Irrigation and Drainage
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Lecture - 51
Surface Drainage System Design

Friends welcome to lecture number 51 on Surface Drainage System Design. So, in this lecture we are going to see the kind of design of surface you know drainage for example. Basically it has two components: one is a hydrologic design and hydraulic design. So, in this lecture I will focus on hydrologic design; so mostly finding out the peak flow rate from a drainage area ok.

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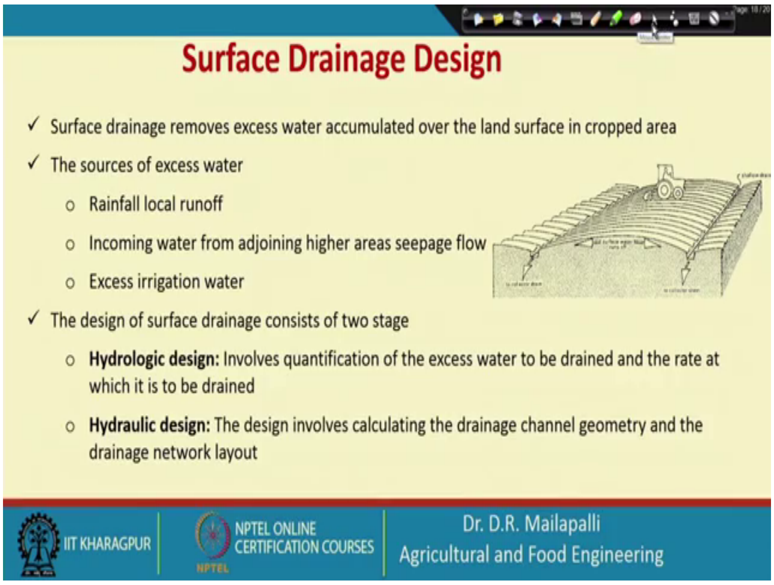

So, the basically these surface irrigation sorry surface drainage. If you see the surface drainage basically the removes excess water accumulated over the land surface in crop area. Since we were interested in you know agricultural fields so our focus is to remove excess water from the farmland.

So, the surface what are the sources of these excess water. So, basically the rainfall local runoff so, and then incoming water from adjoining higher area of seepage flow suppose this is kind of a you know inter base flow and excess irrigation water. So, when you apply a lot of irrigation water on top of the irrigated field. So, definitely that is going to cause an excess water or generally the natural runoff. And then sometimes you know I mean the lateral seepage which is taking place from one field to another field. So, these they may cause the surface water pounding or water logging or that requires you know surface drainage.

So, the design of surface drainage consists of two stages. So, I said first one is a hydrologic design and hydraulic design. So, hydrologic designs basically involves the quantification of excess water to be drained and the rate at which it is to be drained. So, these two things we need to determined in case of hydrologic design whereas, in hydraulic design the design involves calculating the drainage channel geometry and the drainage network layout. So, once the channel geometry is estimated based on the peak flow rate, so then we are going to decide which layout basically we need to use ok.

So, like parallel grid design or random designs all these things we already discussed in the previous lectures.

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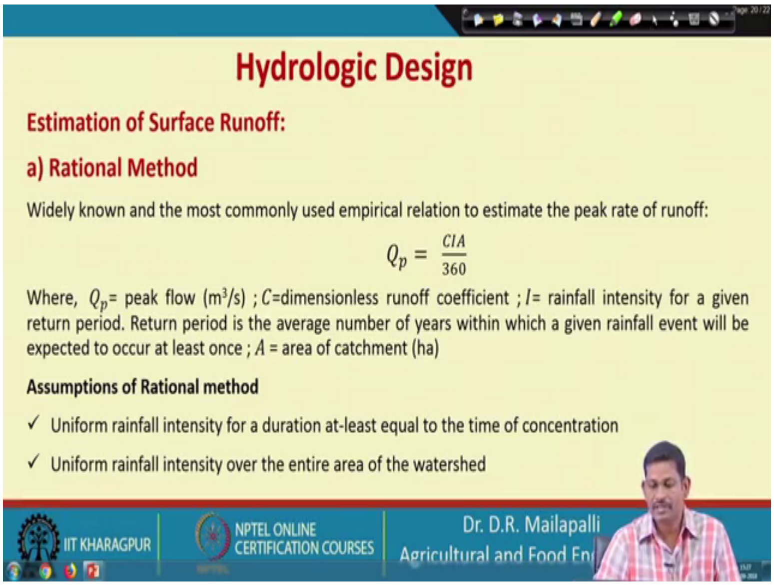

So, the next is hydrologic design; so in this the estimation of surface runoff. So, the most famous you know methodology used to estimate the surface runoff is Rational Method. So, this is mostly common and empirical relationship. So, if you see this is a (Refer Time: 03:27) Q p that is a peak runoff rate which is equal to CIA by 360. So, this is unit conversion in a way. So, where is Q p meter cube per second, C dimensionless runoff coefficient ok, and I is a rainfall intensity for a given return period. So, generally we consider it has a time of concentration as a return period and A is the area of catchment. So, that is hectares.

So, I mean combining everything you get the amount of you know runoff taking place from the particular area there is a peak runoff rate. So, there is a maximum or the peak and the maximum runoff rate you get from the area. So, basic assumptions in Rational Method or the uniform rainfall intensity for a duration at least equal to time of concentration. So, this is very important because this will lead to the time of concentration definitely will lead to the peak runoff rate and uniform. So, the rainfall should be uniform and also and the intensity though it should have uniform intensity throughout the area of watershed. So, the first thing is the uniform rainfall intensity of duration at least time of concentration. So, the second is the uniform rainfall intensity is throughout the watershed ok. So, these two basic assumptions we need to consider in case of a Rational Method.

