Surface Water Hydrology
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Lecture 32
Unit Hydrograph of Different Durations
Method of Superposition

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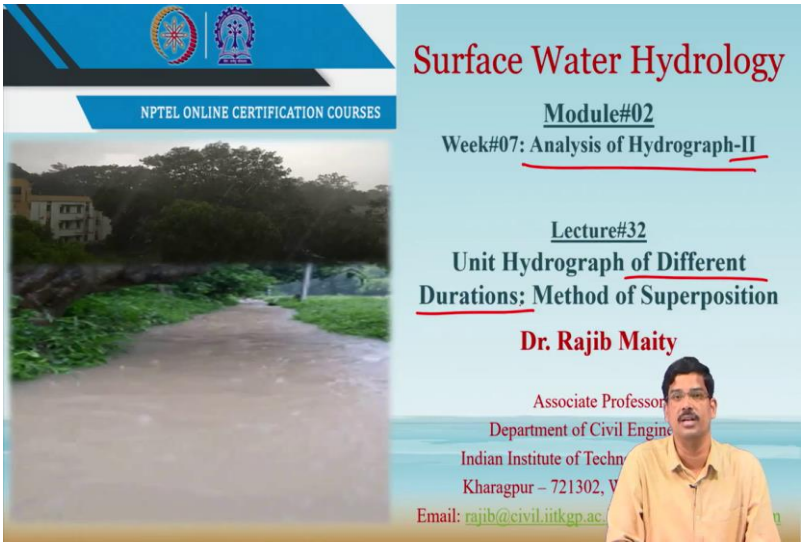

In this particular week, we are discussing the Analysis of Hydrograph II. In lecture 32, we are starting the two particular methods, this method will help us to develop the unit hydrograph for different durations. And today we are covering the method of superposition.

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The concept covered in this lecture is to develop the unit hydrograph of different duration and methods of superposition.

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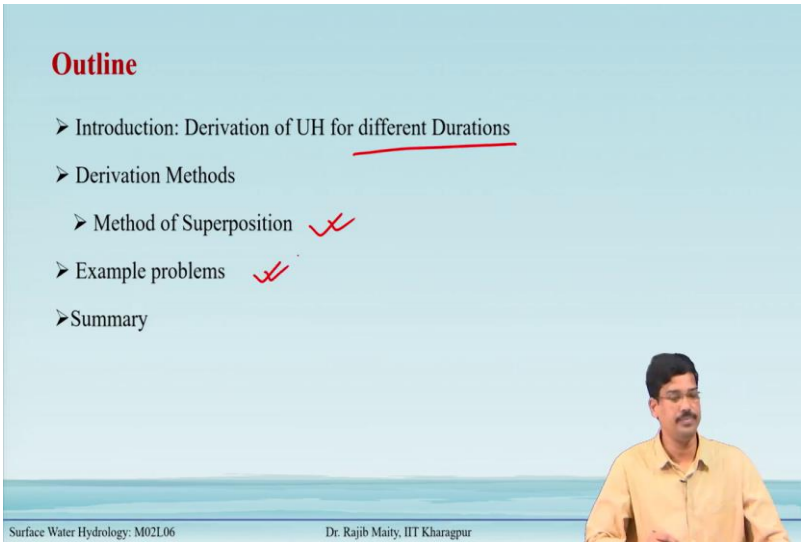

The outline goes like this introduction to the derivation of unit hydrograph for different durations and that method of superposition. We will take up some example problems before we go to the summary.

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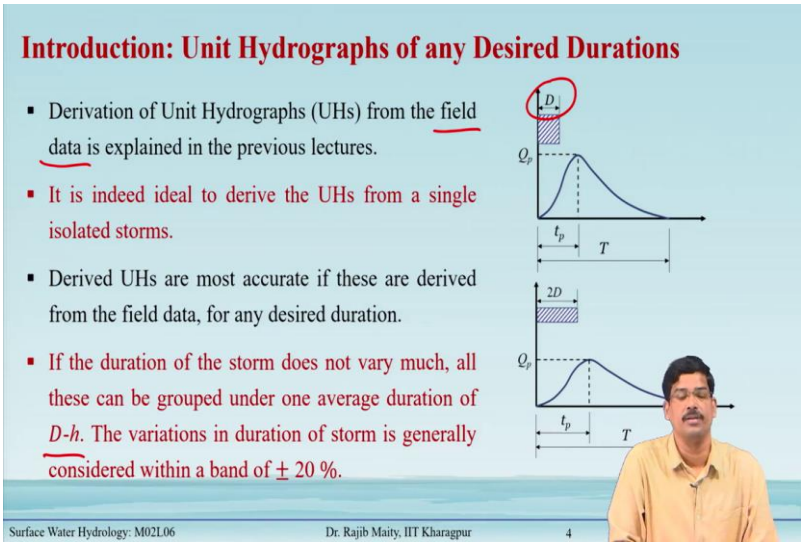

