CHAPTER 2 ACTION OF RUNNING WATER

Objectives

After studying this chapter, students should be able to:

- describe the concept of running water as an energy system.
- identify and describe the various stages of river course development.
- describe the processes of erosion, transportation and deposition in river, as well as the resultant landform features.
- describe the concept of drainage pattern and the various types of drainage patterns.

2.1 Concept of Running Water

A mass of water moving over the land surface from its source in a spring or marsh and backed up by an aquifer until it empties into bigger water body is known as a **river.** As a river flows to the sea or ocean, it connects tributaries, and these tributaries and the river form a **river system.** The area from where the water enters the channel of a river system is known as **river basin** or its **catchment area.** The basin is demarcated by the **watershed** or hydrographic divide. The land surfaces between rivers are called **interfluves**.

Spring is a natural outflow of water from underground to the surface of the Earth. The water may seep out gently or gush out strongly depending on the nature of rock aquifer. The outflow of water occurs at or below the plane where the water table intersects the surface.

Formation of spring: In areas of tilted strata, where permeable and impermeable rocks alternate, water emerges at the base of the permeable layer. In well jointed rocks, water may percolate downwards until it reaches a joint which emerges at the surface. The intrusion through permeable rocks causes the water table to reach the surface and water issues out as spring. In limestone or chalk escarpments, where the permeable rock lies between impermeable strata, water is released at the foot of the scarp as spring. In karst regions, spring often disappear underground and may re-emerge as **resurgence.** The continuous pouching out of rock from the source of spring makes it to recede while the widening of the source of spring as it recedes is called **spring sapping.**

2.2 River as an Energy System

The seasonal variations in the volume of water in a river is called **regime.** This **regime** of a river depends on some factors such as sizeable catchment area, nature of underlying rocks, seasonal variation in precipitation and the nature of vegetation cover.

River generates a lot of energy which is a product of **gradient** of the surface and the **volume** of the water. The energy is expanded in erosion, transportation, and counter-balancing the force generated by **friction.** Part of the energy is transformed into heat and the **heat** overcomes friction between the valley sides, bottom of the stream and the wetted perimeter. Energy lost depends on the roughness of the river bed and bank straightness of the stream profile and the cross-sectional area of the channel. Therefore, the efficiency of the cross-sectional form of channel is measured by the **hydraulic radius,** which is defined as the ratio between the cross-sectional area and the length of the wetted perimeter. The higher ratio denotes higher efficiency in river as external friction is less. Also, a

channel of semi-circular cross-section is the most efficient, followed by a rectangular cross-section where the depth is half of the width. Large streams do more work than small ones, while rivers do greatest amount of work when they are in high volume. Energy is also lost due to sharing between turbulent currents.

2.3 The Functions of River Erosion

Rivers perform three distinctive but interrelated functions in landform evolution and these are: **erosion, transportation** and **deposition.** In each of these processes, energy is spent due to the velocity and volume of the river as well as slope nature.

The average velocity of a river increases down stream even though the gradient may steadily decrease. The velocity of the river influences the quantity of load that it can carry over time. Thus, the greater the speed, the larger the materials carried. The term **load** is used to describe transported materials.

Load is the main agent of **erosion,** but the erosive work of a river consists of **four** interacting processes: **Hydraulic action, Corrasion, Attrition and Solution.**

i. **Hydraulic Action:** This occurs when a river with surplus energy cuts down the beds or cavities and dislodges particles from the banks and channels, and moves with the current. The materials now in transit serve as tools for cutting down the river channel. Thus, hydraulic action is a function of velocity of the river and structure of the rock along the profile. The result of this process is feasible in the upper course of a river where pothole develops into plunge-pools below a waterfall. This results to V-shaped value at the upper course of the river.

ii. **Corrasion:** This is a process whereby increase in depth and width of a river leads to wearing away of sides and floor with the aid of gravel, sand and silt carried by the river especially on the upper course of a river. The drilling of sediments creates different particle sizes as well as the hollow and spiral effects which culminate in the formation of pool-holes on the river beds, examples are found in the course of Shing Mun River (Hong Kong), Sam Tam Lo Valley (Brides pool) at the head of plover clove.

