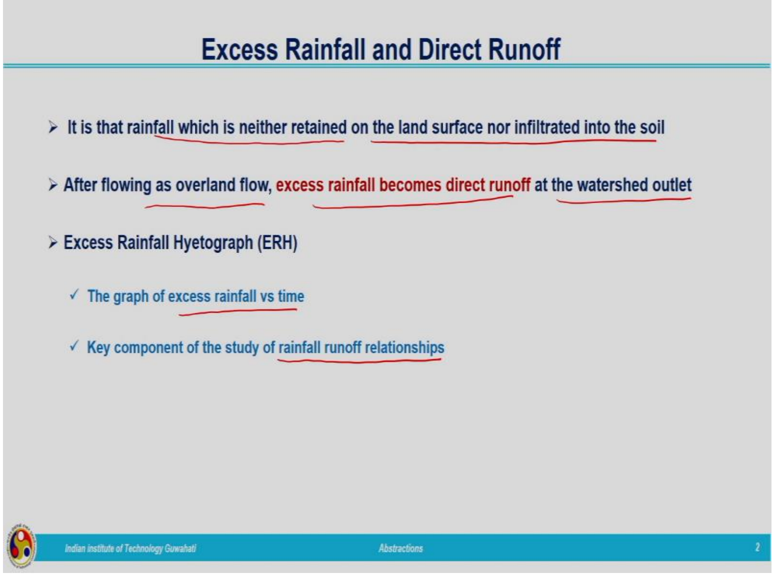
Engineering Hydrology
Professor Doctor Sreeja Pekkat
Department of Civil Engineering
Indian Institute of Technology, Guwahati
Module 4 - Lecture 44
Excess Rainfall and Direct Runoff

Hello all, welcome back. In the previous lecture, we have started with Module 4 that is related to surface water. We have discussed about what happens when a storm is occurring. We have found whenever there is a rainfall, in the beginning all the storage components will be satisfied, after that the runoff will be starting.

Today we are going to discuss about excess rainfall and direct runoff, that is whenever we are having the storm or rainfall, after satisfying the storage components whatever remaining from the total rainfall that is the excess rainfall, that is contributing to the direct runoff. So, let us see how it can be determined and what are the different methods utilized for finding out the initial abstractions or total abstractions.

(Refer Slide Time: 01:41)

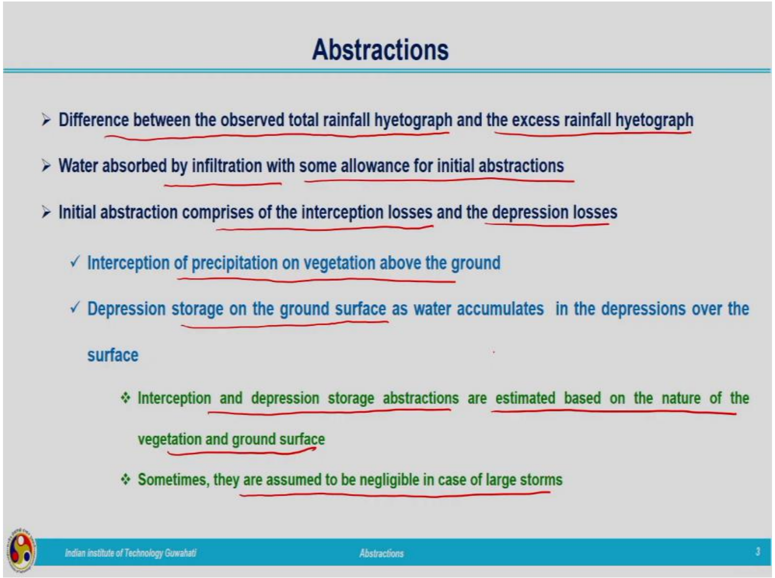


So, excess rainfall and direct runoff. When we talk about excess rainfall, it is that rainfall which is neither retained on the land nor infiltrated into the ground. So, we can understand that whenever there is a rainfall, some amount of water will be utilized for satisfying initial abstractions that is the interception storage, depression storage. After that the infiltration will be starting and once the soil layer at the top becomes almost in a saturated level, even though infiltration is continuing or the rainfall intensity is more than that of the rate of infiltration water starts accumulating on the ground surface and then starts the direct runoff and initially, it will be flowing as overland flow and excess rainfall becomes direct runoff after that at the watershed outlet. So, when there is an excess rainfall initially it starts ponding and once it is free from the retention forces, it starts flowing as overland flow and then it will be concentrating into channel flow small-small channels will be formulated and finally, it will be reaching at the outlet point.

Now, what is meant by excess rainfall hyetograph? This is the graph which is showing the excess rainfall versus time. We have seen what is meant by hyetograph. Hyetograph is the representation of rainfall intensity versus time. In the similar way, this is also a representation of rainfall but here we are not representing the total rainfall, we are representing the excess rainfall that is the rainfall which is obtained after deducting the storage components or initial losses.

So, that rainfall intensity is plotted against time that is the excess rainfall hyetograph This is very important when we do study related to rainfall runoff relationship because whenever there is a hydrologic study, we are in need of these rainfall runoff relationship or out of the total rainfall how much water is lost initially and after that what is remaining that is contributing as runoff.

(Refer Slide Time: 04:17)



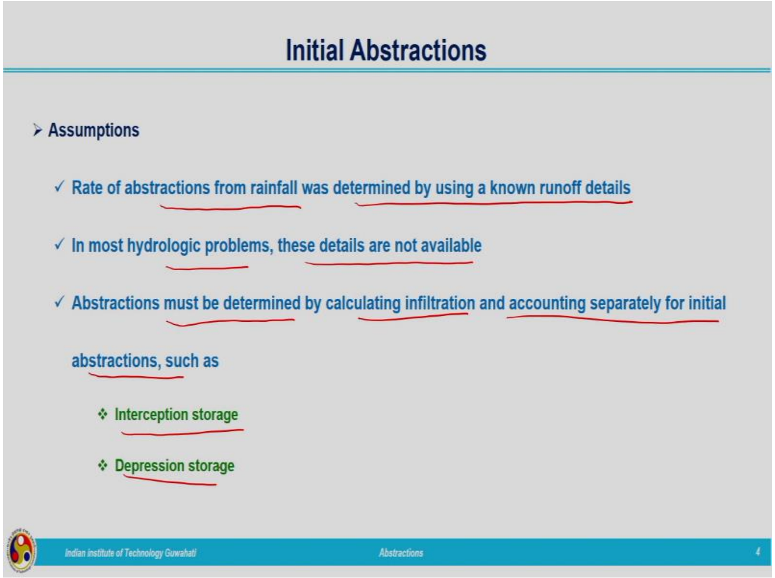
Now, we will look into abstractions. Abstractions is a general term which is used for representing the losses taken place from the rainfall which is occurred on the ground. So, the abstractions we can define as the difference between the observed total rainfall hyetograph and the excess rainfall hyetograph.

When we were defining excess rainfall hyetograph, I have mentioned that excess rainfall hyetograph can be obtained after deducting the water which is lost to satisfy the storage components and also water which is lost as infiltration. Abstractions we are defining as the difference between the total rainfall hyetograph and the excess rainfall hyetograph, that is it is representing the water which is retained and also which is infiltrated into the ground.

