Surface Water Hydrology
Professor Rajib Maity
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 41
Introduction to Flood Routing

In week 9 will we learn different methods for Flood Routing and will give some introduction to Flood Routing.

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Three concepts will be covered. The first one is the different types of Flood Routing then two different terms which are important and why we need this Flood Routing to know beforehand is the Attenuation and Lag and there are some basic equations of this Flood Routing there that is utilized in different methods.

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The outline goes like this introduction to Flood Routing categories of Flood Routing under this there are the Reservoir Routing is there and Channel Routing is there and under the category of this Flood Routing methods, there are two types one is Hydrologic Routing and another one is Hydraulic Routing is there.

And the basic equations are again for two different types Hydrologic Routing and Hydraulic Routing, we will end up this particular lecture is through a very important relationship between the storage and the discharge. Finally, we go to the summary.

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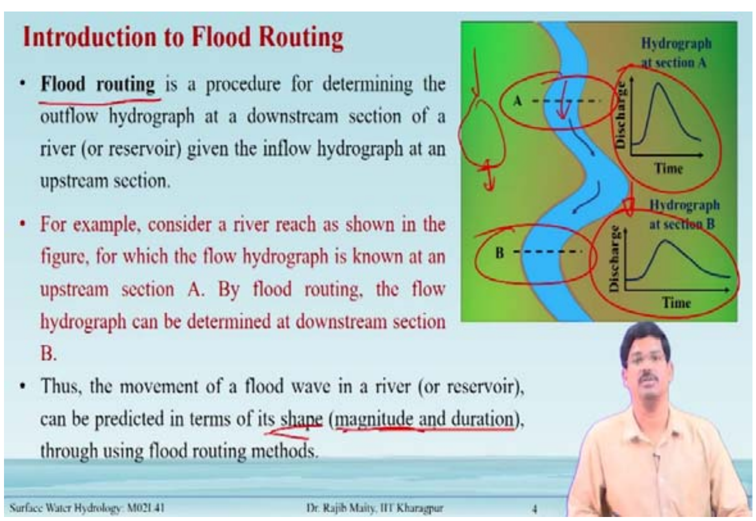

Introduction to Flood Routing

Introduction to Flood Routing

Flood Routing is a procedure for determining the outflow hydrograph at a downstream section of a river or reservoir given that the inflow hydrograph at an upstream section, as shown in fig.1. I consider the upstream section and another section B which is downstream of this river here, but it is not a not necessarily a B river also this inflow can come to one reservoir and there is a there is some sand it can come out from this reservoir also.

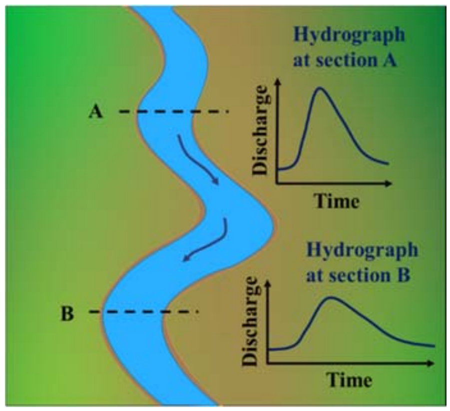

Figure 1: A typical diagram of the river reach

The flood Routing method is that there is a hydrograph means the discharge versus time that comes through section A if we know this information, then is it possible to know what will be the set of the hydrograph at section B.

The procedure of knowing the information of the hydrograph at a downstream section is the Flood Routing and how this flood comes and proceeds through a channel or in a reservoir. In other words, the Flood Routing of the flow of the hydrograph can be determined in the downstream section as you have shown in this diagram in the section B that is the movement of the flood wave in a river or reservoir can be predicted in terms of the shape (magnitude and the duration), through using the Flood Routing methods.

