# Geomorphic Processes: Landforms and Landscapes

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## Lecture - 15
## Fluvial Processes and Related Landforms (Part I)

Welcome back. So, last lecture we discussed about the plate tectonics and of course we talked about the mega landforms like Himalayas. Now, as I mentioned in one in my previous lecture that Himalaya is one of the major physiographic division of the Indian subcontinent and in total it controls the monsoon that is the season which we have in our country and the precipitation which we experience in form of rainfall during the monsoon season is one of the reason for the formation of the drainage on the surface.

And this drainage has given rise to the development of mighty river systems like Ganga, Brahmaputra, Satluj, Beas, Indus etc and along with its tributaries. So, these are the major basins or mighty river systems which we terms as fluvial landforms. So, the fluvial landforms or the fluvial system are one of the important systems in our day-to-day life.

So, we will spend considerable time learning about the system that is a fluvial system in this course as well as we will try our best to make you learn and understand the hazard associated with it. Of course, the precipitation is not the only agent which is responsible for the formation of landforms but the erosion, which has been triggered by the flow of water on the surface in different areas will result into the formation of landforms.

And that we will discuss in this lecture and particularly the sediment transport and where exactly this sediments which are eroded are getting deposited and finally resulting into the formation of different landforms. So, the landforms which we are going to talk could be erosional or depositional.

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So, let get started, the picture which you see here is of Brahmaputra river, the aerial photograph which was been taken during its flooding state. So, we will see what are this type of channels which are been termed as and how they evolve. So, the fluvial landforms let us get started or the morphology of the surface sculptured or curved by drainage or river system.

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So, what you see here some winding up of the channel. Channel is coming here, getting winded up tightly and then flow and there are few features which you see as an isolated channels and then on the right hand side, there is an inundation by water during the flooding state.

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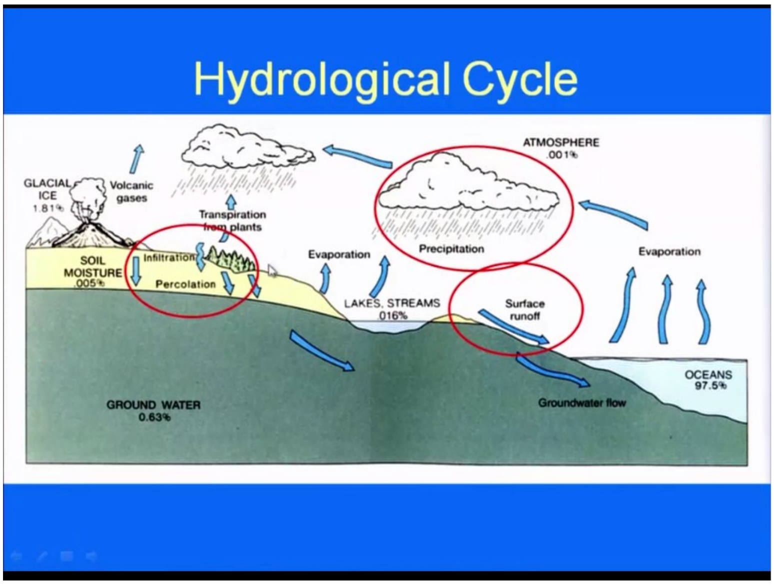


So, the most important aspect what we should discuss in this topic of fluvial landforms is hydrological cycle. So, hydrological cycle in total if you take then what we have is comprise of the water in different state, one is in ice, then vapour and then what you see is the water. So, mainly what we are able to see is a complete cycle that there is transpiration, evaporation from the surface which results into the formation of the cloud and then we have precipitation.

When the precipitation comes in, then there is slightly infiltration or you can say percolation to the interior of earth, basically it is to the groundwater and close to the surface and some flows into the streams and surface runoff and get into the ocean through fluvial system. So, precipitation, then precipitation will result into the percolation or infiltration and then partly there will be surface runoff and the cycle continues through evaporation and all that from the ocean.

