# Advanced Hydrology

**Prof. Dr. Ashu Jain**
**Department of Civil Engineering**
**Indian Institute of Technology, Kanpur**

**Lecture – 25**

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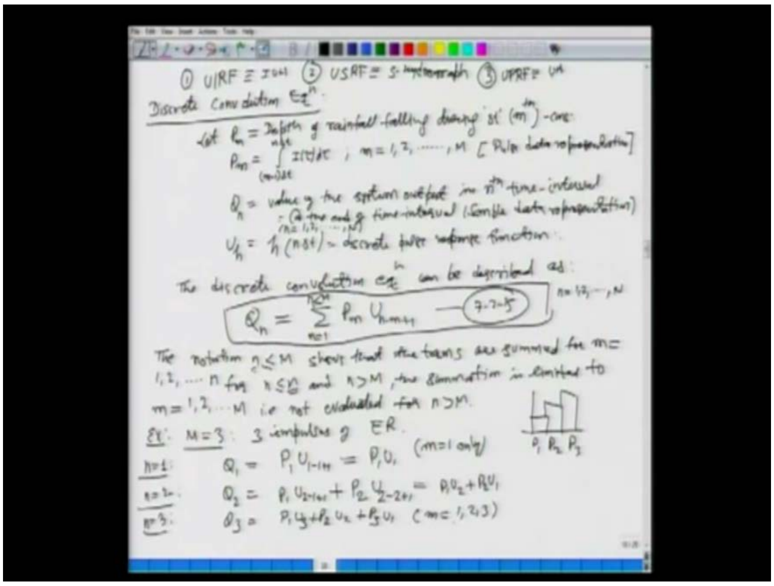

Good morning and welcome to the postgraduate video on Advanced Hydrology. We are in chapter 6 these days. In the last class, we looked at certain important functions which are necessary to understand the linear hydrologic system. These 3 functions which we looked at... I am just going to briefly write them down; first 1 was the Unit Impulse Response Function all right. We defined it and we looked at how we can get it, and this is nothing but is instant in its unit hydrograph which you may have seen in your earlier classes, that was the first 1. The second function which we looked at was the Unit Step Response Function and which we said is nothing but your S hydrograph. And the third function which we saw was Unit Pulse Response Function, and which is nothing but your unit hydrograph.

And then what we did is we saw the equations or the expressions in terms of each other and the inter relationships of all this 3 different functions, that is instantaneous unit hydrograph the s curve and the unit hydrograph. What we will do today is we will start with the discreet convolution equation. We had seen the integral form of the convolution equation, which is helpful when we have the data at continuous time domain. However, that is not the case for hydrologic variable most of the data which we measure or observe rainfall whether it is rainfall or run off, we have them at discreet time steps. So what we are going to do is, we look at the discreet convolution equation first, and then we will come back to the simpler things on unit hydrograph.

Discrete Convolution Equation which will be very important, not only from the point of view of being able to calculate the direct runoff hydrograph response, given a complex effective rainfall heterotrophy and a unit hydrograph all right. So if we have the unit hydrograph for a catchment and we know the rainfall, we can find out the direct runoff hydrograph response using this discreet convolution equation, all right from the complex term or this is also useful in the reverse process.

That is we can find out the unit hydrograph, given the direct runoff hydrograph and the rainfall data in a catchment all right. So this process of this convolution equation on the discreet time domain is is an important 1 and actually we have seen it earlier in the last chapter with reference to the time area diagram, all right. But we are going to revisit it with reference to the effective rainfall and the unit hydrograph.

So, let let us first define the variables that are involved in this. P m is the depth of rainfall, falling during delta t time interval which is m-th actually. That is why, that subscript is m and let us says it is in centimetre or some suitable units ok. How can this be defined, all this is nothing but the area under the curve between m minus 1 delta t to m delta t of what? Of your intensity curve, so you have this i t or i tau. This in10sity curve, which is available and then you just integrate it or find the area under that curve.

And this is true for all values of m; m is the index which represents the time interval, from 1 to let us say all the way to capital M all right. And what is this? This is what we call is the Pulse Data Representation. This is the Pulse Data Representation. Let us define Q subscript n. Q subscript n has the value of the system output in the n-th time interval or during the nth time interval. Which is actually, normally at the end of the time interval? If we are using this sample data representation which is for your flow hydrographs, we had seen that in earlier chapter. How these variables are defined in a different manner. U h is equal to your h h times steps of your n delta t, which is the Discreet Pulse Response Function or nothing but your unit hydrograph, all right.