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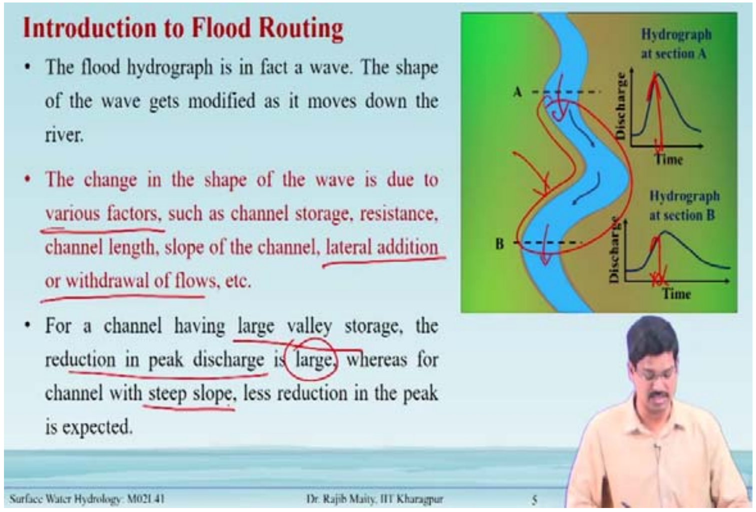

The flood hydrograph is a wave. The shape of the wave gets modified so that it moves down to the river channel. So, this change in the shape of this wave is due to various factors it can be due as the channel storage, the resistance the channel length, the slope of the channel, lateral addition or withdrawal of the floor, etc.

So, for a channel having large value storage, when this channel itself is having the storage amount is significant, the reduction of the peak discharge is large whereas, for the channel with a steep slope, less reduction in the peak is expected. So, what is happening, this is what we are calling the peak. So, there are different conditions, it depends on this channel's various factors, and the channel characteristics are one of them.

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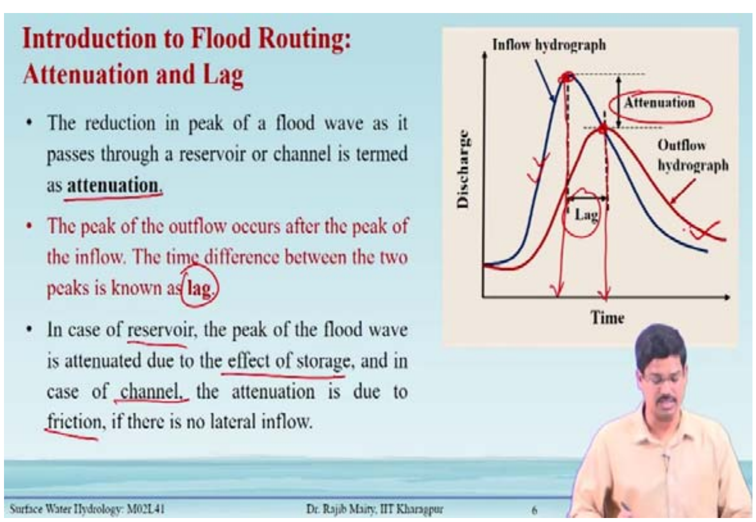

