Surface Water Hydrology
Professor Rajib Maity
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 44
Channel Routing: Parameters of Muskingum Method

This week we are discussing about the Flood Routing.

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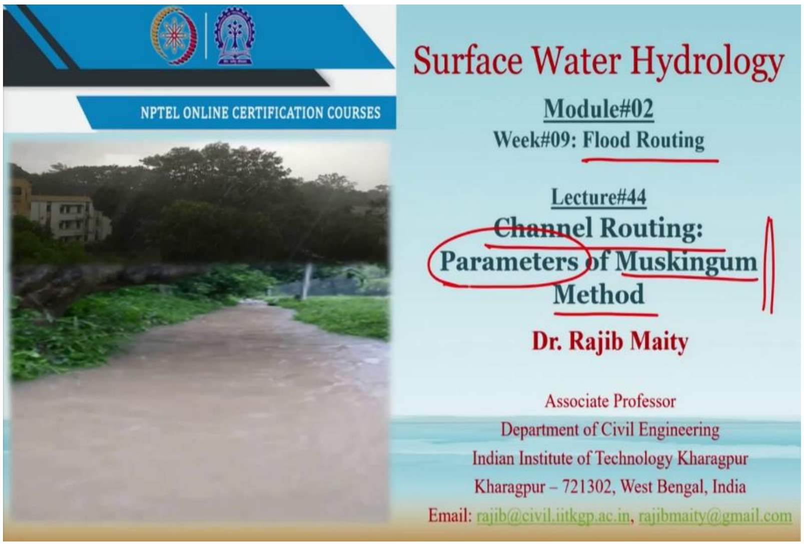

From this week onwards we will start the new thing that is called Channel Routing. So, in this Channel Routing part, we are starting today and for this particular lecture, which is called the Muskingum method, but, this particular lecture will be we will be concentrating on the parameter estimations for this Muskingum method.

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The concept covered in this lecture is the Channel Routing and the overall methodology of the Muskingum method.

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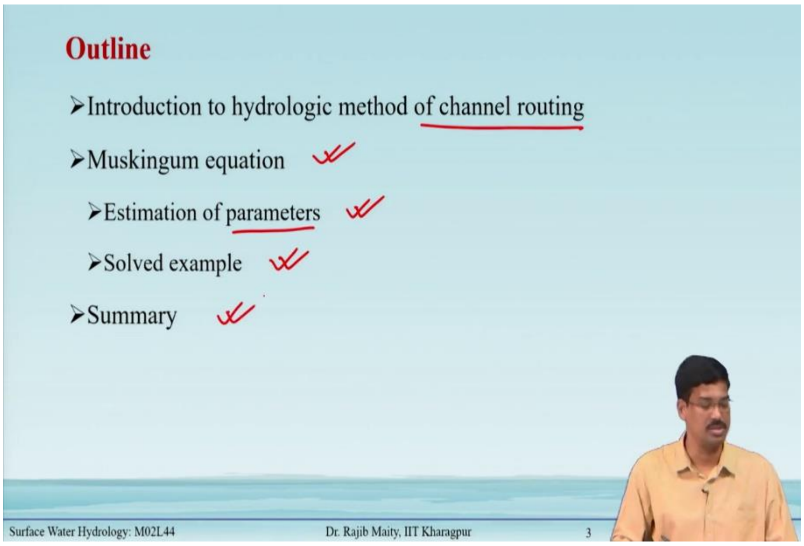

The outline goes like this. So, first, we will give some introduction to Channel Routing. And then the Muskingum equation that we will see how it works and inside that, there are some parameters. So, that parameter estimates and is our main focus for this particular lecture, we will have some solved examples and then we will go to the summary.