So with these notations, we can write the Discreet Convolution Equation. Then can be described as the following equation. Which is, as you may have seen it earlier? What is Q? Q is the direct runoff hydrograph at any time and delta t all right. And can vary from 1 to capital N all right. Let me say that here, where your n is 1, 2 all the way to capital N ok, all right. And this is summation of P m U n minus m plus 1 and I am going to call it as 7.2.15 and this summation runs from m is equal to n such that it is less than or equal to capital M ok. We have seen this concept earlier. So it should be easy to understand. Let me rephrase or retreat the notation on that summation, we have seen n less than equal to M means, what? It shows that the terms are summed for the values of m varying from 1, 2 all the way to small n, all right this number here.

For n less than equal to M and what happens for if the value of n becomes greater than M, well the summation is limited to same thing which is m is equal to 1,2 all the way to capital M. So capital M is kind of the upper limit up to which you will go in that summation all right. Because that represents what, that is the maximum number of rainfall impulses that are existing. Because there is no effective rainfall after that, so there is not going to be any output due to a rainfall after M.

So it is basically that is what it means all right. That is, it is not evaluated all right for your values of n greater than M all right. So if we want to just look at an example, of how we use this summation or this convolution equation. Let us say your capital M is equal to 3. What does it mean? It means that you have 3 pulses on your e r h, let us say this is P 1, P 2 and P 3, there only 3 impulses of your effective rainfall.

Now, when I apply this equation this 1. Capital M is equal to 3, what will happen let us say, you do it for n is equal to 1 first, small n can vary from let me write it here small n can vary from 1 2 all the way to capital N all right and capital N can be more than capital m all right so what will be q 1 as per that summation if you open that summation you will have how many terms only 1 why because n is equal to 1 and we are writing writing the expression for q 1 so it will be p 1 u 1 minus 1 plus 1 like we have d1 earlier n is 1 m is 1 and then you have plus 1 so this is nothing but your p 1 u 1 all right so m we are taking this 1 only for this co-ordinate what will be q 2 corresponding to n is equal to 2 it should be easy to see that it will be p 1 u 2 minus 1 plus 1ok, p 1 u 2 minus 1 plus 1 all right.

And that will be second term corresponding to p 2 because now n is equal to 2 so summation is going from 1 to 2 right so p 2 u of your the 2 minus 2 plus 1 which is going to be p 1 u 2 plus p 2 u 1. I hope this would be clear and similarly, you can write other ordinates for n 3 it will be q 3 is equal to I am going to write it directly, so it will be p 1 u 3 plus p 2 u 2 plus p 3 u 1, and then what do we have here is m is 1 2 and 3 so basically you have 3 terms.

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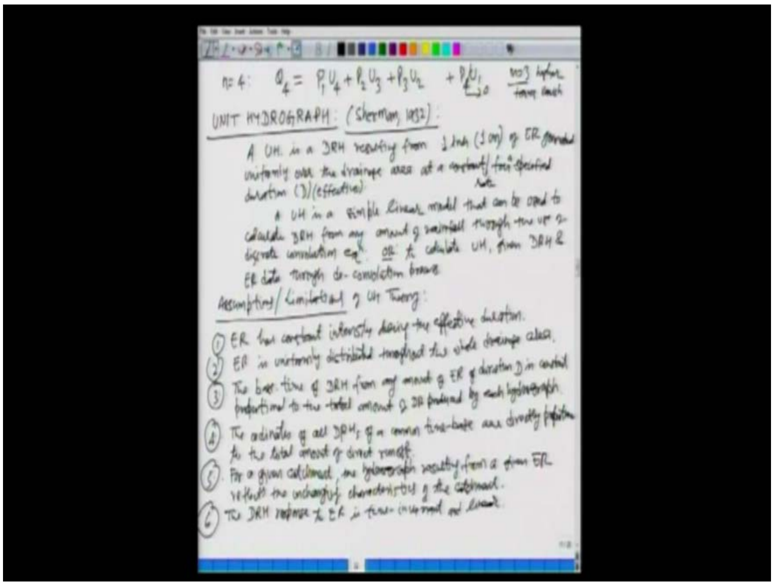


Now what happens? When n is 4 or you are trying to find out the d r h ordinate at the end of lecture 4th however how many terms were going to be there in the summation. Well 3 only because there is only 3 impulses of effective rainfall and which 3 terms will be there. Well you can work it out it will be p 1 u 4 plus it will be p 2 u 3 and p 3 u 2 all right ideally let me write it here, there should be 1 more term which is p 4 u 1 all right. But your capital m is equal to 3 right, so there is no p 4, so this term is actually zero so we are not writing it.