Introduction: Unit Hydrographs of any Desired Durations

The derivation of unit hydrograph from the field data, how to develop this unit hydrograph that was covered in the previous lectures last week. We also focus on the fact that when we develop the unit hydrograph from the field data that gives the best possible estimate on the unit hydrograph for a catchment. However, sometimes this type of field data may not available to us for all the required duration.

To develop one D-hour unit hydrograph we need the more or less similar duration uniformly distributed storms events either isolated or the complex term for D-hours. If the duration of the storm does not vary much, all these can be grouped under one average duration of *D*-h. The variations in duration of the storm is generally considered within a band of ± 20 %.

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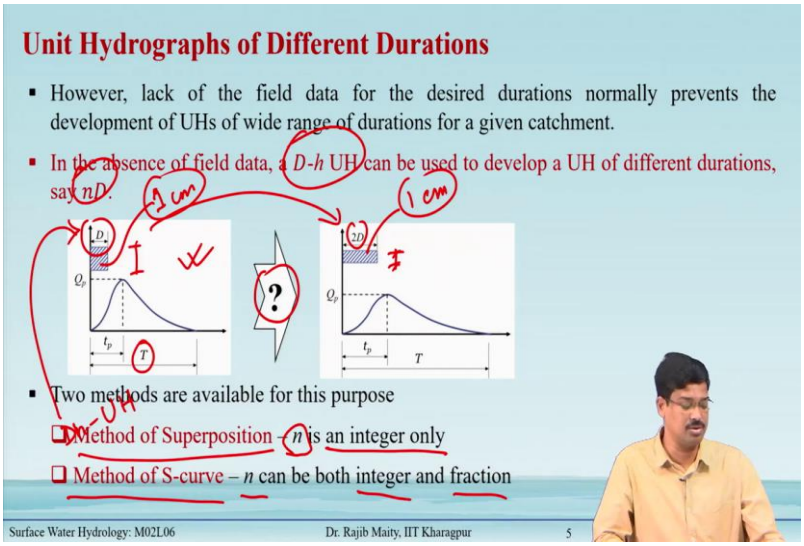

However, lack of the field data for the desired durations normally prevents the development of UHs of a wide range of durations for a given catchment. In the absence of field data, a D-h UH can be used to develop a UH of different durations, say nD. In the D-hour unit hydrograph, D is referred to the duration of the effective rainfall, not that time base. Two methods are available for this purpose

i. Method of Superposition – n is an integer only.

ii. Method of S-curve – n can be both integer and fraction

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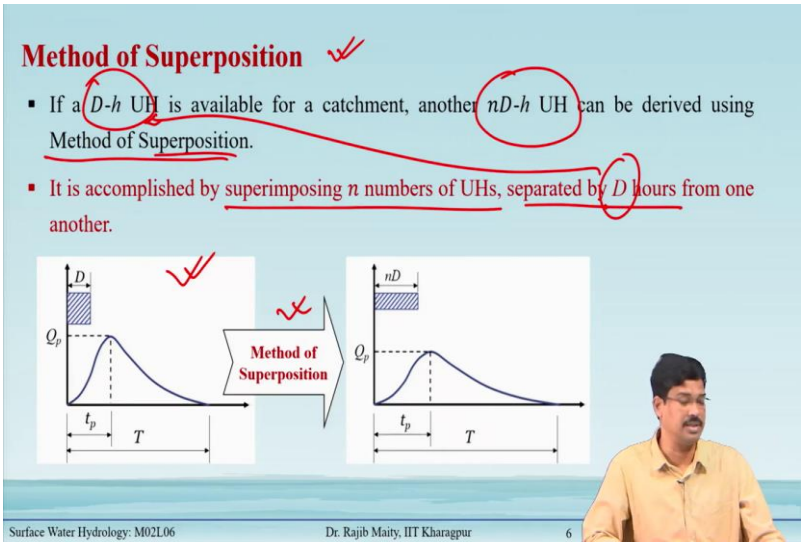

Method of Superposition

If a D-h UH is available for a catchment, another nD-h UH can be derived using the Method of Superposition. Superpositions means have to superimpose in numbers of unit hydrographs of the original D-hour unit hydrograph that is available to us and while superimposing this n numbers of unit hydrographs we have to keep them in D-hours separated. So, separated by D-hour.