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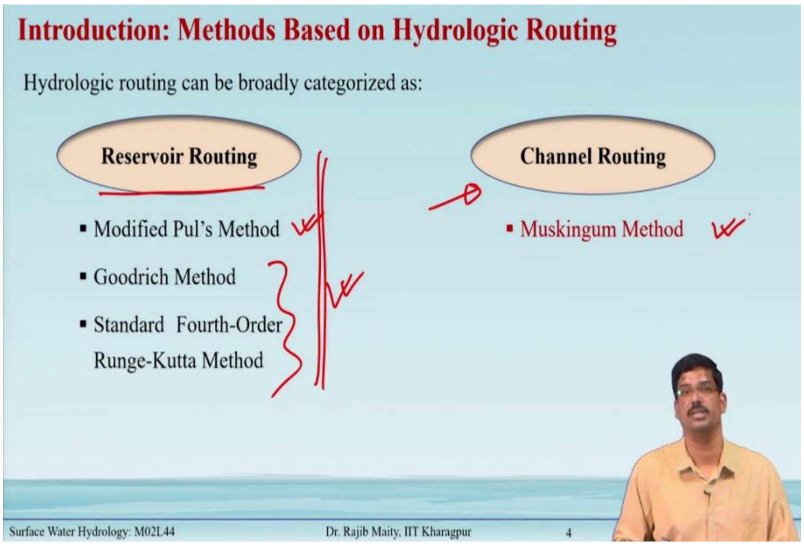

Today, from today onwards, we are shifting to the Channel Routing method and in that one, one of the very popular methods is the Muskingum method and that is our focus now.

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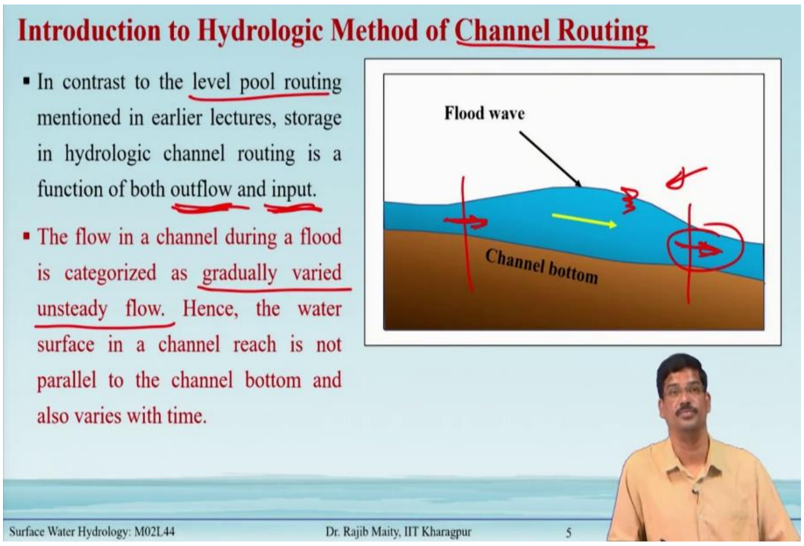

Introduction to Hydrologic Method of Channel Routing

In the case of the Channel Routing, the storage in this Hydrologic Channel Routing is a function of both the outflow and inflow. When a flow in a channel during a flood is categorized as a gradually varied unsteady flow, the surface is no longer horizontal in this case. So, the water surface in the channel reach is not parallel to the channel bottom and it also varies with time.

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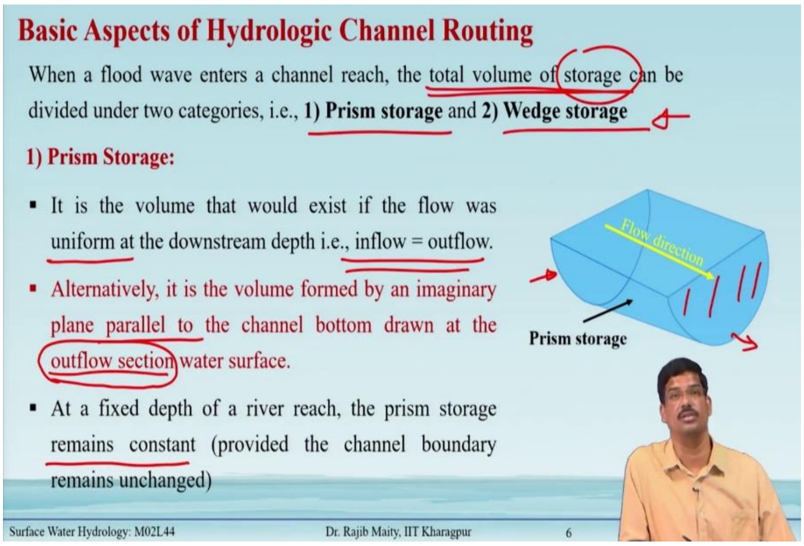

Basic Aspects of Hydrologic Channel Routing

When a flood wave enters a channel reach, the total volume of storage can be divided into two categories, i.e.