So, that is what it means? That if you have only capital M number of impulses anything more than that does not exists so that term will drop out all right. So let me just let me not delete it and say that higher terms vanish and then so on all right so this way we can use this equation which is your discreet convolution equation either in a forward direction or in a backward direction to find the direct runoff response or to find the unit hydrograph through the d convolution processes. So the next thing we are going to do is we will move on to some basic stuff all right which is on the definition of the unit hydrograph what are the assumptions or the limitations of a unit hydrograph, how we can determine, how we can calculate a unit hydrograph given the data from a catchment in terms of a flow and the area and so on.

So let us then look at from first principles, the concept of unit hydrograph ok. As I said earlier it was proposed by Sharman in 1932, all right and this concept of unit hydrograph is still used in the same form or the original form ok. It is so practically useful all right, how do we define a unit hydrograph let me just write the definition first and then we will revisit it. A unit hydrograph is a direct runoff hydrograph all right resulting from 1 inch or 1 centimetre or unit basically, of effective rainfall generated how it is important uniformly, over the drainage area. What does it mean? That the unit hydrograph is generated uniformly over the drainage area means, the amount of rainfall is uniform over the space. The whole drainage base in or the whole catchment, so there is a variation with respect to space is not there all right it is assuming so it is a lumped model ok.

So, the uniformly now over the drainage area at a constant rate, so you see that there is another assumption inherent in the definition of the unit hydrograph at the constant rate means, the distribution of the rainfall with respect to time also is uniform ok. For a specified duration for a specified duration each and every term is very important let us say d all right. So a unit hydrograph is defined for a particular duration d and the value of d can be 1 hour 2 hour 3 hour 6 hours 12 hours whatever all right.

So whenever we say a unit hydrograph we always put a d hour unit hydrograph in front of it right. What does that mean? That means it is a unit hydrograph of 12 hour duration or d hour duration, what does that duration represent? That is nothing but the duration of the effective rainfall ok, all right. So, the rain is falling a uniformly over the drainage area at a constant rate at a constant I think I need, the term rate here a constant rate for a specified duration, and this duration is let me, say effective for the effective rainfall ok, not the total duration all right.

Now a unit hydrograph is a simple linear model all right, which can be used or that can be used to do what, to calculate d r h from any amount of rainfall how through the use of your discreet convolution equation which we have just seen, discreet convolution equation or I should say rather and it can also be used how to calculate or determine u h given the d r h all right given the d r h and effective rainfall data how through a d convolution process, that is using the discreet convolution equation in the reverse direction that process is called the d convolution.

We will come to that little later in this course today ok. So this is the definition of a unit hydrograph and as I said it is very important to understand, it is the direct run of hydrograph response from a catchment, when the catchment is subjected to 1 centimetre of effective rainfall and how is that rainfall that rainfall is uniformly distributed over the space and time both space and time all right.

And another condition is that this a unit hydrograph is defined for a specified duration all right, d hour and that d is hat that is the duration for the time during which the effective rainfall is occurring ok. So this is the complete definition of your unit hydrograph.

So the next thing we are going to look at is some of the assumptions or some of the limitations of this theory ok. Many of these you may have seen earlier but we will just retreat list all of them, so that we understand when we can use this and when we cannot use this all right. So let me list the assumptions or some of them may be limitations of your u h theory all right.

So the first 1 is the effective rainfall has constant intensity during the effective duration ok, this assumption is actually inherent in the definition of the unit hydrograph itself. We said that the rate at which rain is falling is constant all right that means the it is a constant intensity during that duration. Why it is important is because we are assuming that rain is uniform all right and so that when we are looking at the data set we have or the historical records. We should find out such data for which in a particular duration the rainfall is more or less uniform.

So, we need to be able to we would meet or satisfy these assumptions or limitations as per as possible when we are developing a unit hydrograph. So, that was the first 1 and we will see that some of these are already inherent in the definition; the effective rainfall is uniformly distributed throughout a whole drainage area. This is also the part of the definition all right. I will not spend much time off that it basically, means that your rainfall is constant with respect to space.

