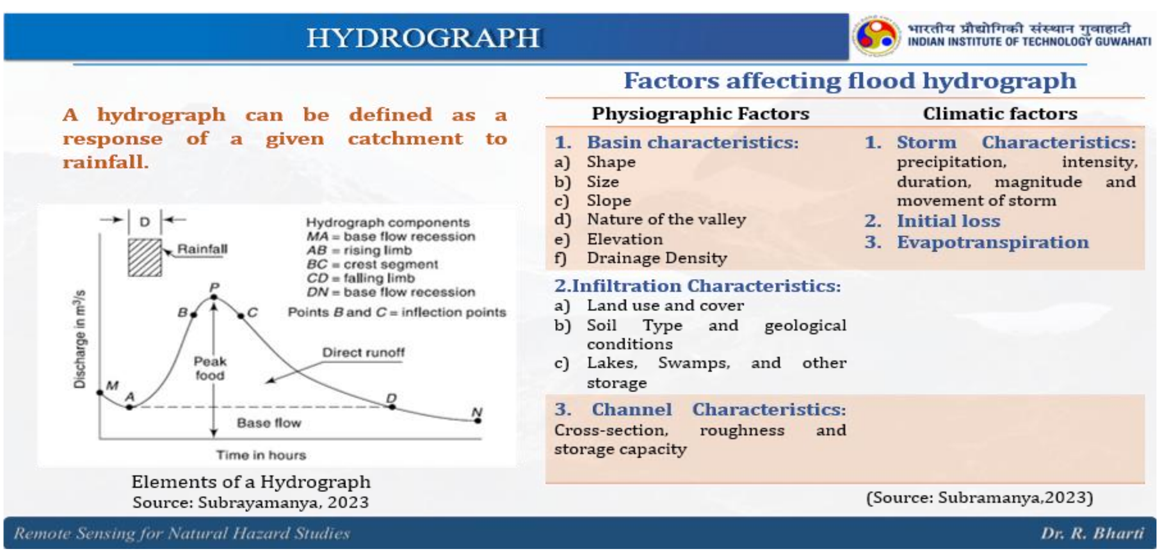
REMOTE SENSING FOR NATURAL HAZARD STUDIES

Course Instructor: Dr. Rishikesh Bharti
Associate Professor
Department of Civil Engineering
Indian Institute of Technology Guwahati
North Guwahati, Guwahati, Assam 781 039, India
e-mail: rbharti@iitg.ac.in
Website: https://fac.iitg.ac.in/rbharti/