1) **Prism storage** **2) Wedge storage**

1) Prism Storage:

- It is the volume that would exist if the flow was uniform at the downstream depth i.e., inflow = outflow.
- Alternatively, it is the volume formed by an imaginary plane parallel to the channel bottom drawn at the outflow section water surface.
- At a fixed depth of a river reach, the prism storage remains constant (provided the channel boundary remains unchanged)

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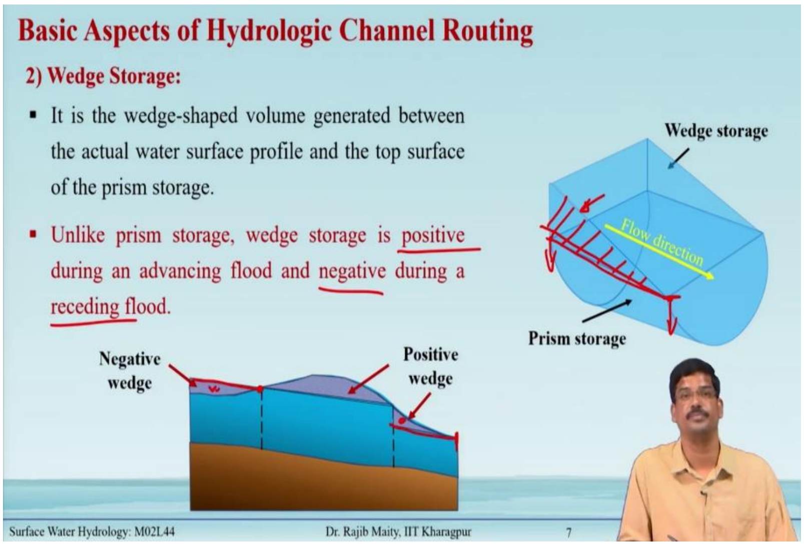
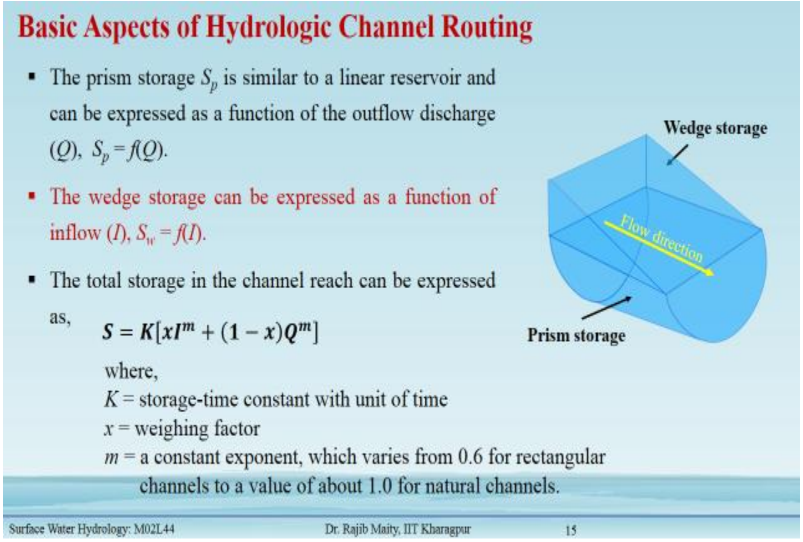


2) Wedge Storage:

- It is the wedge-shaped volume generated between the actual water surface profile and the top surface of the prism storage.
- Unlike prism storage, wedge storage is positive during an advancing flood and negative during a receding flood.



The prism storage S_p is similar to a linear reservoir and can be expressed as a function of the outflow discharge (Q), $S_p = f(Q)$.