Water absorbed by infiltration with some allowance for initial abstractions. Initial abstraction comprises of the interception storage and the depression storage. So, whenever rainfall is occurring initially some amount of water will be stored on the plant leaves and vegetation. This is termed as the interception storage and sometimes on the ground surface we will be having so many depressions. So, water will be stored in the depression storages and after satisfying that storage, then only it will be contributing as direct runoff.

So, initial abstractions are considered as the interception storage and the depression storage. Interception of precipitation on vegetation and also water storage in the depressions which are present on the ground surface. These together that is the interception of precipitation on the vegetation and the water which is stored on the surface depression together termed as initial abstractions. So, interception and depression storage abstractions are estimated based on the nature of the vegetation and ground surface. Sometimes during heavy storms, we may not consider these initial abstractions which includes the interception storage and the depression storage that is in comparison with the intensity of large storm, this interception storage values will be very less in such cases we will be neglecting that.

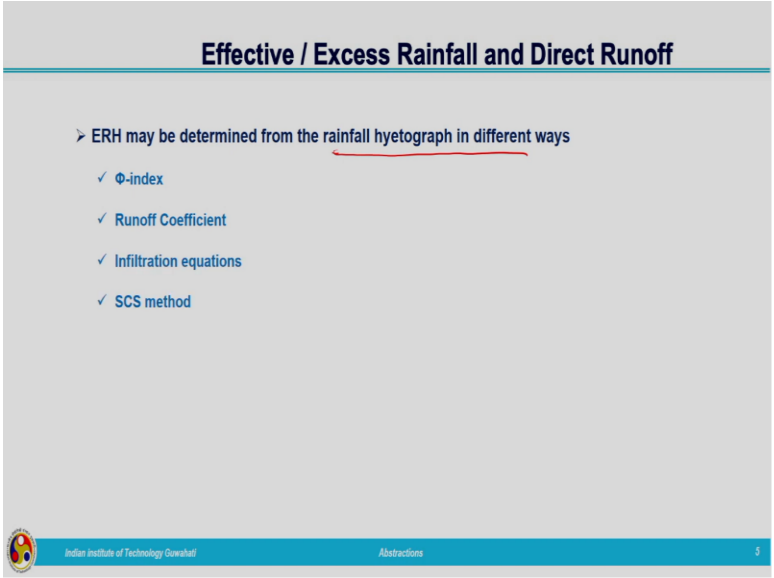
(Refer Slide Time: 06:54)



Now, coming to the assumptions. The rate of abstractions from rainfall was determined by using known runoff details, that is if we want to determine how much quantity of water is lost as abstractions that is directly if we are detecting the runoff depth from the rainfall depth that much water is lost as abstractions. So, for that the disadvantage is that we need to have the idea about the runoff depth, how much runoff has taken place in the catchment that need to be quantified then only we can calculate the abstractions. So, the assumptions in this case is that the rate of abstraction from the rainfall we can obtain based on the runoff depth. But in most of the hydrologic problems or most of the studies related to watersheds, these details related to runoff will be lacking. We will not be having the runoff details corresponding to a particular watershed. If runoff depth is available, we can calculate the abstractions. So, the abstractions must be determined by calculating infiltration and accounting separately for initial abstraction.

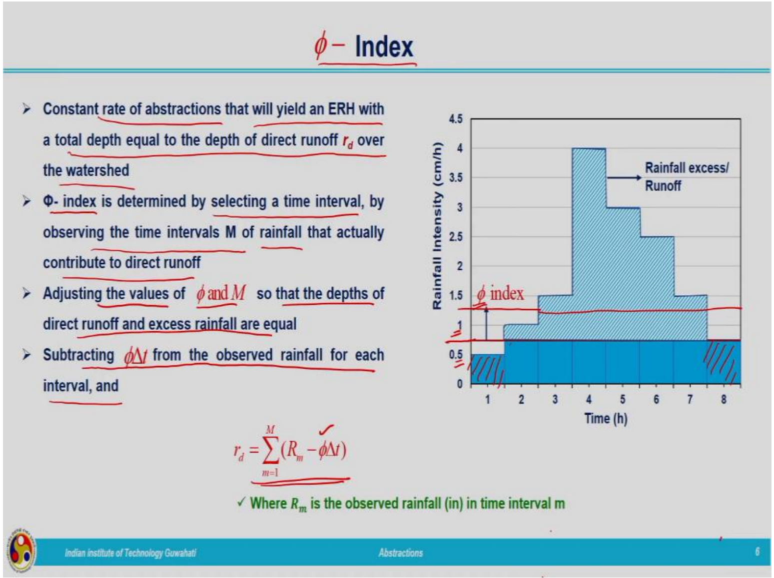
In the catchments in which we are not having the runoff details, how do we quantify these abstractions? So, these abstractions can be quantified by calculating the infiltration and also by quantifying the initial abstractions which include the interception storage and the depression storage that is initial abstraction include the interception and depression.

(Refer Slide Time: 08:33)



Now, let us move on to the determination of effective rainfall hyetograph. There are different methods for the determination of effective rainfall hyetograph from the rainfall hyetograph. They are phi index, runoff coefficient, infiltration equations and also SCS method. So, here we are going to see different methods which can be utilized for the determination of effective rainfall hyetograph. So, definitely we need to quantify the abstractions initially then after deducting those abstractions from the rainfall hyetograph we will get the ERH.

(Refer Slide Time: 09:13)



So, first one is the $\phi-index$. $\phi-index$ is a certain value corresponding to a constant rate of abstraction. So, this index will be representing the abstractions which are taking place in a catchment, that we will be deducting from the total rainfall and after detecting the values which we are getting will be representing the effective rainfall hyetograph.

So, $\phi-index$ is the constant rate of abstraction that will yield an ERH with a total depth equal to the depth of direct runoff over the watershed. Depth of direct runoff is represented by the notation r_d and what we are assuming that it is the abstractions from the catchment is having a constant value and this constant value of abstraction will be deducted from the rainfall depth, so that what is represented by effective rainfall hyetograph will be equal to the runoff depth from the catchment. So, how to determine $\phi-index$? So, definitely we need the value corresponding to r_d or the runoff depth.

So, this is the rainfall hyetograph that is the representation of rainfall intensity versus time and from this what we will be doing, we will be finding out the constant rate of abstractions that is represented by $\phi-index$. So, once we deduct this $\phi-index$ value, $\phi-index$ value multiplied by the corresponding time intervals will be giving us the runoff depth. So, here we are having the rainfall hyetograph and $\phi-index$, after deducting that much of abstractions from the total rainfall whatever remaining these ordinates are representing the excess rainfall hyetograph.

So, remaining rainfall is the excess rainfall hyetograph which is contributing a runoff equivalent to a depth of r_d. So, this is the rainfall excess or runoff depth that is we are assuming whatever rainfall excess is coming that is equivalent to the runoff depth. So, how to determine this $\phi - index$? That is the next question. So, for this we need to have the idea about the runoff depth. So, this method can be applicable to the catchments where we are having proper measurement of runoff. So, $\phi - index$ is determined by selecting a time interval, by observing the time interval of rainfall that actually contribute to direct runoff. This is done by a trial and error method. What we will be doing, we will assume a certain value for this $\phi - index$ and we will understand in which time interval it will be contributing that much rate of rainfall will be coming. Based on that we can understand that whatever coming above this constant rate value will be contributing as runoff depth and below can be detected as the abstractions but initially we do not have the idea about the $\phi - index$ value.