So, they form evaporation from the land as well as from the ocean, in the atmosphere the precipitation will result into the rain and so on.

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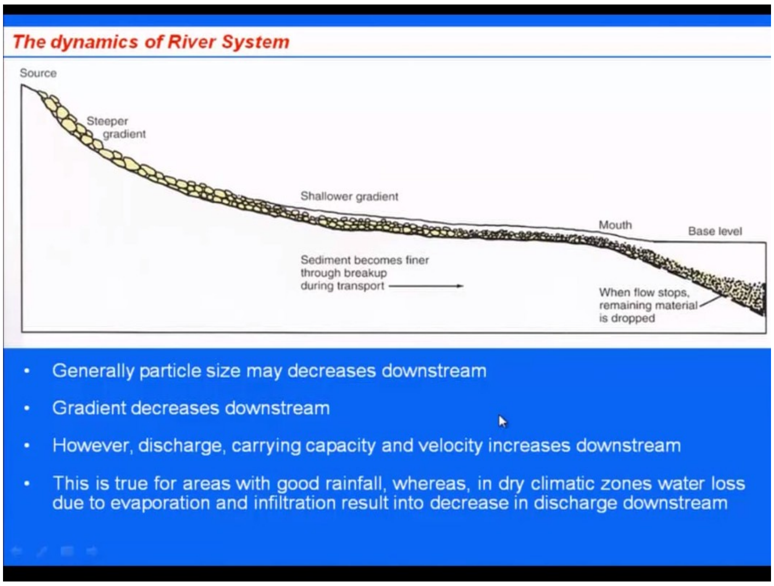


So, this is the cycle but the most important part that is the carrier of this precipitated water that is the rainwater, on the surface is the river system. Now, to understand the complete cycle of the sediment transport and then formation of different landforms, it is extremely important for us to understand the dynamic of river system. So, dynamic of river system right from its origin up to the mouth where it meets the ocean or any river body or you can say the river system or water body at the end of its journey.

So, generally what we see is that from the source up to the mouth, the particle size which it carries that is a river system decreases downstream, gradient decreases downstream, discharge, carrying capacity and velocity increases downstream. Now, this is true for the area with good rainfall, whereas in the dry climate, water loss due to evaporation and infiltration result into decrease in discharge downstream.

Otherwise, the carrying capacity and the velocity increases downstream. So, in short if you see in this figure, what it shows us that close to the source in the uplands or the upper reaches or watershed area, you have coarser sediments, steeper gradient. Then, the sediments become finer through breaking up during transport. So, it becomes comparatively finer. The gradient is shallow and further towards its mouth where it meets the ocean or any water body or river, major river or the trunk stream, it becomes more finer.

So, the material become finer towards the mouth, it is further downstream. So, steeper gradient is shallower, coarser sediments and medium to finer sediments towards the end of its journey. So, this part is extremely important to understand.

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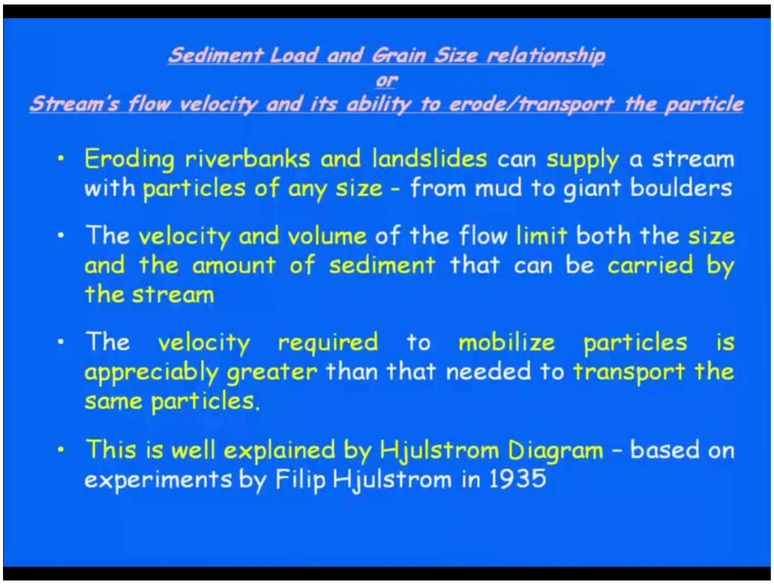