The wedge storage can be expressed as a function of inflow (I), $S_w = f(I)$.

The total storage in the channel reach can be expressed as,

$$S = K[xI^m + (1-x)Q^m]$$

Where,

K = storage-time constant with unit of time

x = weighing factor

m = a constant exponent, which varies from 0.6 for rectangular channels to a value of about 1.0 for natural channels.

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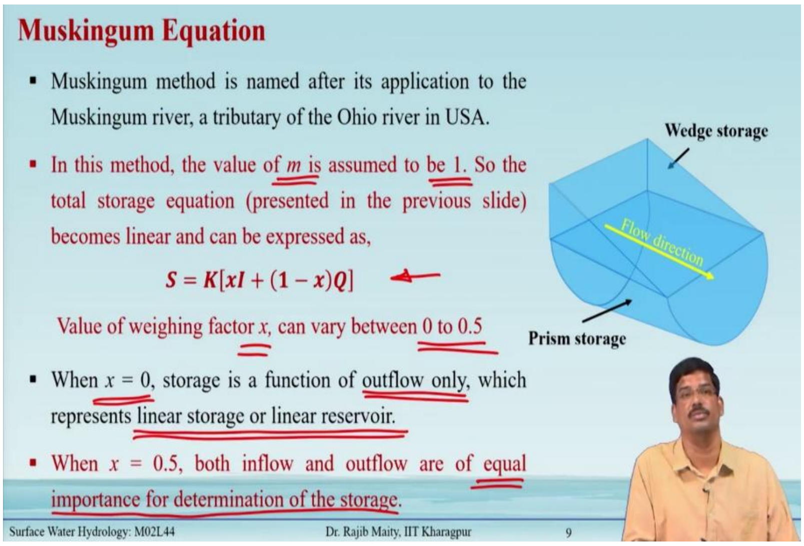

Muskingum Equation

The Muskingum method is named after its application to the Muskingum River, a tributary of the Ohio River in the USA.

In this method, the value of m is assumed to be 1. So the total storage equation (presented in the previous slide) becomes linear and can be expressed as,

$$S = K[xI + (1-x)Q]$$

The value of weighing factor x can vary between 0 to 0.5

When x = 0, storage is a function of outflow only, which represents linear storage or linear reservoir.

When x = 0.5, both inflow and outflow are of equal importance for the determination of the storage.

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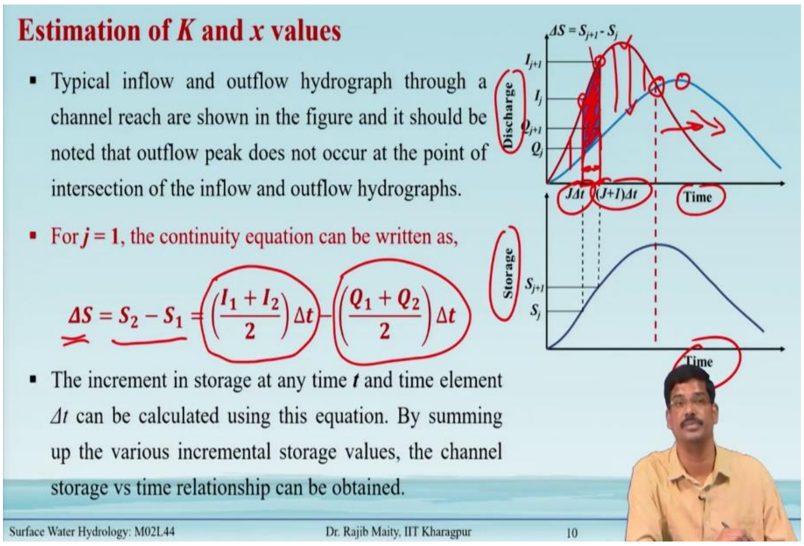

Estimation of *K* and *x* values

Typical inflow and outflow hydrographs through a channel reach are shown in Fig.1 and it should be noted that the outflow peak does not occur at the point of intersection of the inflow and outflow hydrographs.