So, what we will be doing? We will make an assumption. You can look into the figure that is here we have considered a $\phi - index$ value between 0.5 and 1 centimetres per hour. This is an initial guess it can be between 1 and 1.5 also. After this assumption we know the rainfall corresponding to first hour, that is this first bar and also corresponding to eighth hour is below this value and also corresponding to the time intervals 2, 3, 4, 5, 6 and 7 up to this value that is this much value it is considered as abstraction. So, whatever coming about that will be contributing to direct runoff. So, that we will be calculating and checking with the runoff depth whether these two are matching then our initial guess is correct and if it is not matching, we have to change this initial assumption of this $\phi - index$, we have to go for a second value and it may be coming in this range. So, the ordinate in which it is contributing that is the value is corresponding 1 and 1.5. So, below this whatever coming will be going as the abstraction and above whatever is there that will be contributing towards the effective rainfall hyetograph.

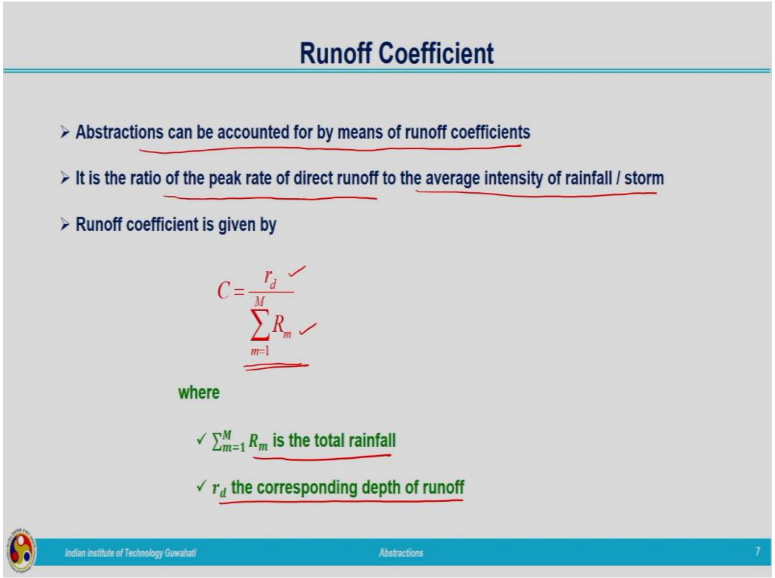
So, that way we will be continuing the process until we get a runoff depth or excess rainfall depth equivalent to the runoff depth measured at the outlet. So, this method is applicable only if we are having the measured runoff depth. So, by adjusting the values of ϕ and *M*, so, that the depths of direct runoff and excess rainfall are equal, we can finalize the value corresponding to $\phi - index$. After getting the $\phi - index$, what we will do, we will be subtracting $\phi \Delta t$ from the observed rainfall for each interval. ϕ is in centimetres per hour that is it is having the unit of intensity, so, that $\phi\Delta t$ will be subtracted from the corresponding rainfall depth. That will be giving us the runoff depth. That runoff will be compared with the runoff which is observed at the outlet of the basin.

So, r_d is given by

$$r_d = \sum_{m=1}^{M} (R_m - \phi\Delta t)$$

So, initial determination of this phi requires the value corresponding to runoff depth, that is we will be finding out the excess rainfall that should be equal to the runoff depth measured at the outlet point based on that will be determining the $\phi - index$ value. Later on, for the same catchment even though the runoff depth is not available by making use of this $\phi - index$ value which is predetermined already can be utilized for finding out the excess rainfall depth and in this R_m is the observed rainfall in that particular interval.

(Refer Slide Time: 16:02)



Now, we will move on to runoff coefficient. So, in this what we are doing, abstractions are accounted for by means of runoff coefficients. Certain runoff coefficients are developed for a watershed and that value will be corresponding to the abstractions in a watershed. It is the ratio of the peak rate of direct runoff to the average intensity of rainfall, that is we are having the rainfall value and corresponding to that we can calculate the average intensity of rainfall and also, we should have the estimate of the runoff depth that is runoff coefficient is the ratio of the peak rate of direct runoff to the average intensity of rainfall.

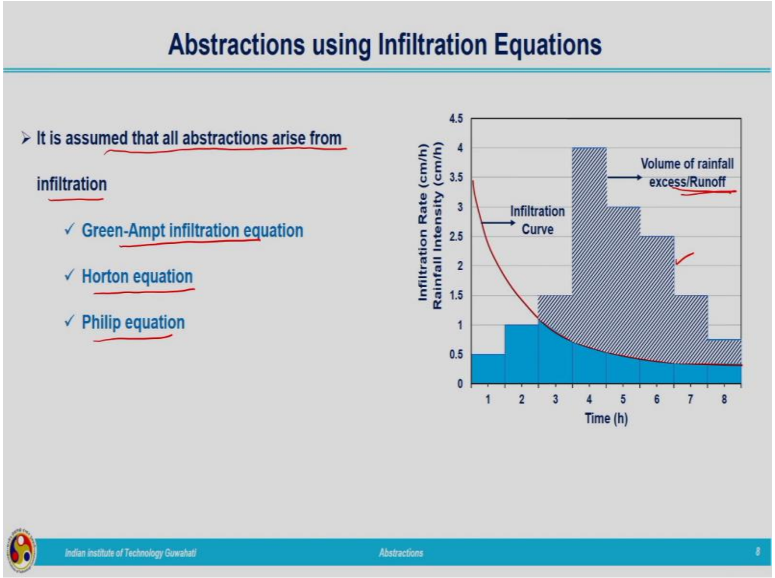
So, runoff coefficient is given by the formula C is equal to

$$C = \frac{r_d}{\sum_{m=1}^{M} R_m}$$

Denominator is representing the average intensity of rainfall and the numerator is representing the peak rate of runoff. So, in this $\sum_{m=1}^{M} R_m$ is the total rainfall and r_d is the corresponding depth of runoff. In this particular formula, we need to have the runoff depth and also the total rainfall value. Based on that we will be determining the runoff coefficient.

So, if the runoff coefficient is available to us, we can calculate how much will be the runoff depth that is by multiplying the C value with the intensity of rainfall and also the area corresponding to a particular watershed, we will get the runoff volume at the outlet of the basin. That is in these two methods, runoff coefficient and also in the case of $\phi - index$, we need to have a value corresponding to runoff depth, we need to have the observations related to runoff depth. If it is not available to us we cannot calculate these values. $\phi - index$ value and also runoff coefficient cannot be determined if we are not having the runoff depth. So, in such cases what we can do?

