Surface Water Hydrology
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Lecture – 30
Unit Hydrograph to Direct Runoff Hydrograph

In this particular lecture, we will see one of the major applications of this unit hydrograph that is from one unit hydrograph, how to get the direct runoff hydrograph, particularly for the actual rainfall events that are complex on the ground.

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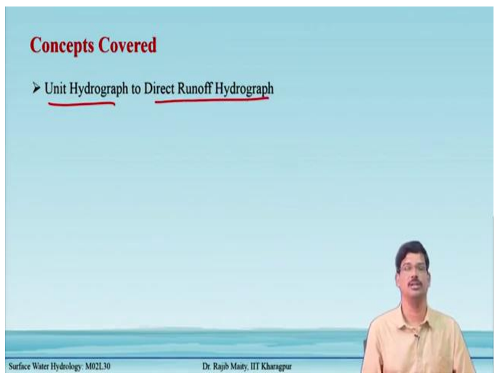

The concept cover is that from the unit hydrograph to the direct runoff hydrograph, this is how we should know this one.

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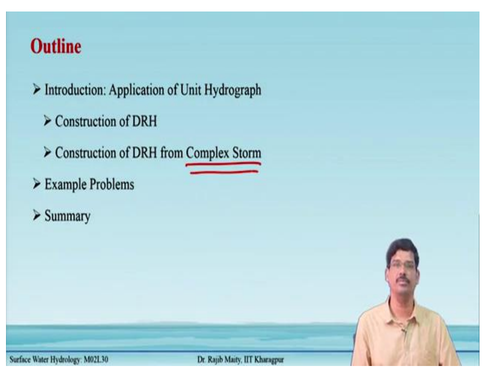

The outline goes like this introduction to the application of UH. There are two things, the construction of the direct runoff hydrograph. Particularly, we are focusing mainly on the construction of the direct runoff hydrograph from the complex storm. And we will explain it through some example problems also.

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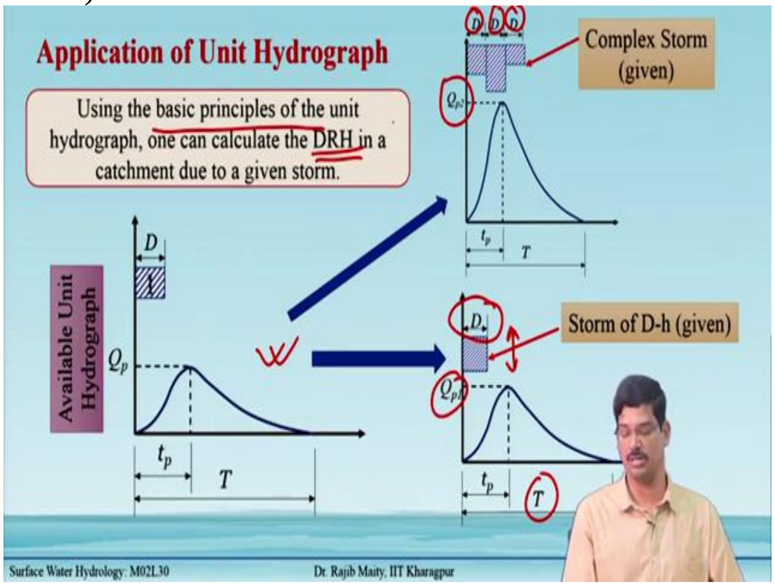

Application of Unit Hydrograph

Using the basic principles of this unit hydrograph, one can calculate the direct runoff hydrograph in a catchment due to the given storm. For example, if there is one unit hydrograph is given to us, now if we just change this retaining this D as the intact, if we just change the intensity to some other time as this basic principle this time base will not change, but the ordinates can be multiplied with the ratio of this intensity from here to here then we can get what is the one, what is the response for that some other different intensity.

This is one thing and which is for the single isolated storm, but in most of the cases we get the complex storm and that is also may have this individually they can have the diverse duration, but the intensity may change to this. So, this is called the isolated storm that is the complex storm. The storm information is given to us we have to find out what is this one using the basic principle of the unit hydrograph.