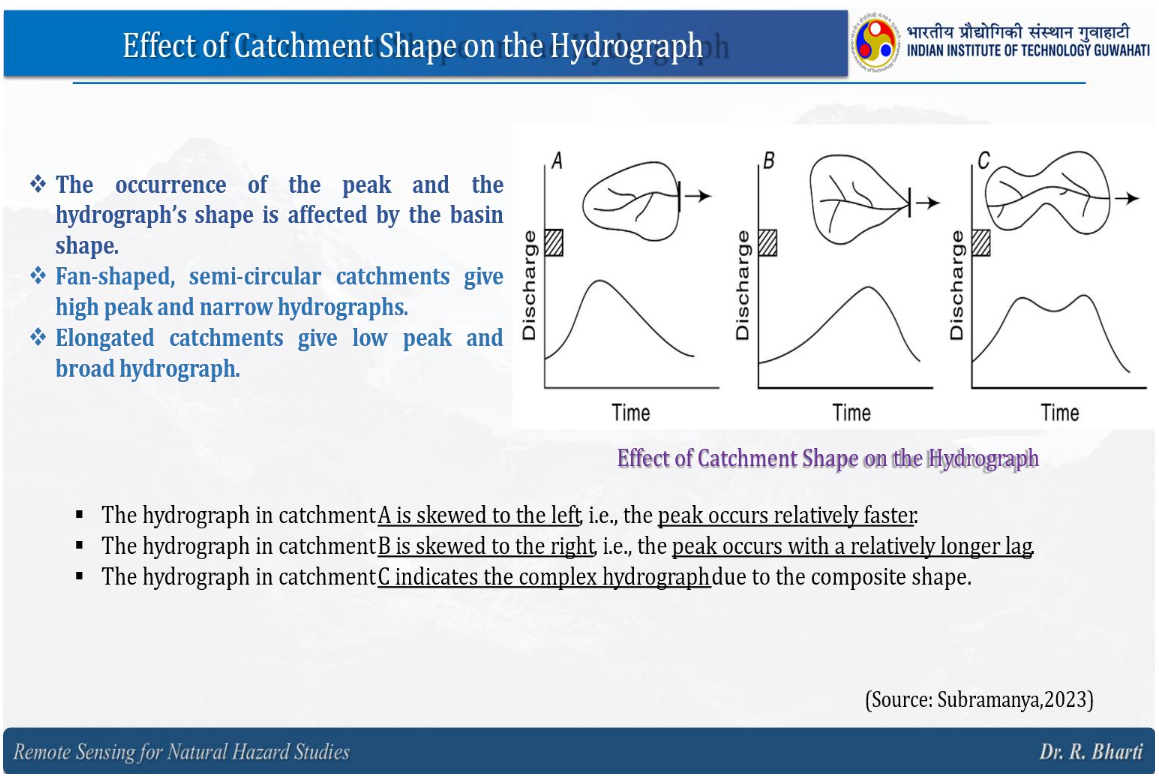
Lec 13b: Introduction to Floods - I Part B

Hello everyone, welcome back to Lecture 13; this is Part 2. So, we will continue our discussion on this introduction to flood. So, we started discussing the hydrograph. So, as you know, the hydrograph can be defined as the response of a given catchment to rainfall. So, if we can describe our catchment with respect to rainfall with the help of a hydrograph, that means we also need to understand what the different factors are that are affecting this hydrograph. So, we have physiographic factors and climatic factors. So, here we have basin characteristics, what are the shape, size, slope, nature of the valley, elevation, and drainage density? So, that falls under the basin characteristic. When we talk about the storm characteristics, precipitation, intensity, duration, magnitude, and movement of the storm. Then we have initial loss and evapotranspiration. Then we can talk about the infiltration characteristics: land use and land cover, how they are playing a role, soil type and geological conditions, lakes, swamps, and other storage in that particular catchment. Then comes the channel characteristics, including cross-section, roughness, and storage capacity, whether it is a wide channel or a narrow channel, as well as the duration and intensity of the rainfall. So, all these things need to be accommodated or considered while analyzing this hydrograph.



So, this is a typical hydrograph from this particular book. So, here you can see that discharge is on the y-axis and time is on the x-axis. So, here we have different elements. So, AB, which is from here to here, is the rising limb; then C to D is your falling limb, and B to C is the crest, and DN. So, this DN is basically a base flow recession, and the point BC is the inflection point from here. So, with the help of this particular hydrograph, we can explain how my catchment is responding to a specific type of rainfall characteristics. So, whether it can accommodate more water or less water, what will be the scenario, and how the discharge will take place, will all be explained by this hydrograph. So, the effect of catchment shape on the hydrograph.

The occurrence of the peak and the shape of the hydrograph are affected by the shape of the basin. Now, here you can see different shapes have been given, so if this is the shape that this kind of discharge is taking. Here, when this is the shape, we have a greater number of tributaries, and the shape is different; this is how the time is delayed for this peak discharge. When you have this shape, it has 2 peak discharges; here we have 1. So, whether it is towards the 0, it means time is very short. That means, immediately after the precipitation, you will have the discharge. Here, in this particular shape, it is delaying the process, so it is taking more time to show the peak discharge. Here, because of this shape, you have immediate peak discharge, and because of this shape, you have another delayed peak discharge.