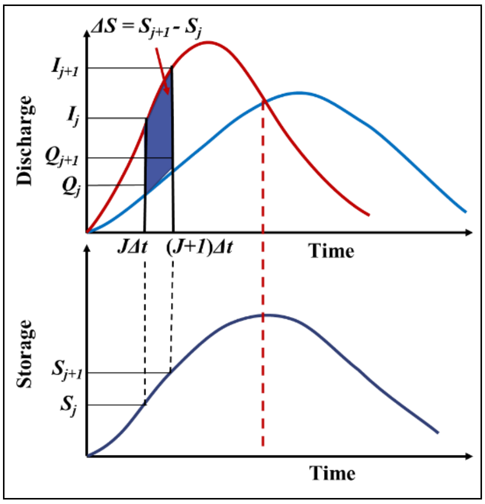

Figure 1: Inflow and Outflow Hydrograph through a Channel Reach

For j = 1, the continuity equation can be written as,

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

The increment in storage at any time ***t*** and time element *Δt* can be calculated using this equation. By summing up the various incremental storage values, the channel storage vs time relationship can be obtained.

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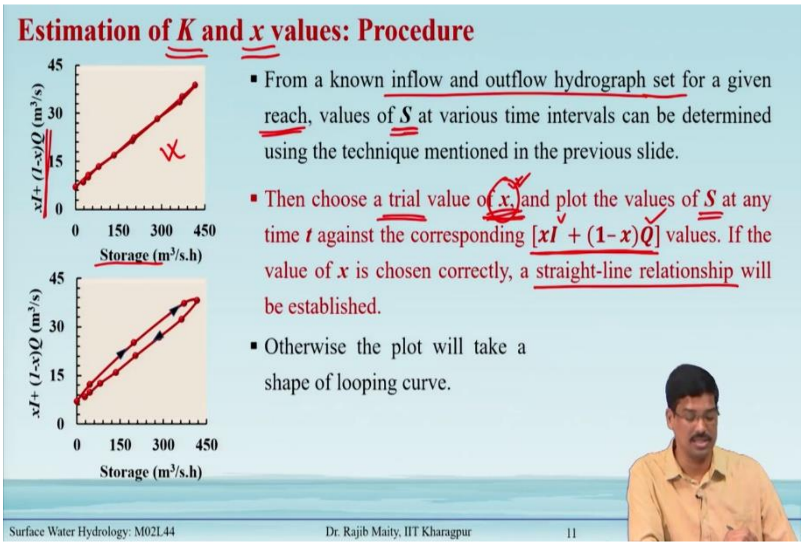

Estimation of *K* and *x* values: Procedure

- From a known inflow and outflow hydrograph set for a given reach, values of S at various time intervals can be determined using the technique mentioned in the previous slide.
- Then choose a trial value of x, and plot the values of S at any time t against the corresponding $[\boldsymbol{xI} + (\mathbf{1} - \boldsymbol{x})\boldsymbol{Q}]$ values. If the value of x is chosen correctly, a straight-line relationship will be established. Otherwise, the plot will take a shape of a looping curve.
- A value of *x* is chosen by trial and error until the plot closely resembles a straight line.
- The value of *K* is determined by the inverse slope of this straight line.
- The value of *x* lies between 0 to 0.3 for the natural channel.
- For a given reach, the values of *x* and *K* are assumed to be constant.

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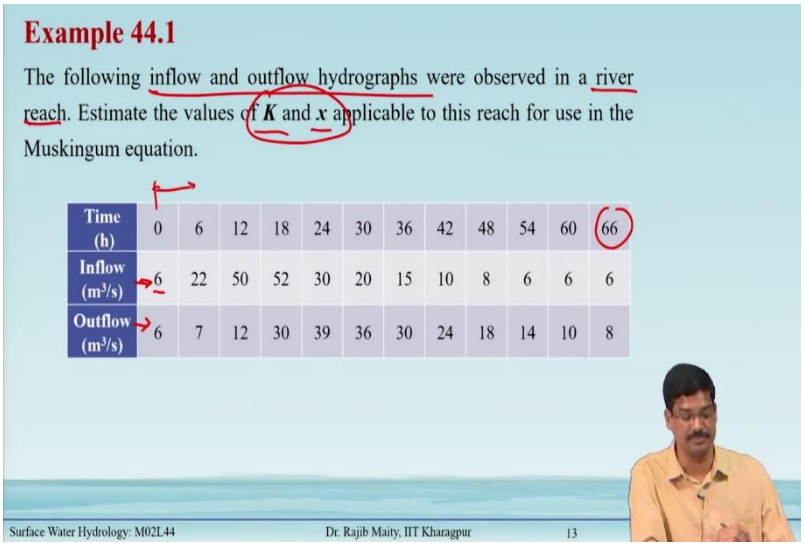

