In the Name of God

Unit 5: Fluvial Geomorphology

The form of a **river channel** can be viewed as the outcome of the continuous struggle between the **erosive potential** of the river and the **resistance forces** of the **valley floor materials**. Over time, rivers develop a channel which is able to carry their normal flow. The form of this channel affects the flow of water in it and, through erosion and deposition, the flow modifies the form. The channel (and often the valley floor) acts as a jerky conveyor belt for the transport of sediment moving intermittently towards the sea.

River channels vary greatly in **cross-sectional** size and shape but are usually bounded by defined **banks** which separate the channel from the **floodplain** or **valley side**. The **bankfull** dimensions of a channel combine with the **velocity of the flow** to determine the **discharge** it can convey. In general, discharge increases with increasing **catchment area**, and the **width and depth of the channel** and the velocity of the water also increase **downstream**. Channel dimensions adjust through erosion and deposition so that the channel can convey all but the highest flows it experiences. Width is easier to adjust than depth and flow velocity, so **channel widening or narrowing** is a common response. Local features such as **bedrock** help to determine whether such change occurs.

The shape of the cross-section is described through the ratio of channel width to depth. The depth of flow in a channel is directly proportional to the force which the water exerts on the bed and to its ability to transport sediment. Any operation which alters the width-depth ratio alters the **channel capacity** for sediment transport and increases the likelihood of future instability.

Rivers are traditionally divided into **straight, meandering and braided planforms** (Figure 1). The planform is the view from above. Meandering channels are sinuous single channels with a series of **point bars**, **deep pools** and **eroding meander bends**. Braided rivers comprise a number of channels split by **gravel bars or islands**, and tend to be highly mobile. Straight channels are rare in nature and tend to be restricted to upland areas with strong bedrock controls. In reality, channel division is **superimposed** in varying degrees on straight and meandering channels, producing **transitional planforms** such as braided meanders.

Rivers which exhibit some characteristics of braiding and some of meandering, are known as **'wandering' gravel bed rivers**. They are highly dynamic and migrate irregularly **across** their floodplains. They have an active channel which is a zone of frequent channel change within the wider floodplain. **Channel change** affecting the rest of the floodplain occurs only during **major floods**. **Channel patterns** vary through time as a result of the impacts of flood events of different size.

