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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Geomorphology**
Module Name/Title	**Drainage Pattern**
Module Id	**Geo-20**
Pre-requisites	
Objectives	**To comprehend the concept of Drainage Basin; Drainage patterns on basis of Empirical and Genetic classification; Channel Patterns**
Keywords	**Watershed, Basin, Antecedent, Superposed, Meander, Braid**

DRAINAGE PATTERN

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1. Drainage Basin

The entire area that provides overland flow, stream flow and ground water flow to a particular stream is identified as the Drainage Basin or watershed of that stream. The basin consists of the streams'valley bottom, valley sides and interfluves that drain towards the valley. Drainage basin terminates at a drainage divide that is the line of separation between run off that flows in direction of one drainage basin and runoff that goes towards the adjoining basin. Drainage basin of the principal river will comprise smaller drainage basins with all its tributary streams and therefore the larger basins include hierarch of smaller tributary basins.

2. Drainage Pattern and Structural Relationship

In a particular drainage basin, the streams may flow in a specific arrangement which is termed as drainage pattern. This streamflow over or through the landscape to carve out its valley, is predominantly controlled by the geological and topographical structure of the underlying rocks. As the stream tries to reach the base level which is generally the sea level, it will encounter several structural obstacles and in its course of descent, tries to seek path of least resistance. In this way, it can be said that most streams are guided by nature and arrangement of bedrocks as they respond directly to structural control. The drainage pattern also reflects the original slope of land, original structure, diastrophism along with geologic and geomorphic history of drainage basin. Two distinct types of drainage patterns identified by geomorphologist are Accordant and Discordant drainage patterns. While the Accordant pattern correlate to the structure and relief of the landscape over which it flows and includes the empirical classification as given by Howard, the Discordant drainage patterns do not correlate with the geology and topography of the region. The genetic classification of antecedent and superposed drainage pattern is included in Accordant.

For geomorphic analysis, Empirical classification by form and Genetic classification of drainage pattern has been given.

2.1 Empirical Classification

In 1967, **Arthur D Howard** gave empirical classification and categorising drainage patterns as basic patterns, modifications to basic patterns and varieties of modified patterns. The basic drainage patterns are Dendritic, Parallel, Trellis, Rectangular, Radial, Annular, Multibasinal, and Contorted.

2.1.1 Dendritic Pattern

Tree like branching or veins of leaf pattern formed by streams is dendritic pattern. The tributaries join the large stream in random fashion but always at acute angles – that is angles less than 90^{o}.

This is the most common pattern in the major streams of the world. The underlying structure does not control the flow pattern of stream as rocks are equally resistant to erosion. Uniformly resistant crystalline rocks, with horizontal sediments with gentle regional slope marks the landscape. The development of dendritic pattern is a two staged process. At the outset the streams flow downwards and increase in numbers. In the final stage, the stream capture of small tributaries by the large ones complete the pattern. The modified basic form of dendritic is Subdendritic, Pinnate, Annastomotic and Dichotomic (Distributary). The dendritic pattern is observed in most of the Himalyan river systems where the trunk stream is joined by several small tributary streams. River Bhagirathi flowing through Uttarakhand is joined by several small streams portraying this pattern.Dhansiri basin portrays dendritic pattern in the upper hilly area where tertiary sedimants and low diiping shales are common.