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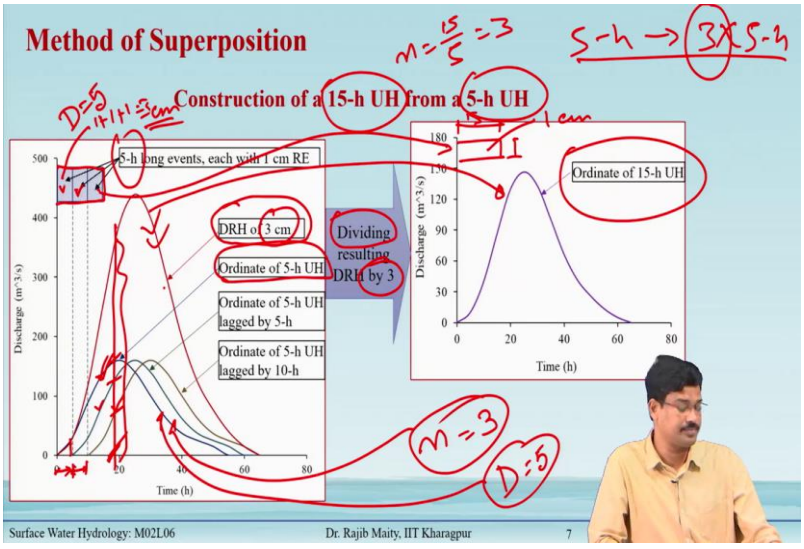

Construction of a 15-h UH from a 5-h UH

Take one example for the 5 hours in-unit hydrograph. So, D is equal to 5 here, we need 15 hours unit hydrograph. Here n is an integer which is 15 by 5 equals 3. So, 5 hours to 3X5 hour's unit hydrograph. I have this one that is ordinates of 5 hours unit hydrograph I first place and several such unit hydrographs of these n numbers of this unit hydrograph where the n here is 3, I have to keep them one after another separated by that D-hour.

After the first rainfall excess of 1 cm put another 1-centimeter rainfall excess of 5 hours duration. In this way, place all three-unit hydrographs one after another. So total rainfall excess equals 3-centimeter rainfall excess.

Now add this ordinate everywhere. So, in this way the resulting one the red one is the direct runoff hydrograph and the direct runoff hydrograph is a result of the 3-centimeter rainfall excess as shown in fig.1.Now directly divide all the ordinates by 3, so that if 15 hours rainfall excess results in this direct runoff hydrograph then 1 centimeter will result is divided by 3 by all these ordinates. So, this is how we are getting the coordinates of the 15-hour unit hydrograph.