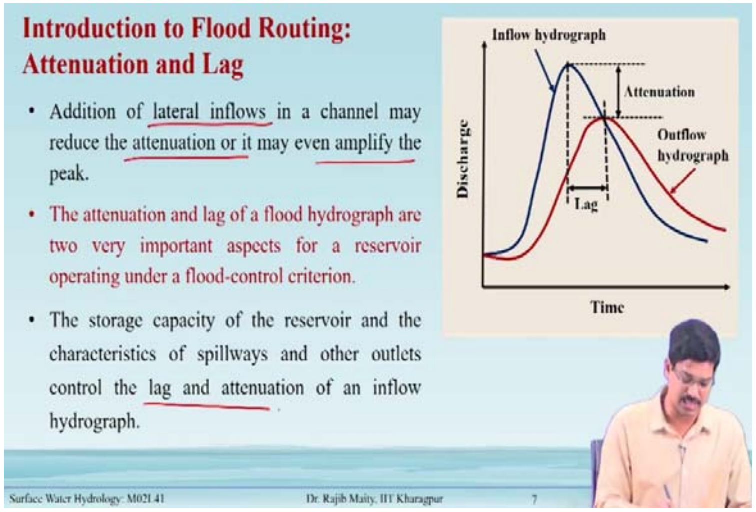

Attenuation and Lag

In the case of Attenuation and Lag the reduction in the peak of the floodway as it passes through the reservoir or the channel, it is termed as this Attenuation. So, in fig.2 two hydrographs are shown together one is this inflow hydrograph that comes in in the upstream section, and whatever is going out from this section is the downstream section.

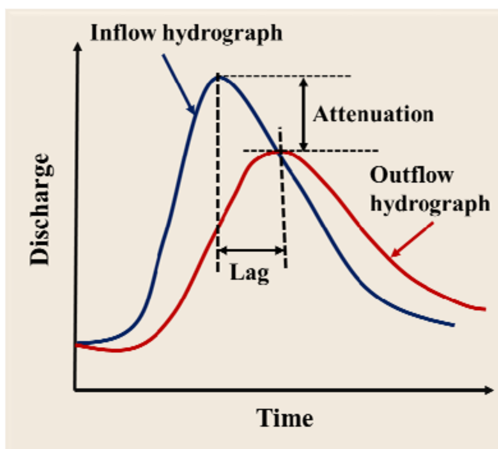

Figure 2: Variation of Inflow and Outflow discharge

The difference between the peak for this incoming inflow hydrograph and the peak for the outflow hydrograph is the Attenuation. So, the overall hydrograph of how much it has changed in terms of its peak flow is termed an Attenuation. Secondly, there is another term is called the Lag. It is the time when the peak occurs for the inflow and after some time the peak of this outflow that is occurring and the difference that time difference between these two is known as Lag. In the case of the reservoir, the peak of the flood wave is attenuated due to the effect of the storage, and in the case of the channel, Attenuation is due to the friction if there is no lateral inflow.

The addition of lateral inflows in a channel may reduce the attenuation or it may even amplify the peak. The attenuation and lag of a flood hydrograph are two very important aspects of a reservoir operating under a flood-control criterion. The storage capacity of the reservoir and the characteristics of spillways and other outlets control the lag and attenuation of an inflow hydrograph.

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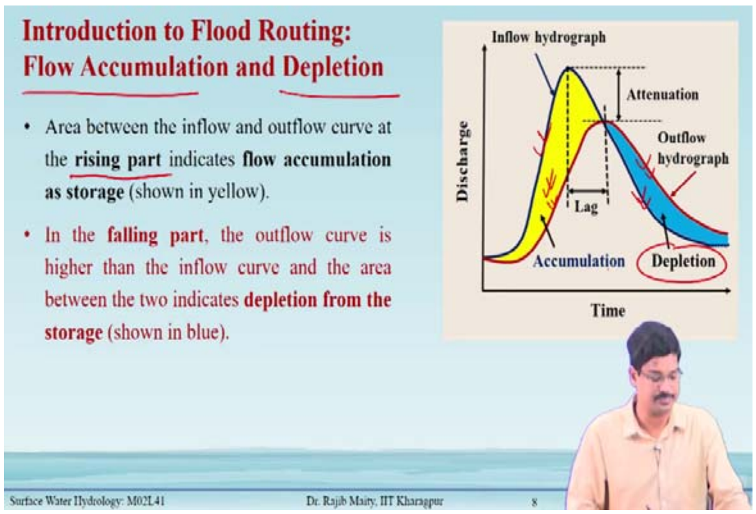

Flow Accumulation and Depletion

The area between the inflow and outflow curve at the rising part indicates flow accumulation as storage.

In the falling apart, the outflow curve is higher than the inflow curve and the area between the two indicates depletion from the storage.