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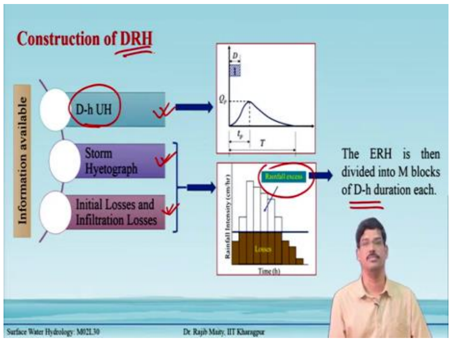

Construction of DRH

The construction of a direct runoff hydrograph depends on the three pieces of information available to us. The first one is that the D hour unit hydrograph is known to us, the storm hydrograph is known to us, and the initial loss and infiltration loss in terms of mostly in terms of the fine decks that are known to us. So, these two pieces of information basically will help us to get that effective rainfall.

And so far as the storm hydrograph and the initial loss can get what is this rainfall excess. Now, this effective rainfall hydrograph is then divided into M blocks of D hour duration each.

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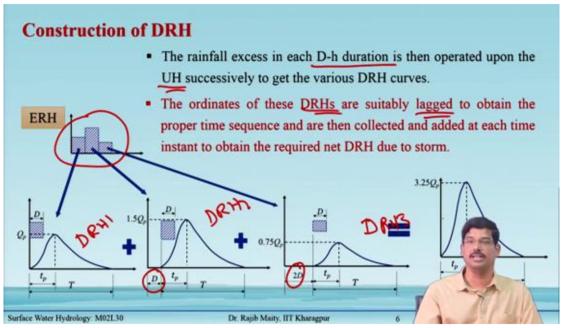

The rainfall axis of each of this D hour duration is then operated upon the unit hydrograph successively to get the various direct runoff hydrograph curves. Now, the ordinance of this direct runoff hydrograph is suitably lagged. It is the D-hour unit hydrograph. So, each block would be lagged by D hour to obtain the proper time sequence and then collect it and add it at each time instance to obtain the required net that D hour, that direct runoff hydrograph due to the storm.

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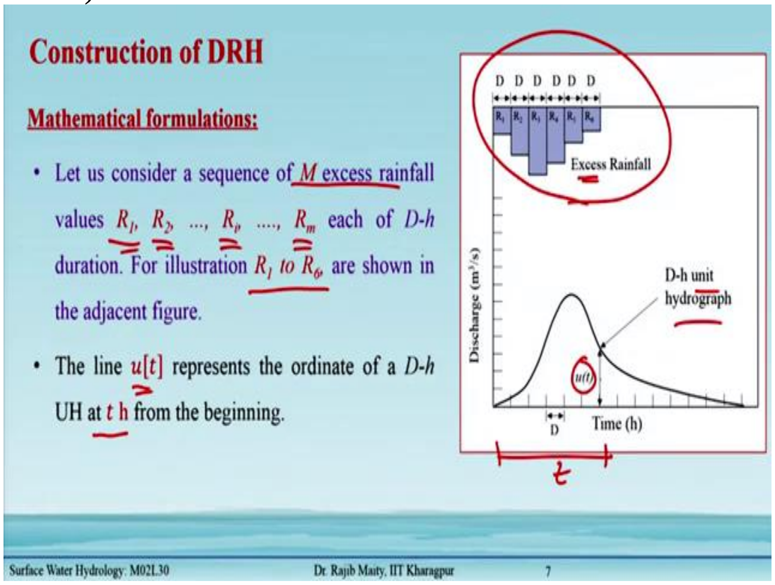

Mathematical formulations:

Let us consider a sequence of M excess rainfall values R_1, R_2, …, R_i, …., R_m each of D-h duration. For illustration R_1 to R_6, are shown in fig.1. This is the excess rainfall only. If it is the total rainfall hydrograph, then we have to deduct that initial loss. Now, the mathematically the line u(t), this u(t) means that ordinate at time t, this is the unit hydrograph the ordinate of the unit hydrograph at time u(t) is the ordinate at time t hour from the beginning.