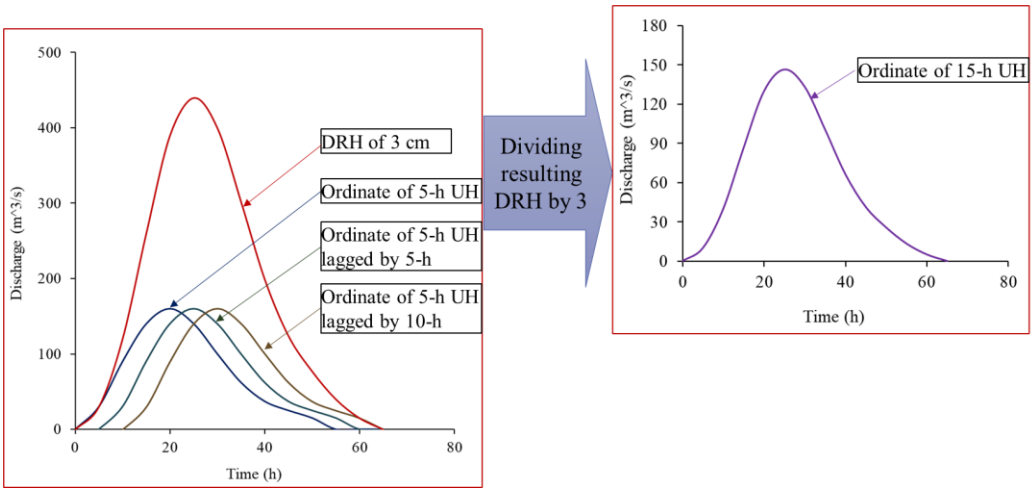

Fig.1 shows the Construction of a 15-h UH from a 5-h UH

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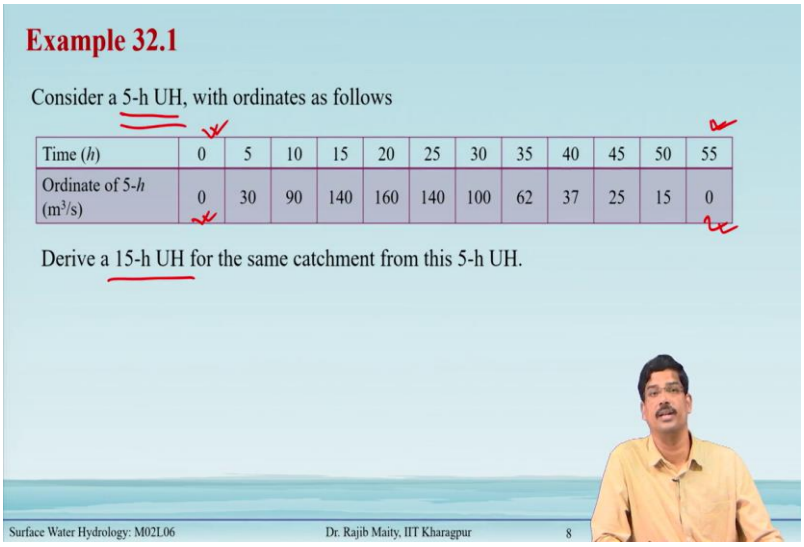

Example 32.1

Consider a 5-h UH, with ordinates as follows

Time (h)	0	5	10	15	20	25	30	35	40	45	50	55
Ordinate of 5-h (m^3/s)	0	30	90	140	160	140	100	62	37	25	15	0

Derive a 15-h UH for the same catchment from this 5-h UH.

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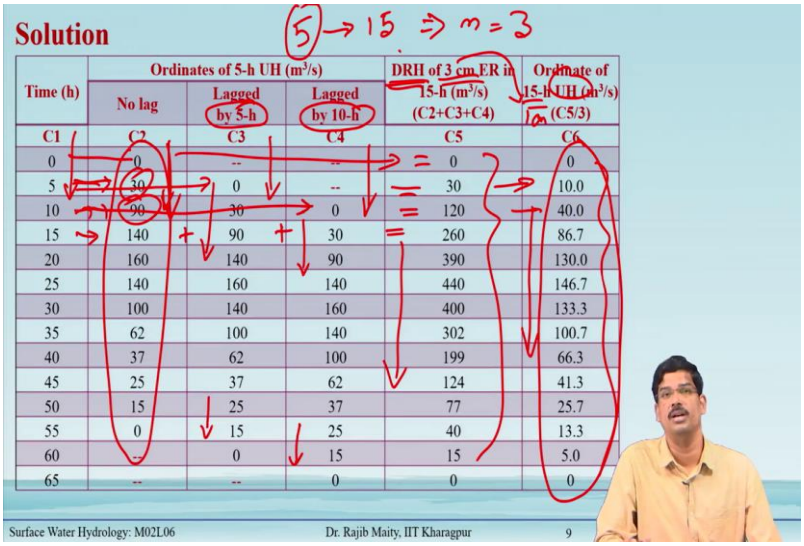