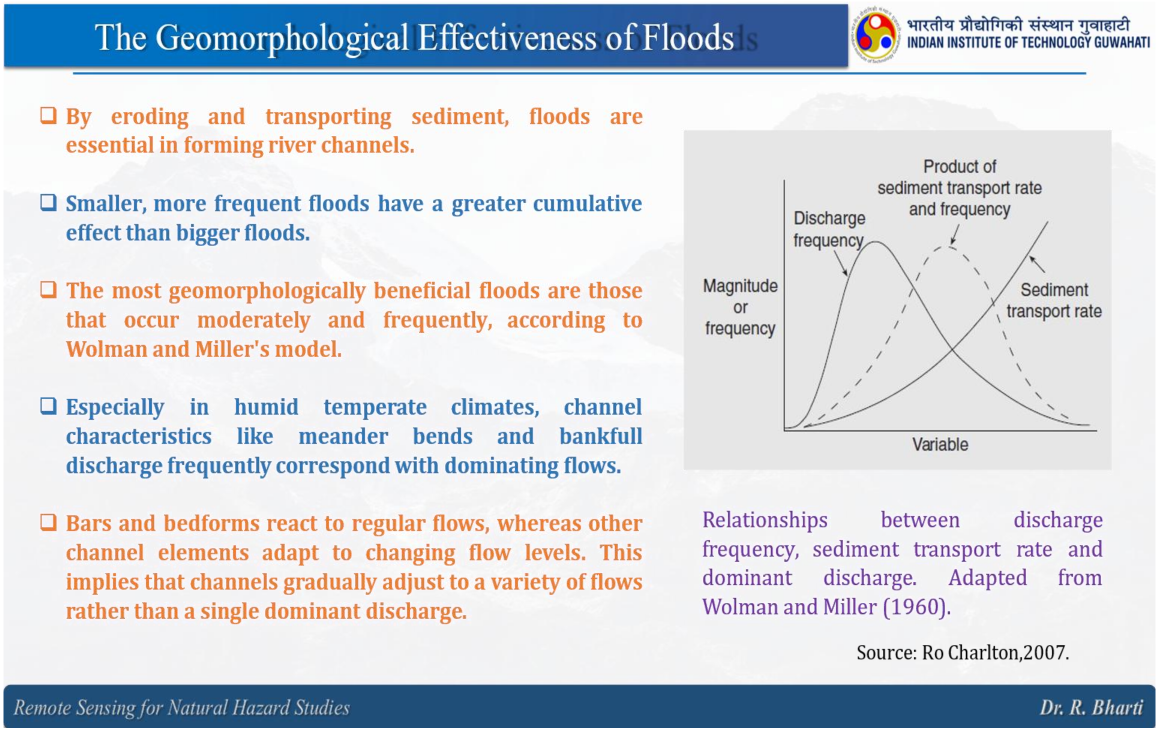


So, the effect of catchment shape on the hydrograph can be understood through this particular diagram. The hydrograph in catchment A is skewed to the left, and the peak occurs relatively faster. When we have this B, the catchment B is skewed to the in the case of B, the hydrograph is skewed to the right side. So, it is taking more time. So, the peak occurs with a relatively longer lag, or lag is the difference between the first and second events. So, you can consider this for a longer time.

The hydrograph in catchment C is a complex hydrograph due to its composite shape. So, here you have these two peak discharges: one at a short period of time and one at a longer duration. When we talk about the size, a small catchment will show an immediate response. Overland flow is predominant over channel flow; thus, land use and rainfall intensity are crucial in the peak flood. When we have a large basin, the channel flow phase is more predominant. When we talk about this slope, large stream slope, quick storage depletion, steeper recession limb of the hydrograph, and smaller time base, we are considering several factors. Smaller catchments, steep catchment slopes, and large peak discharges. So, you can take a piece of paper, and with these lines, you can draw and try to understand what the meaning of these lines is.