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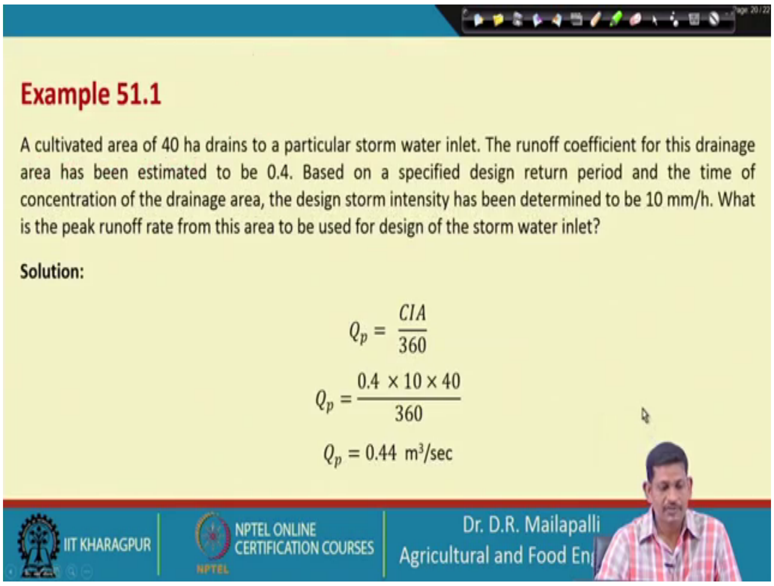

So next, here a straight example giving the values and finding out the Q p. So, let us see here the cultivated area so this is areas given right 40 hectares drains to a particular storm water inlet, the runoff coefficient for this drainage area has been estimated to be 0.4. So, this is see you got and then based on specified design return period and the time of concentration of the drainage area the design storm intensity has been determined to be; so 10 mm per hour. So, this is your I; so what is the peak runoff rate from this area to be used to design the storm water inlet? So, this is the equation Q p is equal to CIA and Q p 0.4 10 40 and 360. So, all values are given the substitute and you get finally, Q p is equal to 0.44 meter cube per second is the peak runoff rate we expect from the 40 hectare of land having a rainfall intensity of 10 mm per hour.

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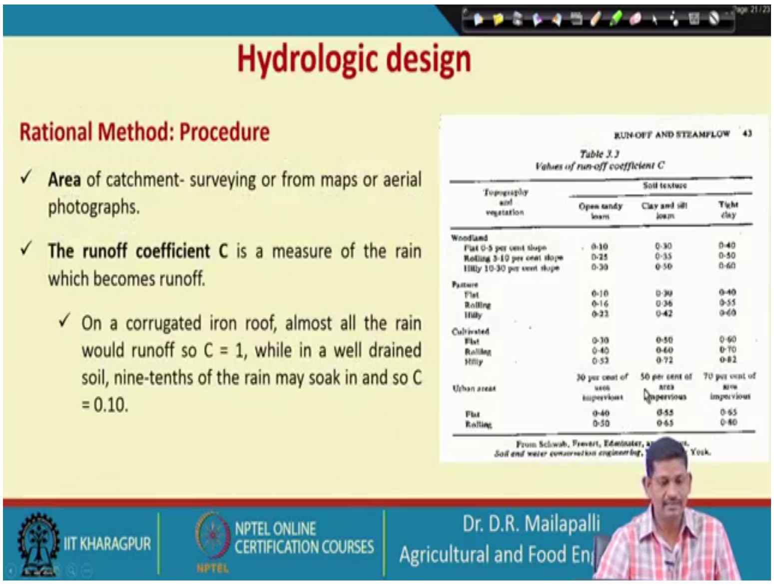

So, then the next is; so the procedure here the rational method procedure. So, the first thing is the area, area of catchment. So, this is basically determined by surveying or from maps of aerial photographs. So, the area of watershed will be determined based on the maps or surveying or aerial map or aerial photography. So, then the next parameter is the runoff coefficient that which is C. This is measure of a rain which becomes runoff. So, this runoff coefficient will give the part of rainfall would become the rain runoff.

So, in case of when C equal to 1 so that means, the runoff is completely rainfall is completely turned into runoff, whereas they if C equal to 0.1. So, that; that means, around 10 percent or you can say nine-tenths of the rain may soak in and so C equal to 0.1, right. So, point C equal to 0.1 that means 10 percentage of the whole rainfall will become runoff.

So, here there is a table you can use in order to find out the runoff coefficient to C. So, the table has the topography on column number one. So, this is a wood land pasture cultivated and urban area. So, they are different topography and vegetation on column number one and the soil texture on column two, three, four, ok. Column number two:

open sandy loam, column number three clay and silty loam and column number three tight clay; so based on these combinations like a particular topography and vegetation and the soil type. So, you can decide the runoff coefficient ok. So, runoff coefficient if you see for tight clay which results generally more runoff because less infiltration. So, the values are really increasing when you go from you know wood land to urban areas ok. So, similarly in case of sandy, so the runoff I mean the runoff coefficient is increasing. That means runoff is resulting higher in case of urban areas right and also the soils, if you see sand will have less runoff compared to silt and clay ok. So, that also you can clearly see here.