iii. **Attrition:** This is the wearing down of the loads as a result of its contact with the floor, banks and other materials in motion. The persistent hitting, polishing and brushing of these sediments against each other lead to the reduction in their sizes as they are been transported downstream. This sequence or process which culminates at reduction in river load is called **attrition.**

iv. **Solution:** This is a chemical or solvent action of river water on the material with which it comes into contact. Load solution such as silts, clay and sand are capable of blocking river channels. Some rocks such as limestone and gypsum contain high degree of calcium carbonate which is more soluble in water than granite and sandstone, hence, they are removed easily in river solution. Therefore, the effect of river solution depends much on the structural (mineral) composition of the underlying rocks on the river beds or banks and their varying degree of resistance to chemical reactions.

Transportation of Load in Rivers

The term transportation is used to describe the movement of load from one location in a river course to another. The size of river load or materials varies from one course to another depending on the geologic formation the

river passes across, i.e. the slope gradient, age of the river, depth and length of the river and speed or volume over a period of time.

The smallest particles appear in a yellow-brownish colour move down stream due to heavy rainfall. These smallest particles suspended in water are carried in a process called **Suspension.** Larger particles are moved in a series of hops or jumps along the stream bed by a process called **saltation.** Larger particles are rolled or pushed on the river bed downstream in a process known as **traction.** Also particles which are dissolved in water loads are transported in a process known as **solution**.

2.4 Landform Features along the River Course

A river course is a pathway through which a river flows. It is also referred to as river channel. It originates from highland areas and terminates either in other rivers or seas. In the preceeding discussion, a river course is divided into three sections, namely the upper course, middle course and lower course.

In the preceding discussion, it was stated that rivers play three distinctive activities, namely **Erosion, transportation and deposition.** Each of these functions leads to the formation of certain features as illustrated in the stages of water.

This course is also called **torrent or youthful stage.** In this stage, a river takes its source from watershed which is often the peak of highland range. The river then flows rapidly down the steep slopes, with the prevailing action of vertical corrasion and erosion. This developes a narrow v-shaped valley along the fault lines and joints of less resistant rocks. This down-cutting is facilitated by hydraulic action. Typical example is in River

Kaduna which develops a gorge along its course known as Shirorro gorge. A **Gorge** often develops in areas where hard, resistant rocks are laid in a narrow steep valley. It could be seen as a receding waterfall as found in Thompsons fall in Kenya. Major features associated with the upper course are as follows:

(a) **Rapids and cataracts**: These features are more peculiar to upper course of a river. The variations in slope and varying degrees of resistance facilitate their development. For instance, when an outcrop of rock which resists erosion along the upper course hinders the movement of water, the soft rocks are easily worn downstream as shown in the diagram.

Fig. 2.2: Rapids and cataracts

The continuous jumping of water down the slope creates a feature called **Rapids.** Common examples of these features are found in Busa and Ewuru in Niger state, Nigeria.

(b) **Waterfall:** This occurs as a result of erosion, when a resistant hard rock is left to form an obstacle. The protruding obstacle now causes

the river to rumble down from a higher ground to lower ground. It may be formed when a river plunges down the edge of a plateau or when a scarp-line lies across a river bed, for example Kwa fall. A plunge pool is a hollow or depression found at the base or foot of the waterfall. It is caused by the force with which the river plunges down from the height.