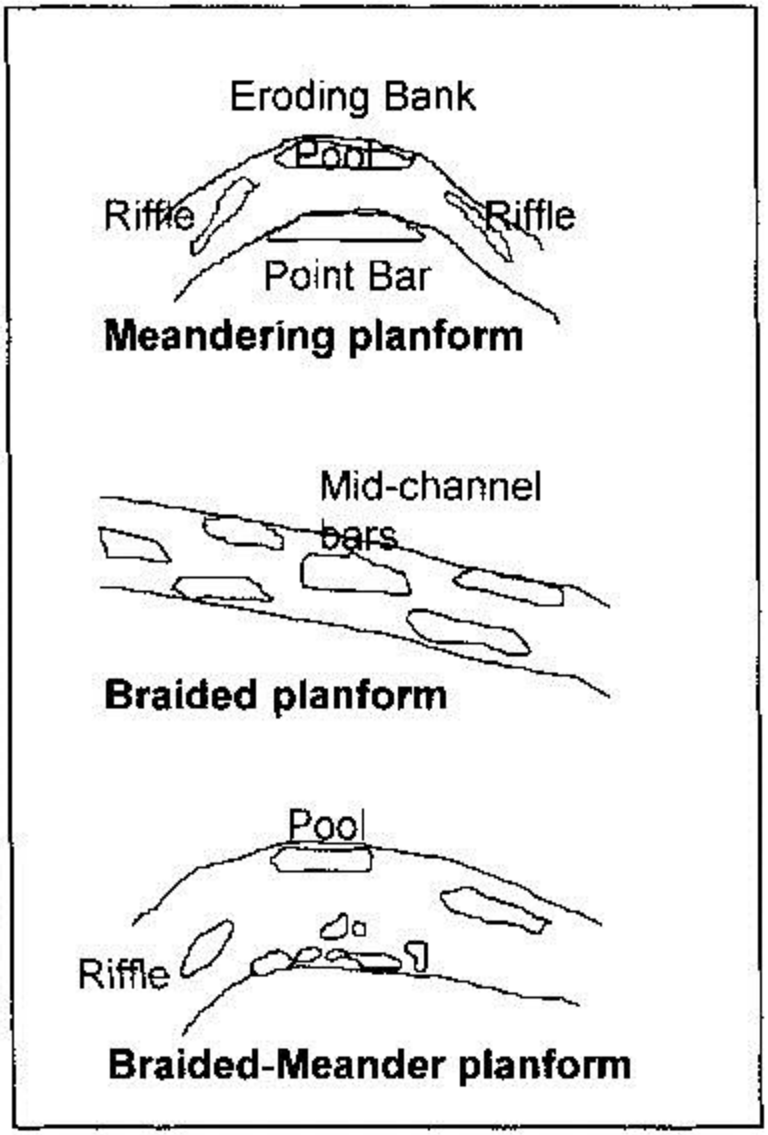

Figure 1: Classification of river planforms

The **longitudinal profile** of a river is a graph of height against distance downstream. Rivers occupy the lowest part of saucer-shaped catchments, so channels tend to have progressively gentler gradients from the **headwaters** to the **river mouth**. The overall slope decline is interrupted where rivers cross bedrock and where **tributaries** join the main channel. The rate of energy supply at the **river bed** available for overcoming **friction** and transporting sediment (stream power), is highly dependent upon gradient, and a reach with a steep local gradient has a high stream power.

If the long profile is examined in detail, a closely spaced alternation of relatively deep and shallow reaches - **'pools' and 'riffles'** - can be identified. Pools are areas of deep slow moving water, often with fine bed material, and they form important habitats for fish and bottom living organisms. Riffles are areas of shallow water generally formed of **coarser bed material**, which are typically asymmetrically shaped. They extend partly or completely across the channel, obliquely or transversely, with steep downstream faces. Some parts of the riffle form excellent spawning gravels for fish, and may support a high diversity of **invertebrates**, especially the **aquatic larval** stage of insects.

The location of pools and riffles in any channel is not fixed and varies over time due to changes in **channel morphology** and planform. Deep pools are especially associated with meander bends, where they form by **scouring** beneath the **concave bank** at, and past, the **apex of the bend**. In actively meandering rivers there is usually a pool at each bend and an intervening riffle where the current spills across the diagonal continuation of one bend into the next on the opposite side of the channel. In straight or gently **curving reaches**, pools are not specifically related to bends and they may also form in the centre of the channel in places where flow converges (e.g. downstream of an island or a confluence). Riffles may be central features around which flow divides; they may be attached to alternate banks as bars, or several bars in a row (complex) may be on the same side of the channel around the inside of a gradual bend.

Sediment size and sorting (the difference between the large and small particles of bed material) change along the **length of the river**. Generally, downstream fining in particle size occurs as a result of the reduction in transport capability with the reduction in slope. Coarse sediment is found in mountain areas and finer, better sorted sediment (including sand) is found downstream. There are exceptions to this. The Lower River Spey for example, has a high slope in its lower reaches due to **isostatic uplift**, and consequently is able to carry large particles all the way to the sea.

River gravels have two significant aspects to their structure (Figure 2):

- bed armouring;
- packing of the surface material.

Bed armouring is a vertical structure and consists of a coarse surface layer overlying finer sediment. This occurs in all types of gravel channel and is an important element of **stream stability**. An armour layer forms when the finer particles are selectively eroded away in small floods leaving the coarser material behind. If the coarse surface layer is disturbed (e.g. through engineering), the underlying finer sediments which are easily eroded are exposed, causing potentially severe problems. An adequate flow of water through the gravels is a requirement for successful **salmon spawning**. For this to occur the proportion of fine material in the gravels must be relatively low. Thus an element of bed armouring is important in fishery management. If the pores between the gravels become blocked with fine sediment, the river bed is regarded as being ‘compacted’ and the potential for spawning is reduced. Fishery managers may use rakes and harrows to disturb the sediment and ‘desilt’ the bed. The outcome of such a procedure depends upon the timing and scale of the operation.

Coarse particles are often clustered together and may form **tightly packed**, imbricated (interlinked) or **consolidated structures**. Particles in an imbricate bed are difficult to loosen by hand. This packing forms an extremely **stable river-bed**, and any disturbance will result in significant instability and erosion. The opposite of an imbricated bed is an overloose or

unconsolidated bed where the surface particles are not packed and can be easily moved. Overloose beds are unstable and form in active reaches where sediment transport occurs for a high percentage of the time.

