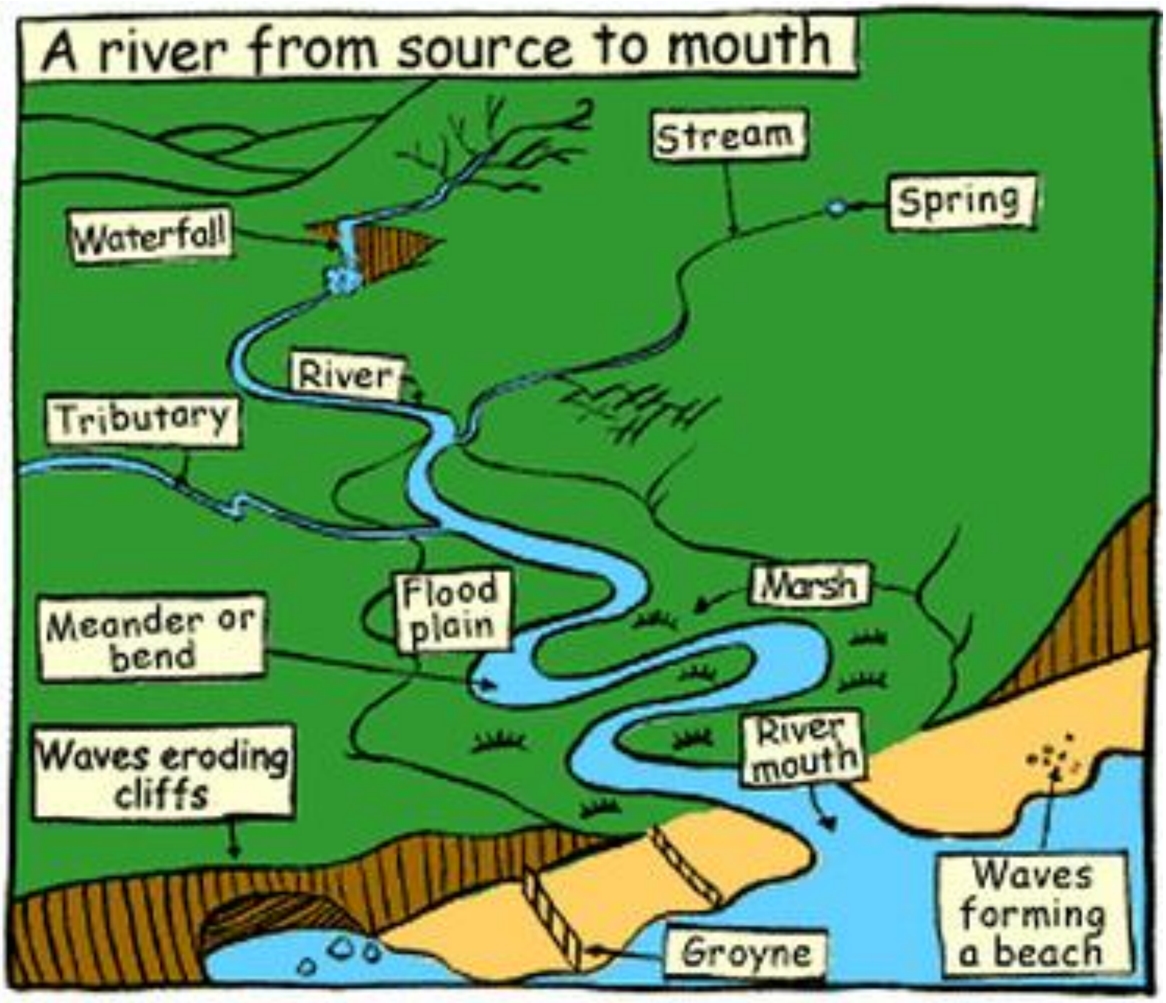
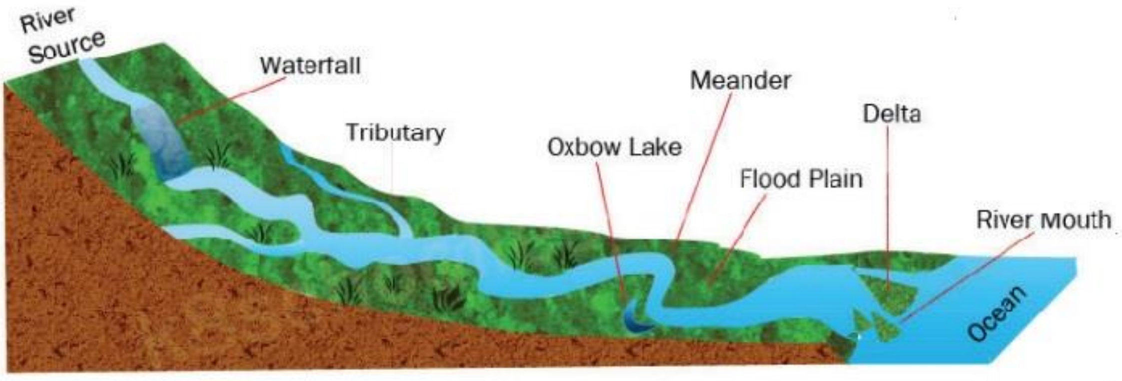
Higher 2 (9173)	Tropical Environments	TMJC
C2 Lecture 10	Channel Morphology and Fluvial Processes	2025





What influences fluvial processes?	• Fluvial processes: – erosion: corrasion, corrosion, cavitation – transportation: traction, saltation, suspension, solution – deposition • Factors influencing fluvial processes: – natural factors – human factors

WHAT IS CHANNEL MORPHOLOGY?

1. Channel morphology refers to the form (size and shape) of the river channel.

2. There are various terms used to describe the morphology of a river channel:

   a. The **width** of the river channel is the horizontal distance across the river from the water's edge of one bank to the other, perpendicular to the general direction of flow of water (Fig. 1).

   b. The **depth** of the river channel refers to the vertical distance from the water surface to the channel bed measured at a particular point of the river (Fig. 1).

   c. The river **slope (gradient)** is the inclination of channel bed with reference to horizontal.