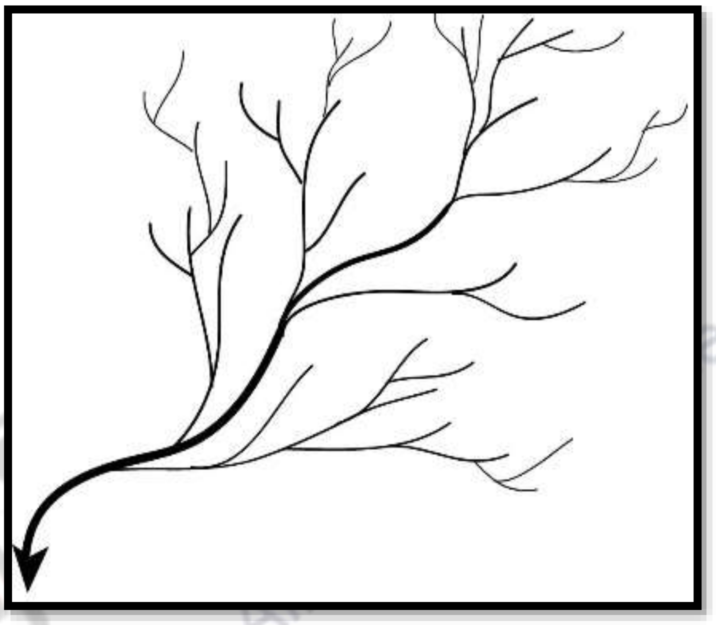

Figure 1: Dendritic Pattern

https://upload.wikimedia.org/wikipedia/commons/c/c6/Dendritic_Drainage_pattern.jpg

2.1.2 Parallel Pattern

Pattern of streams running parallel to each other is found in areas of moderate to steep slopes with some relief. The streams flow in a swift and straight fashion with few tributaries, following the same direction. There are intermediate slopes and structural control exerted by subparallel landforms. It is found in areas between linear loess and sand ridges. The modified basic pattern is Subparallel and Collinear.

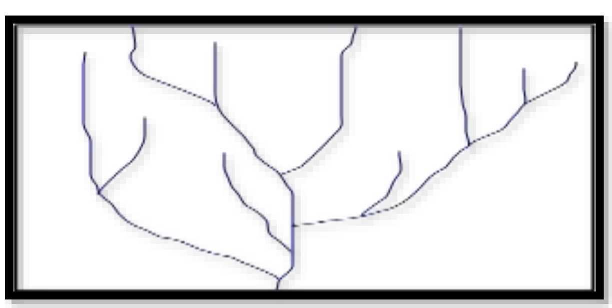

Figure 2: Parallel Pattern

https://commons.wikimedia.org/wiki/File:Parallel.png

2.1.3 Trellis Pattern

Mostly commonly observed in landscapes where the underlying structure comprises of alternating bands of tilted hard and soft strata. In areas with dipping or folded sedimentary, volcanic or low grade meta-sedimentary rocks; in areas of exposed lake or seafloors ribbed by beach ridges. The streams run parallel linked by short, right angled segments. The small tributaries on both sides of long parallel subsequent streams are of same size. The modified basic pattern of the trellis is Subtrellis, Directional Trellis, Recurved trellis, Fault trellis and Joint trellis. In the Appalachian mountains, alternating weak and strong strata has been truncated by stream erosion displaying trellis pattern. Around the Colorado front range in which strong and weak rocks resting against a core of crystalline rocks portray a trellis pattern.In Nagaland trellis pattern is well developed in Dayang subbasin where faulted Disang group of rocks are present. The Nihang Langso subbasin also portrays a distinct directional trellis pattern.

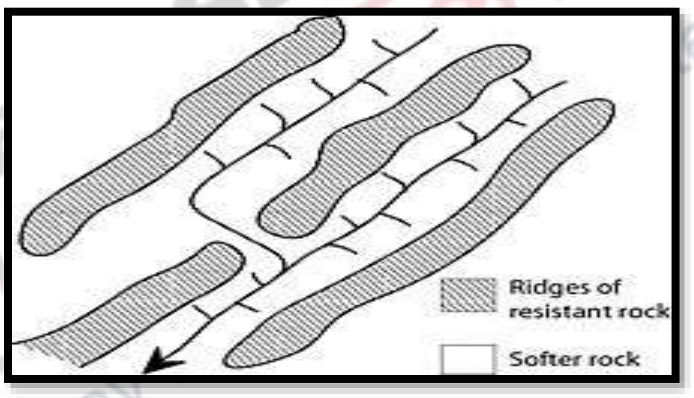

Figure 3: Trellis Pattern

https://en.wikipedia.org/wiki/Drainage_system_(geomorphology)