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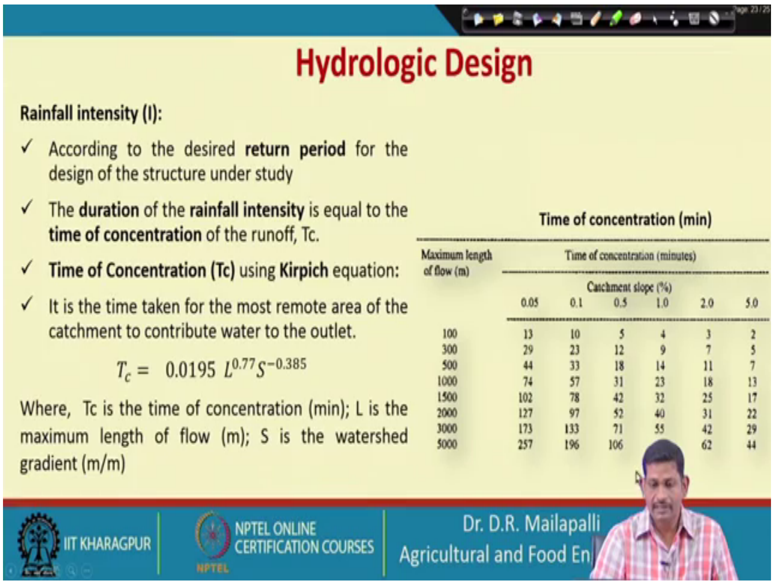

So, and the next is rainfall intensity. So, the third parameter rainfall intensity: so according to the desired return period for the design of the structure under this study. So, generally we are talking about the structure I mean we adopt the return period or the design procedure for designing a structure to soil conservation structures and similarly we use the rainfall intensity.

So, the duration of the rainfall intensity is equal to the time of concentration of the runoff or T c we call. So, here as I said in Rational Method; so the basic assumption is the duration should be at least time of concentration. So, here we know in our design we are going to assume the duration is equal to time of concentration. So, generally for estimating time of concentration, so this Kirpich equation which is equal to T c is a function of the; I mean the drainage length and then slope ok. So, this is the famous equation they remember it or so the same equation I mean you can translate it into a tabular form. So, here this is the maximum length of flow that is the L ok. This is L and then time of concentration this is the T c in minutes you get and catchment slope S. So, knowing L and S you get what you call these time of concentration values ok. So, either use equation or a table. So, both can work.

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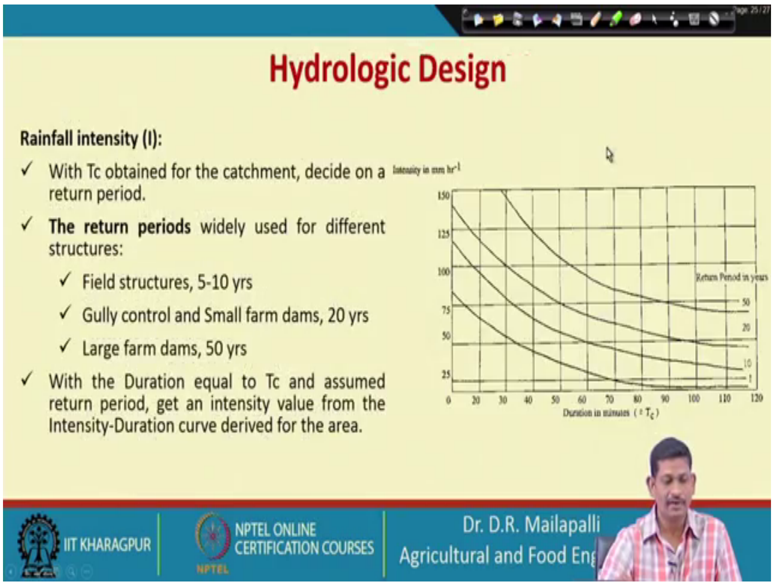

And then, how to find out the in rainfall intensities? Once you know the time of concentration right and how to find out the rainfall intensity?

If you see the, I mean the sorry if you see the table here I mean the picture here right at the graph. So, duration in minutes that is in T c because our assumption is the duration is equal to time of concentration ok; so then the rainfall intensity I in y axis and if you see this plot the curves so those gives a return period ok.

So, the return period so knowing the return period and duration there is a time of concentration we can find out intensity. So, T c we estimated previously I mean using previous equation of previous table. So, for a 60 let us say for 60 minutes and then 20 year return period so, I can expect a rainfall intensity is you know around 70 around 70 mm per hour all right. So, this way you can find out the rainfall intensity. So, generally here we use the return periods for field structures 5 to 10 years we use and gully control and small form dams 20 years and large form dams 50 years.

So, based on these thumb rules we can select a particular return period and for a particular time of concentration you can estimate intensity in mm per hour. So, knowing area intensity and runoff coefficient you can find out the peak discharge from the particular area.

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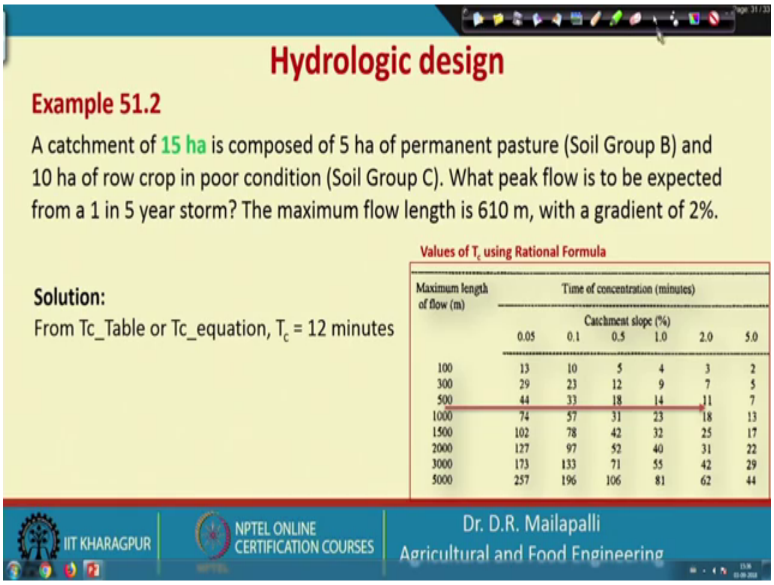

So, here the example two, so a catchment of 15 hectare is composed of 5 hectare of permanent pasture, the soil group of this pasture land is group B; and 10 hectare of row crop in poor condition, so that is soil group C ok. So, what peak flow is to be expected from 1 in 5 year storm right? The maximum flow length is 610 meter with a gradient of 2 percent. So, here the length is given right, the maximum flow length L is given and S is given ok. Either you can use directly the formula or from the table you can get.