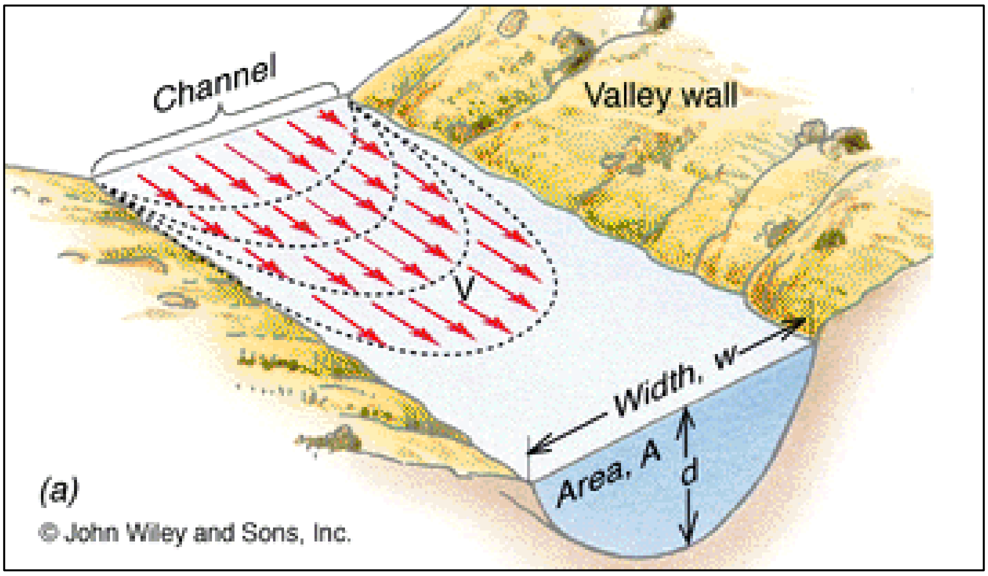


Fig. 1: Width, cross-sectional area and depth

   d. The **width-depth ratio** refers to the ratio of the bankfull width by the average depth of the river channel. The higher the ratio, the more inefficient the river channel, as a lot of energy is lost through friction with the channel bed and bed load transport.

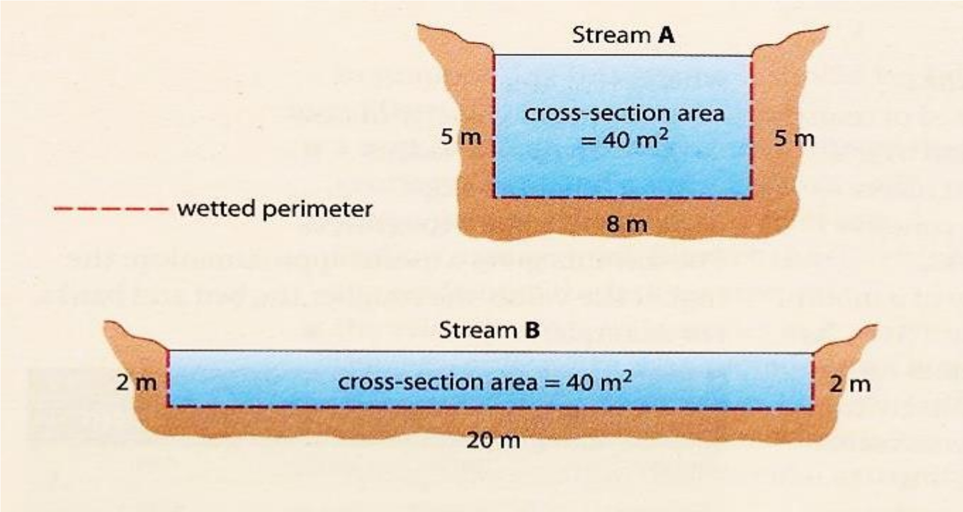
   e. The **<u>wetted perimeter</u> refers to the length of the channel cross-section that is in contact with the water in the channel.**

   f. The **cross-sectional area** of a river channel refers to the area in square metres of a vertical slice across the river channel at any point (Fig. 1).

   g. The **<u>hydraulic radius</u>** of a river channel **is the proportion of water that comes in contact with the river channel**. It is <u>a measure of **a channel's efficiency**</u> (i**.e. how well a channel is able to allow water to flow within it)**. The larger the hydraulic radius, the more efficient the channel (Fig. 2).

Calculating the hydraulic radius:

Hydraulic radius (Rh) = cross-sectional area (m^2) / wetted perimeter (m)



Wetted perimeters	**Hydraulic radius**
Stream **A**: $5 + 5 + 8 = 18$ m	Stream **A**: $\frac{40}{18} = 2.22$ m
Stream **B**: $2 + 2 + 20 = 24$ m	Stream **B**: $\frac{40}{24} = 1.66$ m

Fig. 2: Contrasting the hydraulic radius of two streams with similar cross-sectional areas but different wetted perimeters. (**The larger the hydraulic radius, the more efficient the channel i.e. Stream A is thus more efficient than Stream B)**

(B) HOW DOES THE CHANNEL MORPHOLOGY ALONG A RIVER VARY?

1. In general, the morphology of a river channel changes along a river.

    a. The **long profile** of a river (Fig. 3) shows how the gradient (slope) of a river channel varies from the source to the mouth of the river.

        i. In the upper stage of a river's course, the river's gradient is steep but it gradually flattens out as the river erodes towards its base level.

        ii. One thing to note is that the long profile of a river shows many irregularities called **knickpoints**. These are points where the gradient of the river changes suddenly and can be caused by features like waterfalls or lakes, where the geology of the river changes and differential erosion takes place.

        iii. Knickpoints can also be the result of rejuvenation, where the base level of the river falls, giving it some extra gravitational potential energy to erode vertically.

        iv. Theoretically, rivers should achieve a condition of equilibrium, or grade, and erode the irregularities. Throughout the long profile of a river, deposition and erosion are balanced, meaning that, given enough time, the river's long profile would become a smooth, concave, graded profile and all the knickpoints would be eliminated as they are either eroded or filled in by deposition.

v. However, it would take a long time for a river's long profile to become a graded profile though so the idea of a graded profile is, essentially, theoretical as it does not really occur in nature.

