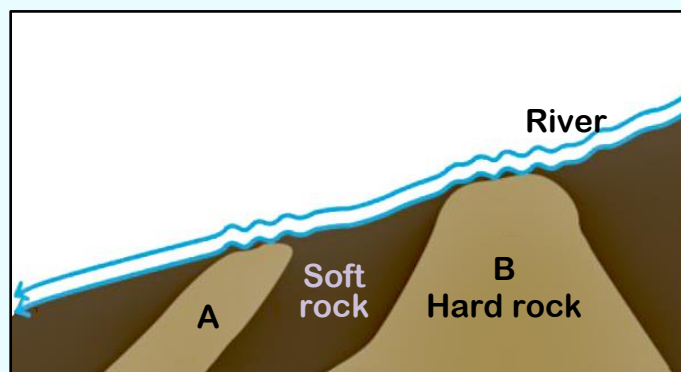
2.2.6. Rapids

- Rapids develop when a stream flows over bands of hard rock which dip upstream (**A**) or outcrops of hard rock (**B**). See diagram below.
- Flow is fast and turbulent.
- The riverbed has a steep gradient and is normally quite rocky.

Popa rapids, Cubango River, Namibia



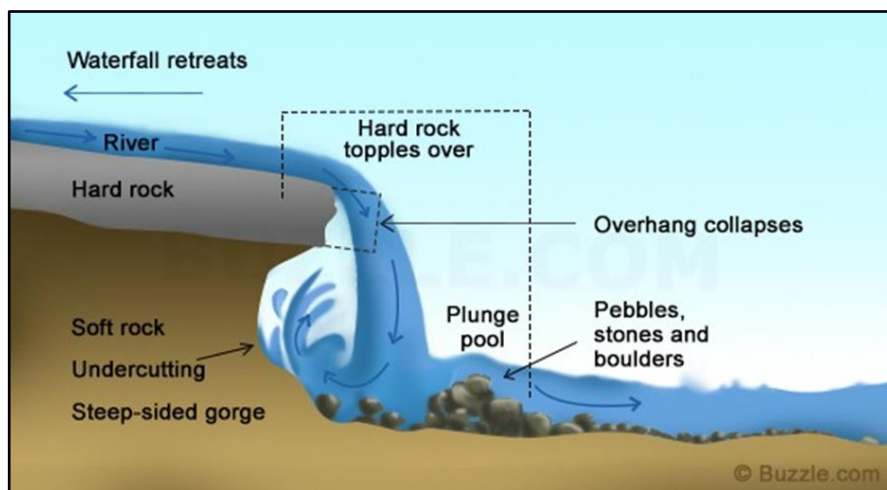
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2.2.7. Waterfalls

- A waterfall develops when a river, flowing over resistant rock such as a sill, meets a band of softer rock.
- Occur in the upper course of the river which is steep and where erosion happens quicker.
- The river erodes the softer rock faster than the harder rock.
- The hard rock will create a waterfall with a plunge pool.
- In time the overhanging hard rock will break off and collapse.
- The deep plunge pool forms because of the hydraulic action of the water and abrasion by the rocks swirling around in the plunge pool.