So, it will be clearer, and you will be able to understand what I am trying to convey. When we talk about the effect of drainage density on the hydrograph, the drainage density is the ratio of the total channel length to the total drainage area. So, here you have two conditions: one is A, and another is B. So, A has a high density, while B has a low density. This basin has a large drainage density, which allows for quick runoff disposal. So, here you can see the peak discharge is coming from the basin with the small drainage density or low drainage density; the hydrograph is squared with a slowly rising limb. So, that means the slow discharge will take place; it is a better condition compared to this one, then we have land use for a given storm duration; the surface runoff peak and volume are proportional to the intensity of precipitation.

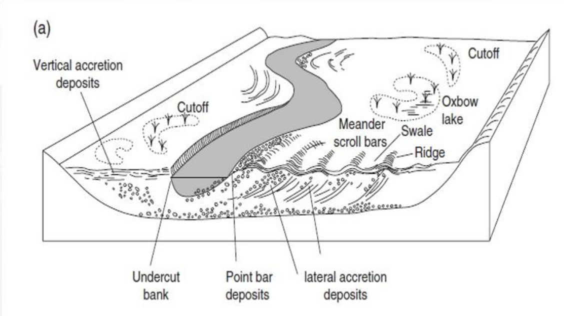
The effect of a strong duration is indicated in the rising limb and peak flow. So, you just try to understand the hydrograph using these lines. If the strong movement is up, the catchment hydrograph will have a lower peak and a longer time base. So, if it is, let us say a storm is moving from this to this. So, what will happen is that we will have more time to see the response to this particular rainfall. If the strong movement is down the catchment towards the outlet, it leads to a quicker concentration of flow at the basin outlet, producing a peak hydrograph. So, you will have an immediate response. So, this is 0, and this is the peak. If it is moving upward, you will have this kind of hydrograph.

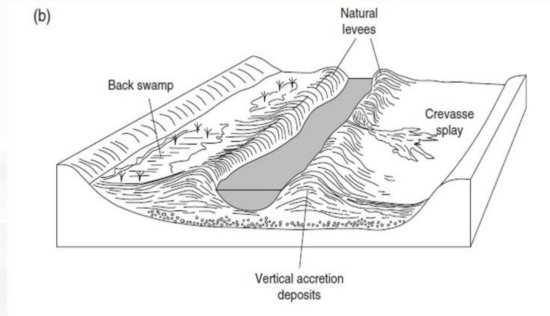


Then comes the geomorphological effectiveness of floods by eroding and transporting sediment. Floods are essential in forming river channels. Smaller, more frequent floods have a greater cumulative effect than larger floods. Because we are talking about the high discharge and frequently occurring events. So, they will have a greater impact than a bigger flood. The most geomorphologically beneficial floods are those that occur moderately and frequently, according to Wolman and Miller's model.

So, you can refer to this model; this is one of the very popular models, especially in humid temperate climates where channel characteristics like meanders, bends, and bankfull discharge frequently correspond with dominating flows. Bars and bed forms react to regular flows, whereas other channel elements adapt to a changing flow level. This implies that channels gradually adjust to a variety of flows rather than a single dominant discharge. So, here you can see the X and Y axes, the variable, and here you have the magnitude or frequency. This is the discharge frequency, and this one shows the product of sediment transport rate and frequency, and this one is for sediment transport rate. So, it shows the relationship between discharge, frequency, sediment transport rate, and dominant discharge, and frequency, adapted from Wollman and Miller, who proposed it in 1960.