Solution

Time (h)	Ordinates of 5-h UH (m^3/s)			DRH of 3 cm ER in 15-h (m^3/s) (C2+C3+C4)	Ordinate of 15-h UH (m^3/s) (C5/3)
	No lag	Lagged by 5-h	Lagged by 10-h		
C1	C2	C3	C4	C5	C6
0	0	--	--	0	0
5	30	0	--	30	10.0
10	90	30	0	120	40.0
15	140	90	30	260	86.7
20	160	140	90	390	130.0
25	140	160	140	440	146.7
30	100	140	160	400	133.3
35	62	100	140	302	100.7
40	37	62	100	199	66.3
45	25	37	62	124	41.3
50	15	25	37	77	25.7
55	0	15	25	40	13.3
60	--	0	15	15	5.0
65	--	--	0	0	0

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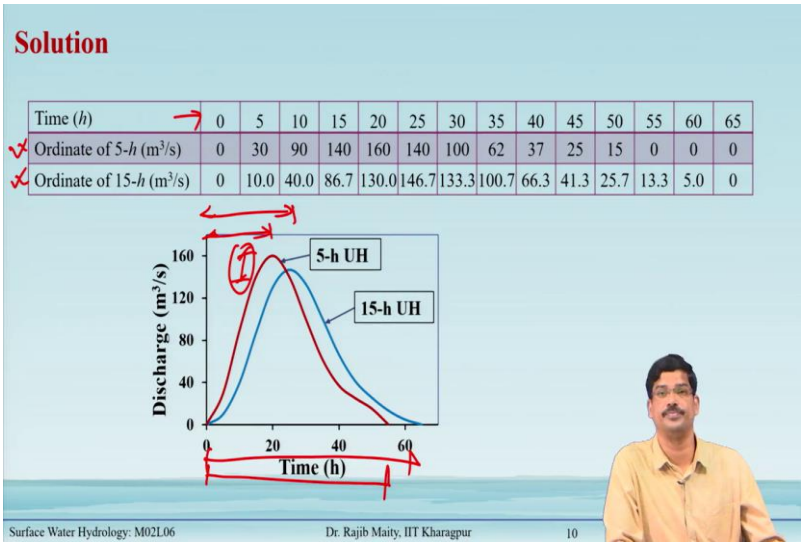

Time (*h*)	0	5	10	15	20	25	30	35	40	45	50	55	60	65
Ordinate of 5-*h* (m^3/s)	0	30	90	140	160	140	100	62	37	25	15	0	0	0
Ordinate of 15-*h* (m^3/s)	0	10.0	40.0	86.7	130.0	146.7	133.3	100.7	66.3	41.3	25.7	13.3	5.0	0

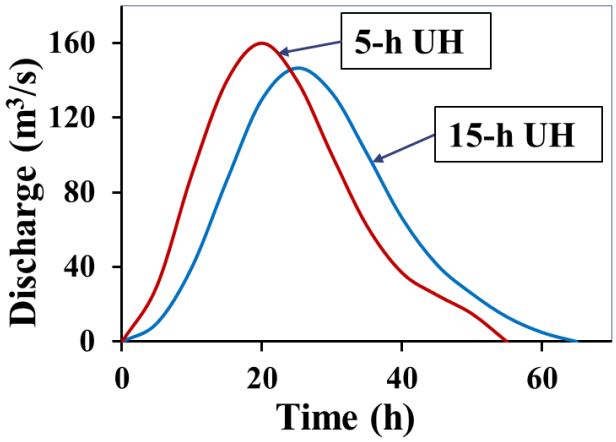

Fig.2 shows the Construction of a 15-h UH from a 5-h UH of example 32.1

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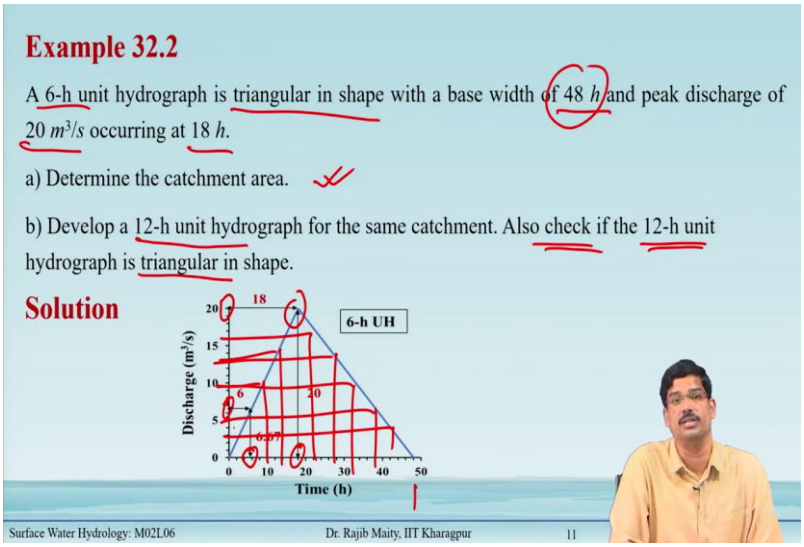