buzzle.com

The Iguassu Falls, border of Argentina and Brazil



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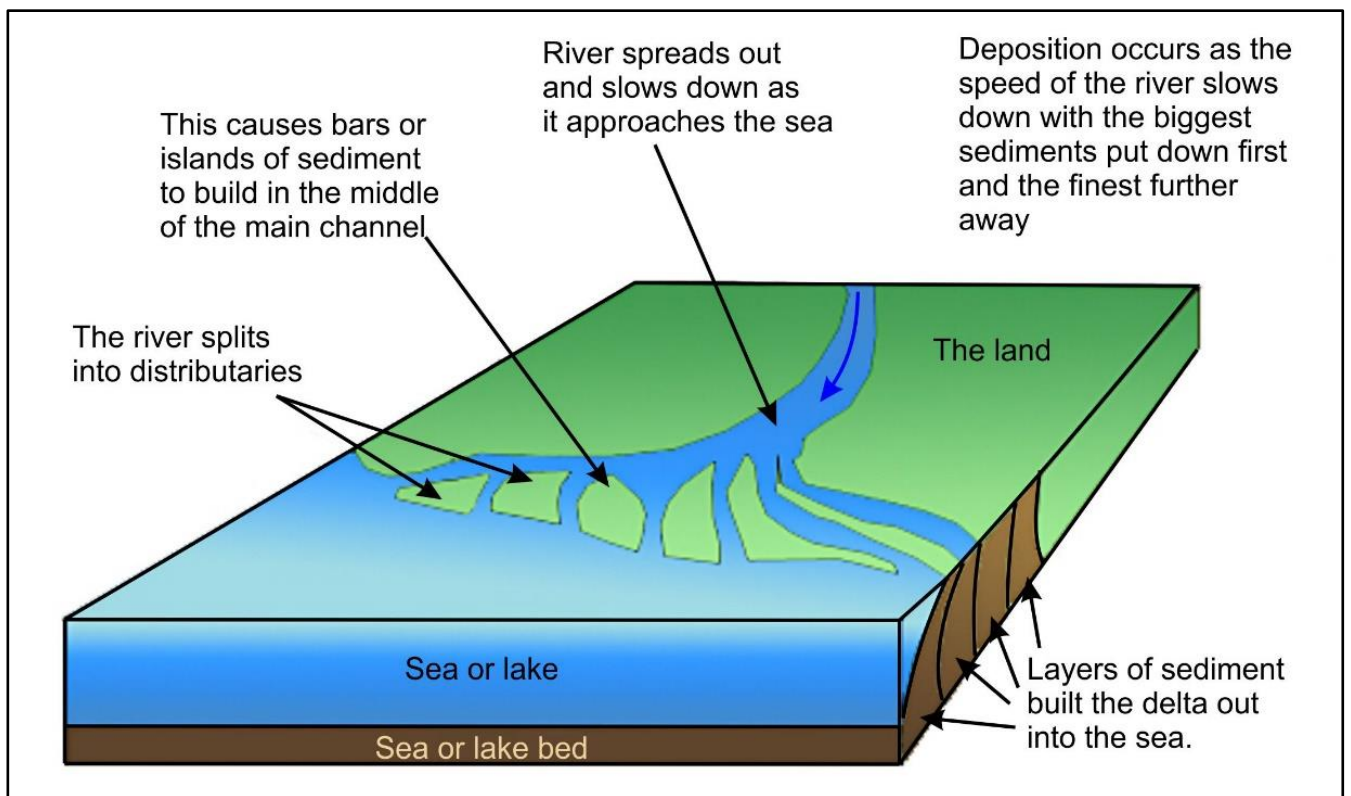
The Victoria Falls, border of Zimbabwe and Zambia



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2.2.8. Deltas

- Large rivers have the energy to carry huge amounts of material to the sea.
- A river's velocity is checked when it flows into the still waters of the sea or a lake.
- Deposition occurs and a delta is formed if the other necessary conditions are favourable.
- Layer upon layer of sediment is deposited until it builds upwards and outwards to form a roughly triangular delta.
- The river divides into smaller channels, called **distributaries**, which cross the delta to reach the sea.

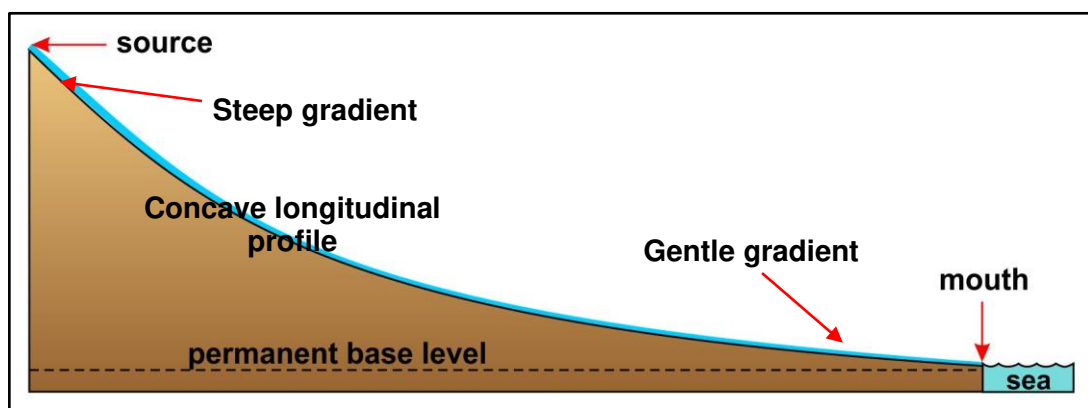


coolgeography.co.uk adapted by Marilda van Niekerk

2.3. River Grading

2.3.1. Graded river

- A graded river is in a state of **equilibrium / balance**.
- A **graded stream** is one which has just enough energy to carry its water and its load without eroding its riverbed or depositing its load.
- Such a stream will have a **concave longitudinal profile** as this shape is best suited to allowing the stream to attain this state of **balance**.