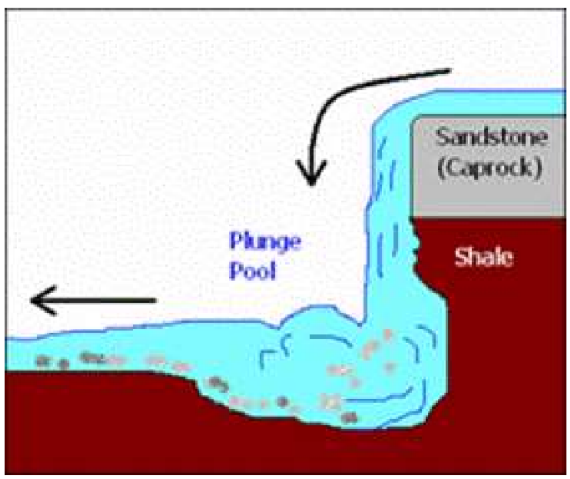

Fig. 2.3: A waterfall with plunge pool

(c) **River Capture**: This feature depends much on the head-ward erosion (back-cutting) which leads to stream divide. An increase in erosive power of a river will lead to an astronomical enlargement of its basin at the expense of a weaker stream. A river may break through its deatide and capture the weaker stream. This bend at which the river captures a weaker stream is called **Elbow of capure**. Such increase in erosive power could be due to increase in water supply by rainfall or tributaries. The changes could cause the river to bend and such bend which a given river undergoes is called **elbow of the capture.** The captured river is called **Misfit.** The

valley below the elbow is known as **Wind gap,** which could be useful as a railway or road routes for movement of people, goods and services. Another name for river capture is **river piracy or river beheading.** Examples abound in Burma in Asia where the Upper SITTANG has been captured by the Irrawaddy, in Ghana, River Pra has captured the head bank tributary, the head waters of river Amisa and Nakwa while bank tributary, the Ofin has beheaded at the Mansi. In Nigeria, Ogunpa Stream (Ibadan) has captured the upper Yemetu. The road linking Mokola with Agodi quarters in Ibadan passes through the weak one created by the river capture. In Jos plateau, River Tilden Filani has cut through the weak formation between the Naraguata Hills and Shere hills to pirate the upper part of River Delimi. This led to the formation of wind gap between the Naraguta Hills and Dogon Dutse.

Fig. 2.4: River capture

Middle Course or Maturity Stage

At the stage, valleys have extended themselves so that the middle course of the river now has a well integrated drainage system. Lateral corrasion tends to predominate over vertical corrasion. The active erosion of the

banks widens the V-shaped valley. The volume of river increases with the adjustment to lithologic variations which is evident in the existence of some longitudinal tributaries along the belt of weak rock. The major work of river at this stage is **transportation** and some **deposition.** Downstream, there are interlocking spurs that cuts back into a line of bluffs. Consequently, Rainwash, soil creep, landslides and gullying continue to widen the valley while the materials carried are gradually deposited due to the reduction of volume and intensity of flow of the river. Thus, flood plain constitutes aspect of the river course as the floor stream divides to be sharp and ridge-like, resulting in a minimum of inter stream uplands. Major features include the following.

i. **Meanders:** These are formed when the rivers are unable to go straight due to reduction in velocity, and resistant rock alternating with less resistant ones. As the river is flowing under gravity, a winding course develops. Persistent irregularities of the ground force the river to swing in loops along the channel. The term **meander** was derived from the winding of River Meanderez in Asia Minor. This is illustrated in Fig. 2.5 below.

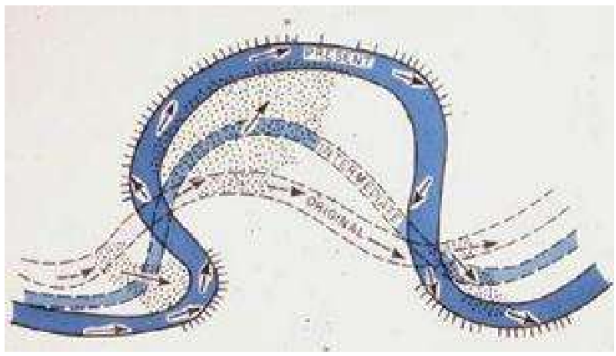

Fig. 2.5: The development of meander

ii. **Interlocking Spurs:** As the valley deepens by vertical erosion, the river twists as it avoids obstacles such as hard rock. The concave

bank of the river is eroded, causing spurs which alternate on each side of the river to interlock.