The third 1 is the base time of the direct run of hydrograph from any amount of effective rainfall of duration d is constant is constant and the proportional to the total amount of direct run of produced by each hydrograph. So what is this assumption telling us it is basically, telling us that the base time of various direct runoff hydrographs ok. What is the base time which you have the unit hydrograph or the direct runoff hydrograph the time at which the run of response starts, direct run of response starts and the time at which the d r rage responds ends that that time left between those 2 points that is called the time base all right. So, the time base of all the direct runs of hydrograph all right which are produced by effective rainfalls of any amount all right. But occurring in the other duration all right let us say you have you are looking at 2 hour duration effective rainfall all right. So in that 2 hour first if you have a rainfall event of 1 centimetre, 5 centimetres, 10 centimetres all right. But occurring in 2 hours d hour that is constant all right the response from the catchment all right, will have the same time base or the base time from all of those different storm events having different magnitudes of effective rainfall. So, that is all it is saying.

Moving on the next assumption states, that the ordinates of all direct run of hydrographs of a common time base of a common time base are directly proportional to directly proportional to the total amount of the total amount of direct run off. It is basically, similar to what we have just said above all right the base time is you know same for all, the d r heads having the same duration for the effective rainfall and all now, what we are saying is the ordinates of different d r heads will be in the proportion of the total amount of d r heads all right.

Again, it sees another way of saying the proportionality ok. The next 1 we will see that many of these may be inter-related to each of them for a given catchment or for given water share, the hydrograph resulting from a given effective rainfall, reflects what reflects the unchanging characteristics of the catchment.

So, let us look at this statement again and then I will try to explain it, for a given catchment, the hydrograph resulting, from a given effective rainfall reflects what, the unchanging characteristics of catchment. What do we mean by that? That’s say you have the data all right. You have collected the data in terms of rainfall or 1 of etceteraetera and then you have developed the unit hydrograph.

So, once you have the unit hydrograph and then you can you are applying it in future for several years all right. Then this unit hydrograph which we have developed is not able to account for the changes that are taking place in your catchment, those changes can be in terms of the development in the catchment for example; the new buildings may be coming up the paved areas may be coming up that will actually, affect the shape of your direct run of response and hence the unit hydrograph. So, if you have a very fastly changing characteristic in a catchment then the unit hydrograph has to be updated at a regular interval all right so basically what we are saying is that it assumes once you have developed that the characteristics of the catchment are same.

The next 1 is the d r h response to effective rainfall is time in variant and linear this is a very famous assumption. I am sure you may have seen it earlier in your undergraduate hydrology course right. So, this is again you know it is again a retration it is a linear system so we are saying that we can use the proportionality and super position all right. So, the unit hydrograph story is linear number 1.

And the number 2 we are saying that it is time in variant what do e mean by the d r h response of the catchment in time invariance. It means that once you have developed the unit hydrograph, we apply it to a rainfall event. Whether, it occurs in January or April or October or December it does not matter. It is going to give you the same direct run of response ok. So, it is it represents a time you know in varying response or the response from the u h will not depend up on when the rainfall has occurred.

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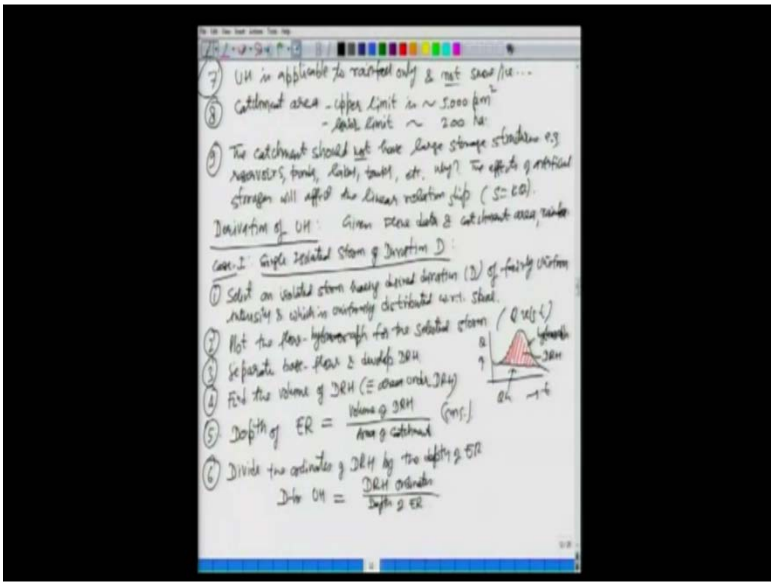

Moving on the next assumption number 7, we say that the unit hydrograph theory is applicable to rainfall only. What do we mean by that? Obviously, we have seen that they are many forms of precipitation. So, it is not applicable to snow ice or any other form of precipitation all right. So, we are saying that the unit hydrograph theory is applicable only to the liquid precipitation form which is the rainfall.