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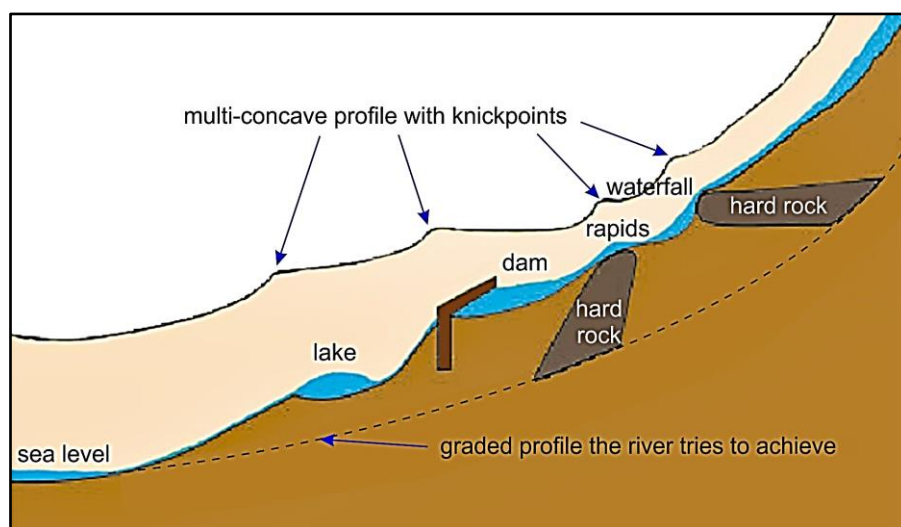
- This balance is very rarely achieved and may only occur in certain sections for short periods in a river.
- Grading most commonly occurs in the lower section of a river where the stream is flowing on sediment.
- This sediment allows the river to adjust itself to changing circumstances.

2.3.2. Over-graded river

- An over-graded river has more energy than is required to move its water and its load and thus it will be able to erode its channels.

2.3.3. Under-graded river

- It is possible for some parts of a river to be graded while others are not.
- If a river does not have enough energy to carry its water and load, deposition will take place. it is called an under-graded river.



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- This sediment allows the river to adjust itself to changing circumstances.
- This is a river with a multi-concave profile.
- Rivers are seldom graded across their entire course.
- Knickpoints or dams can interrupt a smooth profile and change the angle of the slope.
- The knickpoints and dams are called temporary base levels and they result in a multi-concave profile.

Base levels of erosion

- The lowest level to which a river can erode is called the **permanent base level**.
- Sea level is the permanent base level because the river cannot erode downwards any further.

Temporary base levels

- They are often present and they prevent the stream from attaining a state of grade.
- Dams and resistant rock masses prevent the stream from attaining a concave longitudinal profile.
- Temporary base levels can be eroded away.

Temporary base levels of erosion result in an ungraded river profile

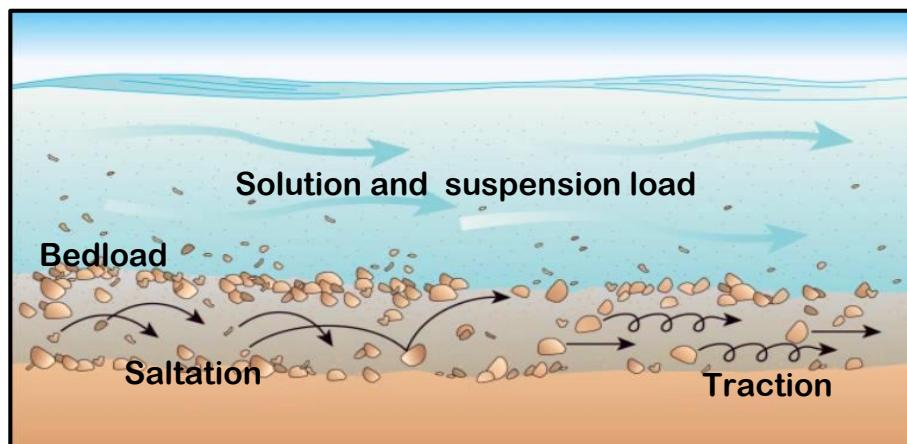
- The resistant rocks and the dam are temporary base levels of erosion.
- As a result, the longitudinal profile of the river does not have a concave shape and the river is said to be ungraded.

2.4. Erosion, transportation and deposition

2.4.1. Definitions

- **Erosion:** This is the lifting or loosening of a particle by the water.
- **Transportation:** This is the transport of the particle in the stream. This can only occur if the velocity of the stream is high enough to transport the particle.
- **Deposition:** This is the deposition of a particle on the streambed. This occurs when the velocity of the stream is no longer sufficient to carry the particle.