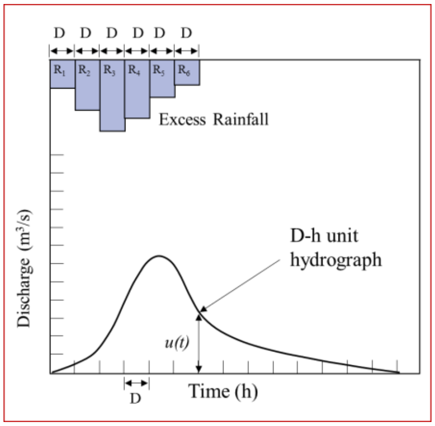

Fig.1 shows the construction of DRH

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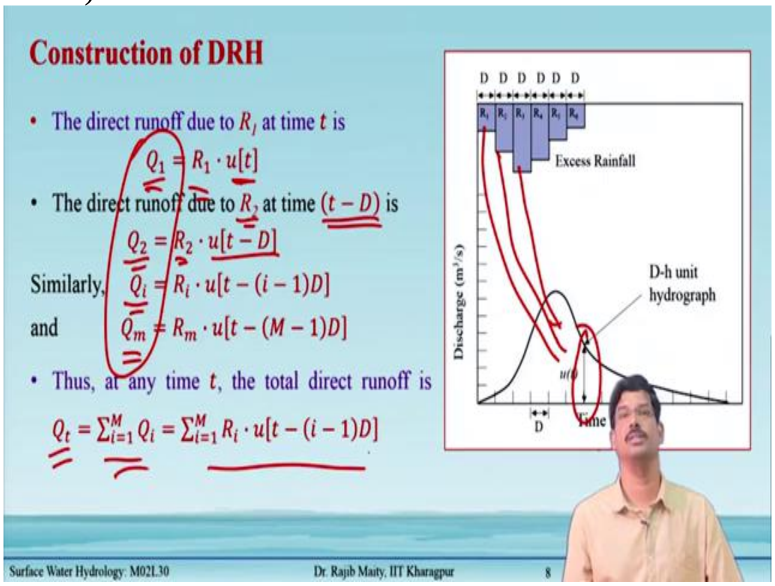

The direct runoff due to R_1 at time t is

$Q_1 = R_1 \cdot u[t]$

The direct runoff due to R_2 at time $(t - D)$ is

$Q_2 = R_2 \cdot u[t - D]$

Similarly, $Q_i = R_i \cdot u[t - (i - 1)D]$

and $Q_m = R_m \cdot u[t - (M - 1)D]$

Thus, at any time t, the total direct runoff is $Q_t = \sum_{i=1}^{M} Q_i = \sum_{i=1}^{M} R_i \cdot u[t - (i - 1)D]$

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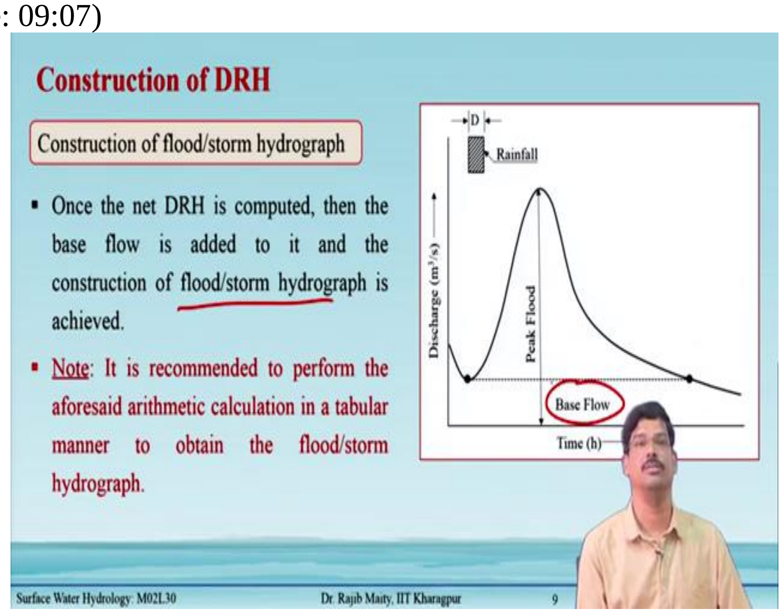