The next 1, the catchment area, drainage area or the water shed area, upper limit of that is approximately 5000 square kilometres and the lower limit is approximately 200 hectares ok. The unit hydrograph theory we apply all right for moderate sized catchment all right not too small and not too large also upper limit. We are saying is 5000 square kilometre and why this limit is because the basic assumptions, which we are making with respect to the uniform intensity and the you, know uniform rainfall with respect to space etcetera. They would no longer be valid if your size of the catchment is cubic all right.

So, due to those reasons we are saying that this unit story hydrograph is applicable to an upper limit of 5000 square kilometres and the lower limit of 200 hectares ok. The next 1 is the catchment should not have the large storage structures, any large storage structures like what for example; reservoirs, ponds, lakes etcetera, may be tanks etcetera. Why the assumption, we are saying is is what the catchment should not have large storage structures all right.

We are talking about the rain fallen of the modelling here ok. We have the effective rainfall and we are using the unit hydrograph theory to convert that into the direct run of all right. So, while we are talking about this rainfall on of process, it is basically, what in 1 of the earlier lectures. We have seen that, while the rainfall is getting converted into run off. What happens is the rainfall goes into various storages in the catchment all right. The natural storage is in the catchment all right. If we have additional artificial storages that will alter these storage characteristics of the catchment all right, due to which the rain the run off response will become more complicated all right, more the complications more will be the violations as per as the assumptions and limitations are concerned, all right.

So, this is theory is actually not applicable or it will not give good results. I should say when you have large ponds or dams and reservoirs in the catchment all right so it is mainly for the virgin flows ok. And why is that because the effects as I said of artificial storages which I have just mentioned here which affect the linear relationship ok. Which is we had seen s is equal to k p as you know the unit hydrograph is based on the linear assumption theory, in which we have storage as a function of k times q all right. But if we have some additional storages in the catchment that will affect this linear relationship like it may become non-linear or it may add to the non-linearity of the storage behaviour of the catchment in which the this theory is actually, not valid.

Moving on to the derivation of the unit hydrograph given the data, we just looked at the definition of the unit hydrograph and also the basic assumptions or the limitations all right. Now we will move on to the derivation of the unit hydrograph given the flow data and the catchment area all right.

And also you will need rainfall for the complex down case all right. So, what we will do is we will look at the procedure of derivation or calculation of the unique hydrograph for 2 cases all right. Case 1 will be when the data are from a simple storm or a single storm isolated rainfall impulse all right. Which is producing certain run of then later on we will look at while these kinds of data are very difficult to find all right.

An isolated storm in which there is no rainfall on either side or then it is nicely isolated all right but we we may have you know the data the very useful data, when you have a complex storm that is, you have back to back you know rainfall impulses of certain duration all right.

So, we should be able to find out the unit hydrograph from the complex storm also, let us look at the case 1 first which is simple storm or single isolated storm, what is the storm? The rainfall event we are talking of duration d all right. So, you have the data corresponding to a isolated storm which occurs for duration d the effective duration d ok. And then you have the slow hydrograph measured at the outlet of the catchment at a river or a stream at some location.

How do e find the unit hydrograph co-ordinates using this data so what I will do is I will give you a step by step procedure first and then we will look at 1 example; of case 1 so let us look at the procedure first in the first step, what we will do well you select, you scan through all the data you have and select an isolated storm, having desired duration d ok, of what well the assumptions are important we say of clearly uniform intensity that is with respect to time and which is uniformly distributed respect to space ok.

How do we determine these 2 things, well we look at let us say your value of d is 3 hours. So, what you do is you scan through all the data in the past for 50 years or 100 years data pick up all those storms, which have duration of 3 hours.