2.4.2. Stream load



earthsci.org

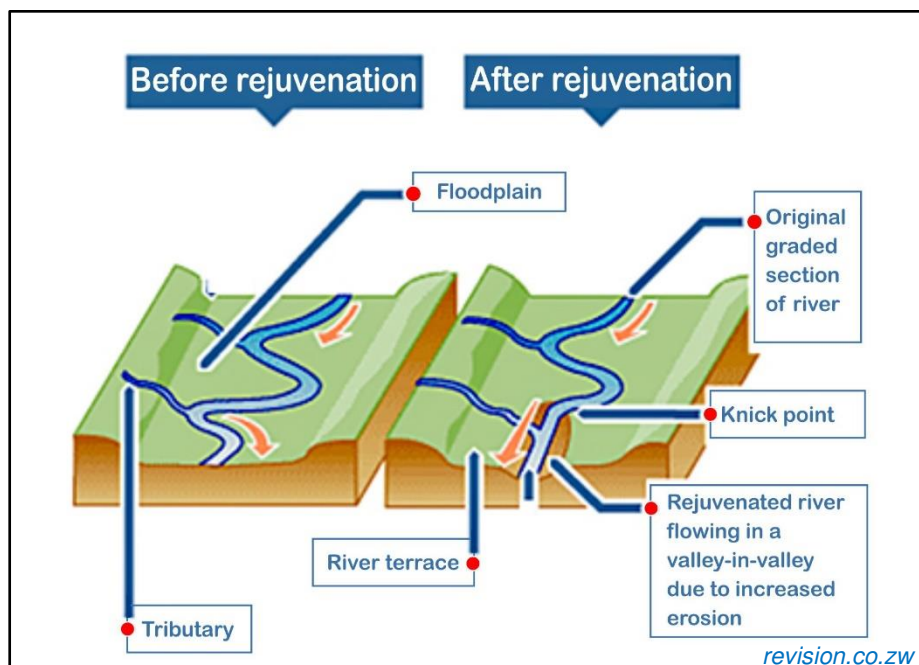
- **Traction:**
Heavy, large rocks are rolled, pushed or bumped over the riverbed. This is called the traction load and forms part of the bottom load.
- **Saltation:**
Pebbles bounce off the riverbed. This is called the saltation load and forms part of the bottom load.
- **Suspension:**
Smaller particles of sand and silt hang in the water and are moved through the water. It's the suspension load, and it's this load that makes the river muddy and gives it a brown colour.
- **Solution:**
Minerals that can dissolve in the water are transported in this way. The solution load is invisible.

2.5. Rejuvenation

- Stream flow ends when a river enters a standing water mass such as a lake or the sea.
- This water represents the lowest level to which a stream can erode - the stream's **base level of erosion**.
- If it is a lake then it is a **temporary base level**.
- The sea is the ultimate or **permanent base level**.

2.5.1. The process of rejuvenation

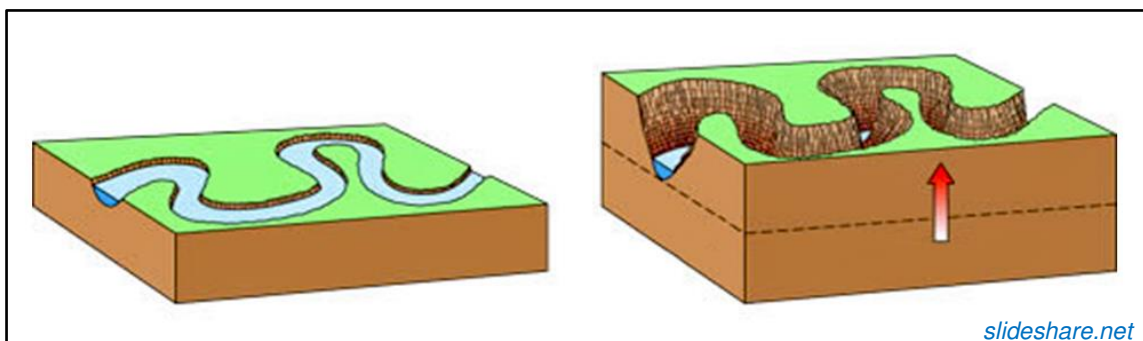
- River rejuvenation can occur because of:
 - A worldwide drop in sea level probably because of the onset of an ice age.
 - Uplifting of the land by internal geologic forces (isostasy).
 - A significant increase in rainfall.
 - A rapidly flowing tributary that joins the main one.
 - After river capture has taken place.
- Any change in base level will have an influence on the gradient of the river's profile – an important source of energy.
- If sea level has effectively dropped then the river will have more energy – it will have been **rejuvenated**.
- **River rejuvenation** takes place when geomorphic processes cause an increase in the river's speed and erosive power.
- The river erodes a new valley into an old one.



2.5.2. Features Resulting from Rejuvenation

a) Incised rivers and meanders:

- Incised meanders develop when a meandering stream has increased energy.
- The river is able to incise its valley faster than the valley widens out.
- This is a meander that has eroded downwards allowing downcutting (vertical erosion).