Example 32.2

A 6-h unit hydrograph is triangular in shape with a base width of 48 *h* and peak discharge of 20 m^3/s occurring at 18 *h*. Determine the following,

a) catchment area

b) 12-h unit hydrograph for the same catchment. Also, check if the 12-h unit hydrograph triangular in shape?

Solution

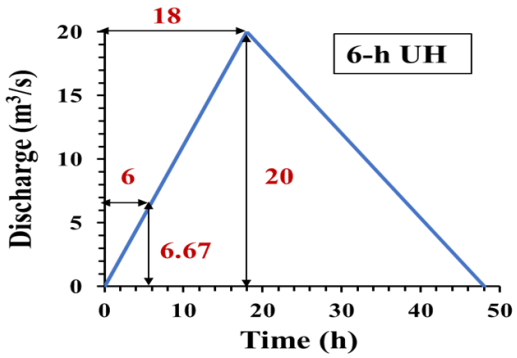

Fig.3 shows the triangular shape 6h UH of example 32.2

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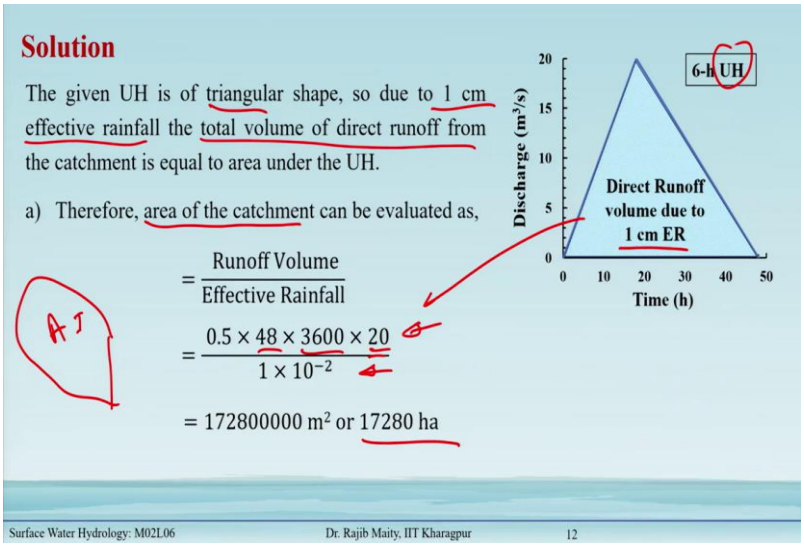

Solution

The given UH is of triangular shape, so due to 1 cm effective rainfall the total volume of direct runoff from the catchment is equal to the area under the UH.

a) Therefore, the area of the catchment can be evaluated as,

$$= \frac{\text{Runoff Volume}}{\text{Effective Rainfall}}$$

$$= \frac{0.5 \times 48 \times 3600 \times 20}{1 \times 10^{-2}}$$

$$= 172800000 \text{ m}^2 \text{ or } 17280 \text{ ha}$$

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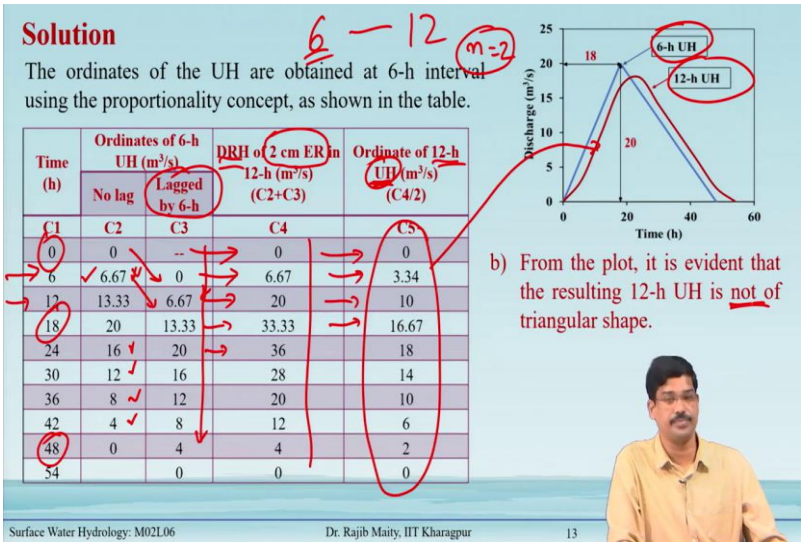