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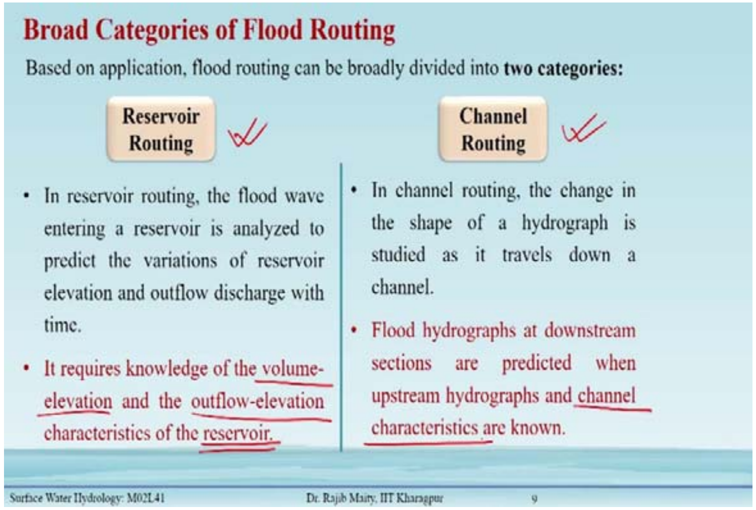

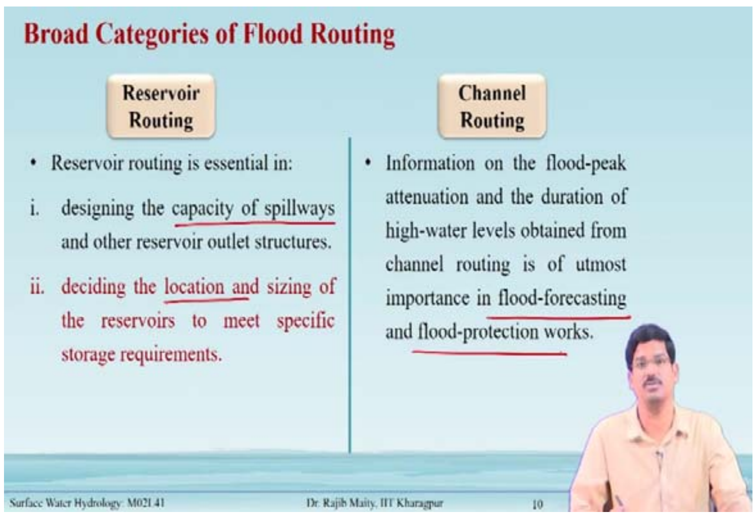

Broad Categories of Flood Routing

Based on application, flood routing can be broadly divided into two categories:

i. **Reservoir Routing**

- In reservoir routing, the flood wave entering a reservoir is analyzed to predict the variations of reservoir elevation and outflow discharge with time.
- It requires knowledge of the volume-elevation and the outflow-elevation characteristics of the reservoir.
- Reservoir routing is essential in:

   I. Designing the capacity of spillways and other reservoir outlet structures.

II. Deciding the location and sizing of the reservoirs meet specific storage requirements.

ii. Channel Routing

- In channel routing, the change in the shape of a hydrograph is studied as it travels down a channel.
- Flood hydrographs at downstream sections are predicted when upstream hydrographs and channel characteristics are known.
- Information on the flood-peak attenuation and the duration of high-water levels obtained from channel routing is of utmost importance in flood-forecasting and flood-protection works.