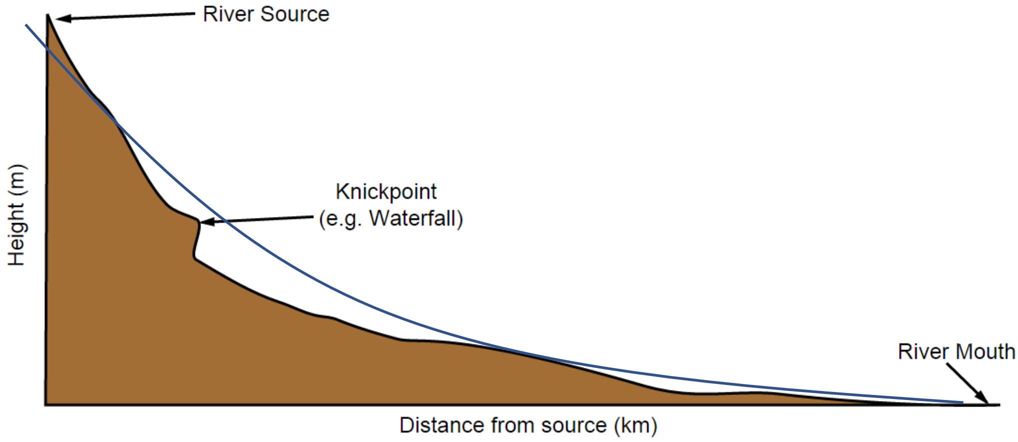


Fig. 3: Long profile of a river

b. The **cross profile** of a river (Fig. 4) near the source at the upper valley is generally V-shaped, and the channel becomes deeper and wider with increasing distance downstream, with the channel being widest and deepest near the mouth.

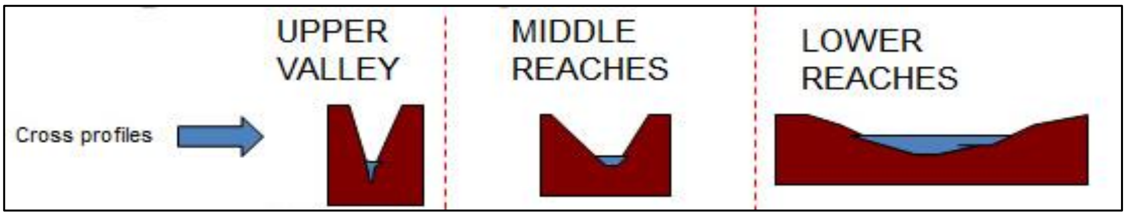


Fig. 4: Changes in cross profiles along a river

c. The change in channel morphology along a river can be further illustrated using Schumm's model (Fig. 5).

i. According to the model, from the source to the mouth of the river, the gradient (slope) of the channel will decrease. On the other hand, channel width and channel depth will increase.

ii. This is caused by the greater amount of energy available by the river downstream, as discharge and velocity increases.

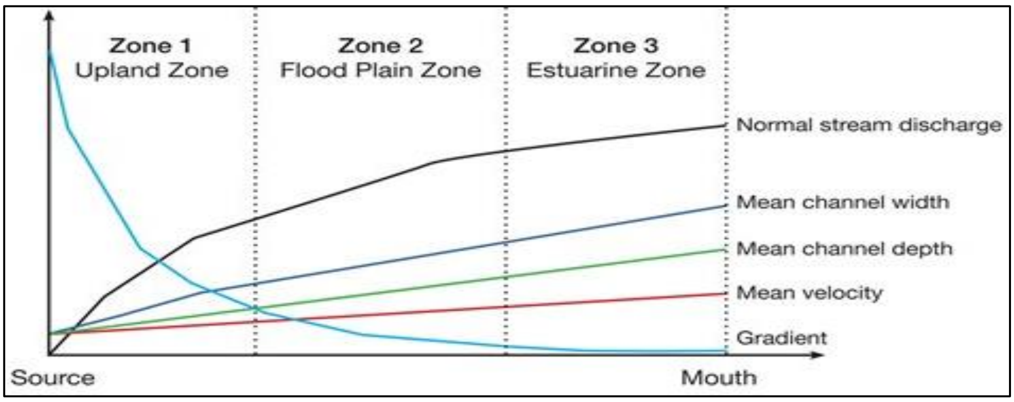


Fig. 5: Schumm's Model (non-arid environment, no human intervention)

d. The changes in channel morphology along a river can also be illustrated using the Bradshaw model (Fig. 6).

i. The model shows how **characteristics of the river channel such as the depth, width <u>increases downstream,</u> while the <u>gradient decreases downstream</u>**.

ii. Similar to Schumm's model, this is caused by the greater amount of energy available by the river downstream, as discharge and velocity increases.