(Refer Slide Time: 18:47)



It is assumed that all the abstractions are coming from infiltration. We are not separately accounting for initial abstractions such as the interception storage and depression storage, we will consider that all the abstractions are due to infiltration. So, after that what we will do, we will be making use of the different infiltration equation which we have studied under the topic of subsurface hydrology. By making use of any of those equations, we can calculate the infiltration rate. So, by subtracting the total infiltrated water from the total rainfall value, we will get the corresponding excess rainfall which is occurring in that particular area. So, that is a representative value corresponding to the runoff depth. That is what is the assumption behind this method, that is all the abstractions which is taking place in a watershed or an area can be assumed by means of infiltration equations or can be quantified by means of infiltration equations.

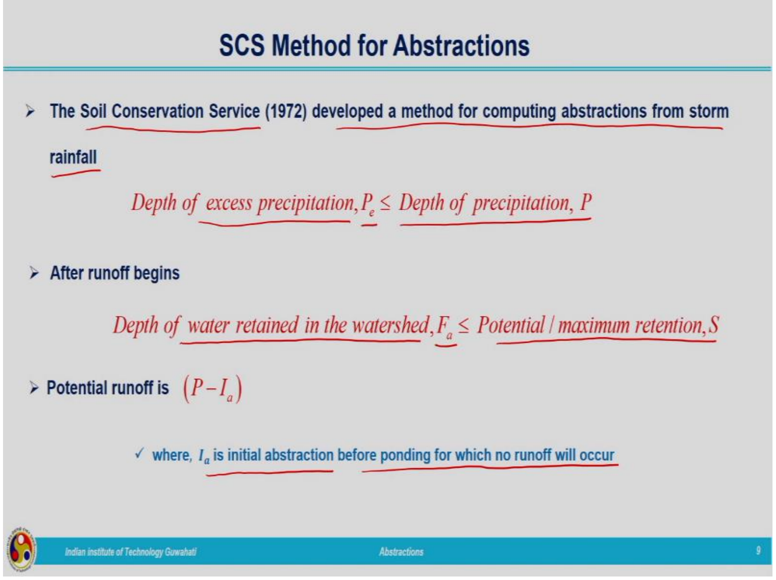
So, different equations which we can utilize our Green-Ampt infiltration equation, Horton's equation and Phillip’s equation. So, how this is utilized for calculating the abstractions? Let us start with the hyetograph. This is a rainfall hyetograph and we can plot the infiltration rate curve by making use of any of these equations and corresponding values which are required for the calculation of infiltration by means of this equation, we can plot the infiltration rate curve.

So, infiltration rate curve will be approximately looking like this. Initially it will be having very high value then it will be reducing and finally it will be attaining a steady state value. What we will be doing? we will be superimposing the infiltration rate curve on the rainfall hyetograph and whatever rainfall is coming below these infiltration curves that will be considered as the abstraction. All the abstractions are assumed to be due to infiltration only. After that from the rainfall value, total rainfall value we will be deducting these abstractions to get the direct runoff.

So, once we determine the infiltration rate curve, we will be deducting that amount from the total rainfall and the volume of excess rainfall or runoff will be represented by this shaded portion. So, this method can be utilized in the case of ungauged catchments where we do not have the value corresponding to runoff depth for the determination of $\phi - index$ and also for the determination of runoff coefficient.

Now, next method is SCS method for abstractions. This is a very commonly used method for the determination of abstractions or we can tell that for the determination of direct runoff depth. Abstractions once determined that can be deducted from the total rainfall we will get the excess rainfall that is equivalent to the runoff depth. So, this is a method which is used for agricultural watersheds. This method is actually developed for agricultural watersheds.

(Refer Slide Time: 22:25)



SCS means full form of SCS is Soil Conservation Service. Soil Conservation Service developed a method for computing abstractions from storm rainfall. This is developed in US and from the watersheds which they have considered mainly for the agricultural watersheds for helping the farmers and also giving idea about the runoff value to the agricultural requirements this method has been developed.

So, in this the depth of excess precipitation represented by means of the notation P_e and total precipitation by means of capital P. So, in this the assumption made is that the

$$\text{Depth of excess precipitation}, P_e \leq \text{Depth of precipitation}, P$$

and after runoff begins

$$\text{Depth of water retained in the watershed}, F_a \leq \text{Potential / maximum retention}, S$$

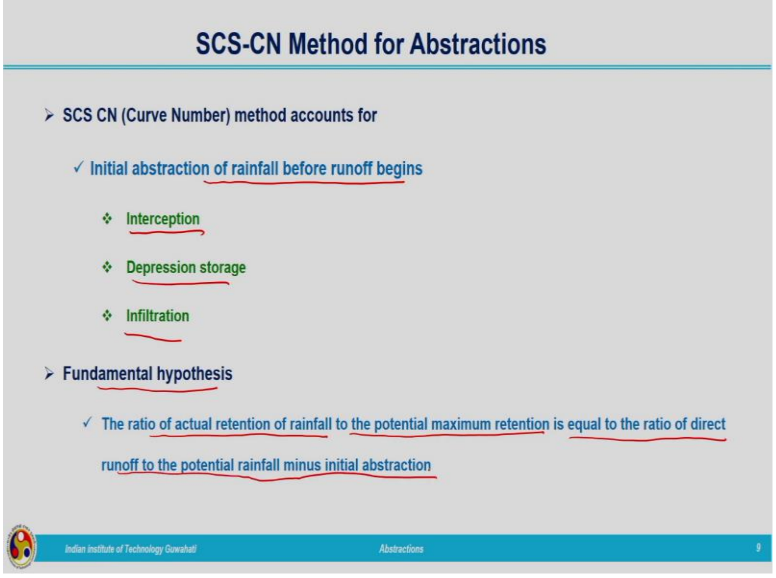
Where depth of water retained in the watershed represented by F_a and maximum retention represented by S.

So, here in this case, what is assumed is that depth of excess precipitation will be less than that of total precipitation. That we already know if some abstractions are taking place from the rainfall so that is represented by the depth of excess precipitation that is ERH, effective rainfall hyetograph. So, that will be definitely lesser than that of the total rainfall.

The second assumption is that depth of water retained in the watershed is less than that of the potential or maximum retention. So, the depth of water retained in the watershed is represented by the notation F_a and the maximum or the potential retention is represented by the letter capital S, that is nothing but the storage of the catchment. So, here four different notations are the P_e is corresponding to excess rainfall, capital P is corresponding to total rainfall and F_a is representing the depth of water retained in the watershed and S is representing the potential retention.

Potential runoff or the maximum runoff can be written as $P - I_a$. Maximum runoff is the difference between the total rainfall and the potential retention and I_a is the initial abstraction before ponding for which no runoff will occur, that is, once the storage components are satisfied, then ponding will be starting after ponding runoff will be starting, overland flow will be starting. So, I_a is the amount of water which is represented by the initial abstraction before the ponding started. This method is also termed as a SCS-CN method SCS curve number method for initial abstractions. So, here in this case a dimensionless number is proposed as curve number, we will discuss about it later.