Construction of flood/storm hydrograph

Now, once the net DRH is computed, then the base flow is added to it and then we will get the flood or the storm hydrograph. So, remember that all this analysis that we get from this unit hydrograph is the direct runoff, runoff hydrograph.

Now, if just add this base flow component to that whatever direct runoff hydrograph we got then we will get that flood or the storm hydrograph. And it is recommended to perform this arithmetic calculation in a tabular manner so that you know the time correspondence between different successive things will be maintained.

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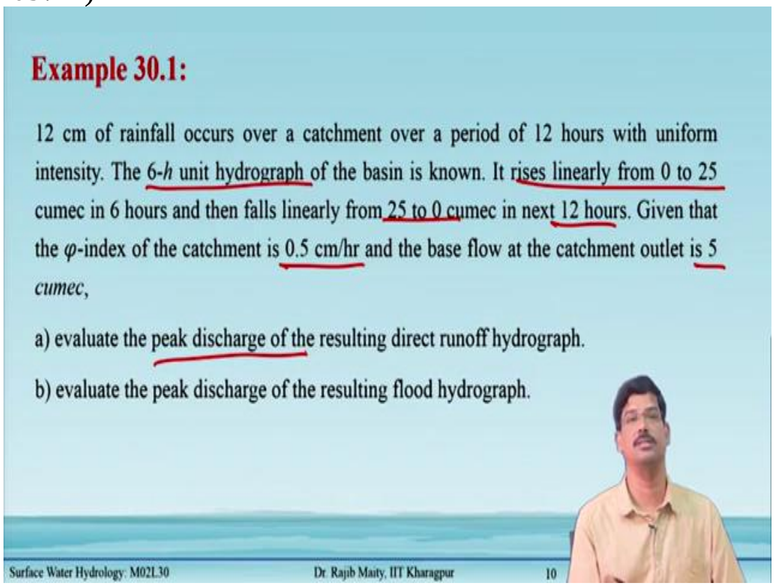

Example 30.1:

12 cm of rainfall occurs over a catchment over a period of 12 hours with uniform intensity. The 6-h unit hydrograph of the basin is known. It rises linearly from 0 to 25 cumec in 6 hours and then falls linearly from 25 to 0 cumec in next 12 hours. Given that the φ-index of the catchment is 0.5 cm/hr and the base flow at the catchment outlet is 5 cumec,

a) evaluate the peak discharge of the resulting direct runoff hydrograph.

b) evaluate the peak discharge of the resulting flood hydrograph.

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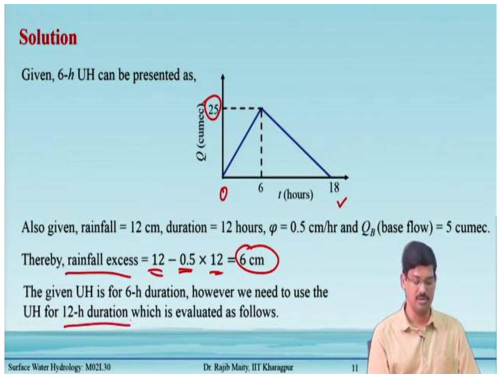
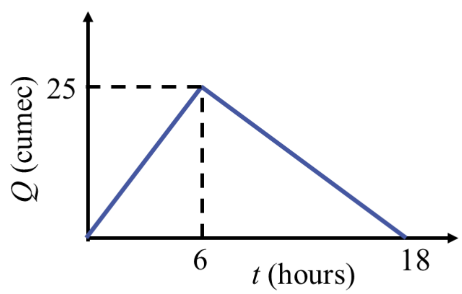


Solution

Given, 6-*h* UH can be presented as,



Also given, rainfall = 12 cm, duration = 12 hours, φ = 0.5 cm/hr and Q_B (base flow) = 5 cumec.