And then you see during those 3 hours in different you know storms, how the rainfall was distributed in respect to time all right. In the first hour how much was the rainfall, in second hour how much was the rainfall, third hour how much was the rainfall and then you pick up the 1 which has uniform or the more or less same amount of rainfall in the 3 hours or continuously. So, you have the same intensity or the constant intensity with respect to time also you want to make sure that the rainfall is uniformly distributed with respect to space all right so how do you make that sure.

Well, we may have different rain gauges in the catchment all right. So we select particular date and time, let us say for these 3 hours on you know January 29 th1970 that is the storm you have selected on that date that time, you see the values of rainfall in different rain gauges in the catchment.

And you find out that the variation from 1 location to the other is not significant all right. So, you pick up a data or a storm, which is isolated and for which your rainfall intensity is uniform with respect to time and it is also uniform with respect to space. So, you see that meeting those assumptions is not easy, so selection of the data is a very important step. So, as per as this exercise is concerned we will assume that we will have this data all right.

What is the next step number 2, what we do is we plot the flow hydrograph or hydrograph, for the selected star or resulting from that star all right. What is a hydrograph? Well basically it is a curve between q and t time verses the total flow all right. Next step is what separate the base flow separate the base flow and develop your d r h all right. So, graphically if I want to explain it to you this is your flow hydrograph or this are your hydrograph which is observed or measured all right. This is t verses q all right and then you want to separate the base flow ok. So that we have the d r h and we have seen 3 different methods of base flow separation in the chapter so we can use any 1 of them and we can quote them in a computer programme also.

So, let us say that you are using straight line method all right. So, this is your d r h everything above is d r h and everything below is your base flow or (( )) all right. So, you subtract the base flow from your total flow all right. So, that gives you the direct run of hydrograph all right, so we developed the d r h that is step number 3,what is the next step number 4, we find the volume of your d r h all right. How do you find the volume of this direct run hydrograph it is nothing but the area under the curve all right. So, you have the q let us say let us say a meter q per second time is in hours all right. So, you just integrate that curve or you can divide it into scripts, all right, get those areas and add all of them all right. So, this is nothing but equivalent to your area under the d r h and if I want to look at here it will be what I am going to hatch it like this, it is this area under this curve.

We have the volume of the direct run of hydrograph. Now you want to find out what is the next step, you want to find out the effective rainfall due to which this d r h was produced, all right. So, what will be the depth of e r or effective rainfall which produces this d r h well it will be nothing but volume of d r h which we have just found in the previous step divided by what the area of the catchment. And you can convert these suitable units so that you have the answer in centimetres.

So, now you have a d r h all right. So, you had the total flow hydrograph you have subtracted the base flow you have the d d r h you also have the amount of effective rainfall that produce this d r h all right, so how can you find a unit hydrograph of the hour duration. It is a very simple problem we can use the principle of proportionality which we have been a lot in this chapter all right.

So, you have a d r h from let us say x centimetre of rainfall. So, how how do you find the unit hydrograph, you just divide the d r h ordinates by h that will give you the coordinates of the unit ok. So, the last step then is number 6 divide the ordinates of d r h by the depth of e r which we just found all right. So, that your d hour u h will be nothing but your d r h ordinates divided by depth of f. You see, that this is a very simple procedure you know and the step by step procedure I have given you how we can calculate or find out the unit hydrograph from an isolated simple single storm ok. What I am going to do is quickly look at an example;

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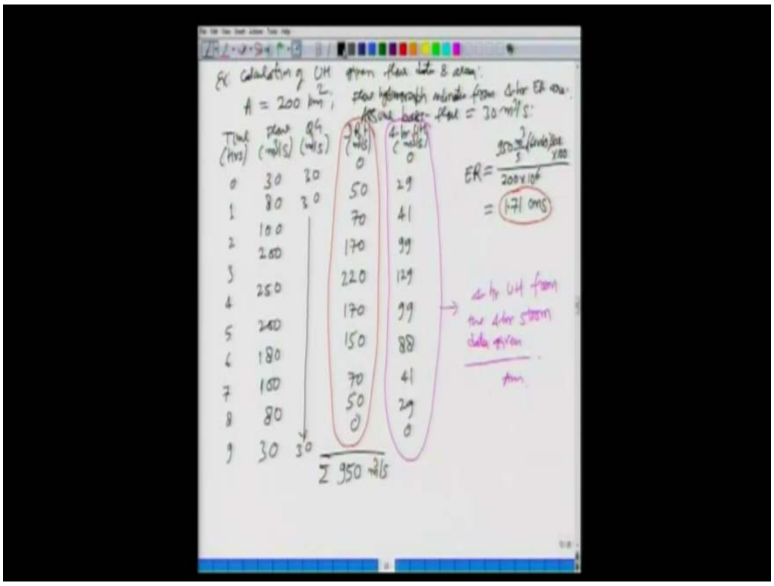