2.1.4 Radial Pattern

The pattern emerges when stream descends from some sort of concentric uplift, like an isolated volcano, domes or erosion residuals. Mount Egmont on the North Island of New Zealand along the Tasman Sea depicts an extraordinary radial drainage pattern (Macknight, 1998).Complex of radial patterns in volcanic field referred as multiradial. Streams on Craters, calderas and other depressions may exhibit this pattern. The modified basic pattern is centripetal. This is opposite of Radial wherein numerous streams converge in a basin. Sometimes occurs at a high scale such as Gulf of Carpentaria basin that is inundated by sea in NW Australia receives streams from hundreds of kilometres.

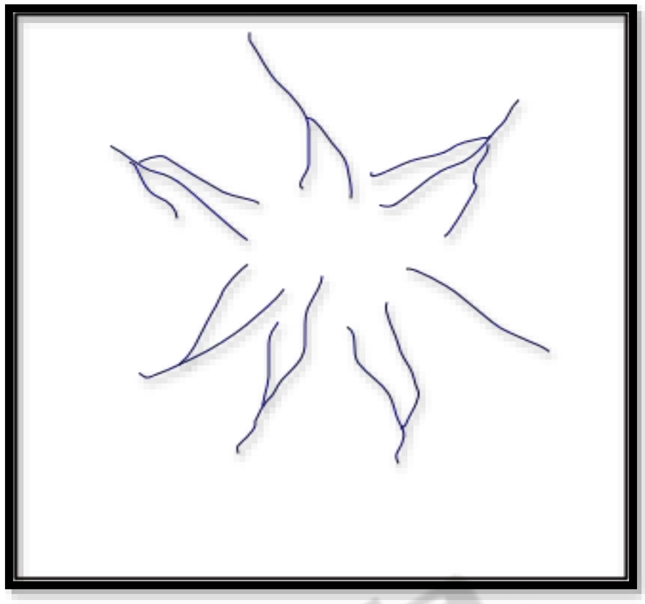

Figure 4: Radial Pattern

https://commons.wikimedia.org/wiki/File:Radial.png

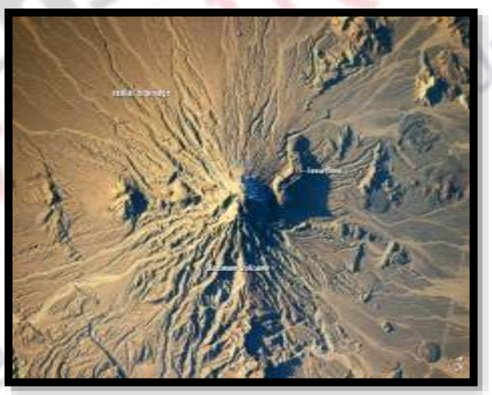

Figure 5: Bazman Volcano – Radial Pattern

https://commons.wikimedia.org/wiki/File:Bazman_volcano_ISS.jpg

2.1.5 Annular Pattern

This pattern develops on a dome or in a basin where denudation has exposed alternating concentric bands of tilted hard and soft rocks. Principal streams follow curving course on soft structure, occasionally breaking through harder layers in short right angled segments. The longer tributaries to annular subsequent streams indicate direction of dip and permit distinction between dome and basin. Maverick Spring Dome in Wyoming is dome of ancient crystalline rock that has been pushed up through a sedimentary overlay. After being deeply eroded, exposes crystalline in higher parts of hills with upturned concentric sedimentary ridges (called hogbacks) around margins. The streams are mostly incised into softer rocks. Another example of Annular pattern is seen in the Race Track or Red Valley which have ring like plans that nearly encircles the Black Hills(Thornbury, 1997).