Thereby, rainfall excess = 12−0.5×12=6 cm

The given UH is for a 6-h duration, however, we need to use the UH for a 12-h duration which is evaluated as follows.

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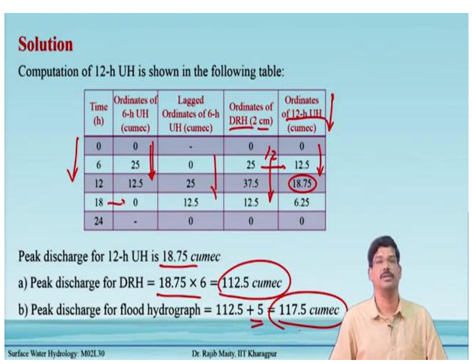

Computation of 12-h UH is shown in the following table:

Time (h)	Ordinates of 6-h UH (cumec)	Lagged Ordinates of 6-h UH (cumec)	Ordinates of DRH (2 cm)	Ordinates of 12-h UH (cumec)
0	0	-	0	0
6	25	0	25	12.5
12	12.5	25	37.5	18.75
18	0	12.5	12.5	6.25
24	-	0	0	0

Peak discharge for 12-h UH is 18.75 cumec

a) Peak discharge for DRH =18.75×6=112.5 cumec

b) Peak discharge for flood hydrograph =112.5+5=117.5 cumec

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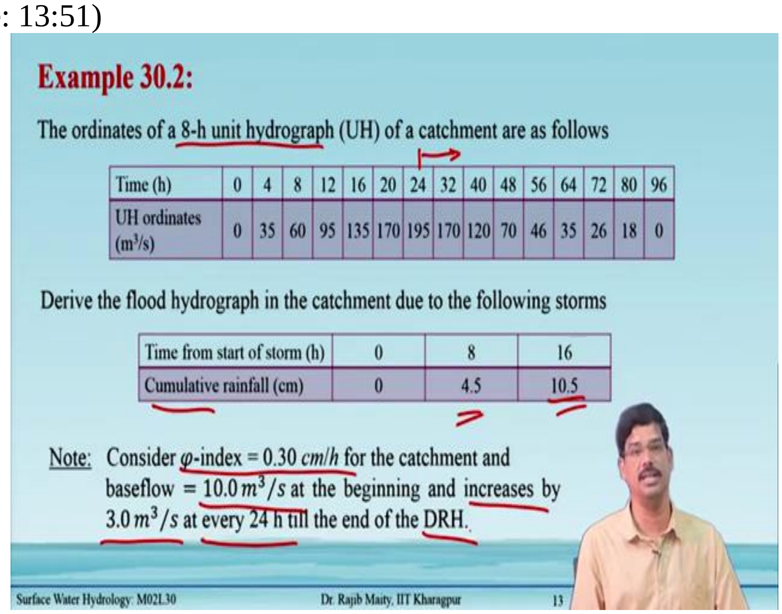

Example 30.2:

The ordinates of a 8-h unit hydrograph (UH) of a catchment are as follows

Time (h)	0	4	8	12	16	20	24	32	40	48	56	64	72	80	96
UH ordinates (m^3/s)	0	35	60	95	135	170	195	170	120	70	46	35	26	18	0

Derive the flood hydrograph in the catchment due to the following storms

Time from start of storm (h)	0	8	16
Cumulative rainfall (cm)	0	4.5	10.5

Note: Consider φ-index = 0.30 cm/h for the catchment and baseflow =10.0 m^3/s at the beginning and increases by 3.0 m^3/s at every 24 h till the end of the DRH.