So, for example, here 610; so that that may be here in between 500 and 1000 and the corresponding slope is 2 percent. So, here you get you know around T c will be 12 minutes. So, based on the interpolation method, if you use interpolation method you get around 12 minutes.

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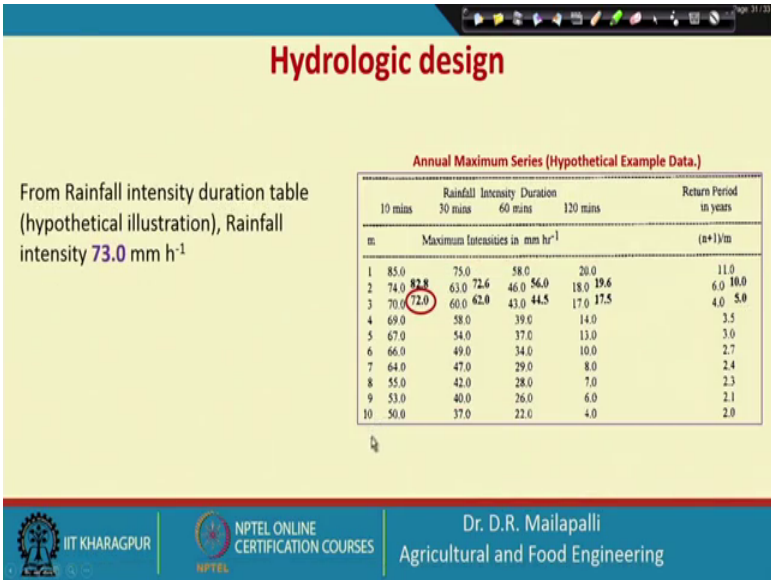

So, that is time of concentrations. So, one parameter is time of concentration is estimated. So, using time of concentration and then the 5 years storm that is a return period and you can estimate the rainfall intensity ok. So, let us see how we estimate rainfall intensity here? So this is the table, this is the return period right and then rainfall intensity and then so this will give, so rainfall intensity durations 10 minutes, 30 minutes, 60 minutes, 120 minutes ok. So, the maximum intensity you can get around 72 for 5 year return period ok. This is a 5 year return period and then you get T c around 12, right around 12 minutes.

So, for 12 minute and 5 you get 72 so or 72 or 73. So, this is also based on the interpolation. So, for this basically you need a 5 year return period and T c value using these 2 you can find out the 73 mm per hour is the rainfall intensity ok. So, from this you will be estimated I that is rainfall intensity.

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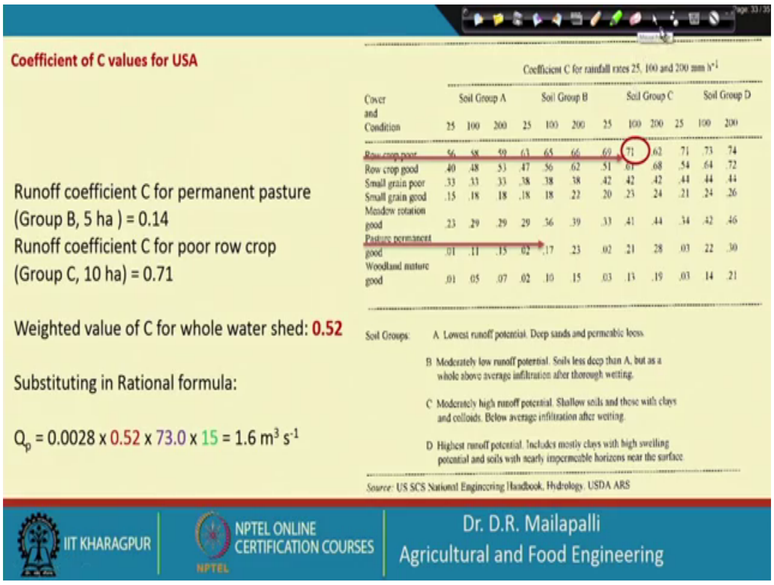

So, the next is, so, next is the runoff coefficient ok; so the runoff coefficient C for C. So, runoff coefficient C permanent pasture. There is another table right which is given by USDA or US USSCS us United States Soil Conservation Services.

So, in this coefficient of C for coefficient of C they gave the two in a soil groups, group number B and group number C. So, here in this table so, the first column number one gives the cover and condition of the land and then the soil group A, soil group B is cause soil group C, soil group D. So, ABCD so that is defined based on the infiltration capacity right and then if you see that so group number B, so the C for permanent pasture. So, look for permanent pasture this is here and the group B. So, this is a group B right and then here if you see the in the rainfall intensity rates.

So, that is around I think what do we get, we get 70. We got 73, right. So, we got 73 so that might be somewhere here and so that is corresponding value ok. So, this corresponding value for group B for 5 hectares, so that will be 0.14 after interpolation, here it is showing 0.17, but if you can interpolate that you get 0.14. Similarly, runoff coefficient C for poor let us say for poor row crop. So, this is the row crops poor and soil group C and here again 73 you know mm per hour and you get around 0.71.