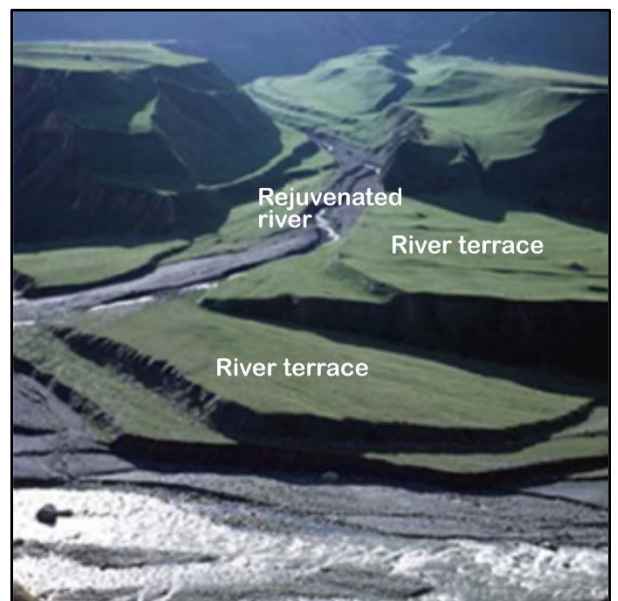
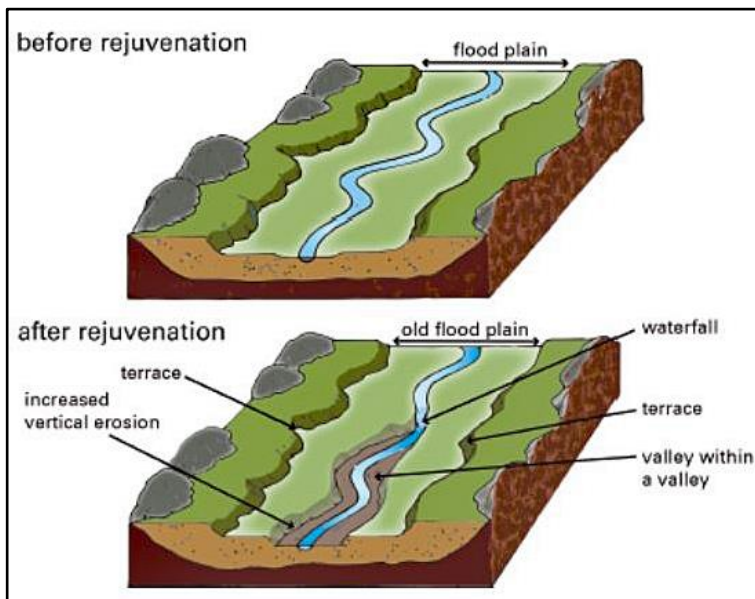




hssgeoinfo.wordpress.com

b) Terraces

- When a river that was flowing in a wide valley floor experiences rejuvenation a new valley is carved into its own floodplain.
- This produces steps or terraces on either side of the valley.
-

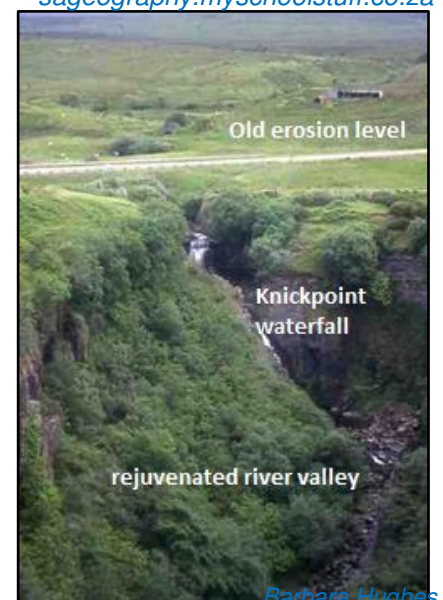


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sageography.myschoolstuff.co.za

c) Knickpoints

- A sharp change in stream profile is seen after rejuvenation.
- This sharp change is called the **knickpoint** and is at the spot at which the new erosion level intersects the old.
- Often there is a waterfall at such a point.
- As the new erosion level works its way upstream, the knickpoint also moves steadily up the river's profile until it disappears, and the river has a smooth concave profile once more.

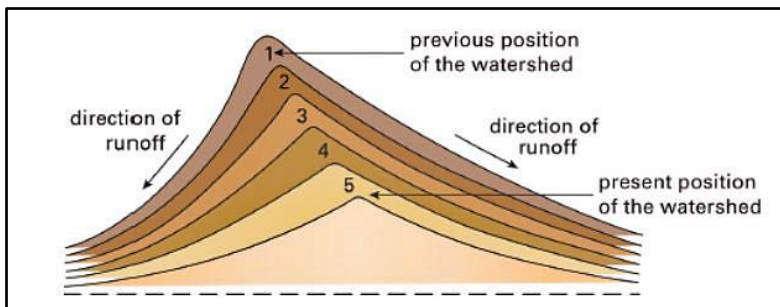


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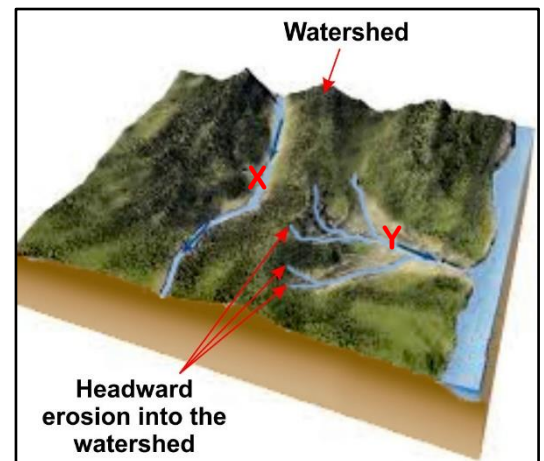
2.6. River Capture / Stream Piracy