Figure 6: Annular Pattern

Source: Adapted from Mcknight, T.L.(2010). Physical Geography – A Landscape Appreciation

2.1.6 Rectangular

The rectangular drainage pattern develops on rocks uniformly resistant to erosion. The joints and faults lie at right angles. Since these may be areas less resistant to erosion, the stream develops along the joints and may consist of straight segments with right angle bends with tributaries joining at right angles. The modified basic pattern is Angulate and a compound rectangular angulate pattern is quite common. Norwegian coast and in portions Adirondack mountains a well developed rectangular pattern is observed.

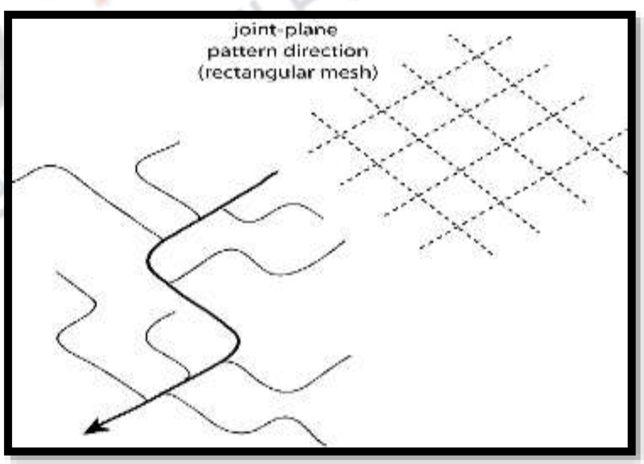

Figure 7: Rectangular Pattern

https://upload.wikimedia.org/wikipedia/en/1/12/Rectangular_drainage_pattern.JPG

2.1.7 Multibasinal Pattern

This multibasinal pattern is suggested for all multidepression patterns when the exact origin is not clear. It may be on hummocky surficial deposits; deferentially scoured or deflated bedrock; areas of recent volcanism limestone solution or permafrost. The modified basic patterns such as glacially disturbed, karst, thermokarst and elongated bay have been identified.

2.1.8 Contorted

This pattern is irregular and seen in areas with contorted, coarsely layered metamorphic rocks. In some areas dikes, veins provide the resistant layer. The longer tributaries to curved subsequent streams indicate dip of metamorphic layers. The pattern differs from recurved trellis as it lacks regional orderliness.

2.2 Genetic Classification

W.M.Davis is credited with giving genetic classification of streams and their valleys. In 1875, Powell had introduced the concept consequent valleys that later Davis expanded.

2.2.1 Consequent Stream

The streams which follow the course determined by the initial slope of land are considered as the consequent streams. This follows that the streams that develop over newly created land surfaces such as glacial plains, newly emerged sea floors, fresh basalt plateaus, or alluvial plains are consequent streams. It can safely be stated that initially all runoff is consequent (Bloom, 1978).

2.2.2 Subsequent Stream

As the initial consequent flows down the newly emerged landscape, it erodes the rocks setting in structural control that further defines the flow of stream. The stream may cut across the easily erodible structure before encountering the next resistant structure. Subsequent streams refer to those that have shifted from original consequent ones to more readily erodible rocks. They develop independent of and subsequent to consequent drainage pattern. The drainage patterns dendritic, parallel and radial are considered consequent while the rest of patterns described above are associated with structural control and are therefore subsequent streams.

2.2.3 Insequent Stream

According to Davis, the streams that show no apparent structural or lithological control are identified as Insequent streams

2.2.4 Obsequent and Resequent Stream

The stream that flows in the opposite direction to the original consequent are named as Obsequent streams while the stream that flows in the same direction as original consequent but at lower topographic strata is name Resequent stream.