Now, sediment load and grain size relationship or you can say this stream flow velocity and its ability to erode and transport the particle. Eroding riverbanks and landslide can supply a stream with particle of any size, which could be in size ranging from mud to giant boulder. The velocity and volume of the flow limit both the size and the amount of sediment that can be carried by the stream.

Further, the velocity required to mobilize particle is appreciably greater than that needed to transport the same particles. Now, this is important because not all the sediments will require similar amount of energy conditions. It will vary from particle to particle. So, the velocity required to mobilize particle is appreciably greater as compared to what is required to transport the same particle.

So, mobilization from one place to another place, the particle is mobilized but once it is carried away into the flow, the energy will not be the same as it is required to mobilize the particle. Now, this is well explained by Hjulstrom diagram, which is based on the experiment by Filip Hjulstrom which was carried out in 1935.

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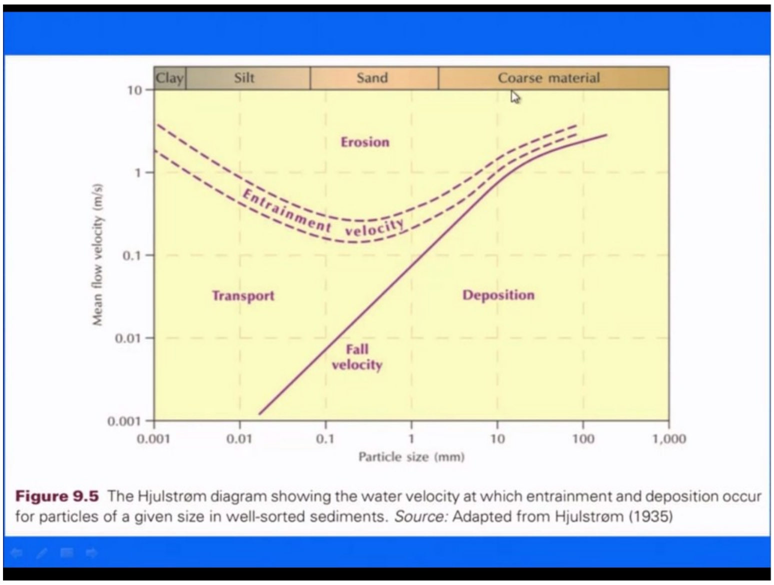


So, what it shows here is the particle size in millimeter which has been shown here on the x-axis and the y-axis is the main flow velocity meter per second. So, Hjulstrom diagram showing the water velocity at which entrainment and deposition occur for particle of a given size in well-sorted sediments. So, what we show here is one is transportation, then you have erosion, you have deposition and the fall velocity.

And the sediments which are finer to coarser which varies from clay, silt, sand and coarser material which will includes coarser sand as well as gravel which comprises pebbles and boulders.