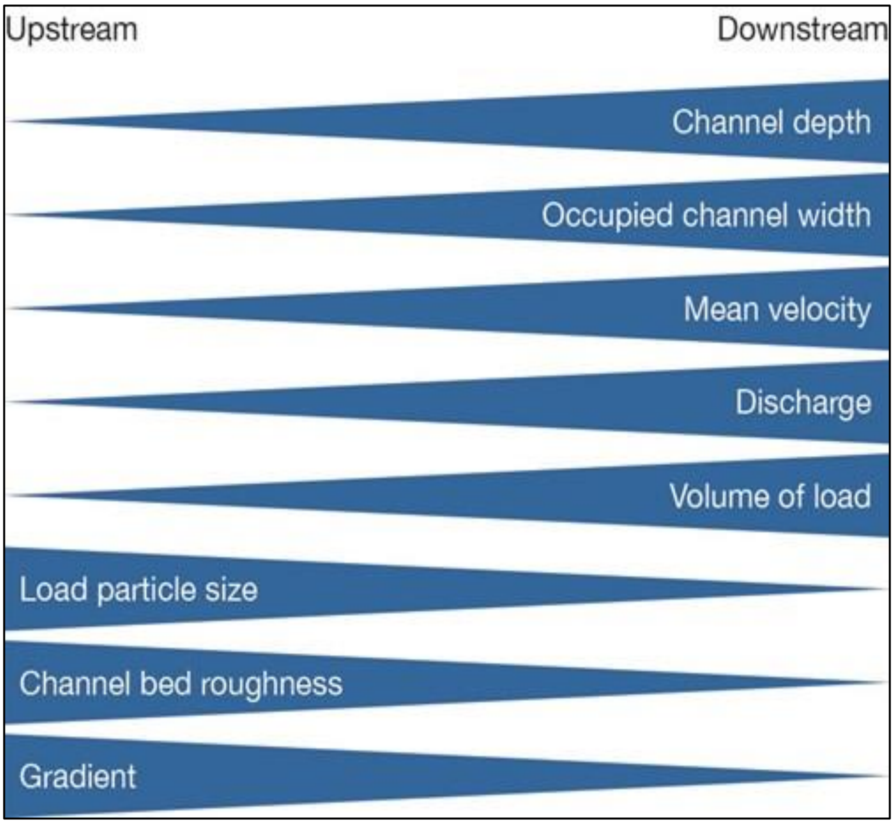


Fig. 6: Bradshaw Model

(C) <u>WHAT ARE THE VARIOUS TYPES OF CHANNEL PROCESSES IN THE RIVER CHANNEL?</u>

<u>1. FLUVIAL EROSION</u>

a) **<u>Fluvial erosion</u> is the wearing away and removal of material from the wetted perimeter of the river channel.** The eroded material is then transported along the channel. <u>All the material transported by the river is called **load**.</u>

b) There are **<u>4 ways in which erosion may occur</u>**. These are the processes of **Corrasion, Corrosion, Hydraulic Action (including Cavitation) and Attrition**

i. **<u>Corrasion</u>** <u>(also known as abrasion)</u> **occurs when rock particles already being moved by the river strike or are dragged along the bed.** Their action is like a hammer chipping the rock or like a file smoothing down the surface and producing small particles which are easily transported. If particles in the load are large, erosion is more rapid. Small particles tend to smooth or polish surfaces. Abrasion may also be known as corrasion.

- Abrasion is possibly the most effective method of erosion and is normally responsible for most of the vertical erosion ('downcutting') in a river channel. If the river carries very little load, abrasion is ineffective. Potholes in the beds of rivers are a common feature of rapid abrasion. They are cylindrical holes drilled into the rock by turbulent high velocity flow.

ii. **<u>Corrosion</u>** (also known as solution) **is the process where soluble minerals in the rocks lining the channel are dissolved and carried away as solute load**. It is most marked on carbonated rocks, such as limestone, where carbonic acid dissolves the rock.

iii. **<u>Hydraulic action</u> refers to the wearing away and removal of material from the force of air and water on the sides of the channel and in cracks.**

- It results in **<u>evorsion</u>** which **is the direct force of flowing water on the river bed**. Evorsion is generally responsible for removing only unconsolidated sedimenst such as sand or fine gravel. The velocities attained in a normal river flow will have little effect on hard, resistant rocks.

- Besides evorsion, hydraulic action can also result in **<u>Cavitation</u>,** which is the force of air exploding. Cavitation occurs as bubbles implode and evict tiny jets of water at high velocities which can damage solid rock.

iv. **<u>Attrition</u> is the reduction in the size of the particles in transport as they strike one another or the bed of the channel.**

- As any particle moves downstream, there is a progressive reduction in size. In addition, sharp edges and angles of the particle become rounded since they are more exposed. The upper stretches of the river therefore tend to contain larger, angular sediment while the downstream parts of have fine, rounded particles.

  Attrition is a way of eroding the river's load, **not** the bed and banks. Attrition is where pieces of rock in the river's load knock together, breaking chunks of rock off of one another and gradually rounding and shrinking the load.

c) Erosion can deepen the river via vertical erosion, widen it via lateral erosion and lengthen it via headward erosion.

- As a river moves downstream, both vertical and lateral erosion occurs, widening and deepening the river. Erosion results in distinctive features like river cliff in meanders and widened channels in braided streams.

- Headward erosion is most active at the source of the river or when the river profile is steeper. An example of headward erosion is that at Niagara falls where the falls on the Canadian side have been retreating at a rate of 1.2m per year, with gorge of about 11km between the base level of lake Ontario and the foot of the falls.

- Fluvial erosion plays an important role in developing the concave banks of meanders creating river cliffs. Lateral erosion also results in widening of the river banks, contributing to wide channel banks in braided channels (*to be addressed in-depth in next lecture).*

2. FLUVIAL TRANSPORTATION

a) Fluvial transport is the movement of a river's load downstream.

b) There are **4 main transportation processes** by which a river may transport its load: **Solution, Suspension, Traction and Saltation** (Fig. 12).