The ordinates of the UH are obtained at a 6-h interval using the proportionality concept, as shown in the table.

Time (h)	Ordinates of 6-h UH (m³/s)		DRH of 2 cm ER in 12-h (m³/s) (C2+C3)	Ordinate of 12-h UH (m³/s) (C4/2)
	No lag	Lagged by 6-h		
C1	C2	C3	C4	C5
0	0	--	0	0
6	6.67	0	6.67	3.34
12	13.33	6.67	20	10
18	20	13.33	33.33	16.67
24	16	20	36	18
30	12	16	28	14
36	8	12	20	10
42	4	8	12	6
48	0	4	4	2
54		0	0	0

b) From the plot, it is evident that the resulting 12-h UH is not of a triangular shape.

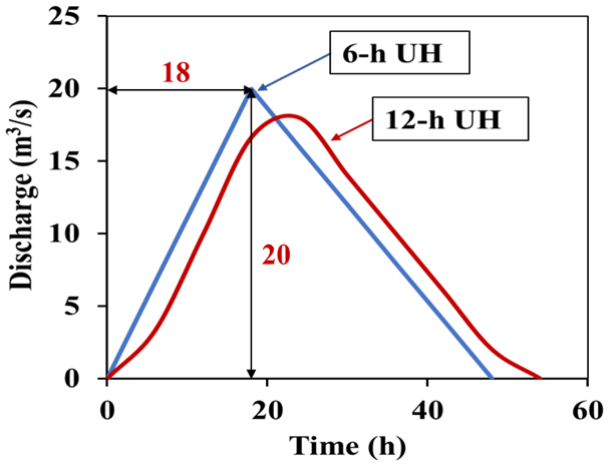

Fig.4 shows the Construction of a 12-h UH of example 32.2

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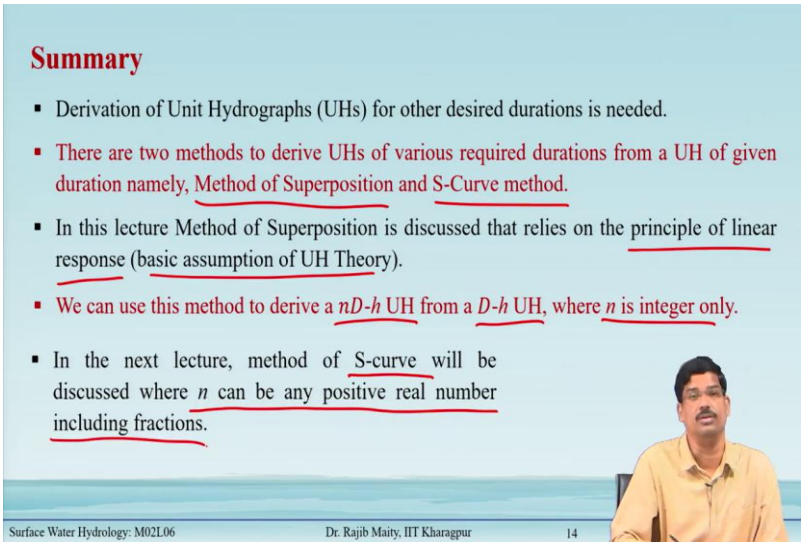

Summary

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

- Derivation of Unit Hydrographs (UHs) for other desired durations is needed.
- There are two methods to derive UHs of various required durations from a UH of given duration namely, Method of Superposition and S-Curve method.

- In this lecture Method of Superposition is discussed that relies on the principle of linear response (basic assumption of UH Theory).
- We can use this method to derive a nD-h UH from a D-h UH, where n is integer only.
- In the next lecture, the method of S-curve will be discussed where n can be any positive real number including fractions.