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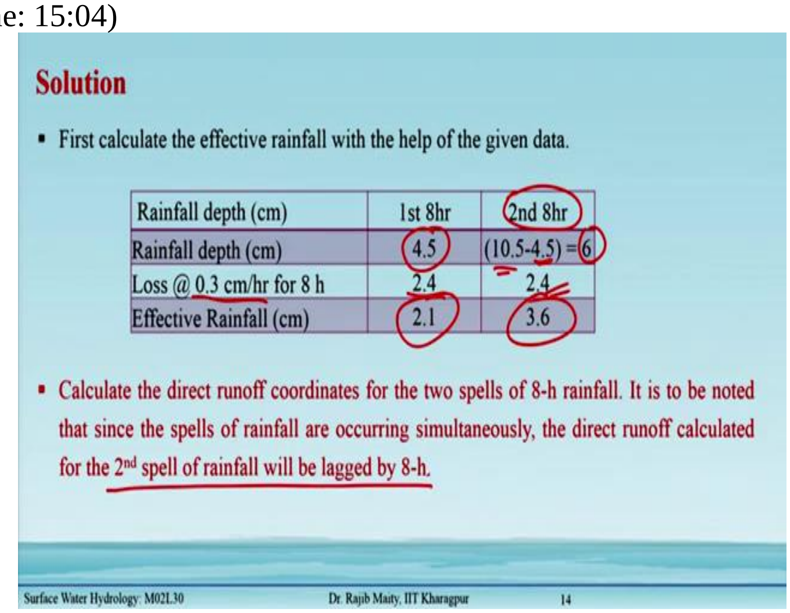

Solution

First, calculate the effective rainfall with the help of the given data.

Rainfall depth (cm)	1st 8hr	2nd 8hr
Rainfall depth (cm)	4.5	(10.5-4.5) = 6
Loss @ 0.3 cm/hr for 8 h	2.4	2.4
Effective Rainfall (cm)	2.1	3.6

Calculate the direct runoff coordinates for the two spells of 8-h rainfall. It is to be noted that since the spells of rainfall are occurring simultaneously, the direct runoff calculated for the 2nd spell of rainfall will be lagged by 8-h.

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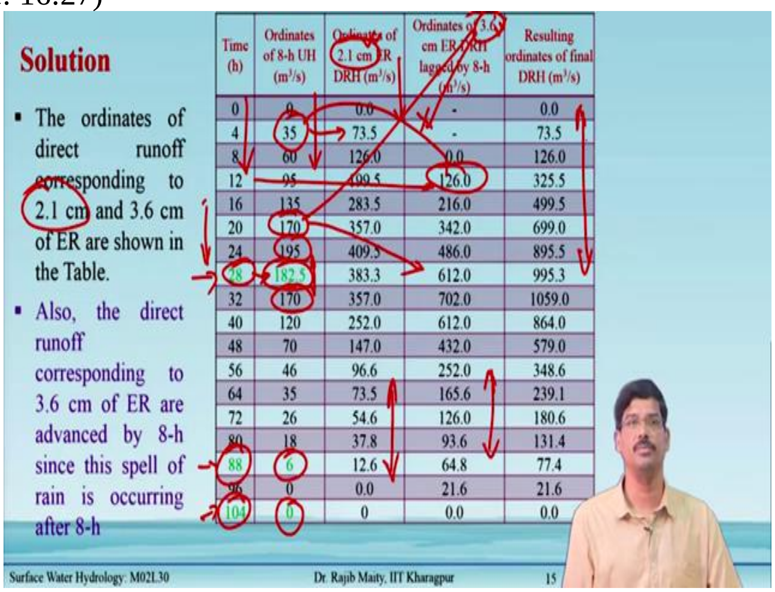

Time (h)	Ordinates of 8-h UH (m^3/s)	Ordinates of 2.1 cm ER DRH (m^3/s)	Ordinates of 3.6 cm ER DRH lagged by 8-h (m^3/s)	Resulting ordinates of final DRH (m^3/s)
0	0	0.0	-	0.0
4	35	73.5	-	73.5
8	60	126.0	0.0	126.0
12	95	199.5	126.0	325.5
16	135	283.5	216.0	499.5
20	170	357.0	342.0	699.0
24	195	409.5	486.0	895.5
28	182.5	383.3	612.0	995.3
32	170	357.0	702.0	1059.0
40	120	252.0	612.0	864.0
48	70	147.0	432.0	579.0
56	46	96.6	252.0	348.6
64	35	73.5	165.6	239.1
72	26	54.6	126.0	180.6
80	18	37.8	93.6	131.4
88	6	12.6	64.8	77.4
96	0	0.0	21.6	21.6
104	0	0	0.0	0.0