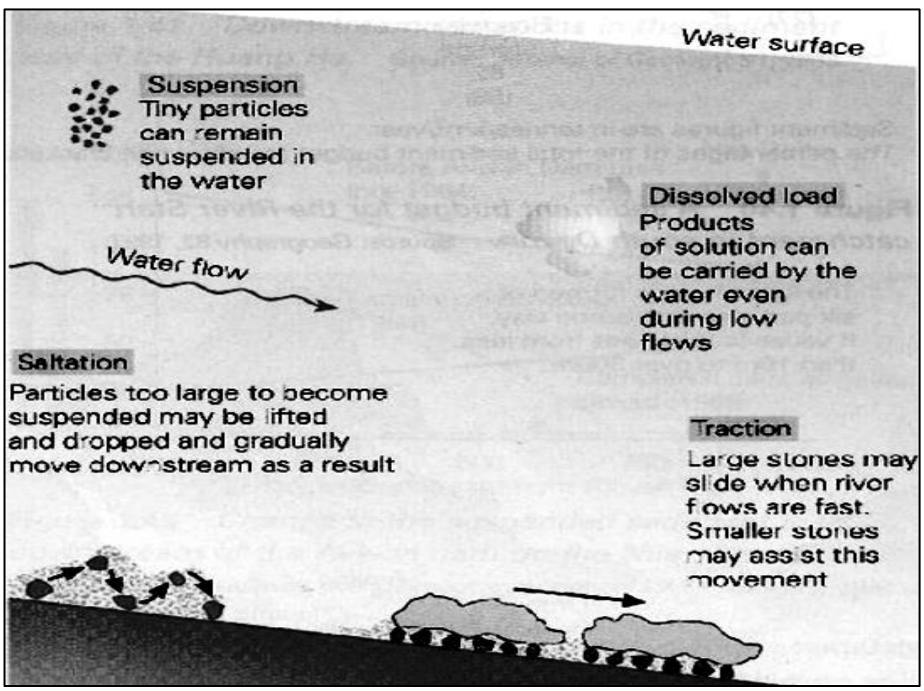


Fig. 12: Ways a river may transport its load

The actual transportation process that occurs depends on the relationship between the river's energy and the size of the load (calibre).

i. **<u>Solution</u> is the transportation of soluble minerals in the water**. This kind of load is called the dissolved load or solute load.

ii. **<u>Suspension</u> refers to the transportation of sediment materials within the water body, held up by turbulence.** This type of load is known as the suspended load. The greater the velocity and turbulence, the larger the quantity and size of particles that can be moved in suspension. Particles such as clay and silt are usually transported in this manner, based on Hjulstrom's curve.

iii. **<u>Saltation</u> is a combination of both traction and suspension**. Particles are first uplifted into the channel flow by turbulent forces. Once raised into the flowing water, these particles are transported along arc-shaped trajectories as gravity pulls them toward the channel bed where they impact other particles, in turn setting them in motion. Particles transported by traction and saltation, moving close to or along the bed of the river, are referred to as bedload.

iv. **<u>Traction</u> is the transport of large particles,** such as large pebbles or cobbles, by rolling and sliding in a discontinuous motion along the bed under the hydraulic force of moving water.

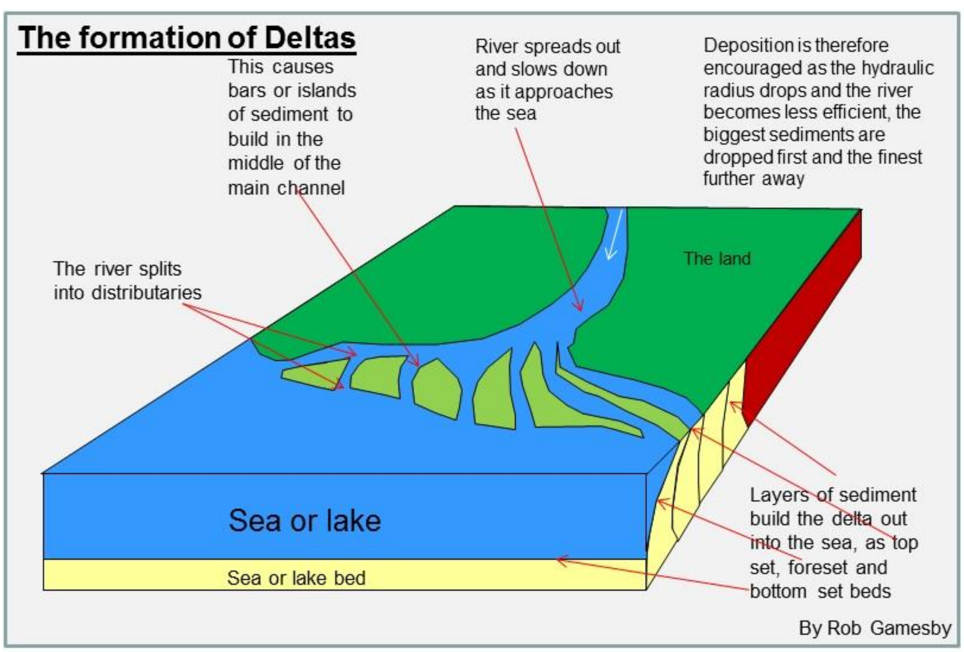
<u>3. FLUVIAL DEPOSITION</u>

a) <u>Fluvial deposition</u> is the process by which a river lays down sediments which it was transporting.

i. It occurs when a river loses energy. This can be when a river enters a shallow area (this could be when it floods and comes into contact with the flood plain) or towards its mouth where it meets another body of water.