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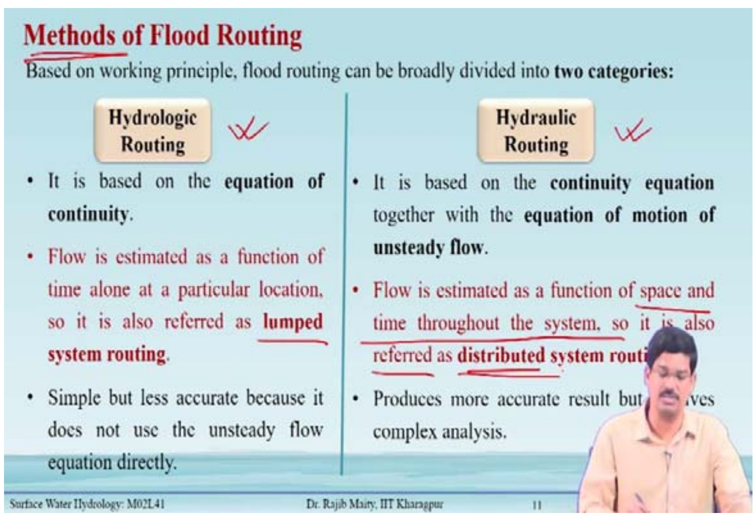

Based on the working principle, flood routing can be broadly divided into two categories:

Hydrologic Routing	Hydraulic Routing
➢ It is based on the equation of continuity.	➢ It is based on the continuity equation together with the equation of motion of the unsteady flow.
➢ Flow is estimated as a function of time alone at a particular location, so	➢ Flow is estimated as a function of space and time throughout the

it is also referred to as lumped system routing.

- Simple but less accurate because it does not use the unsteady flow equation directly.

system, so it is also referred to as distributed system routing.

- Produces more accurate results but involves complex analysis.

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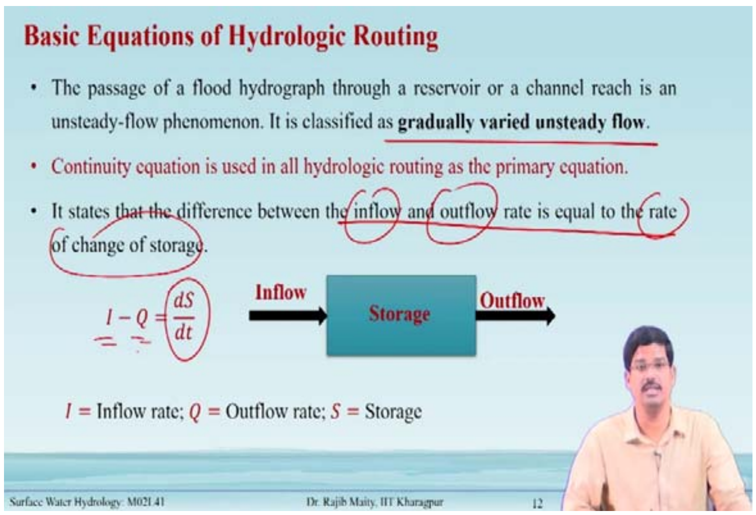

Basic Equations of Hydrologic Routing

The passage of a flood hydrograph through a reservoir or a channel reach is an unsteady-flow phenomenon. It is classified as a gradually varied unsteady flow.

The continuity equation is used in all hydrologic routing as the primary equation.

It states that the difference between the inflow and outflow rate is equal to the rate of change in storage.

$$I - Q = \frac{dS}{dt}$$

Where, I= Inflow rate; Q= Outflow rate; S= Storage

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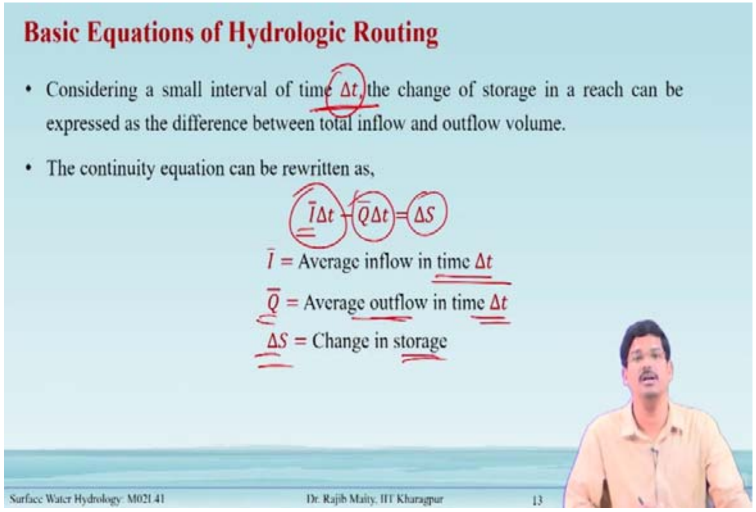