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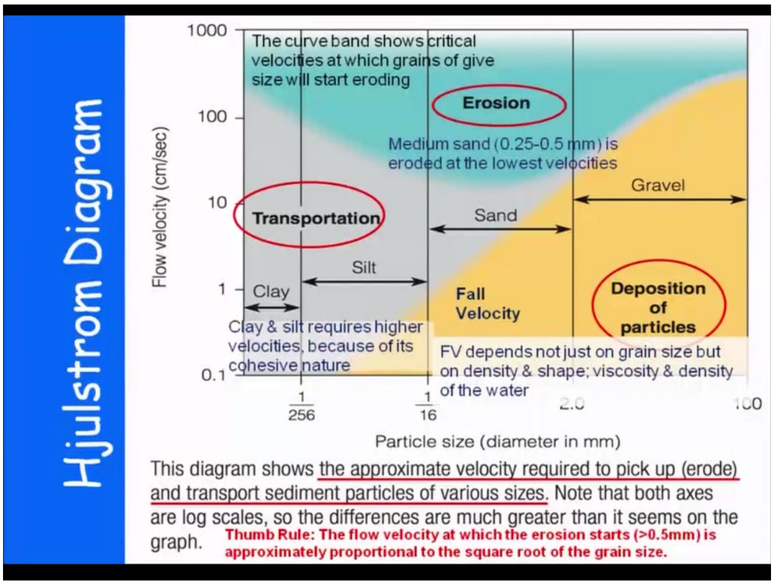


So, the same diagram here which shows the grain size or the particle size in millimeter, so you have clay, silt, sand and gravel. So, the diagram shows the approximate velocity required to pick up that is transport that is pick up is mobilization and transport the particle of various size ranging from clay to gravel. Note both the axes are these are the log scales, so the differences are much greater than it seems on the graph.

Now, the Thumb Rule is the flow velocity at which the erosion starts is greater than 0.5 millimeter is approximately proportional to the square root of the grain size. So, the erosion of clay requires much more energy as compared to sand. So, the curve band shows critical velocity at which grain of given size will start eroding. So, medium sand which is 0.25 to 0.5 millimeter is eroded at lower velocity whereas the clay and silt are eroded at higher velocities as which has been shown here.

So, the erosion over here requires more energy as compared to the transportation. So, the lifting or mobilization of the sediments from a point requires much more energy as compared to what is required to transport the sediments and this has been shown here is by this curve that much more energy is required for clay, silt as compared to the medium sand. So, the clay and silt require higher velocity because of its cohesive nature.

Now, this is the most important point which you should remember. So, if you have the sediments, which are finer will require much more energy or higher velocities to be eroded or mobilized than transportation as compared to the coarser material and this is basically because of the cohesive nature of the material. So, this is what we have the Hjulstrom diagram which explains the erosion, transportation, deposition of the particles ranging from clay to gravel.

And the fall velocity is mentioned here that is basically when the deposition starts taking place. So, the fall velocity depends not just on grain size but on density and shape, viscosity and the density of the water. So, the density and shape of the grain is extremely important and it plays an important role as well as the viscosity and the density of the water plays an important role in the fall of velocity. So, the fall velocity depends not just on the grain size.

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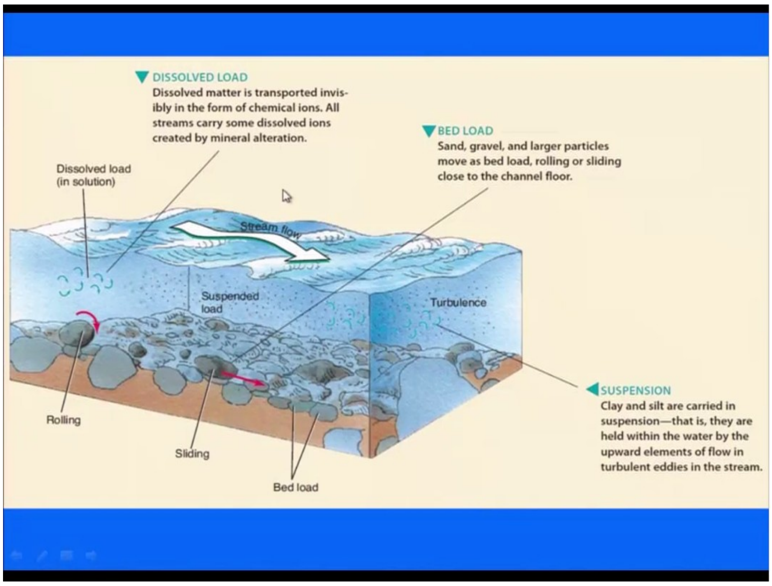


So, this is the diagram which shows that the sediments, which are been carried in bed load at the bottom either it has been carried or moved in form of rolling or sliding or in case of the turbulent flows where mostly you will find the clay and silt are carried in suspension and the suspended load may have the bed load something like gravel and larger particles. So, bed load basically is comprised of sand, gravel and larger particle moves as bed load rolling and sliding close to the channel floor.