So, then weighted C for whole watershed is 0.52. So, that is 5 hectares into 0.14 plus 10 hectares into 0.71 divided by 5 hectare plus 10 hectare. So, if you can do this math and you get 0.52 is a weighted C substituting rational formula. So, CIA then Q p is equal to so this is again unit conversion based on the units. So, the basically Q p is equal to CIA. So, that is a so based on the required units the meter cube per second and you need to multiply with the factor this ok. So, C A 0.52 I 73 15 is the total area and Q p is equal to 1.6 meter cube per second.

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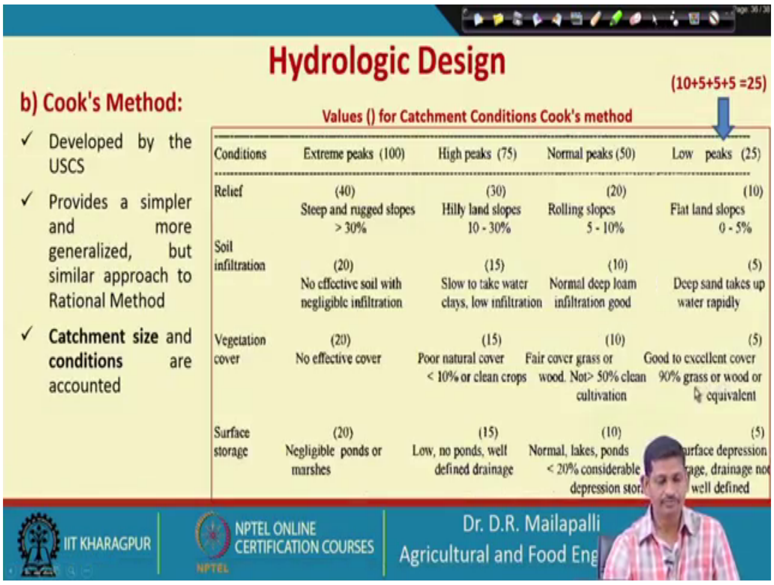

And Cook's Method: so the Cook's Method which is developed by USCS. So, this is United States Soil Conservation Service, USC SCS and it provides a simpler. So, this is a simpler than the Rational Method or you can also Cook's Method is a generalized Rational Method.

So, the basically it requires a catchment size and the condition. So, these two with these two thin things will be able to find out the peak discharge. So, here the table look at the table. So, take column number one, it is the conditions that is a relief, soil infiltration, vegetation cover, surface storage. So, these four are the conditions. And the extreme peaks; so the peaks are classified into four classes right, extreme peaks, high peaks, normal peaks, and low peaks.

So, based on the peak type so, what the magnitude of peak right; so, you have to these are the weights basically 40, 20, 20, 20. So, if you can sum up all these 40 percent 20 percent sorry 40, 20, 20, 20 is that gives 100. So, similarly high peaks case so hilly land slopes 10 to 30 percent will be 30 weight is and slow to take what take water clays and low infiltration 15. So, like that you get 75 normal peaks 50 and low peaks 25. So, 25 is 10 plus 5 plus 5 plus 5. So, that is about 25.

So, the maximum you get 25. So, this is called a Catchment Condition ok. So, Catchment Condition value so that is a 25 50 70 500 if anything is missing, so we can add accordingly ok.

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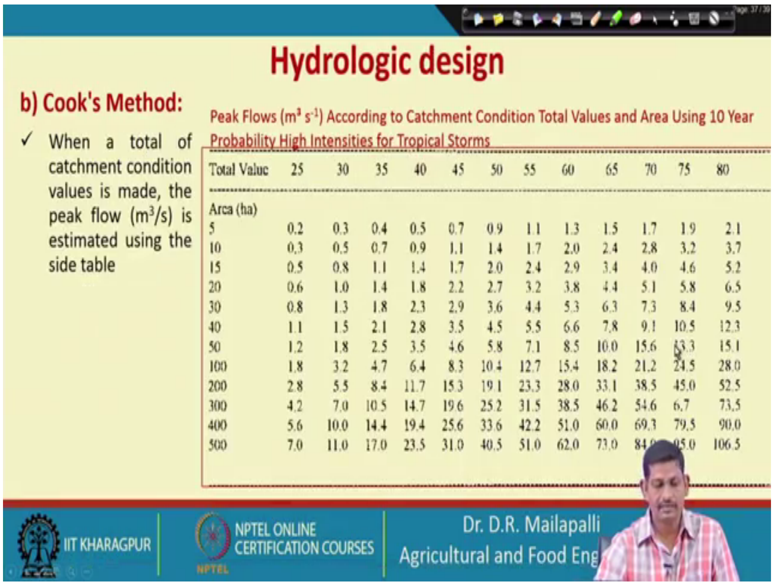

So, then the next is next step is, so once you know the Catchment Condition. So, knowing the area right sorry; so knowing the knowing the total value here this these are the total values and area. So, we can find out the peak flow rate in meter cube per second right. So, this is that tabular you know method. So, when a total of catchment condition value is given and peak flow meter cube per second is estimated using this table.