Example 44.1

The following inflow and outflow hydrographs were observed in a river reach. Estimate the values of ***K*** and ***x*** applicable to this reach for use in the Muskingum equation.

Time (h)	0	6	12	18	24	30	36	42	48	54	60	66
Inflow (m^3/s)	6	22	50	52	30	20	15	10	8	6	6	6
Outflow (m^3/s)	6	7	12	30	39	36	30	24	18	14	10	8

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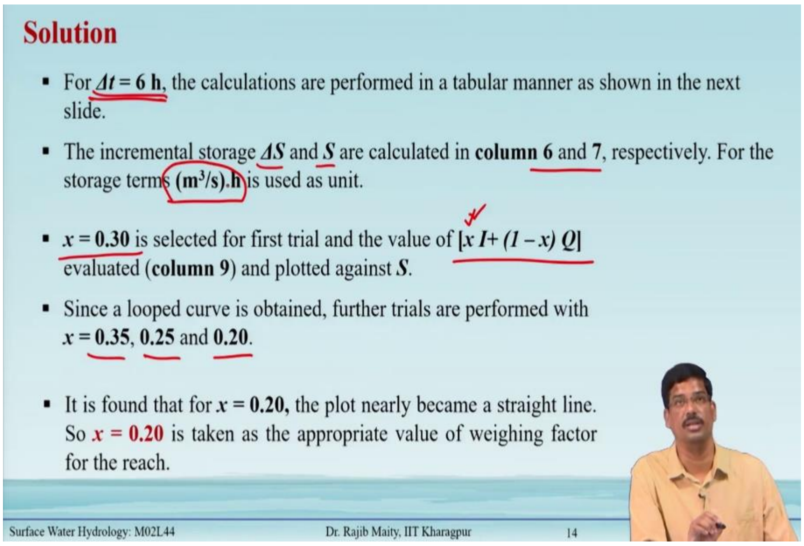

Solution

- For Δt **= 6 h**, the calculations are performed in a tabular manner as shown in the next slide.
- The incremental storage ΔS and S are calculated in **columns 6** and **7**, respectively. For the storage terms $\mathbf{(m^3/s).h}$ is used as a unit.
- x **= 0.30** is selected for first trial and the value of $[x\ I + (1 - x)\ Q]$ evaluated (**column 9**) and plotted against S.
- Since a looped curve is obtained, further trials are performed with x **= 0.35**, **0.25,** and **0.20**.
- It is found that for x **= 0.20,** the plot nearly became a straight line. So x **= 0.20** is taken as the appropriate value of the weighing factor for the reach.

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Solution

Time (h)	I (m³/s)	Q (m³/s)	I-Q (m³/s)	Average (I-Q) (m³/s)	ΔS = col 5 × Δt (m³/s.h)	$S = \sum \Delta S$ (m³/s.h)	$xI + (1-x)Q$ (m³/s) x = 0.35	x = 0.30	x = 0.25	x = 0.20
col 1	col 2	col 3	col 4	col 5	col 6	col 7	col 8	col 9	col 10	col 11
0	7	7	0			0	7	7	7	7
6	22	8	14	7	42	42	12.9	12.2	11.5	10.8
12	51	14	37	25.5	153	195	26.95	25.1	23.25	21.4
18	52	31	21	29	174	369	38.35	37.3	36.25	35.2
24	34	40	-6	7.5	45	414	37.9	38.2	38.5	38.8
30	24	36	-12	-9	-54	360	31.8	32.4	33	33.6
36	17	31	-14	-13	-78	282	26.1	26.8	27.5	28.2
42	12	25	-13	-13.5	-81	201	20.45	21.1	21.75	22.4
48	9	19	-10	-11.5	-69	132	15.5	16	16.5	17
54	7	15	-8	-9	-54	78	12.2	12.6	13	13.4
60	7	11	-4	-6	-36	42	9.6	9.8	10	10.2
66	7	9	-2	-3	-18	24	8.3	8.4	8.5	8.6