Whereas in suspension mode will be the clay and silt are carried in suspension. That is they are held within the water by upward elements of flow in the turbulent eddies in the stream and finally on the surface you have the turbulence flow which is the particles are carried under suspension.

And on the channel floor you will mostly see the bed load where most of the material that is the coarser material has been carried either or moved either in form of rolling or sliding and the dissolved load is transported invisibly in form of chemical ions. All streams carry some dissolved ions created by the alteration of minerals within the rocks.

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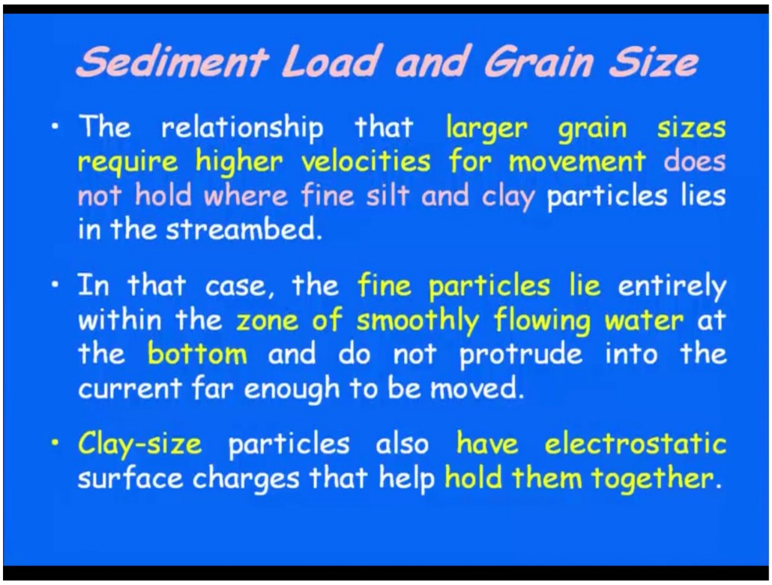


Now, the relationship between the sediment and the grain size, sediment load and the grain size. Now, this is one of the important aspect which talks about that the larger grain size requires velocity that is a relationship which we understand that the larger grain size require higher velocity for the movement does not hold where fine silt and clay particle lies in the stream bed.

Whereas compared to the coarser particles, the finer particles will require more energy as we have seen in the Hjulstrom diagram and the reason for this is that the clay material basically have the electrostatic surface charges that allows them to hold together and this will restrict their smooth flowing or smooth movement to a greater distance and this will require more energy or velocity to move it.

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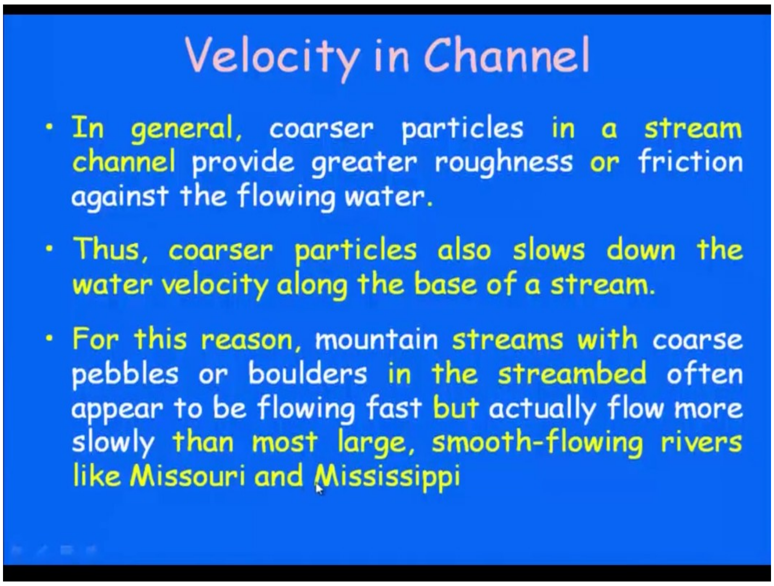