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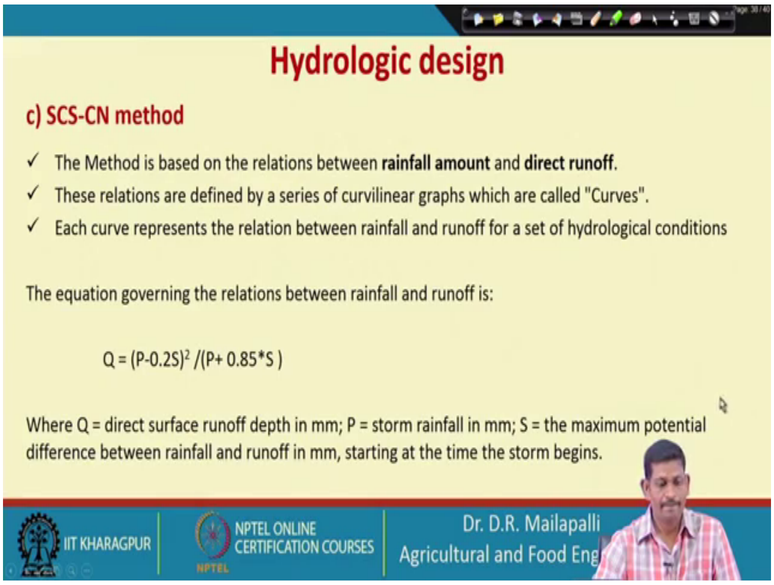

So, the next is SCS-CN method. So, that is a Soil Conservation Service Curve Number Method. So, the method is based on the relationship between rainfall amount and direct runoff.

So, the basically the relationships are defined in series of curvilinear graphs which are called as you know Curves. So, each curve represents the relationship between rainfall and runoff for set of hydrological conditions. So, hydrological conditions we have seen so, therefore, groups depend on the soil. So, soil group ABCD, so the soil group A is more porous and you get more infiltration compared to soil group OD. So, the equation governing the relationship between rainfall and runoff is Q is equal to P minus 0.2 S square divided by P plus 0.85 into S. Where Q is the direct surface runoff in depth units that is mm, P is a storm rainfall in depth units and S is the maximum potential difference between the rainfall and runoff in mm starting at the time of storm begins. So, when the storm begins? So, the soil water reservoir. So, soil reservoir which can accept the inflow in accept the infiltration you can say or all losses or abstractions ok, so that is S right. So, here we have to find out S. So, S is a function of curve number.

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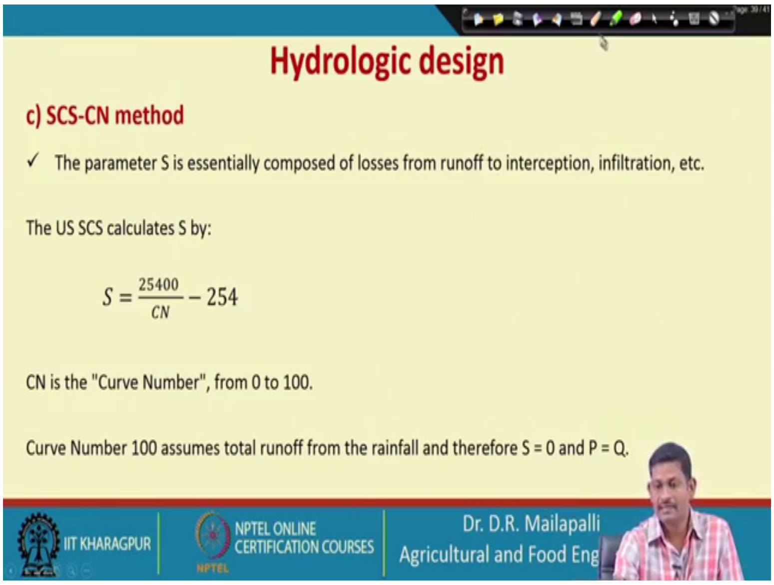

Now if you look at this. So, S which is so, the parameter S is essentially composed of losses from runoff to interception or infiltration etcetera. So, United States Soil Conservation Service calculated S by 25400 divided by CN by 2500 254 ok. So, this is the finding out S value where CN is the curve number. So, curve number generally varies from 0 to 100. So, if suppose curve number is 100, curve number is 100 write S is equal if you substitute 100. So, that will be; so S will be 0 so that means, no storage.

So, mostly the rainfall is being converted into runoff ok. So, 100 assumes total runoff rainfall, therefore S equals 0 and P is equal to Q. So, entire precipitation will be equal to your Q.

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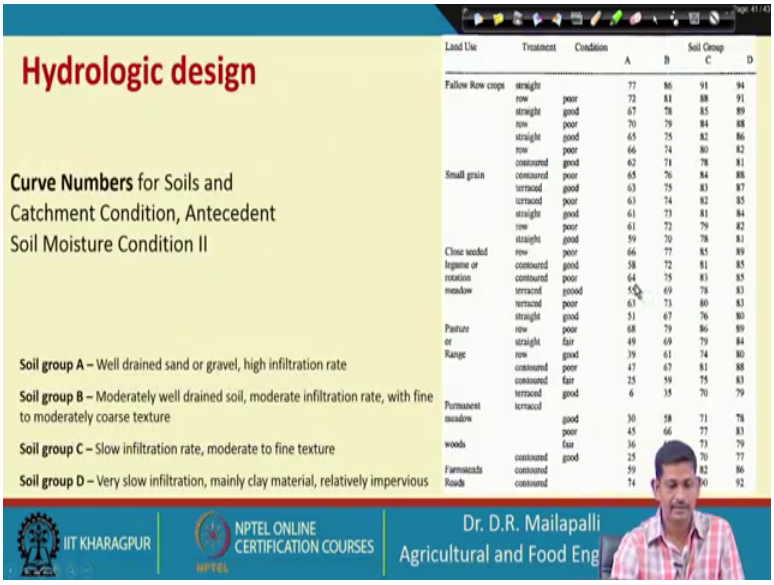

So, the next is Hydrologic design. So, curve numbers so, here this table clearly gives the curve numbers for different soil groups. Look at this so, curve number 1, land use. So, land use fallow row crops small grain ok. So, close seeded legumes pasture or range, permanent meadow woods. So, all these things and treatments are straight row crop or rows I mean these fallow row crops they are in rows are straight or maybe. So, then contoured terraced ok. So, all these treatments and then condition is poor condition, good condition, poor good, poor good and based on the soil group.