2.6.1. Abstraction

- During stream capture the headwaters of a more energetic stream headward erodes through the watershed (this process is called **abstraction**) and captures the water of the slower flowing river.
- Abstraction refers to the lowering and moving of the watershed (position 1 to 5 on diagram on the next page) in the direction of the less energetic stream through **headward erosion**.



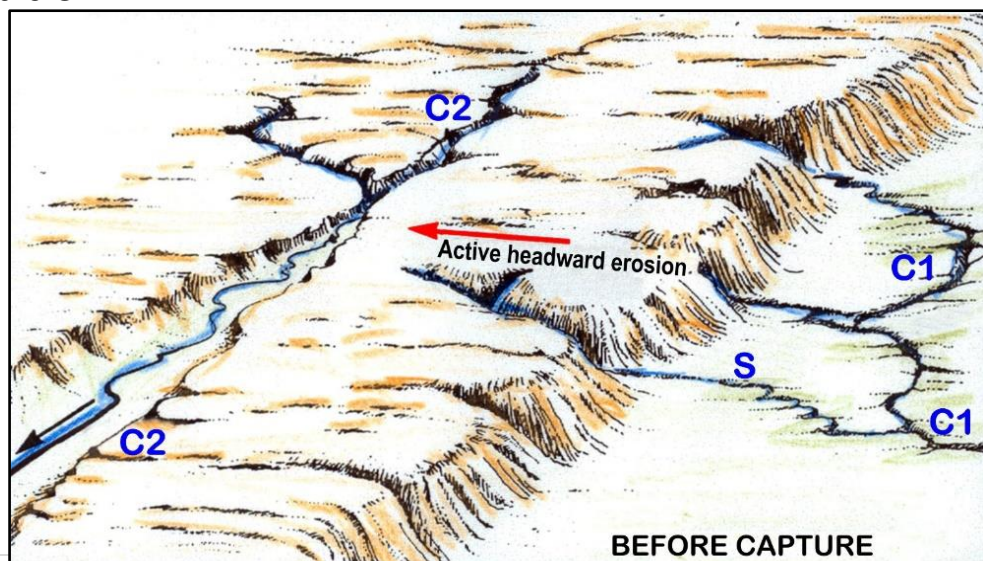
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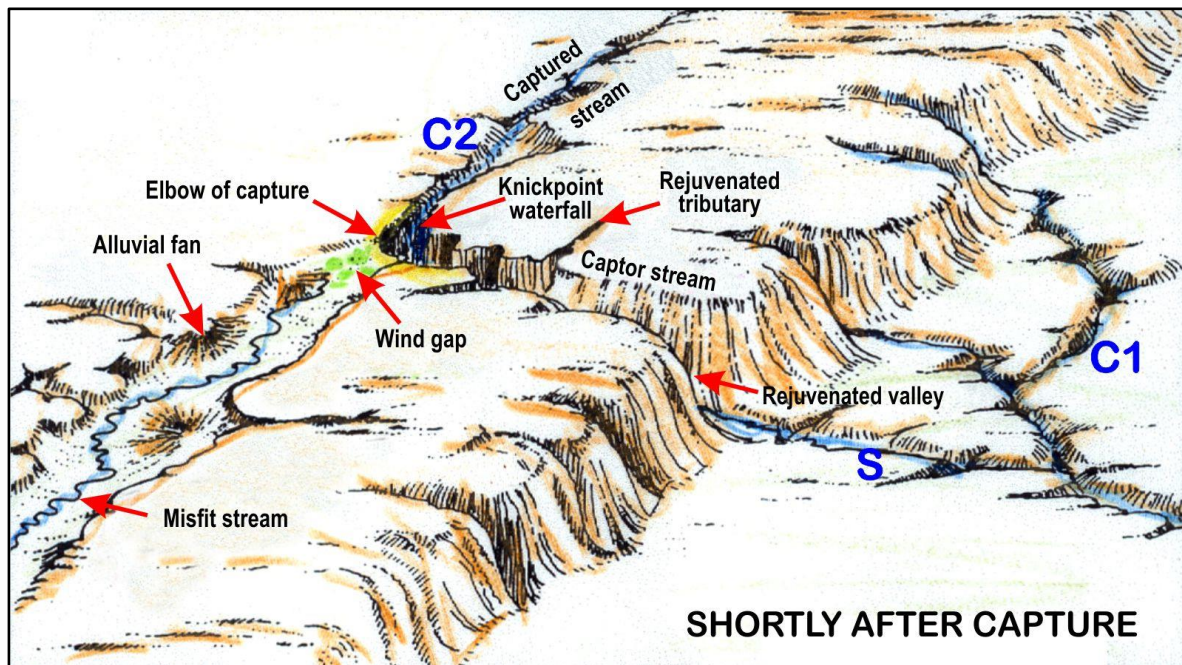
pitt.edu