Velocity in channel; in general, coarser particle in a stream channel provide greater roughness or friction against the flowing water. Thus, coarser particles also slow down the water velocity along the base of a stream that is in the stream bed it will slow down the velocity. For this reason, the stream in the mountains with coarser bed load for example pebbles or boulders in the stream bed often appear to be flowing very fast.

But actually flow is very slow than most large, smooth-flowing rivers like Missouri and Mississippi are the best example. So, the water flow in the mountains basically are not flowing faster but the sound which is resulted because of the development of the friction against the flowing water by the coarser particles will mimic that the flowing water is very fast but actually the water is moving very slow.

And the best example of such rivers the mighty river is Missouri and Mississippi and of course in India is Ganges and Brahmaputra.

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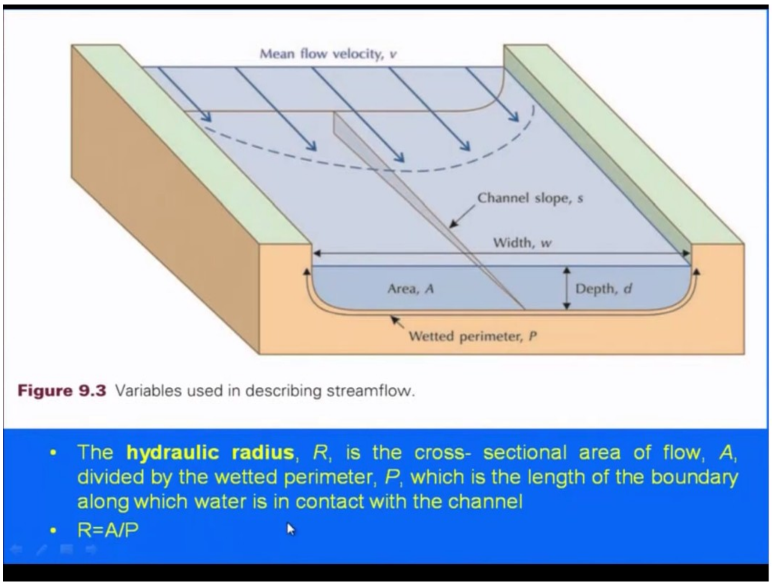


So, if you go in the hilly areas, you will find that the water in the hilly areas or the upper reaches are moving very slowly but it appears to be flowing very fast. So, variables used in describing the stream flow. So, if you have the cross-sectional area that is the perimeter of the channel, then you have the area of the channel depth, width. Based on that, you can calculate the area and the slope will help you in talking about the flow velocity of the stream.

So, the hydraulic radius R is the cross-sectional area of flow which includes the channel dimension, the depth which includes depth, of course the width and the area where A divided by the wetted perimeter P which is the length of the boundary. So, A is the area of the flow, R is the hydraulic gradient; P is the wetted perimeter which is the length of the boundary along which water is in contact with the channel.

So, this is the P is the wetted perimeter, A is the area and d is depth here, w is width and s is the slope of the channel. So, R that is your hydraulic radius will be A/P. So, the ratio or the area divided by perimeter will give you the hydraulic radius of the channel.