2.3 Antecedent and Superimposed Drainage

Sometimes the upliftment of land is so slow that stream is able to maintain its established course by downward erosion, carving deep gorge through the mountains. As this stream antecedates or predates the uplifted landscape it is known as **antecedent drainage.** In other words, the valleys that were eroded may develop new tectonic ridges on their landscape. The river in some case is able to maintain its valley across the tectonic ridge, thereby forming the antecedent stream – that means the river is antecedent to deformation of landscape (Bloom, 1978). Streams that originally existed on a higher landscape, that is completely or largely eroded away in such a way that original drainage pattern gets incised/embedded into underlying rocks of entirely different structure. This drainage system is termed **superimposed or superposed** and bears no relation to present local structure (McKnight, 1998). Let us assume, a newly emerged land from sea with a thin veneer of sediments, under which is buried an older terrane of complexly folded strata. The first step will be formation of consequent stream with dendritic pattern on the newly emerged landscape. With gradual erosion by streams, it will eventually reach the older complexly folded strata. At this time the dendritic stream pattern gets superposed on older rocks without regard to structural control. The anomalous position of river valleys after the covering beds have been completely removed reflect the superposed nature of the stream (Bloom, 1978). The situations will be more complicated if the underlying strata was deformed, folded thrust sheet or nappe. So, there can be enumerable drainage anomalies superposed on the kind of structural rocks.

Geomorphologists have sometimes found it difficult to differentiate whether a river is antecedent or superposed, particularly when major rivers cross mountain ranges in narrow gorge. Example of Middle Rocky Mountains shows that geomorphologists previously considered Rivers Yellowstone, Bighorn and Laramie to be antecedent, meaning that the mountain blocks had uplifted and the rivers had continued their downward erosion. But later geologists have confirmed that in mid-Cenozoic, that the mountains were buried under lacustrine and alluvial deposits. These rivers flowed over alluvium and superposed on resistant rocks of buried ranges while the area continued to be uplifted and dissected. The evidence that supports the rivers being superposed is that at suitable altitudes, there is presence of remnants of former alluvium and secondly there is similarity between the alluvium found upstream and downstream of the gorges (Bloom, 1978).

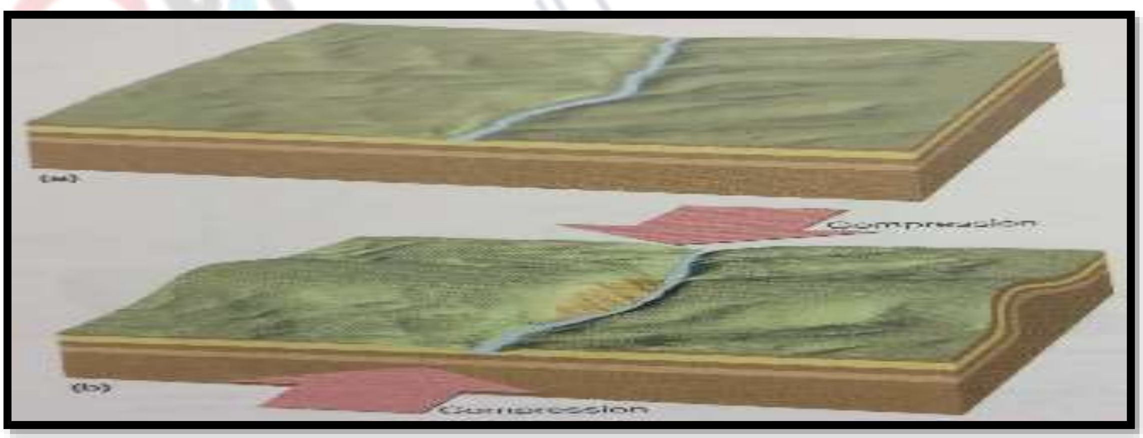

Figure 8: Antecedent Drainage

Source: Adapted from Mcknight, T.L.(2010). Physical Geography – A Landscape Appreciation

2.4 Stream Capture

In case of stream capture, one stream actively attacks and erodes drainage of another stream that results in diversion of parts of its waters to pirating stream. The main reason for piracy iscapacity of one stream to preserve and extend its valley at a lower level than that of an adjacent stream. This means that either by chance or structural advantage, one stream cuts into the drainage basin of another stream, progressively or abruptly cutting off or diverting new tributaries. This process also termed as *capture* and the trunk stream that is deprived of its stream is said to be **beheaded.** Stream piracy may take place due to abstraction, headward erosion, lateral planation and subterranean diversion (Thornbury, 1997).