(Refer Slide Time: 25:48)

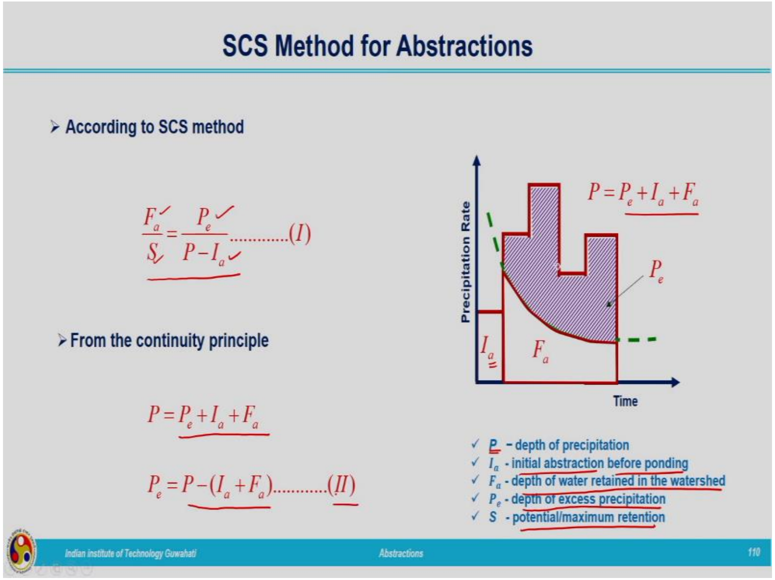


So, let us see in a SCS curve number method, initial abstractions of rainfall before runoff begins is accounted for and those initial abstractions include the interception storage and the depression storage and also it includes the infiltration. So, whenever we are talking about the abstractions in the case of SCS method, it is inclusive of the initial abstraction such as the interception storage and depression storage and also the infiltration.

Fundamental hypothesis related to SCS curve number method is the ratio of actual retention of rainfall to the potential maximum retention is equal to the ratio of direct runoff to the potential rainfall minus initial abstraction. The main hypothesis behind Soil Conservation

Service curve number technique is that the ratio of the actual retention to the potential retention is equal to the ratio of actual runoff to the potential runoff.

(Refer Slide Time: 27:01)



So, we can consider the hyetograph like this and in this our precipitation rate is plotted against time and P is the depth of precipitation and we are plotting the infiltration curve and out of that I_a is representing initial abstraction before ponding and remaining portion which is coming below the curve is considered as F_a. F_a is the depth of water retained in the watershed. And once we deduct these two I_a plus F_a from the total precipitation P we will get the excess precipitation represented by P_e. P_e is the depth of excess precipitation.

So, the abstractions which are considered here in this case are inclusive of I_a and F_a, initial abstractions and the abstractions coming from the infiltration together. So, P can be written as the sum of P_e plus I_a plus F_a and according to SCS method, that is the hypothesis which we have seen in the previous slide, it can be mathematically written as

$$\frac{F_a}{S} = \frac{P_e}{P - I_a} ....(I)$$

i.e., the ratio of actual retention to the potential retention is equal to the ratio of the actual runoff to the potential runoff.

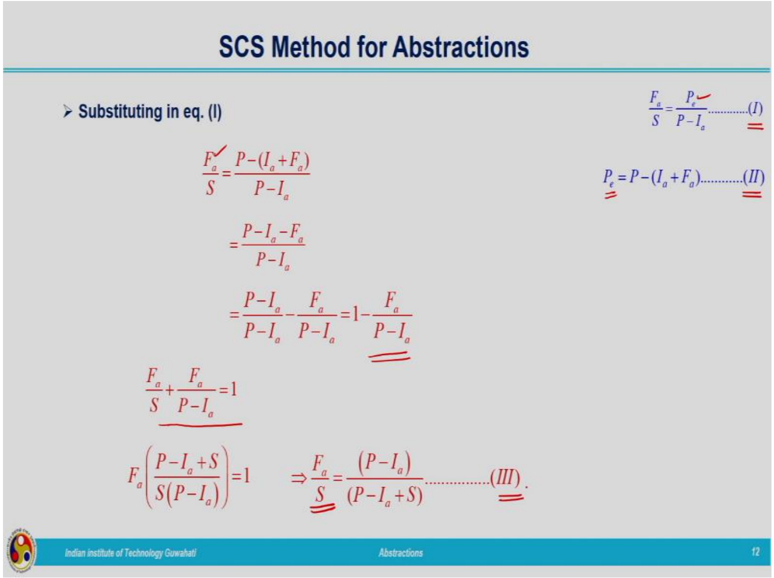
So, S is the potential or maximum retention. Now, based on continuity equation we can write

$$P = P_e + I_a + F_a$$

So, from this we can write

$$P_e = P - (I_a + F_a)............(II)$$

(Refer Slide Time: 28:59)



And this is the equation based on the SCS hypothesis and this is based on the continuity principle. Now, what we will do we will substitute this P in the equation one. So,

$$\frac{F_a}{S} = \frac{P - (I_a + F_a)}{P - I_a}$$

From this we will find out the value corresponding to F_a. For that we are readjusting the terms so, it will be

$$\frac{F_a}{S} = \frac{P - I_a - F_a}{P - I_a}$$

After certain readjustment, we will get the expression as

$$\frac{F_a}{S} = \frac{P - I_a}{P - I_a} - \frac{F_a}{P - I_a} = 1 - \frac{F_a}{P - I_a}$$

$$\frac{F_a}{S} + \frac{F_a}{P - I_a} = 1$$

From this we can take out the value corresponding to F_a.

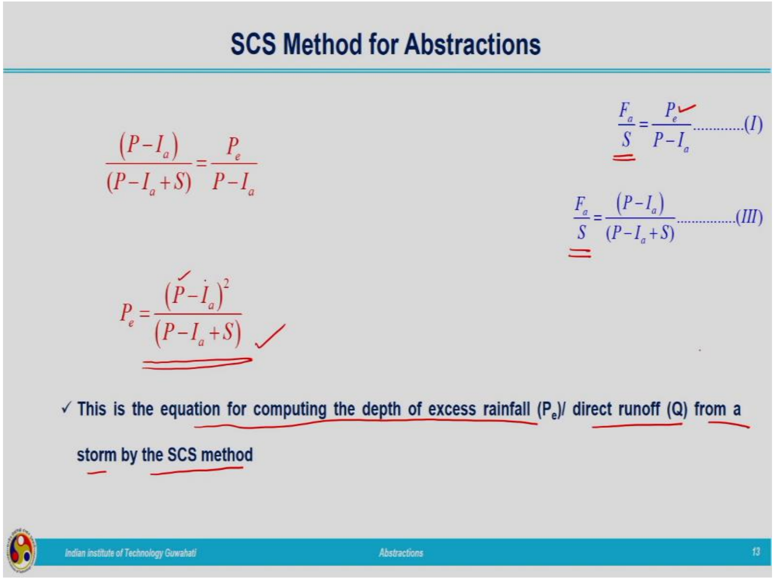
$$F_a\left(\frac{P - I_a + S}{S(P - I_a)}\right) = 1$$

So, from this we can get the ratio i.e.,

$$\frac{F_a}{S} = \frac{(P - I_a)}{(P - I_a + S)} ....(III)$$

So, from this equation by making use of the continuity principle, we have found out an expression corresponding to the ratio F_a divided by S that is the ratio of the actual retention to the potential retention. So, let that equation be equation number three.