2.6.2. The process of capture

- Stream Capture or Stream Piracy occurs when a tributary stream with a high capability for erosion cuts through its watershed and intercepts a stream in a neighbouring drainage basin which is on a higher level.
- The captured river loses the water from the captured tributary and conducts less water to the sea.
- **Why can one stream capture another? It may:**
 - be on the windward side of the watershed and will therefore have more energy from the rain that it receives.
 - have a **steeper gradient** which will also give it more energy.
 - be eroding quickly through **weak or fractured rock**.
- **C1** and **C2** are parallel flowing streams but **C1** is at a lower level than **C2**.
- **S** is a tributary of **C1**.
- Tributary **S** has been able to erode back into its valley by **headward erosion** and capture **C2**.



- The water from **C2** will now flow into **S** and then into **C1**.
- This will rejuvenate **C1** as it has more energy.
- **C1** will start to incise its valley.



Window on the World, Standard 10 adapted by Marilda van Niekerk

2.6.3. Features of capture

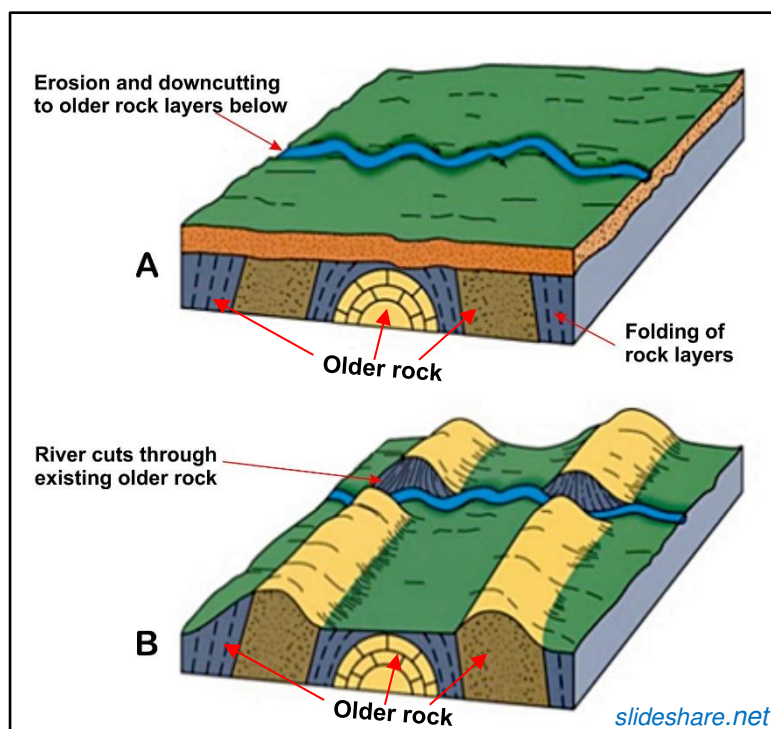
- The lower section of **C2** has lost much of its volume and it appears too small for its valley – **a misfit stream**.
- The sharp bend where **S** has captured **C2** is called the **elbow of capture**.
- Between the elbow and the misfit stream is a dry valley with gravel deposits called the **wind gap**.
- This process can be repeated until several parallel flowing rivers have had their headwaters captured, making **C1** the dominant river in the region.

2.7. Superimposed and Antecedent Drainage Patterns

- A river's drainage pattern is usually determined by the underlying geology. (Remember how dendritic and trellis drainage patterns developed)
- However, in some cases the present-day drainage pattern bears no relation to the underlying geology and relief of the landscape.
- This happens because of the removal by erosion of the rocks on which pattern was developed.
- The river is now flowing on very different rocks to the ones on which its drainage pattern developed.
- Superimposed and antecedent streams are older than the structures through which they flow.