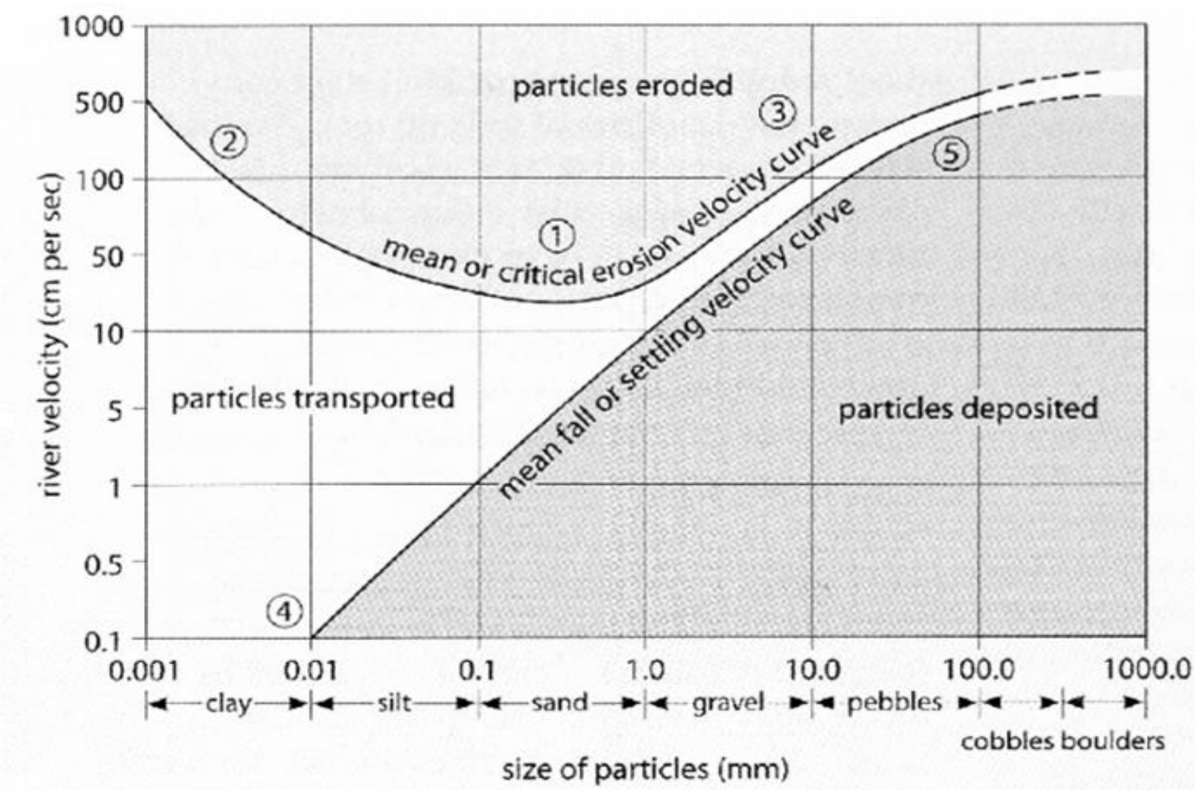
ii. Deposition results in the formation of slip off slopes along meandering rivers and eyots (mid-channel bars) in braided streams.

iii. Deposition occurs when the river meets the sea (forming Deltas) – learning in lecture 11



(D) WHAT IS THE RELATIONSHIP BETWEEN PARTICLE SIZE, CHANNEL VELOCITY AND CHANNEL PROCESSES?

1. The **Hjulstrom Curve** illustrates the relationship between the velocity of the river, sediment size (calibre) and the type of channel process that would take place, whether erosion, transportation or deposition.



2. The Hjulstrom Curve consists of two curves, namely, the critical erosion velocity curve and the settling velocity curve.

   a. The <u>**critical erosion velocity curve**</u> indicates the <u>minimum river velocity</u> required in order to entrain a particle of a particular size, by eroding and suspending it. However, when the velocity falls below the critical erosion velocity, transportation in the form of suspension will still occur.

   b. Deposition will not occur until the settling velocity is reached, indicated by the settling velocity curve. Thus, <u>the **settling velocity curve**</u> indicates the river velocity at which suspended particles will end up being deposited onto the river bed.

3. The <u>**channel competence**</u> is the <u>**maximum sediment particle size that can be carried at a particular velocity**</u>. The <u>**channel capacity**</u> is the <u>**total amount of sediment load that the river can carry**</u>**.** These will **vary with both discharge and velocity**.

(E) <u>WHAT ARE THE FACTORS INFLUENCING CHANNEL PROCESSES?</u>

1. CHANNEL VELOCITY

1. Channel velocity can affect channel processes as it influences the amount of energy available in a river to do work.

2. The **channel competence** of a river refers to the **maximum calibre (size) of a load that it can transport.**

3. Higher velocities increase the stream's energy, and thus the increment in calibre of the particles it can carry. The relationship between velocity and competence is given by the 6th power law: i.e. if velocity doubles, competence increases by a *corresponding 2^6 times* (64 times).

4. According to the Hjulstrom Curve, for particles less than 0.5 mm in diameter such as silt and clay, there is a negative relationship between the size of the particle and the river velocity required to entrain (erode and suspend) the particle.

   This is because of the **high internal cohesion** of these particles. **More energy is thus required to overcome these forces of cohesion**. This is in contrast to particles such as sand which is less cohesive and thus requires lower velocities in order to be entrained.

Channel capacity refers to the **total amount** of suspended load that the river can carry. It is positively related to energy and thus positively related to discharge and velocity.

5. Velocity can vary both vertically and laterally across the river.

   a. The distribution of velocity in a cross-sectional area of a river is shown by **isovels (lines joining points of equal velocity).** The zone of highest velocity in a channel is located in the area least affected by friction with the channel bed and sides.

   b. For a stream that is symmetrical in shape, the zone of highest velocity lies just below the surface in the middle. The lowest velocities are found where the river is shallow and so friction is greatest. The maximum velocity is found near the river's surface where the channel is deep. At this point, friction with both the air and the channel is minimal.

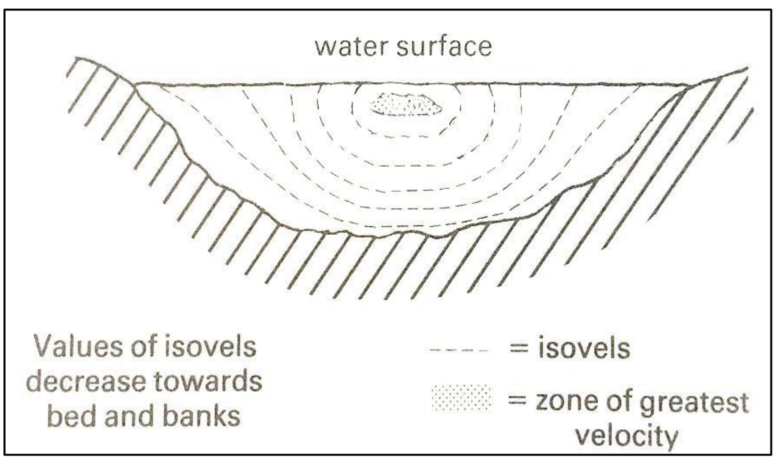


Fig. 8: Velocity profile of a river channel

a. There is a positive relationship between channel velocity and hydraulic radius as the greater the hydraulic radius, the more efficient the river channel and the smaller the frictional loss. Thus, the ideal shape of a river channel in terms of its greatest hydraulic radius is semi-circular.

b. There is also a positive relationship between channel velocity and channel gradient as an increase in gradient will result in a greater amount of potential energy being converted into kinetic energy, produced by gravity and downflow of the water.

c. There is a negative relationship between channel velocity and channel roughness because channel roughness causes friction which slows down the velocity of the water. Also, when there is contact between the water and irregularities in the river bed and bank e.g. boulders, trees and vegetation, the velocity of the water will similarly decrease.