Processes of Floodplain formation



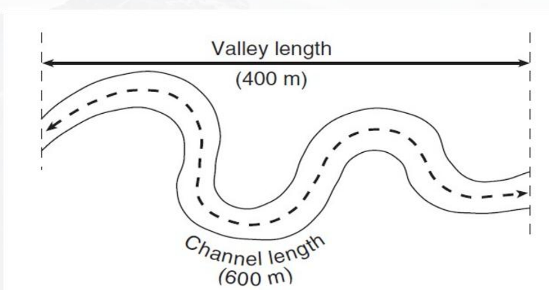


The fig shows some of the features which are associated with (a) medium-energy non-cohesive meandering floodplains and (b) low-energy cohesive floodplains. Adapted from Nanson and Croke (1992)

Source: Ro Charlton,2007

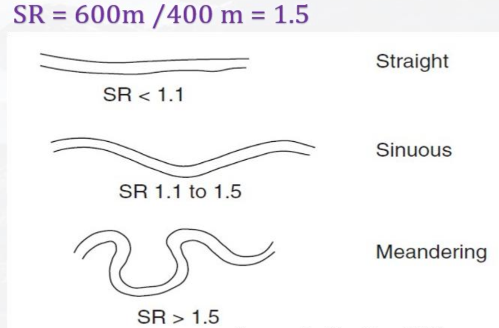
So, when we talk about the floodplains and how they form, you will be able to understand from these figures. So, here you can see we have two (a) and (b). The figure shows some of the features that are associated with medium energy non-cohesive meandering floodplains. So, here the flow has medium energy and the (b), which is showing low-energy cohesive floodplains, low energy, you can see adapted from Nanson and Croke (1992). So, here you can see different parameters: the Oxbow lake, meandering scroll bars; this is a cutoff. So, these figures can help you understand how the floodplains are formed. So, here the floodplains will be adjacent to this, here you have, these are the floodplains, So, this will temporarily accommodate the water when you have excess water. So, how do we define the sinuosity of whether a particular river is sinuous or meandering? So, we have a sinusitis index that is very, very popular.

Sinuosity Ratio



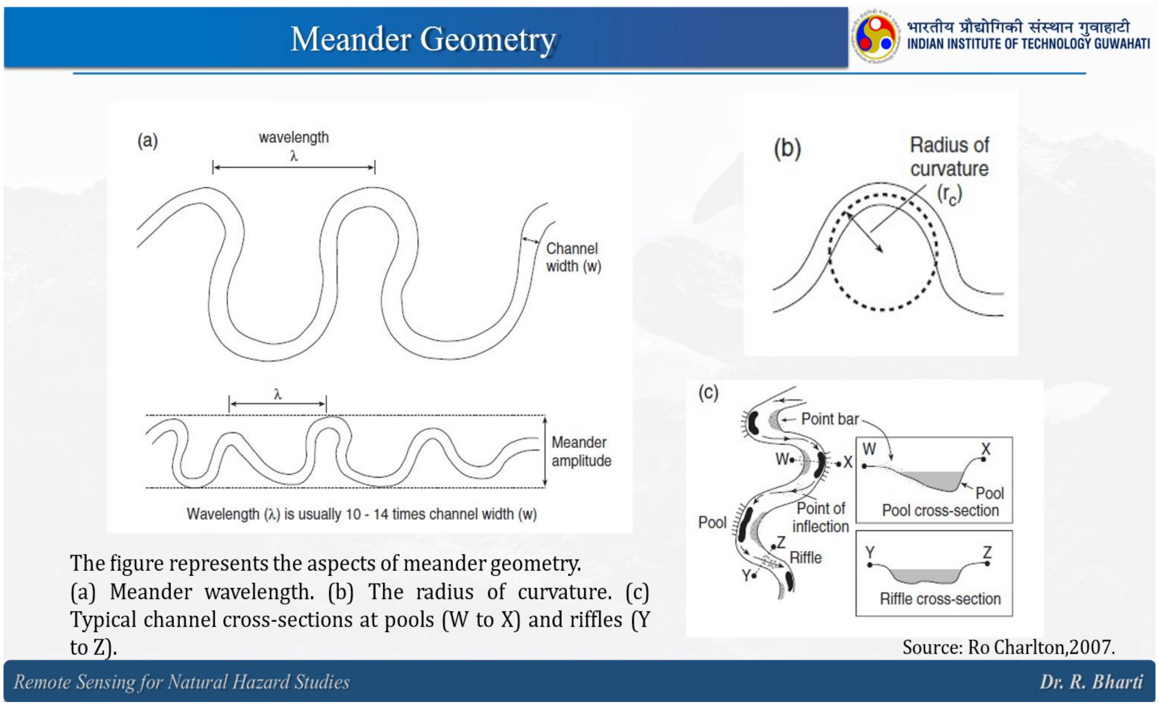
Sinuosity Ratio (SR) = Channel Length / Valley Length