So, the curve number is been assigned 77 is the curve number in case of soil group A. So, soil group A is more infiltration ok. So, if you see the curve number D which has you know greater curve numbers, soil group D has greater curve number; that means, more infiltration is I mean its less infiltration and more runoff is possible in case of soil group D.

So, here there is soil groups are defined. So, well drained sand or gravel high infiltration rate this soil group A, soil group B moderately well drained soil moderate infiltration rate with fine moderately coarse texture. And group C slow infiltration rate moderate fine texture a group D very slow infiltration mainly clay material relatively impervious. So, that you get you know the curve numbers are close to 100. So, that the runoff the rain falling mostly converts into runoff and then let us see and ok.

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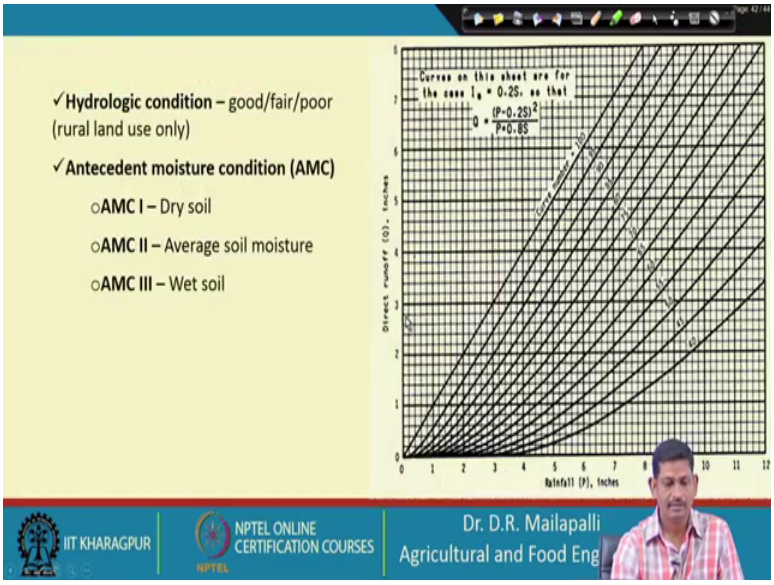

So, there is also table from where you can get the direct runoff. So, on x axis there is a rainfall knowing the rainfall and these lines are the curve numbers ok. So, curve number 100 and curve number 40 and y axis is a direct runoff. So, knowing the rainfall for example, 8 is the rainfall write on let us say on 65 curve number and then the corresponding runoff will be 4 inches here runoff will be 4 inches and here this is 8 inches.

So, out of 8 inches of rain 8 inches of rain; s 4 inch turns into direct runoff for a curve number of 65, so here antecedent moisture current. So, AMC dry soil AMC two average soil moisture AMC 3 wet soil. So, this based on so these curves will be adjusted based on the AMC values. So, general for wet soil because the soil condition. So, the AMC is very important Antecedent Moisture Content. So, if suppose the soil is initially wet.

So, it results more runoff right compared to your AMC 2 and AMC 1 ok. So, that is why here once we get the direct runoff from the particular curve number. So, based on the AMC it will be adjusted for particular AMC values.

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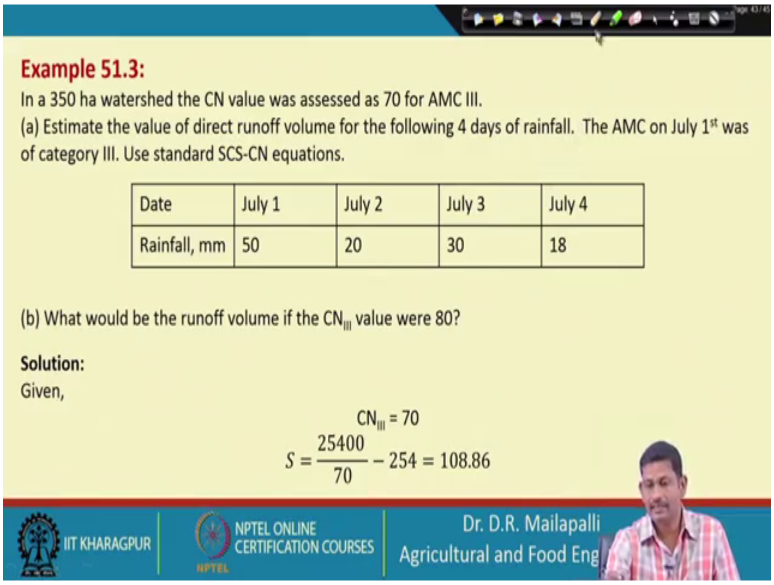

So, let us see an example here. So, this is an example. So, in a 300 hectare watershed the curve number values value was assessed as 70 for AMC III ok. AMC III that is a wet soil and estimate the value of direct runoff volume the following 4 days of rainfall, the AMC on July 1 was of category 3 use standard SCS-CN equations.

So, the data given here is date and rainfall July 1, 2, 3, 4 and the corresponding rainfall for an mm and what would be the runoff volume: if CN the category three value were 80; so, here CN 70. So, what is the rainfall volume and CN 80? What is the rainfall volume for the antecedent moisture content thought ok? So, three category.; so here given CN values given 70. So, knowing the CN value find out S using the 25500 or 400 divided by 70 minus 254 will give 108.86 as yes ok. So, the next is once you knowing the S you can find out Q value by using the formula, Q is equal P minus 0.2 S square by P plus 0.8 S.