On, how we actually apply this method. So let us look at the example on calculation of u h given the flow data and the area of the catchment. So, let us say that the area of the catchment is 200 square kilometres and you are given that the flow hydrograph ordinates from resulting from this 4 hour e r given as follows; let us say this is your time in hours and this will run from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and the flow which is given is in let us say metre q per second ok. This is measured hydrograph this data we have given to us I am just showing some numbers here 30 all right.

So, what you have is the flow hydrograph given to us and these are the time in hours all right. So, this is the blood hydrograph which is measured at the outlet of some basin which has an area of 200 square kilometres ok. What is the first step which we had looked at? If you go back the first step is well it is the select the isolated storm let us say, we have selected that and we have the data not this all right. We can plot this and plot that and the first step that is separates the base flow and develops the d r h all right. So, in this case what we are going to do is we will not plot it but we will see that or we will find out what is the base flow you see that the first ordinate all right at time 0 or when the rainfall has not given all right is 30 all right at the end also it is 30.

So, you can assume the base flow let us say is 30 meter q per second rather than plotting and then dividing a line we can do that but for the demonstration purposes. We will take the value of the base flow as 30 meter q per second. So, with that may be you may have a column which says q g meter q per second, so it will be 30, 30 at least 9 steps here all the way it is 30.

Now the next step is to find the d r h how you find the d r h if you step track the base flow from the measured total flow all right that will give you the ordinates of the direct run of hydrograph. So, you have 30 minus 30 is 0 and then 80 minus 30 is 50 and so on. So, you keep on subtracting 30 from this you have 70, 170, 220 and 170 and 150, 70, 50 and then last 1 is 0.

Ok, so this is the direct run of hydrograph in meter cube per second, what is the next step? Once you have found the direct run of hydrograph all right. Find the number 4 is find the volume of the d r h which is what, area under the curve ok. How do you find that area under this well we can divide this into scripts all right and let us say we already have this script of 1 hour is all right on the time domain. We have 1 hour you have the ordinate. So what you can do is the best way to do is just sum these b r s ordinates and multiplied by the time or delta which is 1 hour all right. You just do that summation assuming that strip to be rectangular. So, there are certain assumptions it will not be very exact but still we can use that. So, if we sum it up it will be 950 what meter q per second all right.

The next step is to find out effective rainfall. Effective rainfall as we said is what is the volume of the direct run of the hydrograph divided by the catchment area, what is the volume well it is 950 meter q per second multiplied by what, delta t per 1 hour the strip is of 1 hour duration each of them. So, it will be captured 36 times 36 sorry 60 times 60 which is 3600 actually, that many seconds in an hour all right. So, that what you have in the numerator is the volume in meter q this divided by the area of the catchment given to us as 200 square kilometre so you have 10 to the power 6.

All right, so this answer will be what this answer will be in meters ok. So, you multiply this whole thing by 100. So, you will have it in centimetre. So, if this is your effective rainfall or the depth of the direct run of hydrograph which will come out to the 1 point 7 1 centimetre ok? So, all we have d h is we have added the d r s ordinates ok. Multiplied that by the amount of the or number of seconds in 1 hour and divided by the area taken care of the units and find or calculate the effective rainfall as 1 point 7 1 centimetres..

The next step is what if you go back the last step is to divide the ordinates, this step your talking divide the ordinates of the d r h by the depth of effective rainfall, the depth of effective rainfall in our case is what 1 point 7 1. What is the d r h? This one this column so you divide this column by 1 point 7 1 that will give you what the ordinates of 4 hour u h in meter q per second ok.

If you do that you are going to have 0 29 is 41 you can verify these numbers 99, 129, 99, 88, 41, 29 and 0 ok. So, this is your n the final answer. What is this? This is your 4 hour unit hydrograph from the 4 hour storm date given from so that we may see that we have looked at the procedure of finding out the unit hydrograph when we have a single storm all right that was our case 1. Now what we will do is we will look at the case 2, in which there is no single storm but there is effective rainfall impulse back to back it may be 1, 2, 3, 4, 5 different impulses. What do we do in that case because the d r h response is complex it is not coming from single storm but it is coming from many effective rainfall impulses..