2.7.1. Superimposed Drainage Pattern

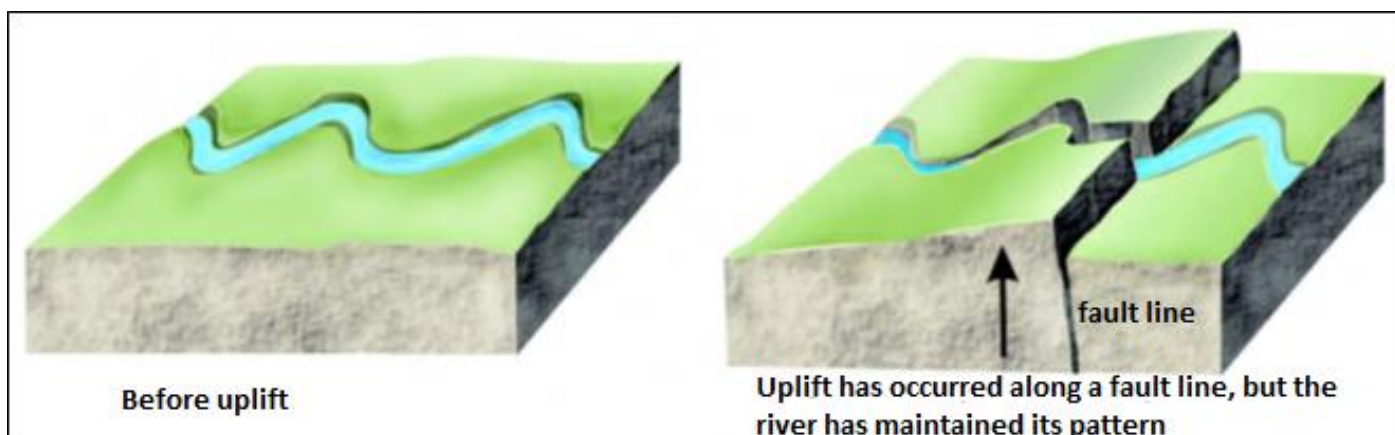
- A stream may develop a pattern on a particular type of geology.
- **Once these rocks have been removed** and new rocks exposed on the surface then the streams will maintain their original pattern and **impose** this pattern on to the new surface geology.
- The development of a Superimposed Drainage Pattern:



- The landscape in **image A** shows a river on a flat plateau with a folded rock structure below the surface.
- After years of downward erosion, shown in **image B**, the river meets the older folded rock.
- Instead of finding a path around the exposed rock, it carves its way through the older rock.

2.7.2. Antecedent Drainage Pattern

- An antecedent drainage pattern existed on an earlier landscape that was **subsequently raised**.
- The stream was able to maintain its original course, in spite of the uplift.
- The streams cut through the obstacle as it was formed.



Via Afrika Geography Grade 12

3. DRAINAGE BASINS AND CATCHMENT MANAGEMENT

- Population growth, the expansion of agriculture and industry and increasing urbanization mean that more and more fresh water is needed.

3.1. Importance of managing drainage basins and catchment areas

- Only 2% of the Earth's water supply is fresh and available as well as suitable for human use.
- Fresh water comes from dams, rivers and underground sources.
- South Africa does not have a lot of water and is regarded as a 'water-scarce' country.
- With a growing population, agriculture and industry is expanding which means more and more water is needed.
- Refer to page 158 of the Via Afrika textbook

3.1.1. Impact of people on drainage basins and catchment areas

- Human activities have an effect on the water that flows through a drainage basin.
- The higher the population the higher the demand on the water resources of a country.
- By 2025 the demand for clean domestic water in South Africa will increase by 10%.
- The following aspects of the drainage basin are affected by humans:
 - The nature and volume of the water that flows in a river.
 - The land surface that the water flows over before it reaches the river.
 - The quality of the water under the surface that reaches the river.
- Refer to page 159 of the Via Afrika textbook

3.1.2. Flood control

- Flooding of a channel is a natural process that can be beneficial it renews the fertility of a flood plain through the deposition of alluvium.
- Flooding is also hazardous because of loss of life and damage to property.
- Floods can be controlled in the following ways:
 - Enlarge the channel so that it can hold more water.
 - Build embankments on either side of the channel to prevent the spread of floodwater.
 - Build extra channels to take floodwater away from towns.
 - Cut through meander loops.
 - Build reservoirs near the source of the river to store water and control peak discharge.
 - Prevent building in areas where flooding is most likely, such as on flood plains.
 - Maintain vegetation and permeable surfaces.
 - Conserve wetlands; restore damaged or drained wetlands.



pngguru.com

3.2. GIS and catchment management (page 162 Via Africa)

- GIS with its capability to store and manipulate data helps catchment managers to analyse spatial information about drainage basins.
- Data can be presented as a series of overlays that include:
- Watershed area; stream channel network; vegetation maps; satellite images; older spatial data to help with comparison with current data; soils
- Through the analysis of GIS spatial data, a 3D terrain model can be developed. (see Fig 141, page 163 in Via Afrika)
- GIS data can also be used to decide on the sites of dams.

Theewaterskloof Dam, Western Cape, South Africa - 2018



abc.net.au