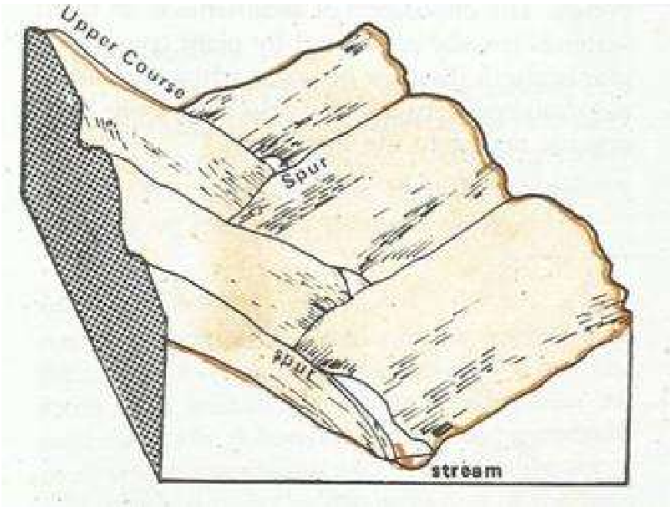

Fig. 2.6: Interlocking spurs

iii. **River cliffs and slip-off slopes:** As the flows of water gets to the bend of the river, it hits the outer bank, erodes it into a steep river-cliff. The water which piles at the bend due to centrifugal force sets a bottom current in a corkscrew motion which is hurled back into mid-stream and the inner bank. Shingles are deposited at the opposite convex part of the eroded bank where the slip-off slope is gentle.

Lower Course or Old Age

At this stage, valleys are extremely broad and gently sloping due to lateral corrasion. The works of a river at this stage is mainly deposition as valley width is greater than the width of the meander bends. Inter stream (tributaries) areas are reduced in height, and stream divides are not very sharp as in the matured stage. Major features include meanders, braided streams, flood plains, ox-bow lakes, and delta terrace.

(a) Delta

A delta is a flat fan-shapes alluvian formed as a result of deposition of fine materials by a river as it reaches the sea or ocean. The river divides into channels called tributaries. Factors affecting the formation of delta are: the rate of sedimentation, the depth of the river and the sea-bed, the character of the tides, currents and waves. These factors also influence the size, shape, growth and importance of delta.

Delta is formed when materials carried from the upper and middle part of the river are deposited at the mouth of the river. As current reduces, sediments block the main river which divides into many channels, which extends into the sea. They are important for they form a good agricultural land, fishing ground and also good for petroleum mining.

Types of delta

There are three types of delta namely:

(i) **Bird's foot:** This is composed of fine silt material. The river channel divide into few channels which maintain definite channels across the delta. Examples include the Mississippi delta in U.S.A. This type occurs where seas have few currents and tides to carry the sedimentation.

(ii) **Estuarine:** This develops when the mouth of a river is submerged. It takes the shape of an estuary. For example, Elbe in Germany, Vistula in Poland.

(iii) **Arcuate:** This is composed of coarse sedimentation such as sand and gravel. It is triangular in shape with a number of tributaries. Examples include Nile in Egypt, Indus, Ganges and Wawaddly in India, Mekong and Hwang-ho in China, Niger Delta in Nigeria.

(b) Floodplain

River in its various courses carries series of materials depending on the energy. These materials are deposited downstream on low lying adjacent areas and gradually build up the fertile flood plain. Accumulation of sediments over time build up Natural levee. These natural levee are low ridges that are parallel to a river course. They are highest near the river and slope gradually away from their banks. They owe greater height near the stream channel to the accumulative effect of sudden loss in transporting power especially when the river floods its bank. Natural levee causes the present meander bend of a river to stand up above the floodplain as low as alluvial ridge. Examples are Mississippi, Hwang-Ho, and China Sonow.