2. CHANNEL DISCHARGE

1. The discharge (Q) of a river channel refers to the volume of water passing through a given point in a given time.

2. **The greater the discharge in a river channel, the greater the amount of energy a river possess to do work**.

3. **The discharge of the river is dependent on the velocity of the river and the cross-sectional area of the channel at that point**. Expressed in cubic metres per second ('cumecs'), discharge is calculated by the following formula:

Discharge (Q) = Velocity X Cross-Sectional Area

4. The higher the discharge (naturally the higher the velocity) but discharge also increases channel capacity → more load can be **transported.**

3. GEOLOGY OF RIVER BED AND BANKS

1. Based on the Hjulstrom diagram, the different types and calibre of sediments influence the specific types of river channel processes taking place. For example, a particle of sand 0.2mm in diameter requires a velocity of 30 cm/s to be eroded and suspended from the river bed.

2. However, once eroded and suspended, only a minimum velocity of 5cm/s is required to continue suspending the same load. Once the river velocity goes below 5cm/s, the particle of sand will be deposited.

3. Thus, the geology of river bed and banks can influence the channel processes. Different types of materials are eroded at different velocities – some are easier to erode (such as sand), some are more difficult to erode (such as clay and silt). But clay and silt are very easy to transport.

4. The amount of load can also affect deposition, if there is too much load and the river cannot transport all of it, it will be deposited.

4. TYPES OF FLOW

1. The type of flow influences whether or not erosion will take place.

    a. **Laminar Flow** (Fig. 9) **occurs when water flows in parallel layers which shear past each other, and no mixing occurs between the layers.** If laminar flow alone occurred in rivers, all the sediment would remain on the river bed.

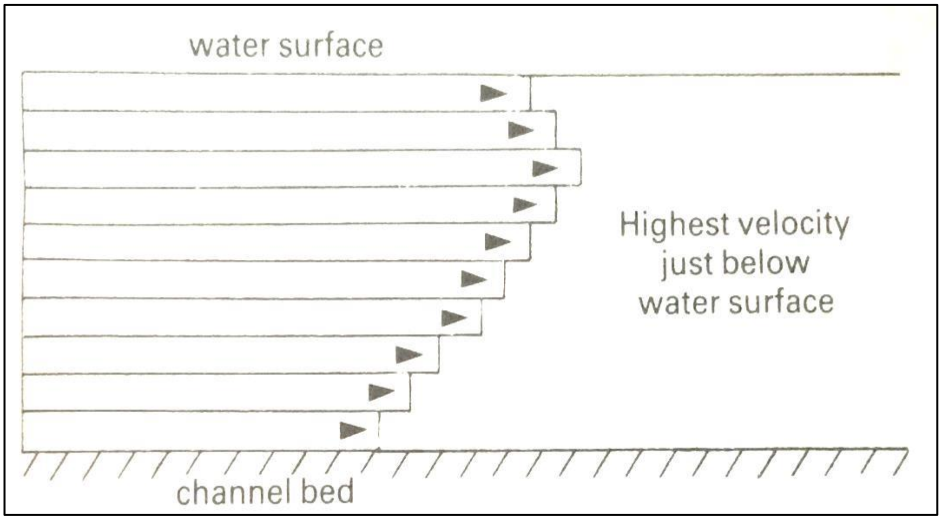


Fig. 9: Laminar flow

    b. Laminar flow is often found in straight channels and the lower reaches of the river where water flows with minimal disruptions from the river bank and bed. There is a limited occurrence in natural river channels.

2. **Turbulent Flow** (Fig. 10) **is a series of rapid eddies and swirls**. Vertical turbulence creates hollows in the channel bed.

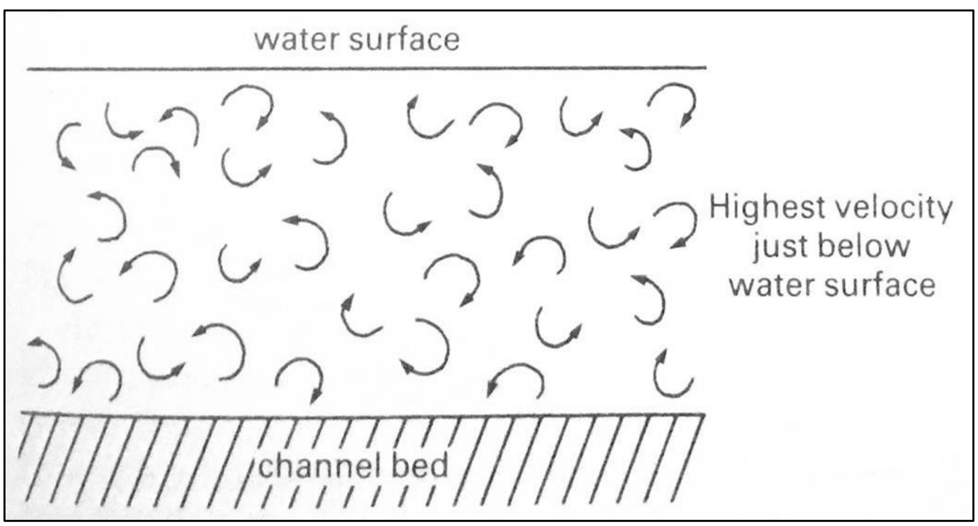


Fig. 10: Turbulent flow

a. It caused by high channel roughness and also in rivers with complex channel shapes causing water to move vertically and laterally in a very irregular manner, leading to the formation of eddies and swirls.

b. This type of flow is dominant in most upland streams (where boulders and obstacles in the channel deflect the river's flow in multiple directions) although they also exist in lowland streams alongside laminar flow.