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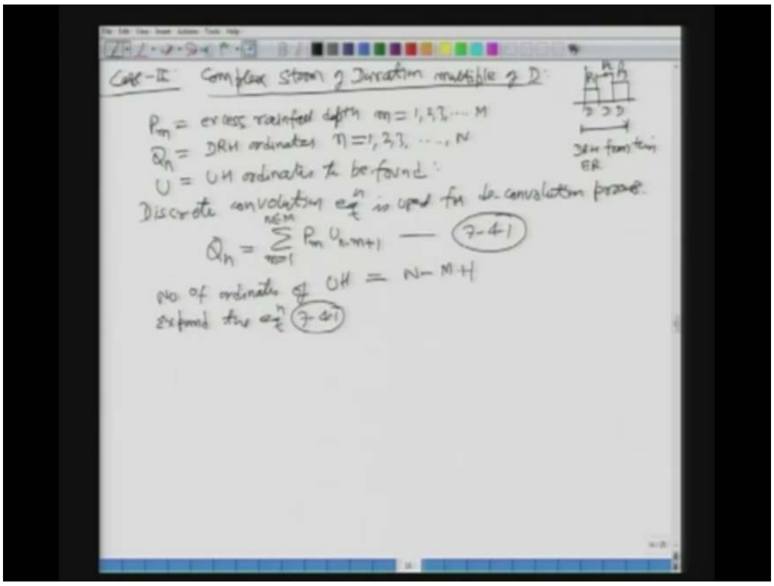

So, we have the case 2 complex storm of duration which are multiples of d multiple of the means what?

For example; I will just take very small example you have this rainfall occurring in d hours this is d that is say this is p 1, then you have right next to it you have same duration d another event rainfall of p 2 magnitude, then the third 1 you have same duration so the total duration is this that all right these are multiples of d all right.

And e are trying to find out the d hour unit hydrograph we have this rainfall data p 1, p 2, p 3 all right. R the complex storm data we also have the d r h from this e r. So, the data which we have let us say p m is the excess rainfall depth and and is varying from say on 2, 3 all the way to capital M. So we are going to be general the example. I have shown here is 3 impulses that. Let us say you have capital m number of effective rainfalls capital m may be 3, 4, 5, 6, 7, 8, 9, 10 any number all right let us say we have the data of q n q n is what the d r h ordinates the d r h ordinates all right such that you n is 1, 2 ,3 all the way to let us say capital N now the data I am saying here is directly or direct run of hydrograph.

If you have the flood hydrograph data the total flow data you carry out that base low separation part. So I am not considering that in this particular case the case 2. So, let us say we had d1 that and the q s here represent the direct run of hydrograph response all right so this will be direct run of all right. Let us say that u is the U H ordinate to find how can we solve this problem, any ideas you think about it today we looked at what we called the discreet convolution equation in which, we said it can be used in a forward direction or for the process of convolution. In which we have the rainfall data given we can find the d r h response all right we can also use that in a reverse direction which is called the d convolution process in which the flow data is given or d r h data is given effective rainfall data is given we can d convolute this data and find out the unit hydrograph all right so we will use the discreet convolution equation here.

How for the d convolution process that is we are using it in a reverse direction so let me first write this equation so what we will do is we will write all the data or all the equations all right using this discreet convolution equation and then we will look at 2 different methods, how we can use this discreet convolution equation in the reverse direction so let me first write it, so we have Q n as we just looked at today I am going from 1 to n less than equal to M of your p m u n minus m plus 1 and let me number this as 7 4 1 the number of ordinates of your unit hydrograph are going to be capital N minus m plus 1. So, we will take it from the story of the linear system in which if you have capital n is the number of d r h ordinates capital M is the number of effective rainfall impulses then the number of ordinates is going to be the n minus m plus 1 all right.

So what we will do is we will expand the equation 7, 4, 1, and then use the convolution process. So I think it is going to take some time I am running out of time today. So what we will do is we will expand this equation 7 point 4 point 1, how many equations capital N number of equations. You see that the discreet convolution equation this q small n all right this small n is varying from 1 to 3 up to capital N .so how may equations. We will have we will have capital N number of equations, so we will write these n equations and then we will find out or then look at 2 methods of finding out the unit hydrograph, so I would like to stop at this point of time and we will start tomorrow.

Thank you.