SR = 600m /400 m = 1.5



Source: Ro Charlton,2007.

So, here we do is take the channel length and the valley length. So, we will try to understand the channel length and the valley lengths. So, let us consider that this is a river system. So, along this main channel, if you consider the length, that will be your channel length, and from the start to the end, if you take the distance, that is your valley length. Let us see, here we are 400 meters, here you have 600 meters. So, the sinusoidal ratio will be 600 divided by 400 meters. So, this is 1.5. Now, how do we analyze and interpret this particular value? So, we have these bases. So, if the sinusoidal ratio is less than 1. 1, that means your channels are straight. If the sinuosity ratio is between 1.1 and 1.5, that means your channels are sinusoidal. When you have a sinuosity ratio greater than 1. 5, that means it is meandering.



So, you can see this is almost straight; it has some sinuosity, and then you have a meandering nature. So, all of this can be defined or identified using this sinuosity ratio. It is very popular, and it is very useful. When we see the main ring geometry, here, like a wave, you can also define the wavelength. So, the wavelength is usually 10 to 14 times the channel width. So, that is your win. So here this is the lambda because we are considering this as a wavelength, and this is the meander amplitude at what rate it is meandering, what is the maximum distance that is covered? So, the figure represents the aspects of meandering geometry. So, it gives you the wavelength and the radius of curvature; the radius of curvature is here. So, you can just try to put the best-fitting circle here that will give you a radius of curvature, and the (c) is a typical channel cross-section at Pool. So, you can see this is a typical cross-section; this is from w to x.