Time (h)	I (m³/s)	Q (m³/s)	I-Q (m³/s)	Average (I-Q) (m³/s)	ΔS = col 5 × Δt (m³/s.h)	$S = \sum \Delta S$ (m³/s.h)	$xI + (1-x)Q$ (m³/s) x = 0.35	x = 0.30	x = 0.25	x = 0.20
col 1	col 2	col 3	col 4	col 5	col 6	col 7	col 8	col 9	col 10	col 11
0	7	7	0			0	7	7	7	7
6	22	8	14	7	42	45	12.9	12.2	11.5	10.8
12	51	14	37	25.5	153	198	26.95	25.1	23.25	21.4
18	52	31	21	29	174	372	38.35	37.3	36.25	35.2
24	34	40	-6	7.5	45	417	37.9	38.2	38.5	38.8
30	24	36	-12	-9	-54	363	31.8	32.4	33	33.6
36	17	31	-14	-13	-78	285	26.1	26.8	27.5	28.2
42	12	25	-13	-13.5	-81	204	20.45	21.1	21.75	22.4
48	9	19	-10	-11.5	-69	135	15.5	16	16.5	17
54	7	15	-8	-9	-54	81	12.2	12.6	13	13.4
60	7	11	-4	-6	-36	45	9.6	9.8	10	10.2
66	7	9	-2	-3	-18	27	8.3	8.4	8.5	8.6

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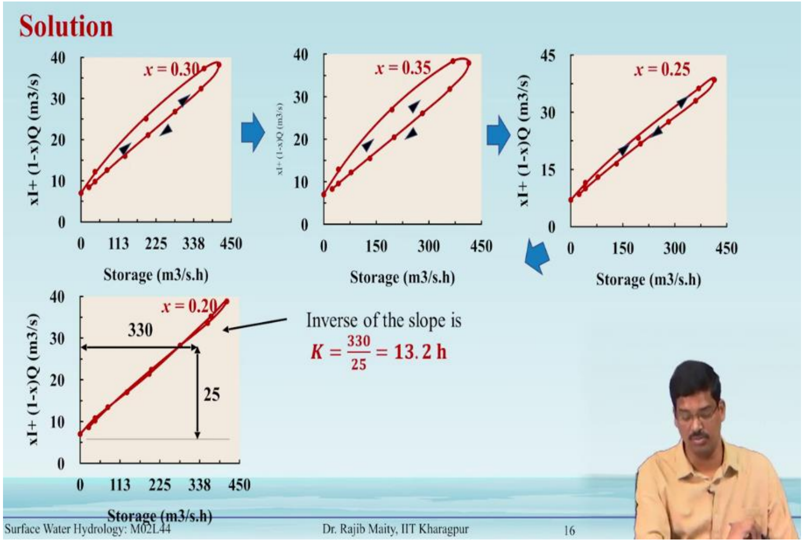