Commonly stream capture is observed in subsequent drainage systems capturing the earlier consequent drainage. Consider two streams flowing across a coastal plain with their valleys separated by interfluves. If Stream A is shorter than Stream B but more powerful and aligned in such a way that the headward erosion of this stream will project in the direction of valley of Stream B. Due to head ward erosion of Stream A, the drainage divide between the two valleys will reduce. Progressive erosion and extension of Stream A in the headward direction into Stream B will eventually take place. Since Stream A is more powerful than Stream B, it *captures* the waters of Stream B. Stream A becomes the **captor** and Stream B is the **beheaded** stream. The upper part of Stream B becomes the captured stream and the abandoned channel of the abrupt bend of Stream B is the **elbow of capture** (McKnight, 1998). Let us consider an initial consequent that is superposed on a folded belt. The subsequent valley expands along weak rock belts, progressively intersecting the previous consequent drainage. The initial consequent by this time may be series of graded reaches alternating with gorges or **water gaps** across the resistant strata. After river capture, the former course is marked by **wind gaps**(Bloom, 1978).Shenandoah River, a tributary of River Potomac through headward erosion along weak rock of Blue Ridge captured waters of streams flowing through Snickers, Ashby and Manassas areas of Appalachian mountain of United States. The Shenandoah River was flowing at a level lower than three other streams and was cutting its valley at a faster rate (Thornbury, 1997). Another example can be cited of the Niger River in West Africa. The headwaters of Niger are near the Atlantic Ocean, but the flow of river is inwards rather than seawards. It flows for about 1600 kilometres in the northeast direction, then turns abruptly in southeast and continues on its journey for another 1600 kilometres before reaching the Atlantic Ocean. It is believed that upper part of what is now Niger River was a separate river, that did not change course but flowed northeast till it emptied its waters in the inland lake in Central Sahara. River after being beheaded by ancestral Niger, produced the great elbow of capture and left behind a beheaded stream that in due course of time dried with rise in aridity (McKnight, 1998).