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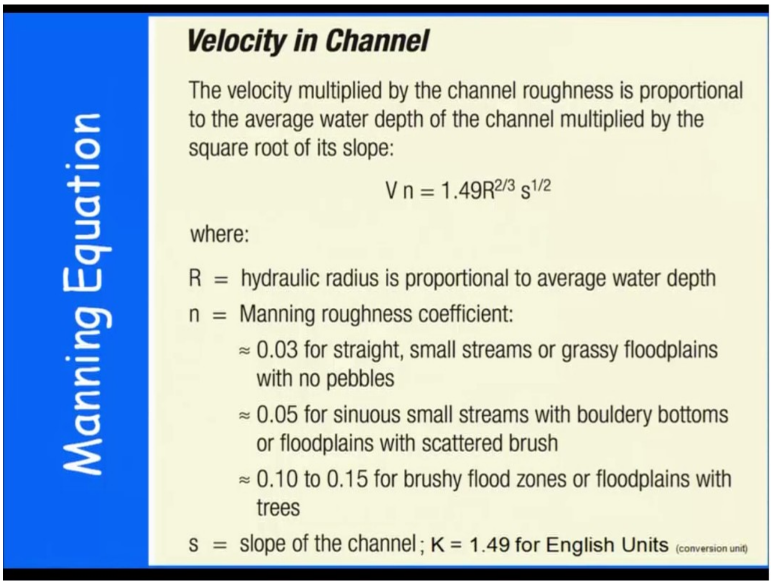


So, the velocity in channel what you have you can also talk in terms of the equation which has been given here that is the velocity multiplied by the channel roughness is proportional to the average water depth of the channel multiplied by the square root of its slope. So, the equation which says here shows here as Vn = 1.49 and this 1.49 is nothing but the constant for English Units, it is in conversion unit where R is your hydraulic radius.

And R is proportional to the average depth which has been hydraulic gradient we have seen in the previous slide hydraulic radius and the square root of slope. So, if you have this parameter, you have R, you have slope and then R can be calculated having the area by the perimeter. Then, you can talk about the velocity and this is important.

That is the manning roughness coefficient for straight channels, small stream and grassy floodplains it is around 0.03, 0.05 for the sinuous small streams with bouldery bottoms and the floodplains and 0.1 to 0.15 is for bushy flood zones of floodplains with trees, s is the slope of the channel and as I told 1.49 is the constant English Unit conversion unit. So, one can have the velocity of the channel with the roughness because the sediments or the landforms or the pattern of the channel will create the friction.

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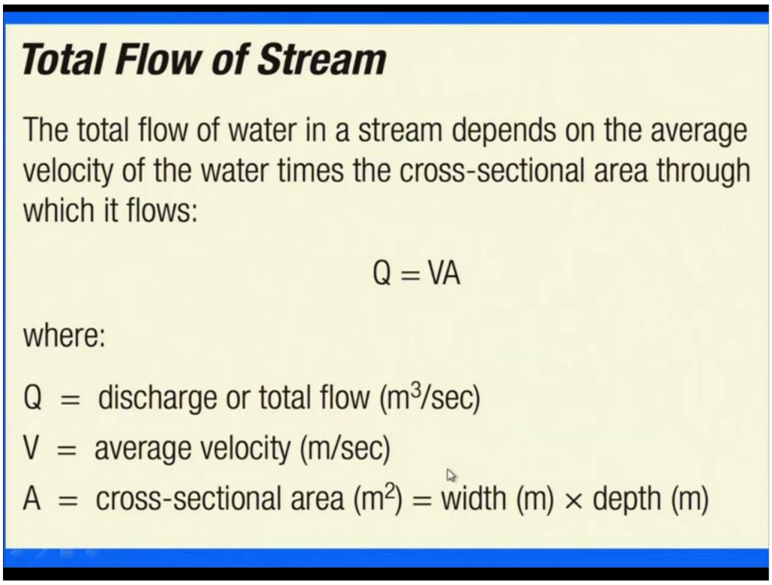


So, total flow of the stream or total flow of water in a stream depends on average velocity of water times the cross-sectional area through which it flows. So, Q is the discharge cubic meter per second, V is the velocity meter per second and A is the cross-sectional area which requires the width and depth of the channel. So, I will stop here and we will continue in the next lecture, discuss more about the landforms and different associated parameters. Thank you so much.