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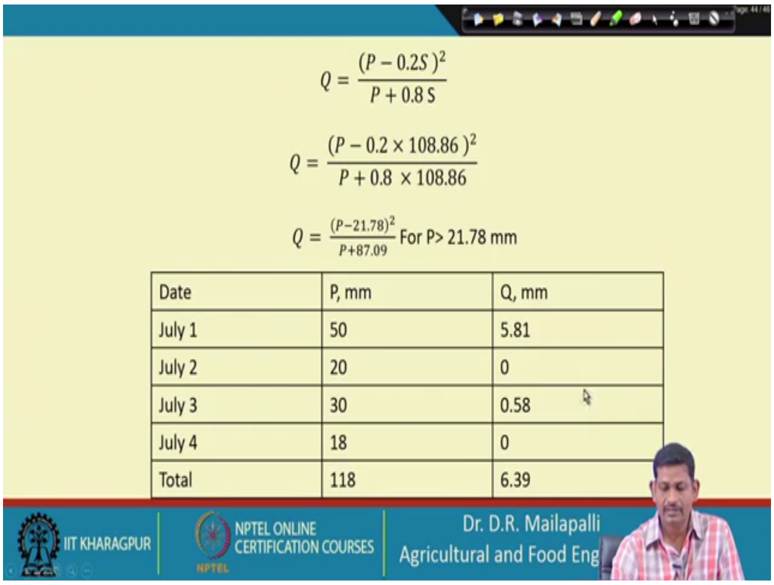

So, then find out here if you see: so I finally, you get equation like this and on numerator P minus you know 21.78 right which is square. So, here P should be at least 21.78. So, that you get Q value, otherwise now Q will be 0. So, that is why P should be 21.78 and if you can recall the precipitations July 1, 2, 3, 4. So, 15 20 30 18 and so the Q will be. So, apply P here right only for 21.0, I mean P is greater than 21.7.

So, not for this right not for this, so and if you apply if you substitute P value here you get Q is equal to 5.81. And similarly 0.58 and the total will be 6.39 is the total runoff from that particular area and corresponding to your curve number correspond to the given curve number and then the next. So, there is the volume. So, the runoff volume over the catchment V r is equal to. So, this is the area into the runoff depth. So, that will be giving the 22365 meter cube.

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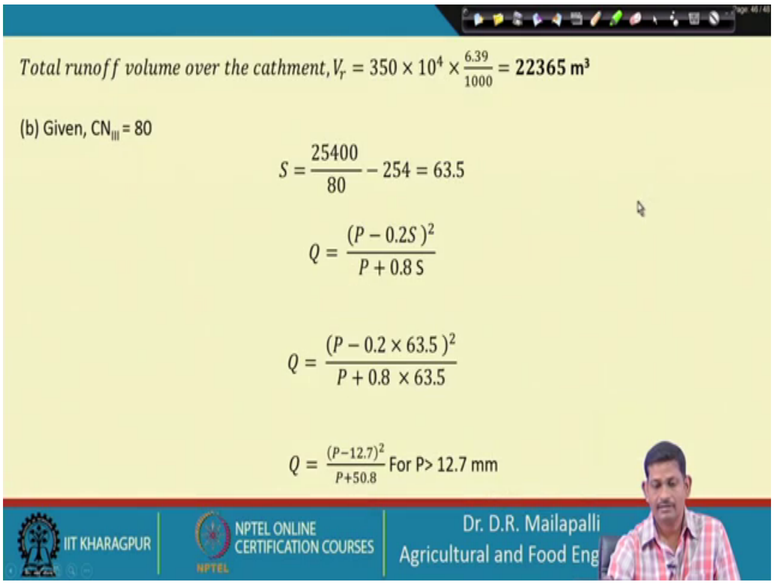

So, similarly for 80 right: so given curve number so find out S. So, that is 63.5, now substitute this 63.5 in this equation. So, now this is the equation. So, now, the Q value I mean P value should be at least 12.7. So now, from the table again we now bring the table and see and find out the.

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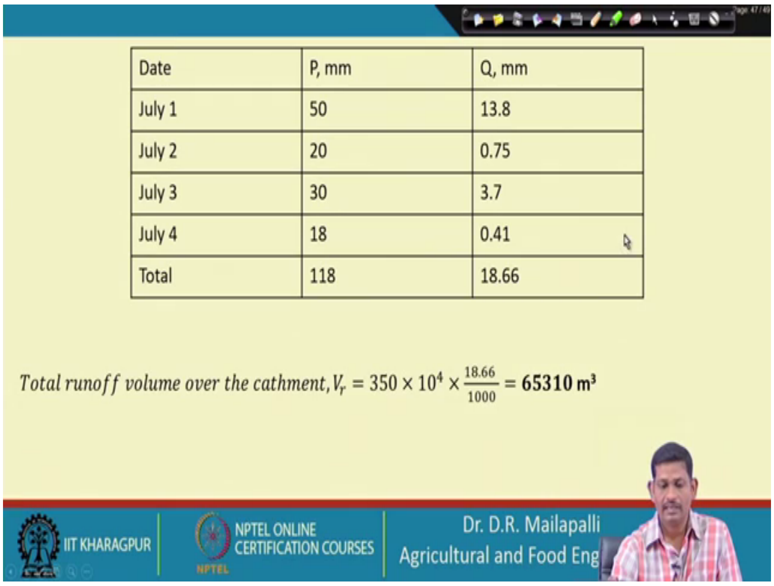

So, we now all precipitation values are going to result runoff in this case ok. So, now, you see 50 substitute P in that previous equation you get 13.8 and 20 which is 12 more than 12 point and 18 also more than 12 point. So, here the total runoff depth would be

18.66 and the total runoff over catchment V r is equal to 350 is the area cross area and then. So, this is the depth and you get 65310-meter cube is the runoff volume. So, for increasing curve numbers runoff volume is increasing look at this.

So, this is all lecture about hydrologic design of surface drainage system. In the next lecture we are going to talk about the hydraulic design of surface drainage system, ok.

Thank you.