The ordinates of direct runoff corresponding to 2.1 cm and 3.6 cm of ER are shown in the Table. Also, the direct runoff corresponding to 3.6 cm of ER are advanced by 8-h since this spell of rain is occurring after 8-h

Time (h)	Ordinates of 8-h UH (m^3/s)	Ordinates of 2.1 cm ER DRH (m^3/s)	Ordinates of 3.6 cm ER DRH lagged by 8-h (m^3/s)	Resulting ordinates of final DRH (m^3/s)
0	0	0.0	-	0.0
4	35	73.5	-	73.5
8	60	126.0	0.0	126.0
12	95	199.5	126.0	325.5
16	135	283.5	216.0	499.5
20	170	357.0	342.0	699.0
24	195	409.5	486.0	895.5
28	182.5	383.3	612.0	995.3
32	170	357.0	702.0	1059.0
40	120	252.0	612.0	864.0
48	70	147.0	432.0	579.0
56	46	96.6	252.0	348.6
64	35	73.5	165.6	239.1
72	26	54.6	126.0	180.6
80	18	37.8	93.6	131.4
88	6	12.6	64.8	77.4
96	0	0.0	21.6	21.6
104	0	0	0.0	0.0

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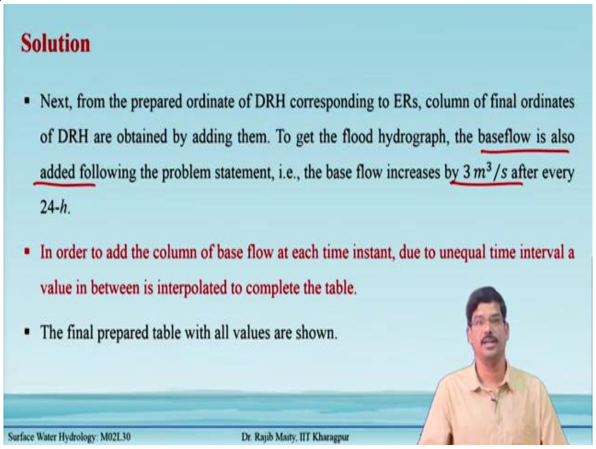

Next, from the prepared ordinate of DRH corresponding to ERs, a column of final ordinates of DRH are obtained by adding them. To get the flood hydrograph, the baseflow is also added following the problem statement, i.e., the base flow increases by 3 m^3/s after every 24-h.

To add the column of base flow at each time instant, due to unequal time interval a value in between is interpolated to complete the table.

The final prepared table with all values is shown.

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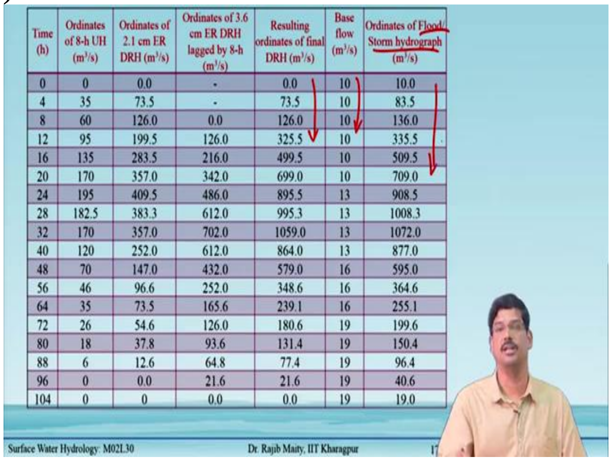