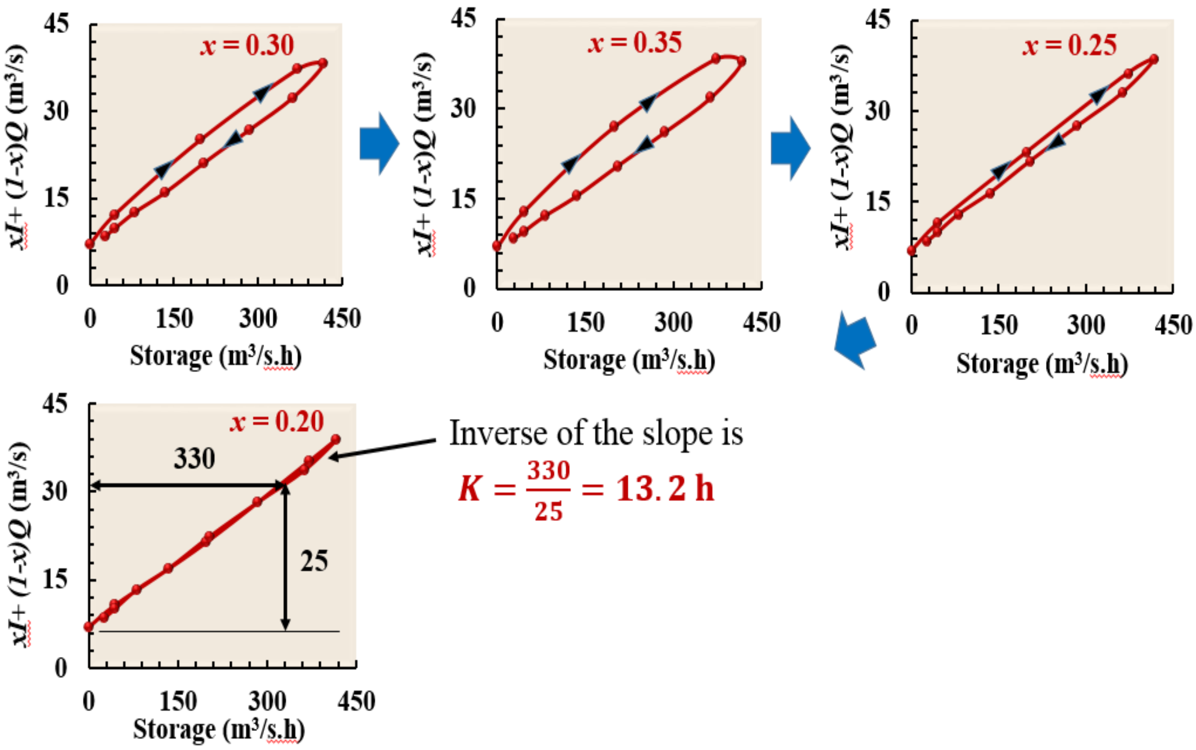

Figure 2 : Determination of K and x for a Channel reach of Example 44.1

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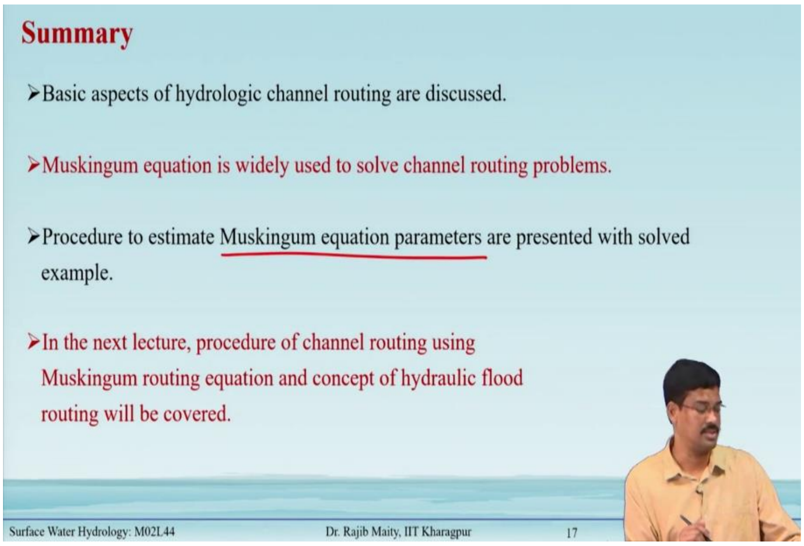

Summary

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

- Basic aspects of hydrologic channel routing are discussed.
- The Muskingum equation is widely used to solve channel routing problems.
- The procedure to estimate Muskingum equation parameters is presented with a solved example.
- In the next lecture, the procedure of channel routing using the Muskingum routing equation and the concept of hydraulic flood routing will be covered.