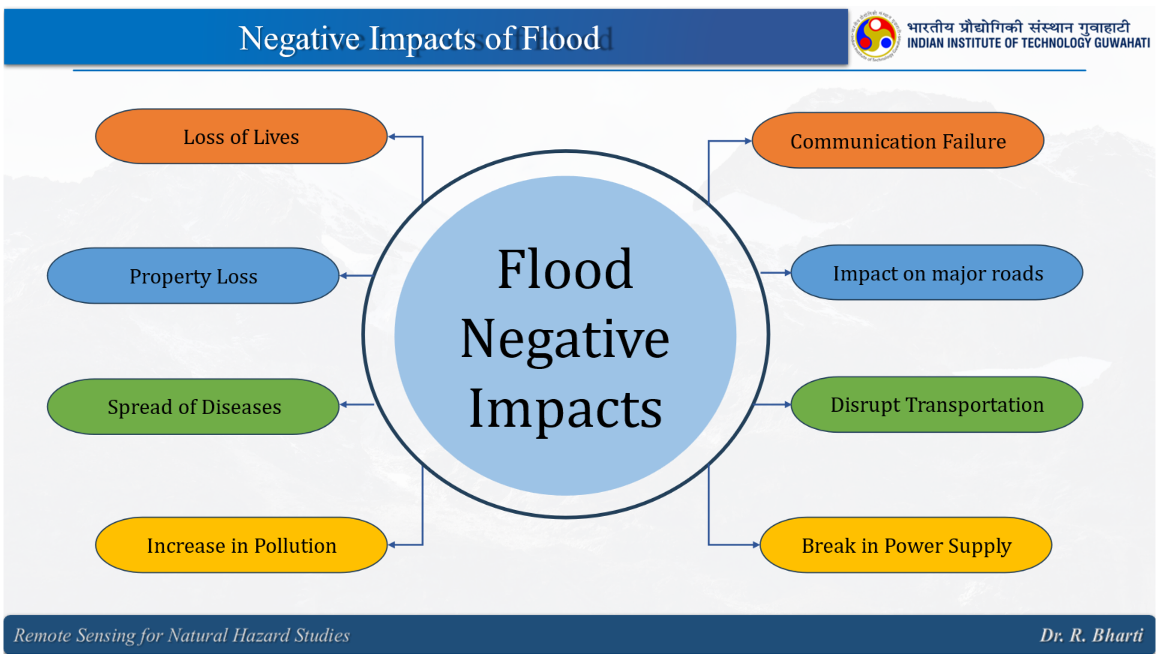
This distance here is from y to z. So, this is the cross-section. So, this will help you see what the status of that particular cross-section is. The transformation of a straight channel into a meander is also possible because these fluvial systems are always active. So, this is stage 1 alternating bar dominants, then stage 2 and stage 3, which are the formation of ripples and pools. Then, stage 4 meandering channel pools are 1.5 times longer. Then, stage 5 additional ripples and pools form as channels lengthen to the right. This figure shows the transformation of a straight channel with a ripple-pool bed into a meandering channel. So, this particular figure nicely explains how a straight channel is becoming a meandering channel. So, when we talk about the different types of floods, whether they are natural or manmade, or caused by anthropogenic activities, we can divide them. So, you can see here that when we have this natural phenomenon, we have different causes: landslides, precipitation, tsunamis, glacial melt, or storm surges; these all come under natural hazards. When we talk about manmade or anthropogenic causes, it is due to releases from reservoirs, breaches of dams, barrages, or embankments, or because of urban flooding caused by urbanization. So, this is all categorized or classified as anthropogenic, and here you have the natural causes. These are some examples of how the tsunami can cause flooding in this particular region. When we have a landslide, this also causes a flood. If there is a lake here, then this will be even more devastating.

Then we have glacial melt. If we have more glacial melt and it cannot be accommodated by our river system, then we will have a flood scenario downstream because of the high intensity and long duration of rainfalls, we have this kind of situation. It is very common. This is the scenario for urban flooding because these floors are impervious. So, they are not allowing this water to percolate, and because of that, we have more surface water. When we have a dam breach, because of the sudden release of water, you will have this kind of scenario. Many people have put their efforts into generating the flood risk map. So, this is one of the examples; this is the global flood risk map.

So, you can see this is for Southern Asia and Sub-Saharan Africa, and here you can see how they have made this prediction. So, an increase in the future between 2010 and 2030. So, this is indicated with this color increasing in the past between 2000 and 2030; it is in yellow, then increasing in the past and future; then you have little change or a decrease in the past and future, which is represented by blue. Then, we also have a few reasons for which we have insufficient data or high uncertainty. So, this is from the global flood database. You can refer to this particular website; you will find many interesting things related to floods. So, when we talk about the types of floods, we have different types. So, we have river floods, flash floods, urban floods, and coastal floods. So, the name itself indicates what kind of flood we are looking at, So. When we talk about the river flood, it is related to the river's overflow. Flash floods are mainly caused by the sudden release of water due to natural or anthropogenic activities. Urban flooding is due to urbanization, and we can expect coastal flooding in the coastal region as well. So, when we talk about the river flood, it is caused by precipitation over a large area or due to snow melting. It occurs in and around the river. So, you can see in both cases we have a river, but because of the flood, you have excess water here. Here, this is also the boundary of this river. The ground conditions affect the runoff. Now, regarding the ground conditions, we have already discussed these parameters: what is the soil type, what is the infiltration rate, what is the precipitation rate, and what rock types are present in the area. So, they are all playing together here, and this is resulting in these kinds of flooding scenarios. When we talk about urban floods and ice jams.