(Refer Slide Time: 30:41)



So, we are having two equation. One is based on the hypothesis that is $\frac{F_a}{S} = \frac{P_e}{P - I_a}$ and second one $\frac{F_a}{S} = \frac{(P - I_a)}{(P - I_a + S)}$, which we have derived in the previous slide. So, what we will do in both equation 1 and 3 on the left-hand side we are having $\frac{F_a}{S}$. So, we can equate the right-hand sides for getting the value corresponding to P_e that is the excess rainfall.

So,

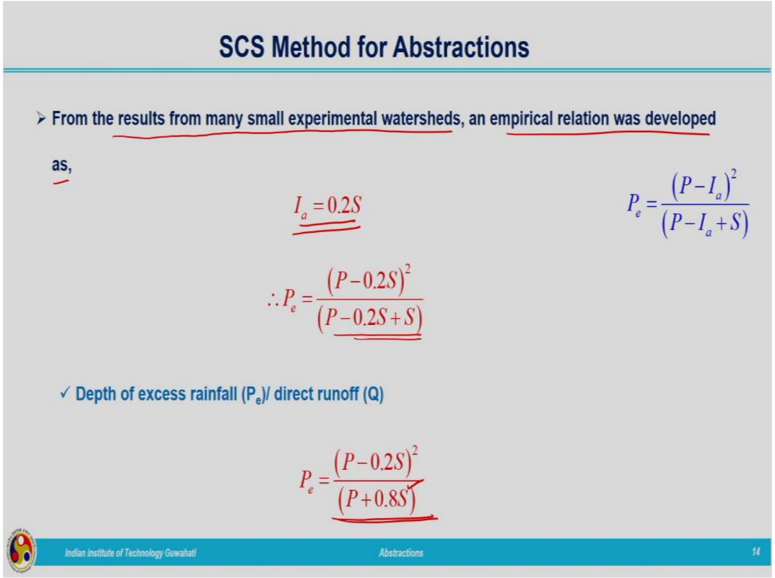
$$\frac{(P - I_a)}{(P - I_a + S)} = \frac{P_e}{P - I_a}$$

From this we can get

$$P_e = \frac{(P - I_a)^2}{(P - I_a + S)}$$

So, P_e is representing our excess rainfall. So, this is the basic equation for computing the depth of excess rainfall that is nothing but our direct runoff from a storm by using SCS method. So, it is a very simple method and also very successfully used method for the agricultural watershed. This has been extended to other types of watersheds also. So, in this excess rainfall or the direct runoff depth can be calculated by using this formula. So, you look at the formula carefully, P is the total rainfall that we will be having and I_a is the initial abstraction and S is the potential retention or the maximum storage. So, there should be a method to calculate I_a and S. So, let us see how these can be incorporated.

(Refer Slide Time: 32:15)



So, from the results from many small experimental watersheds an empirical relation was developed relating S and I_a. I_a was found out to be

$$I_a = 0.2S$$

So, initial abstraction, from the studies from small watersheds it is found that initial abstraction can be assumed as 0.2 times the potential retention. So, after this can be substituted in the previous equation for excess rainfall.

So,

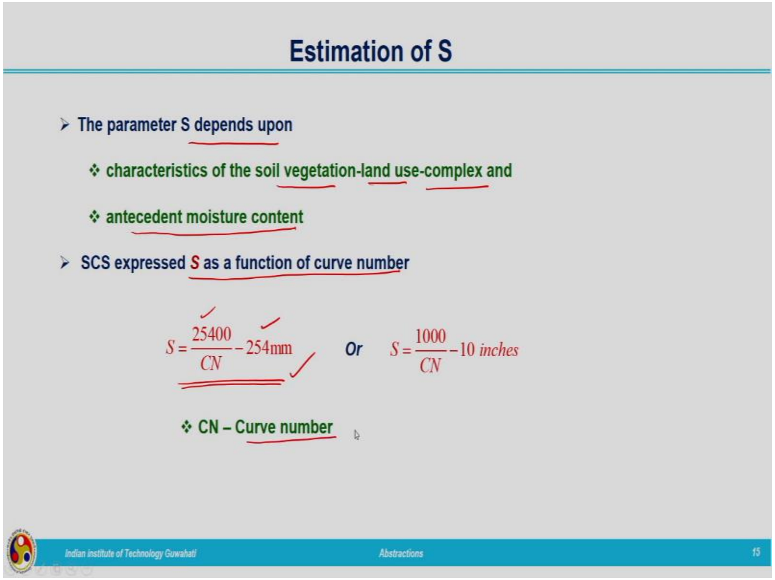
$$\therefore P_e = \frac{(P-0.2S)^2}{(P-0.2S+S)}$$

So, it will be taking the form

$$P_e = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

So, in this equation, we are having only one unknown value that is related to the potential retention. So, P_e is our excess rainfall, capital P is our measured rainfall in a particular watershed and S is the potential retention.

(Refer Slide Time: 33:29)



Now, we need to have a method to calculate the value corresponding to this potential retention S. So, the parameter S depends on the characteristics of soil vegetation land use complex. So, this S storage or the retention is definitely depending on the land use characteristics, and soil properties. So, it may be vegetative surface, it may be a marshy land or it may be of different types of land use will be present. So, based on the land use properties and also the soil properties, this S can be determined and also one more thing, how much will be the potential retention that depends on the moisture content prevailing in the soil at a particular moment. So, that is what is termed as the antecedent moisture content. So, the parameter S is depending on the soil land use properties and also the antecedent moisture content. So, SCS expressed S as a function of curve number. Curve number is a dimensionless number which is derived under this method and S can be written as

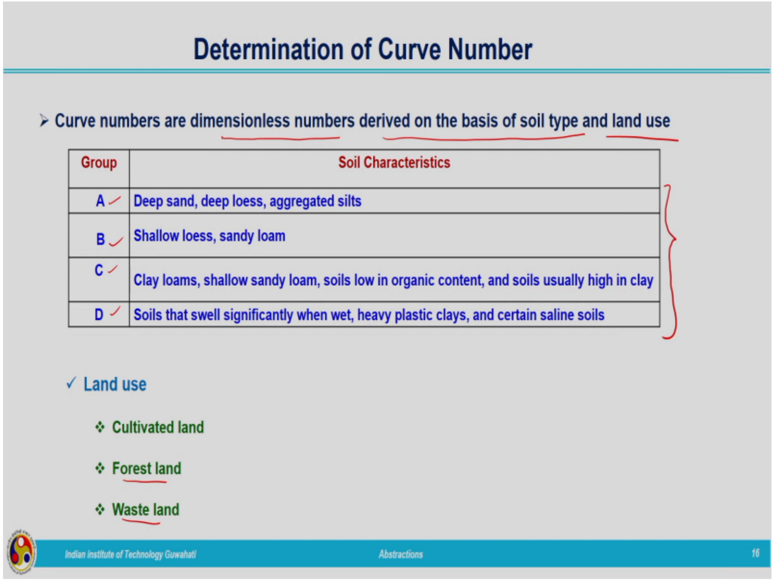
$$S = \frac{25400}{CN} - 254 \text{ cm}$$

If it is in inches, it can be written as

$$S = \frac{1000}{CN} - 10 \; inches$$

So, these *CN* is the dimensionless curve number.