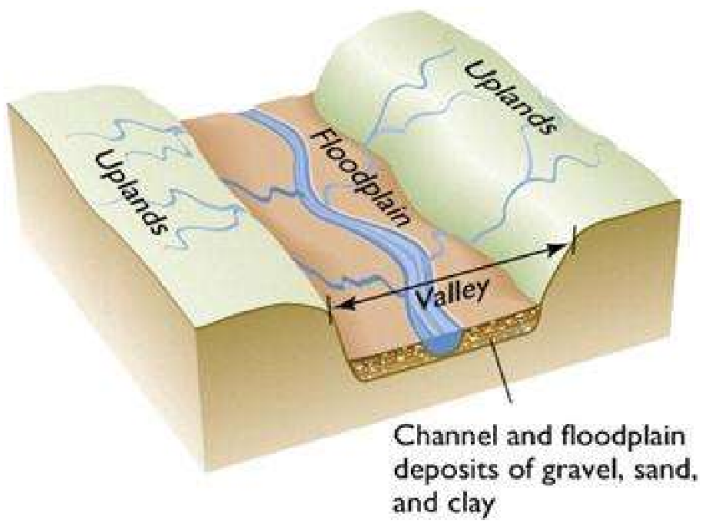

Fig. 2.7: Formation of floodplain

(c) Ox-bow lake

This is a narrow meander channel that has been abandoned or cut off in the development of a new course in a river. When a meander becomes more pronounced and the outside bend or concave bank is so rapidly eroded that the river becomes almost a complete circle, further erosion of

the new bank or deposit of sediment at the course could culminate in the circular meander being cut off leading to the feature called **ox-bow lake** or **cut-off** or **bayous.** The river then flows straight due to subsequent flood the Ox-bow lake may be silted up, becomes marshy and dries up finally.

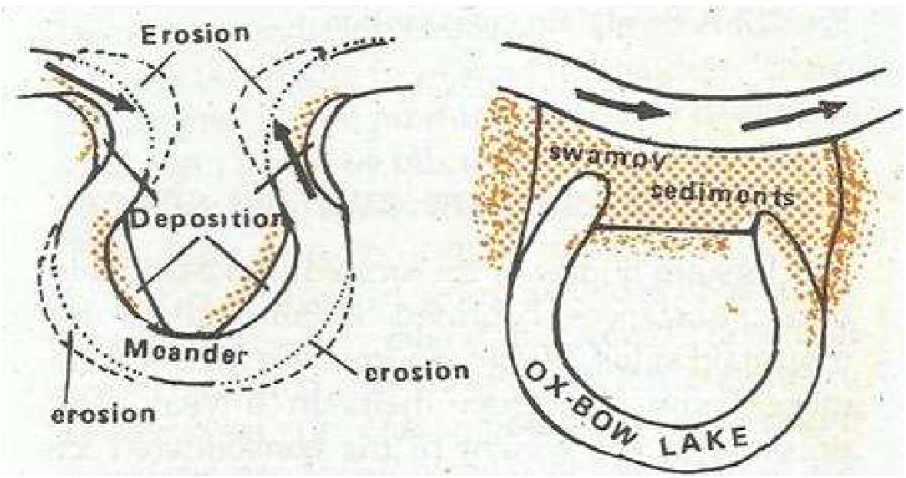

Fig. 2.8: The formation of an ox-bow lake

2.6 Drainage Patterns

Drainage pattern is defined as a network or pattern in which the individual stream forms as it flows along its course. A river system usually develop a pattern which is related to the structure of its basin, initial slopes, irregularities in rock hardness, landform history, etc.

Types of drainage pattern

There are many types of drainage patterns but the most commonly encountered ones include dendric, trellis, and radical pattern.

i. **Dendric patterns:** The word "dendron" is derived from Greek, meaning "tree". Dendric pattern represent irregular branching of tributary stream at an angle less than a right angle often like branch of trees. They often develop upon rock with uniform characteristics,

resistant to erosion and notable lack of structural control. This could be in a nearly horizontal sedimentary rocks or in areas of massive igneous rocks or metamorphosed igneous/sedimentary rocks.

ii. **Trellis pattern:** This develops in a region of alternate belts of hard and soft rocks which dip in the same direction and which lie at right angles to the general slope, down the principle underflows. The principle river which flows down the slope is called consequent river while that which do not flow down the slope is called subsequent rivers. It is developed in a rapid which is made up of alternate hard and soft rocks that dip in the same direction and lie at right angles to the general slope, down which the principle river flows.