So, urbanization prevents the ground from absorbing rainfall, leading to urban flooding. When urban floods strike, streets are inundated, resembling rivers, while basements fill with water. So, you can see it looks like it is a river channel, but it is not. It is a lane, right, and it is an urbanized area. So, because of this flood, it looks like a river channel. When we talk about ice jams, an ice jam occurs when floating ice accumulates in a natural or artificial waterway, obstructing the water's flow. Because of this, suppose you put the ice in the right formation. Then what will happen again is that you will have more water in these areas, so that is the case when we talk about ice jams. When we talk about coastal floods, it is because of the tides, storms, tropical cyclones, or tsunamis. So, you can see how the water is coming into this because of the tides, and the storms, tropical cyclones, and tsunamis are very common, and they are causing flooding in the adjacent areas.

You can see some examples here. When we talk about this flash flood, it occurs for a very short time but contains a great volume of water. So, here it is very important to note that it is for a short period of time, and it will have a great volume of water. It is a life-threatening flood that begins within three to six hours of the rain event. If you have high-intensity rain, then it will occur within the next 3 to 6 hours. Most flash flooding is caused by slow-moving thunderstorms, thunderstorms repeatedly moving over the same area, and heavy rains from hurricanes and tropical storms. So, again, your area is receiving more precipitation that will lead to this flash flood; it may result from the failure of dams; that is another case. Several factors contribute to flash flooding; the two key elements are rainfall intensity and duration, as we discussed in this area. Rainfall or thunderstorms are moving into this particular region; what will happen? You will be receiving more water. So, if the rainfall intensity is high and the duration is long, you will have this flash flood scenario. A combination of high rainfall rates with rapid and often very efficient runoffs is common to most flash flood events. Ice jam formation on rivers can also play a role in rapid-onset flash flooding, particularly upstream of the river. Ice jam area. So, there are three critical soil properties that we consider when we analyze flash flooding. So, the first one is soil moisture, soil texture, and soil profile. Soil moisture is often considered the most important factor for rapid runoff and flash flooding. There is some validity to this reasoning, in that if the soil is saturated, there is no room for additional rainfall to infiltrate. So, if this particular column is already saturated, there is no room for additional water. So, what will happen? This will start flowing, and all rainfall will become runoff regardless of the soil texture. So, if the intensity is high and the duration is long, it does not matter what soil type you have; everything will lead to a flood. Flash flooding occurs with high rainfall rates that often exceed the soil infiltration capacity, even when the soil is dry. Certain soil textures, such as clay and, to some extent, silt, can be associated with low infiltration rates and result in rapid runoff during intense rainfall. Therefore, runoff from intense rainfall is likely to be more rapid and efficient in clay soil than in sand. So, this is clay soil, which, compared to sand, will have more problems with flooding. Although sandy soil permits greater infiltration of intense rainfall, rapid runoff can occur if there is only a thin layer of soil. So, the geology of that area is also important as the soil. What is the depth of the soil, what is the soil texture, and what is the soil profile that are equally important? So, this is an example of a flash flood. You can see these are some of the generated images. As we discussed in the beginning, the flood is the deadliest natural disaster, but it also has positive impacts. So, we will see some of the negative and positive impacts.



So, when we talk about the negative impacts of the flood, we refer to communication failure and the impact on major roads. Disrupting transportation, breaking in power supply, increasing pollution, spreading disease, property loss, and loss of lives are the negative sides of floods. But we also have some of the benefits: flood water supports life in arid to semi-arid regions, increases nutrients that mean it will help you grow more crops, increases fish production, creates more fertile soil, and maintains freshwater ecosystems in river corridors and groundwater recharges. These are some of the positive impacts of floods. So, it is also important to note that some of the areas are dependent on the flood. So, every year they know that we will have the flood, and after the flood, what benefit they will have, and that they are utilizing it rightly. So, with this, I will end this lecture, and we will continue the topic in the next lecture.

Thank you very much.