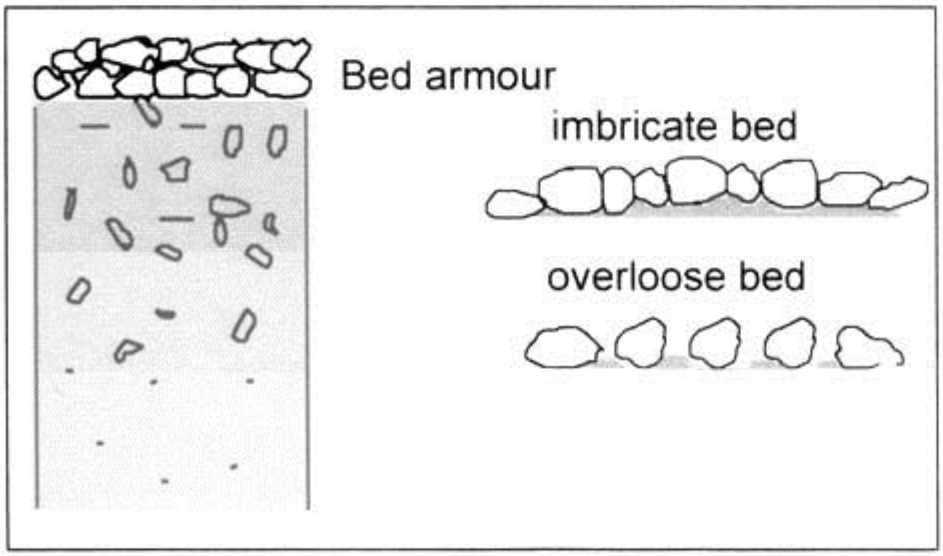

Figure 2 River bed particle structures

Natural streams rarely have **flat beds**. The stresses operating in the channel mould the bed material into distinct forms. The **geometry of the form** depends on complex flow parameters, which are in turn influenced by the **bedforms**, producing a complex feedback relationship. Bedforms are an important means of **channel adjustment** in the vertical dimension.

Bars are large-scale bedforms which have lengths around the order of the width of the channel (or greater). They are composed of a variety of particle sizes and are usually exposed at, or below, a certain stage of flow. Bars are classified according to their shape and position, and the main types of bar are:

- **point bars** - these form mainly on the inner bank of meanders;
- **alternate bars** - these are distributed along first one and then the other bank of a channel (also called lateral or side bars);
- **channel junction bars** - these develop where tributaries enter a main channel;
- **transverse bars** - these include riffles and may be diagonal to the flow;
- **mid-channel bars** - typical of braided reaches.

Bars can move downstream through erosion of their upstream faces and deposition on their downstream faces. The downstream side is usually steeper (it is sometimes known as an avalanche face), and particles sliding down it may orientate themselves so that bedding planes parallel to the face are formed. Bar faces can be cut into at discharges which would not transport the whole bar.

In a given reach, a river has the potential both to scour material from its bed and banks and to transport material which has been brought into the reach from **upstream**. The rate of transport is determined in part by channel gradient, discharge and sediment size. The sediment moves either as **bedload** where the coarse material **rolls, slides or bounces** along the bed, or as **suspended load** where fine particles are moved in suspension or become **dissolved in solution**. The overall transport rate is also governed by the bed armouring. Lower flows are unable to break the armour layer, so the quantity of sediment transported is limited. Flood flows are capable of breaking the armour layer and it is then that the majority of bedload material is transferred downstream.

Change in the position of the channel in the floodplain commonly occurs through:

- lateral migration (where the outer bank is eroding with deposition on the inner bank);
- avulsion (where the shift in channel position to a new course is rapid and usually initiated by overbank flow during a large flood);
- meander neck cut-off (where bank erosion at the apex of a sinuous meander bend breaks through to the channel at the other side of the bend, forming a direct channel);
- downstream movement of meander beds through erosion and deposition of the banks.

Bank erosion is one of the principal means of **sediment supply** to streams. A sudden reduction of this supply through, for example, **revetment of the banks**, will produce an abrupt change in the sediment and water balance and may mean that the river will seek to erode more sediment from its bed to compensate. A gradual reduction of the sediment supply for example, through reestablishment of **riparian vegetation**, is more in keeping with the timescale of natural channel processes and will lead to a gradual change in **channel behaviour**. There are two main ways in which banks may erode:

- removal of bank material by erosion of individual particles. This occurs mainly at high flow, and large scale eddying may be induced through irregularities in the bank.
- mass failure of sections of the bank. This is dependent upon the materials forming the bank, and fluvial scouring of the materials at the base of the bank may enhance failure. Repeated rotational slipping through failure along lines of weakness within the bank may produce a stepped profile.

Frost action and **trampling** by animals may enhance bank failure mechanisms, and characteristics such as bank vegetation (in particular its root structure), bank height, bank geometry, material composition and bank stratigraphy determine the propensity of the bank to erode.

Top 10 Scientific Journals related to Fluvial Geomorphology

1. ***Geomorphology***
2. ***Geografiska Annaler***
3. ***Progress in Physical Geography***
4. ***Earth Surface Processes and Landforms***
5. ***Geographical Review***
6. ***Geographical Analysis***
7. ***Geographical Journal***
8. ***Geography***
9. ***Applied Geography***
10. ***Area***
11. ***Bulletin of the American Geographical Society***
12. ***Geographical & Environmental Modelling***