Considering a small interval of time Δt, the change of storage in a reach can be expressed as the difference between total inflow and outflow volume.

The continuity equation can be rewritten as,

$$\bar{I}\Delta t - \bar{Q}\Delta t = \Delta S$$

Where $\bar{I}$ = Average inflow in time Δt

$\bar{Q}$ = Average outflow in time Δt

ΔS= Change in storage

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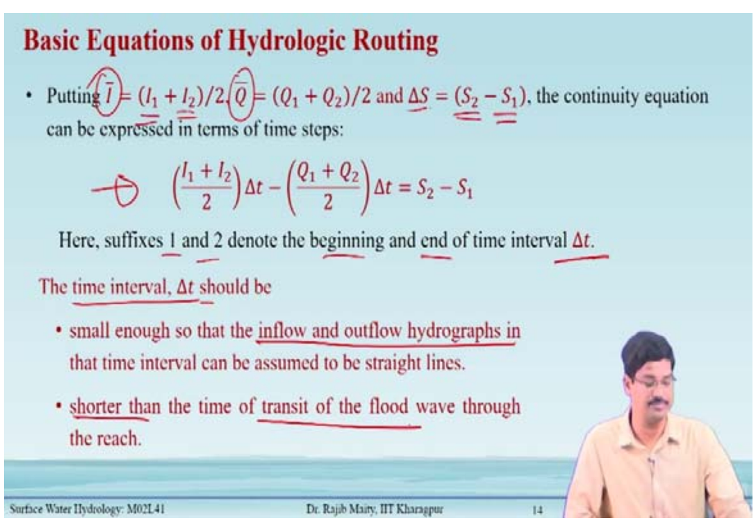

Basic Equations of Hydrologic Routing

Putting $\bar{I} = (I_1+I_2)/2$, $\bar{Q} = (Q_1+Q_2)/2$, and $\Delta S = (S_2-S_1)$, the continuity equation can be expressed in terms of time steps:

$$\left(\frac{I_1+I_2}{2}\right)\Delta t - \left(\frac{Q_1+Q_2}{2}\right)\Delta t = S_2 - S_1$$

Here, suffixes 1 and 2 denote the beginning and end of time interval Δt.

The time interval, Δt should be

- Small enough so that the inflow and outflow hydrographs in that time interval can be assumed to be straight lines.
- Shorter than the time of transit of the flood wave through the reach.