(Refer Slide Time: 34:57)

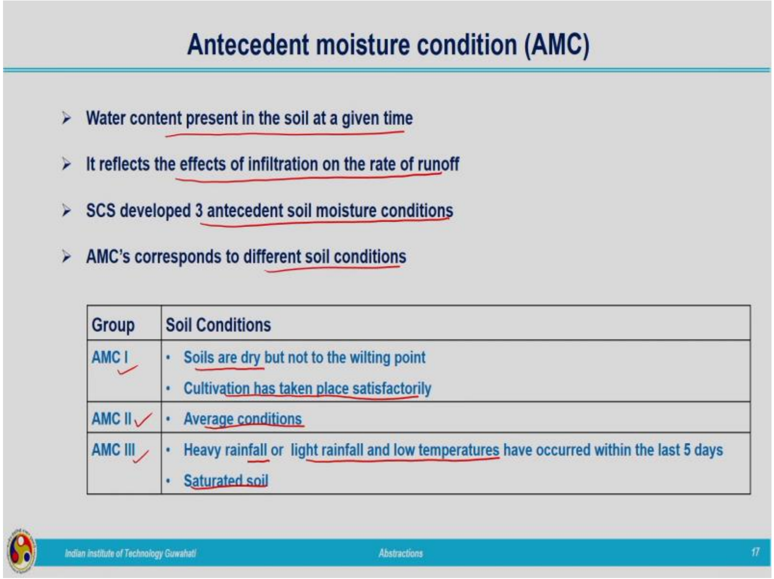


Now, how to determine this curve number? Initially we were having problem with initial abstraction, there we have found out a relationship between initial abstraction and the maximum or the potential retention. After that now *S* is related to a dimensionless curve number. Now, everything in terms of curve number we can write but how to determine this curve number that is the next question.

So, this curve numbers are dimensionless numbers derived on the basis of soil type and land use. This curve number is also dependent on the soil type and land use properties. So, based on different soil type, different groups have been defined by SCS related to different types of soil and those groups are four groups have been defined group A, B, C and D and these four groups are based on these types of soil properties.

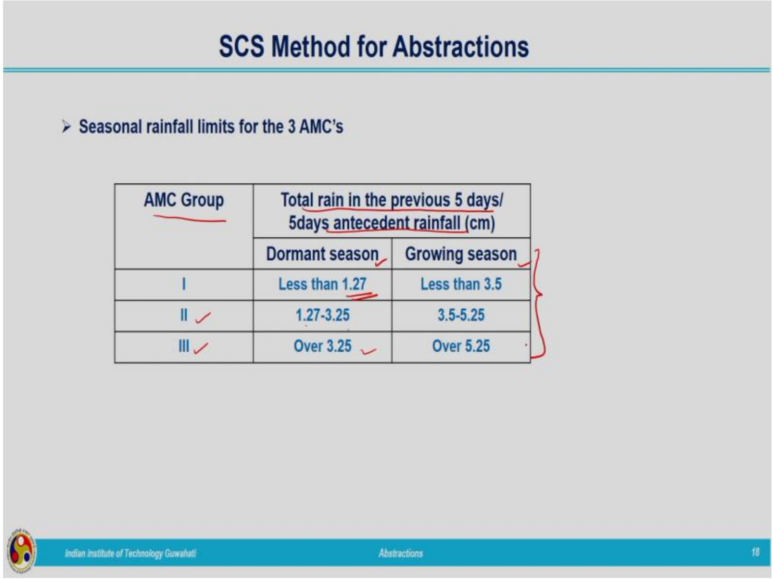
So, different soil characteristics are given over here and corresponding to a particular soil property, you can classify it in any of these groups coming under A, B, C, D and the land use characteristics involves the cultivated land, forest land, wasteland, scrub land, that way one table is given in all the textbooks you can refer to that and based on the land use properties and also soil properties, you can find out the curve number value.

(Refer Slide Time: 36:34)



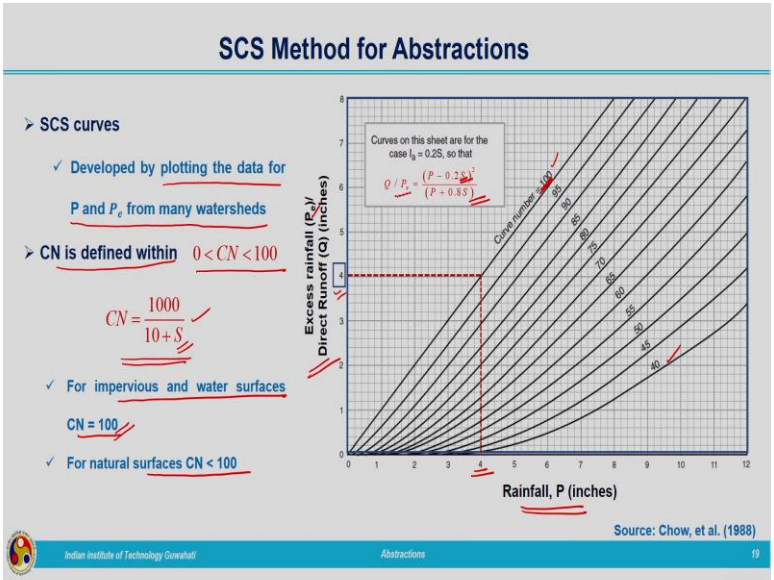
Now, one particular term antecedent moisture condition I have mentioned earlier. So, that is the water content present in the soil at a given time. Present moment what is the water content present in the soil that is the antecedent moisture content that is the prevailing moisture content within the soil. So, it reflects the effects of infiltration on the rate of runoff. Definitely the rate of infiltration depends on the moisture content which is present in the soil. SCS developed three antecedent soil moisture conditions, those are corresponding to different soil condition: AMC I, AMC II and AMC III. So, soil conditions are there. AMC I is corresponding to soil which is under dry condition. Dry condition does not mean that it is at the level of wilting point but the soil condition is considered as dry based on the moisture content and cultivation has taken place satisfactorily. Second AMC II represents the average conditions and AMC III is representing the saturated condition that is either we are having heavy rainfall or it may be due to light rainfall and low temperature, not much losses taken place soil is in the saturated state itself. So, that way we are having three different AMC condition AMC I, AMC II and AMC III.

(Refer Slide Time: 38:11)



Seasonal rainfall limits for three AMCs are all the three AMC groups are given over here. We are considering total rain in the previous 5 days or 5 days antecedent rainfall in centimetre and we are considering two seasons: one is dormant season and other one is the growing season that is the it is related to agricultural watershed, so, it is related to cultivations. So, one season is dormant season and the second season is the growing season. So, corresponding to AMC I, the previous five days rainfall, if it is dormant season, it should be less than 1.27. If it is between 1.27 and 3.25 is AMC group II. If it is over 3.25 it is AMC group III. So, that way for growing season also the rainfall is defined.