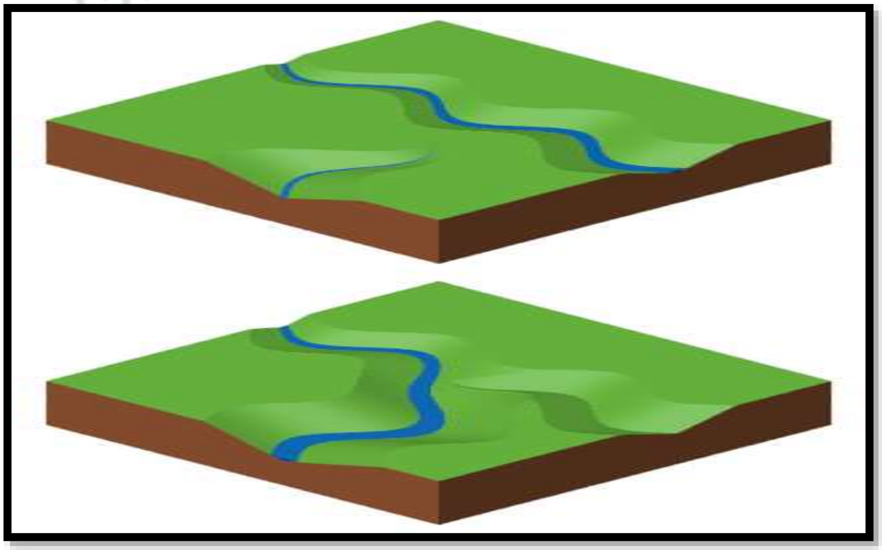

Figure 9: Stream Capture

https://upload.wikimedia.org/wikipedia/commons/e/e8/Stream_capture.png

2.5 Stream Channel Pattern

Stream flows are generally irregular, confined to channels that gives it a three dimensional nature and are visible through variations in channel patterns. Smooth and regular stream flow will result in straight and direct steam channels but it is obvious that in nature very few streams exhibit straight and uniform channels over a long distance. Most steam channels tend to wind their way across the landscape, sometimes showing great sinuosity. Stream channel patterns can be Straight, Sinuous, meandering and Braided. Any large river system such as Ganga or Brahmaputra are made up of all the four types of channel pattern.

2.5.1 Straight Channel These are short and uncommon and reflect a strong structural control due to underlying rock formation. A straight channel would not mean that a river is running in a straight line. The deepest part of the channel known as thalweg hardly ever follows an absolute straight line and may move right and left across the channel.

2.5.2 Sinuous Channel These are winding channels most commonly found in various topographical structures. Even when the stream flows down a steep slope with a high gradient the channel exhibits a sinuous characteristics. On a flat topography, with low gradient steam channels flow with greater sinuosity.

2.5.3 Meandering Channels These are most common and are depicted by a serpentine course contorting and curving, showing twisting behavior. The word meander means to proceed sinuously and aimlessly. Flat topography with low gradient are characteristic of meandering channels where in most streams have fine sediment loads. The meandering channels have cohesive alluvial banks and the sinuosity of the river is expressed as ratio of the river channel length over the valley length and can depict varying ratios including one. In a typically meandering river the wavelengths are tightly clustered around a dozen times the river width (Anderson & Anderson, 2010). The inside bend of the meander may have a sandy deposit termed as point bar – forming part of active drainage system. The thalweg will be located on the outside bend against the far bank of the river. Scroll bars and ox bow lakes are the geomorphic expression of the meandering system. These are commonly observed in the Mississippi valley of North America. In India, the fluvial flood plain of River Burhi Gandak in Bihar shows several scroll bars and Ox bow lakes.

Figure 10: River Meander
https://pixabay.com/en/meanders-vltava-%C5%A1umava-river-1316553/

2.5.4. Braided Channels

These comprise multiple interwoven and interconnected channels that may be separated by low bars or islands of sand, gravel and other loose debris (McKnight, 1998). The pattern of braided channel is explained through the process in which the banks lack cohesion, transport is by bedload only and the flow of water in the stream fluctuates frequently. These patterns are common in glaciated landscapes as glacial outwash plain channels where the coarse-grained bed load is supplied by a glacier to the meltwater. In arid landscapes with dry seasons and period of low water discharge predominates, the streams show the characteristic braided channel. Since there is deficiency of fine material and vegetation, there is lack of cohesion of the river banks. The flow in the braided channel at any given point of time occupies two or more channel segments simultaneously. The flow threads are separated by mid-channel bars. Sometimes the entire valley cross section may have many tens of threads. This means that at any given point of time active channels may cover less than one-tenth of the width of the entire channel system. But in a year the most or all of surface sediments may be reworked by the lateral flow in the stream channel. The flow depths may range to a few metres only. As the flow depth increases, the shear stress exerted on bank becomes sufficient to entrain bank material and the channel widens locally (Anderson & Anderson, 2010). Chitina River, Alaska shows extensive braided stream channel and is formed from major glaciers of Wrangell Mountains.

Figure 11: Braided River
https://commons.wikimedia.org/wiki/File:Rakaia_River_NZ_aerial_braided.jpg

Summary

Two classifications of drainage patterns are empirical and genetic. The empirical classification emphasizes the structural control where the streams are accordant to the landscape on which they flow. The genetic classification of drainage pattern talks about the antecedent and superimposed patterns. The channel patterns can be straight, sinuous, meandering and braided depending on the amount and grain size of the bed load.