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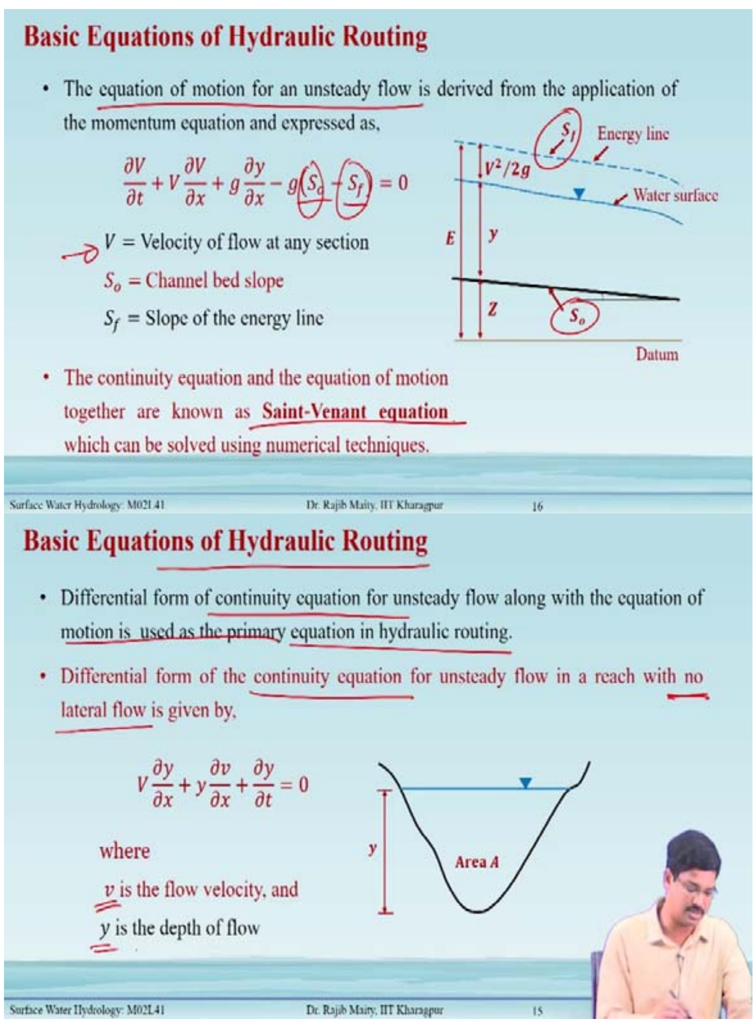

A ddifferential form of the continuity equation for unsteady flow along with the equation of motion is used as the primary equation in hydraulic routing.

A differential form of the continuity equation for unsteady flow in a reach with no lateral flow is given by,

$$V\frac{\partial y}{\partial x} + y\frac{\partial v}{\partial x} + \frac{\partial y}{\partial t} = 0$$

Where v is the flow velocity, and

y is the depth of flow

The equation of motion for an unsteady flow is derived from the application of the momentum equation and expressed as,

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

V= Velocity of flow at any section

S_o= Channel bed slope

S_f= Slope of the energy line

The continuity equation and the equation of motion together are known as the Saint-Venant equation which can be solved using numerical techniques.

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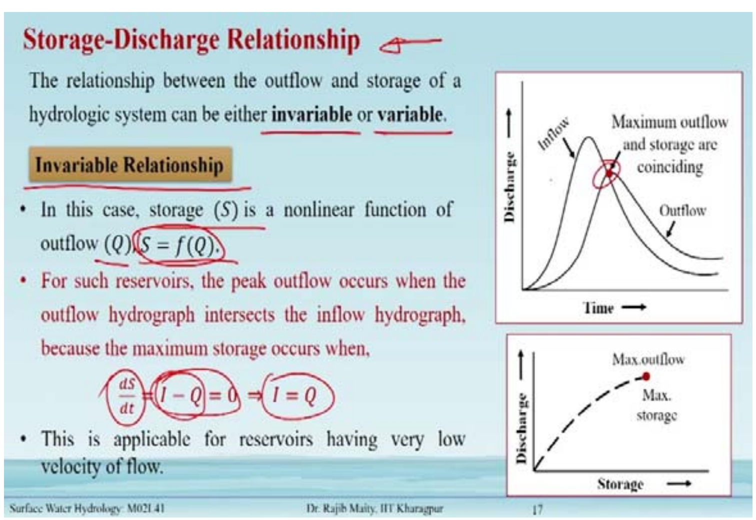

Storage-Discharge Relationship

The relationship between the outflow and storage of a hydrologic system can be either invariable or variable.

In this case, storage (S) is a nonlinear function of outflow (Q), ***S= f (Q)***

For such reservoirs, the peak outflow occurs when the outflow hydrograph intersects the inflow hydrograph because the maximum storage occurs when,

$$\frac{dS}{dt} = I - Q = 0 \;\Rightarrow\; I = Q$$

Another important thing that we need to know before we start on the different methods for this Flood Routing is the Storage-Discharge relationship. This relationship between the outflow and the storage of a hydrologic system can be two types one is that can be time-invariant or it can be fixed. So, we will call it invariable and variable.