iii. **Radial patterns:** These may be formed by stream diverging from a central deviated track. They develop on domes, volcanic cones and other types of isolated conical or sub-conical slopes which lead to regular spacing of parallel or under-parallel streams. The radial pattern takes the form of a bicycle wheal and is found in mount Egamont in Northern Island, New Zealand.

iii. **Rectangular & parallel drainage pattern:** In this pattern, both the main stream and its tributaries display right-angles bends. They reflect control of joint and fault system upon stream courses, which certainly may determine stream locations.

iv. **Parallel pattern:** This is usually found where there are pronounced slope or structure control which lead to the near parallel streams.

v. **River rejuvenation:** This is a process by which a river comes back to life when the base level is lowered. The river power to erode is increased, which results in the production of new features. The lowering of the base level may be caused by:

- uplift of the land

- a fall in the level of the sea

When a river is rejuvenated, the valley eroded which will be a young valley may occur in an old landscape. One of the features produced is terraced which is as a result of downcutting effect by the river when a flood plain is rejuvenated.

Kick point is the point where the river crosses from original flood plain to the new flood plain marked by rapids and waterfalls.

Summary

- Running water is a dominant agent of landform development.
- The seasonal variation in the volume of water is called **regime. Energy** generated by the river is a product of gradient of the surface and the volume of the water.
- Load is the main agent of river erosion through four interacting processes known as hydraulic action, corrosion, attrition and solution.
- Courses of a river and their features include the upper course (gurges, waterfalls, rapids and river capture); middle course (interlocking spurs, meander, rivercliff etc); lower course (flood plain, ox-bow lakes, deltas).
- Drainage pattern is a particular plan or design which the individual stream courses collectively form e.g. dendritic, trellis, axial, radial, etc.

Objective Questions

1. Depositional plain is plain refers to all the following accepts?

   (A) Deltaic plains (B) Alluvial plain (C) Drift plain (D) Flood plain (E) Structural plain

2. A drainage pattern with the form of a "bicycle wheel" often flowing from a gill down stream is known as
   (A) conical hill (B) dentritic pattern (C) radial (D) trellis (E) angular
3. River erosion consists of the following complementary processes except?
   (A) hydraulic action (B) corrosion (C) attrition (D) solution (E) traction
4. In a captured river, the valley below the elbow of the misfit is called?
   (A) wind cap (B) plunge pool (C) beheaded river (D) falls (E) meander
5. River regime is influenced by the following factors except
   (A) vegetation (B) amount of rainfall (C) rock structure (D) wind direction (E) size of Catchments
6. At what stage of river course is erosion not rent common?
   (A) Torrent stage (B) Valley stage (C) Senile stage (D) Transportation stage (E) Middle stag.
7. Oxbow lake is a depositional feature. It is also called
   (A) cutoff (B) meander (C) delta (D) slope
8. Saltation is a river processes associated with_____
   (A) deposition (B) erosion (C) transportation (D) sedimentation (E) gullying
9. The process whereby the spring disappears in karst topography and Suddenly reappear later is called
   (A) misfit (B) re-surgence (C) piracy (D) run-of (E) migration
10. Which of these is not a source of water?
    (A) Rainfall (B) Spring (C) Ocean (D) Sea (E) Temperature

Essay Questions

1. With the use of diagrams, differentiate between delta and waterfalls.
2. Defined the term "drainage".
   (i) Highlight any four factors that influence the development of drainage pattern.
   (ii) Distinguish with appropriate illustrations, between river meander and river piracy.
3. (i) What are the various stages of river course development?
   (ii) Why do deposition occur most at the final stage?
4. (i) Identify the major difference between drainage basin and drainage pattern?
   (ii) Explain by well-labelled diagrams, the main differences between the following pairs of features:
   (i) waterfall and rapid
   (ii) distributing and tributary
   (iii) radial and deadvitic drainage pattern
5. (i) What is spring?
   (ii) Explain its modes of formation.