(Refer Slide Time: 39:08)



SCS curves have been developed by plotting the data for total precipitation and the excess precipitation from so many watersheds and the curve number is defined between the range of 0 to 100. So, curve number varies between 0 to 100 and within this depending on the different type of land use, we will be selecting the value corresponding to curve number and curve number can be calculated by using the formula

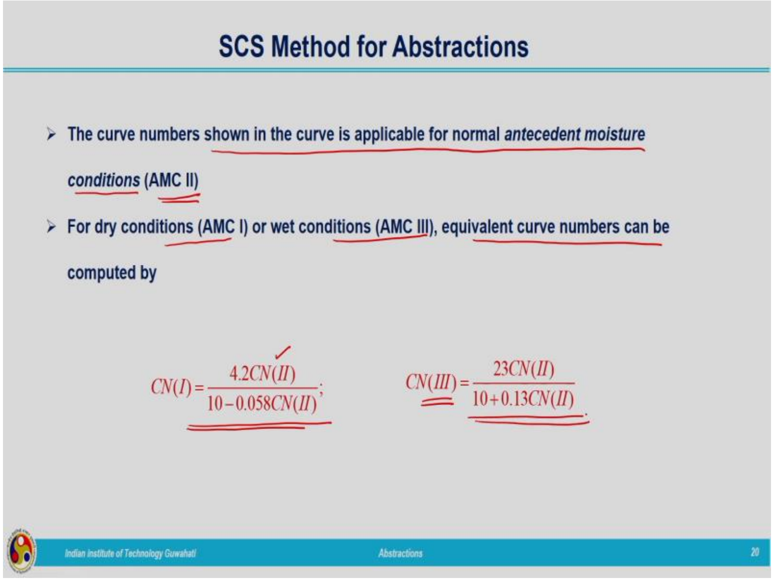
$$CN = \frac{1000}{10 + S}$$

This is based on the formula which I have already shown to you regarding the relationship between the curve number and the potential retention. In this S is in inches and SCS curves have been developed with respect to excess rainfall or direct runoff that is P_e is our excess rainfall and total rainfall P. This curve is in inches. So, here we are having different curves having different curve numbers. So, for your particular watershed, what is the curve number based on the land use and soil type you can determine, that is tables have been given in the textbooks from that you can determine the curve number, corresponding to that you can choose the curve out of this and you can calculate the value corresponding to total rainfall, how much the excess rainfall will be coming.

So, for impervious and water surfaces, curve number will be 100. You look at the formula cover number equal to $CN = \frac{1000}{10 + S}$. If it is an impervious surface, the water which is infiltrating into the ground will be 0. So, whatever rainfall is falling on the ground surface will be converted to direct runoff, no loss is taking place from that, even those small interception losses will be the that we will be neglecting. In such cases S is equal to 0 then CN will be $CN = \frac{1000}{10} = 100$.

So, in the case of water surfaces and also impervious surfaces, CN value is the maximum value that is 100 and for natural surfaces CN is less than 100. So, now in the case of an impervious surface where CN values equal to 100 we can look into the curve. For a rainfall, total rainfall of four inches, you can consider the curve number corresponding to 100 that curve is chosen and we will be getting the runoff value or the excess rainfall as 4 inches itself. So, that means, if curve number is 100 that is representing a water surface or impervious surface, entire water is converted to runoff. So, in this way once the curve number is determined based on the land use and soil properties, you can calculate the excess rainfall or the direct runoff depth or if the curve number is determined you can calculate the potential retention S by making use of the formula which has been shown in the previous slide. If S value is determined, you can make use of this formula based on SCS for P_e that is $Q/P_e = \frac{(P-0.2S)^2}{(P+0.8S)}$ for calculating the excess precipitation. Either you can make use of this formula or by making use of the SCS curves, you can determine the excess precipitation. Details related to different tables corresponding to soil group and also land use is given in the textbooks.

(Refer Slide Time: 43:01)



The current numbers shown in the curve is applicable for normal antecedent moisture condition. We were having three moisture conditions AMC I, AMC II and AMC III. So, the curve numbers which is shown or the curves which is shown is corresponding to AMC II. AMC II is representing the average conditions and what we will do in the case of AMC I and AMC III. So, AMC I is for dry conditions and AMC III is for wet conditions. So, we can derive equivalent curve numbers by making use of the curve number corresponding to AMC II. So, curve number corresponding to AMC I can be calculated by using this particular equation in which we are having the curve number corresponding to average condition

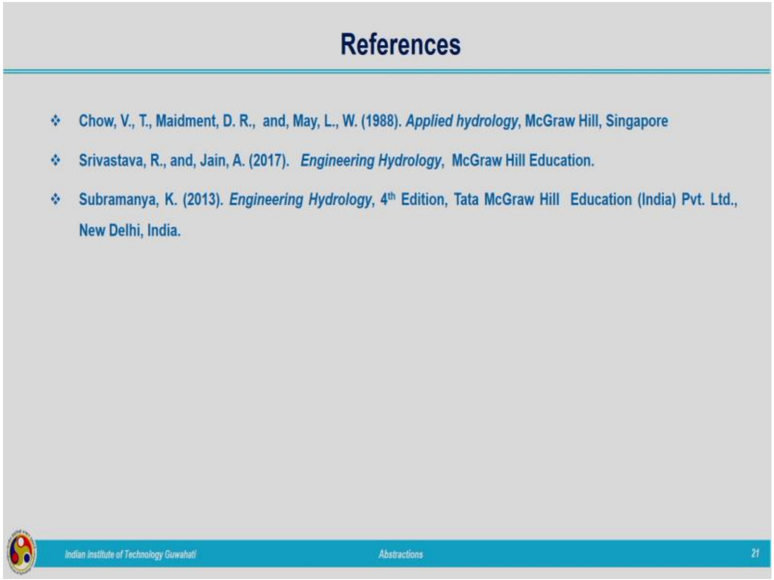
$$CN(I) = \frac{4.2CN(II)}{10-0.058CN(II)}$$

and CN III that is curve number corresponding to AMC III can be calculated by using this formula:

$$CN(III) = \frac{23CN(II)}{10 + 0.13CN(II)}$$

So, once curve number is obtained, you can make use of the curves or by making use of the formula corresponding to P_e we can calculate the excess rainfall which is equivalent to the direct runoff.

(Refer Slide Time: 44:28)



So, here I am winding up this lecture and related to these topics you can go through this reference textbooks. In this lecture, we have covered different methods to compute the abstractions. First two methods that is the $\phi - index$ method and the runoff coefficient method can be utilized in the case of gauged catchments, that is we should have the value corresponding to the runoff depth. If those values are not available or the catchment is ungauged in that case, we can make use of the infiltration equations. We are assuming that all the abstractions are due to infiltration only and we will be superimposing the infiltration curve on the hyetograph and the values which are coming below the infiltration curve will be deducted from the total rainfall hyetograph to get the excess rainfall hyetograph. That excess rainfall hyetograph is representing the direct runoff depth. After that we have moved on to a SCS-CN method, Soil Conservation Service curve number method for finding out the runoff depth. In that case the hypothesis I have explained to you based on that hypothesis, we have proceeded to get the final expression for getting the direct runoff depth or the excess precipitation. So, different land use details and soil details and different tables related to SCS method, you please refer the textbook that I have not included in this PPT. So, here I am winding up this lecture. Thank you.