So, this is the one when this inflow is equalled to outflow and this is applicable for the reservoir having a very low velocity of the flow.

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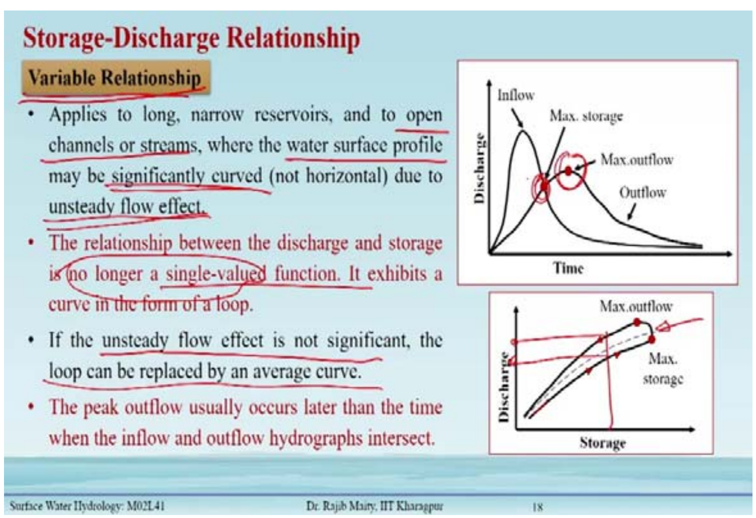

Variable Relationship

- Applies to long, narrow reservoirs, and to open channels or streams, where the water surface profile may be significantly curved (not horizontal) due to the unsteady flow effect.

- ➢ The relationship between the discharge and storage is no longer a single-valued function. It exhibits a curve in the form of a loop.
- ➢ If the unsteady flow effect is not significant, the loop can be replaced by an average curve.
- ➢ The peak outflow usually occurs later than the time when the inflow and outflow hydrographs intersect.

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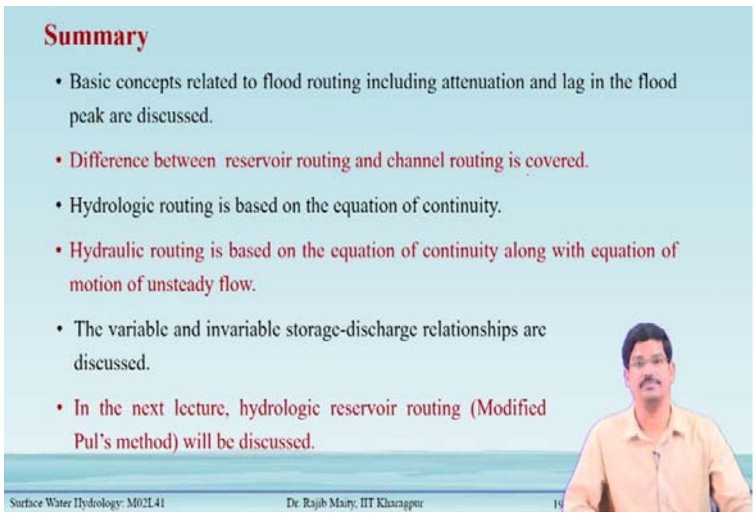

Summary

In summary, we learned the following points from this lecture:

- ➢ Basic concepts related to flood routing including attenuation and lag in the flood peak are discussed.
- ➢ The difference between reservoir routing and channel routing is covered.
- ➢ Hydrologic routing is based on the equation of continuity.
- ➢ Hydraulic routing is based on the equation of continuity along with the equation of motion of the unsteady flow.
- ➢ The variable and invariable storage-discharge relationships are discussed.
- ➢ In the next lecture, hydrologic reservoir routing (Modified Pul's method) will be discussed.