3. **<u>Helicoidal Flow</u>** (Fig. 11) **is a type of corkscrew flow which moves across a meander, causing water to be raised on the outer surfaces of pools and the circular return flow to occur at depth.** It is **<u>a secondary flow</u>** generated by the swinging thalweg in a meander. It results in the cross-section of a river channel to become more asymmetrical.

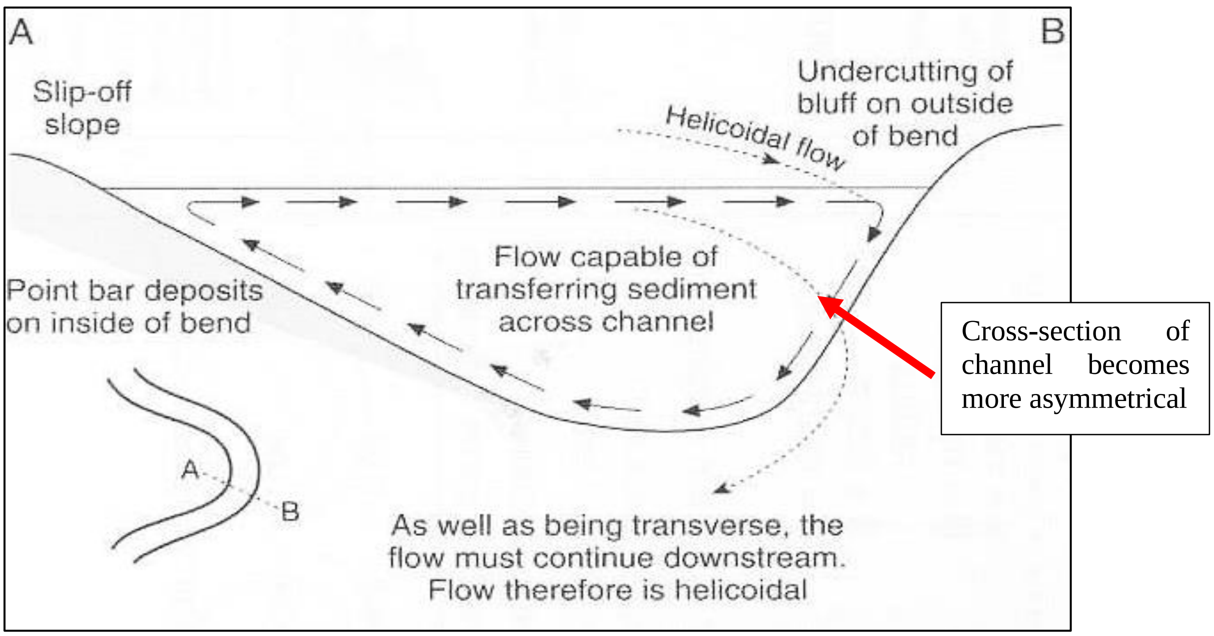


Fig. 11: Helicoidal flow

5. HUMAN FACTORS AFFECTING FLUVIAL PROCESSES

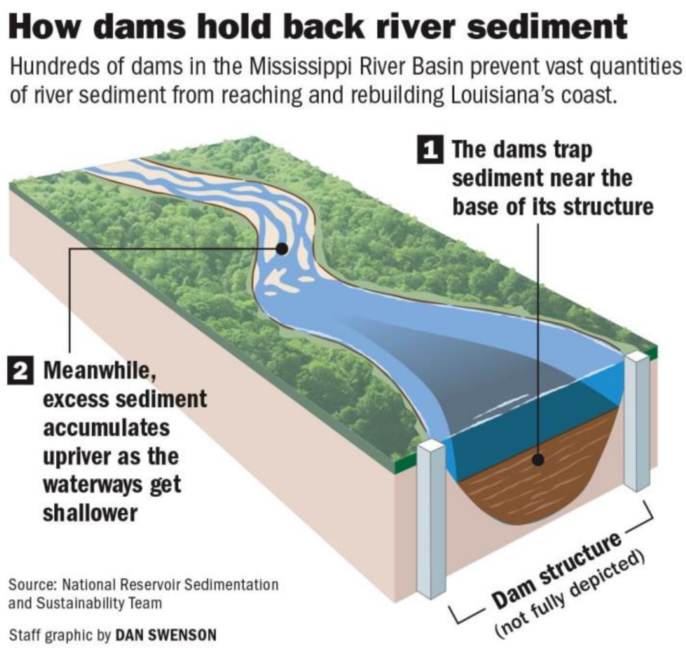
Human activities can definitely affect erosion, transportation and deposition through how they influence the river channel or by modifying its discharge/velocity,

1. Channelisation

Humans can straighten rivers, or to reshape them using concrete – this type of structural adjustment will change the wetted perimeter of the river, as well as the materials making up the river bed and banks. While a straighter channel can have higher river velocity due to increased efficiency, this would likely increase the rate of erosion. However, concrete might be more difficult to erode compared to sand, silt, clay, pebbles found in natural rivers.

2. Construction of Dams

Humans can construct Dams which can alter the discharge of the rivers. Oftentimes, deposition is very high behind the dams due to the loss of velocity when the dam is closed. However, sudden release of water from the dams which then increases discharge would then affect erosion and amount of sediments being transported downstream.



3. Diversion of river away for irrigation/agriculture

If parts of the river are diverted away for irrigation and for agriculture, this would cause the discharge of the river channel to fall. This in turns has implication on its ability to erode, transport and deposit sediments.