Time (h)	Ordinates of 8-h UH (m^3/s)	Ordinates of 2.1 cm ER DRH (m^3/s)	Ordinates of 3.6 cm ER DRH lagged by 8-h (m^3/s)	Resulting ordinates of final DRH (m^3/s)	Base flow (m^3/s)	Ordinates of Flood/ Storm hydrograph (m^3/s)
0	0	0.0	-	0.0	10	10.0
4	35	73.5	-	73.5	10	83.5
8	60	126.0	0.0	126.0	10	136.0
12	95	199.5	126.0	325.5	10	335.5
16	135	283.5	216.0	499.5	10	509.5
20	170	357.0	342.0	699.0	10	709.0
24	195	409.5	486.0	895.5	13	908.5
28	182.5	383.3	612.0	995.3	13	1008.3
32	170	357.0	702.0	1059.0	13	1072.0
40	120	252.0	612.0	864.0	13	877.0
48	70	147.0	432.0	579.0	16	595.0
56	46	96.6	252.0	348.6	16	364.6
64	35	73.5	165.6	239.1	16	255.1
72	26	54.6	126.0	180.6	19	199.6
80	18	37.8	93.6	131.4	19	150.4
88	6	12.6	64.8	77.4	19	96.4
96	0	0.0	21.6	21.6	19	40.6
104	0	0	0.0	0.0	19	19.0

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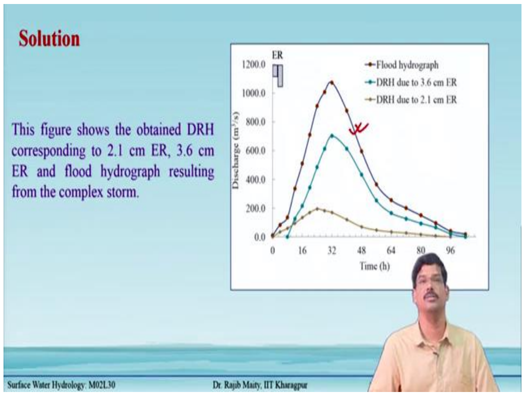

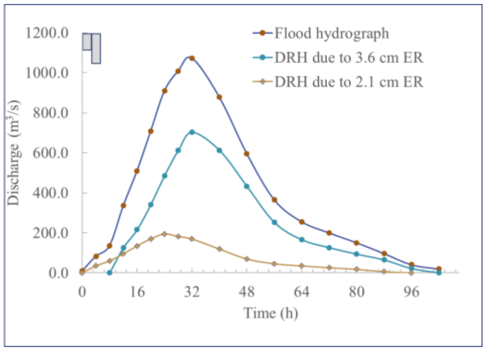

Fig.1 shows the obtained DRH corresponding to 2.1 cm ER, 3.6 cm ER, and flood hydrograph resulting from the complex storm.

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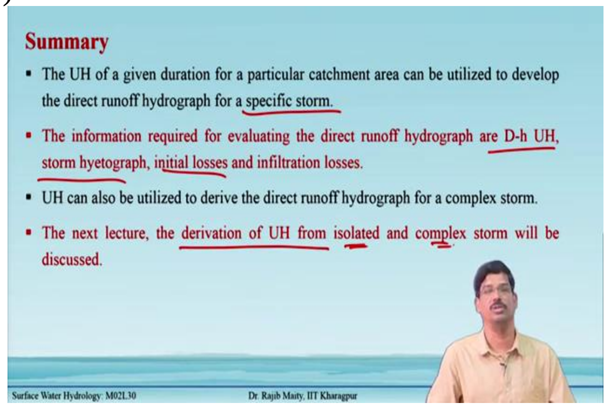

Summary

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

- The UH of a given duration for a particular catchment area can be utilized to develop the direct runoff hydrograph for a specific storm.
- The information required for evaluating the direct runoff hydrograph is D-h UH, storm hyetograph, initial losses, and infiltration losses.
- UH can also be utilized to derive the direct runoff hydrograph for a complex storm.
- In the next lecture, the derivation of UH from the isolated and complex storm will be discussed.