Availability and Management of Groundwater Resources
Prof. Prasoon Kumar Singh
Department of Civil Engineering
Indian Institute of Technology (ISM), Dhanbad

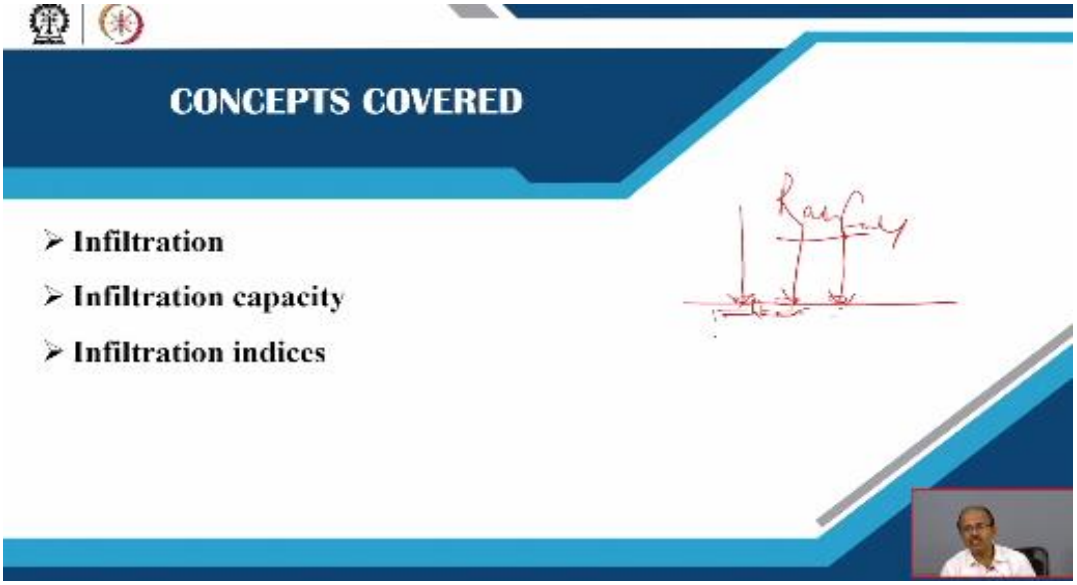
Lecture - 39
Measurement of Rainfall, Index of Wetness, Infiltration Rate (Contd.)

Welcome you all in the part 5 of the module 8, Measurement of rainfall index of wetness and filtration rate. So, in the last four different parts we have discussed in greater detail about the precipitation, types of precipitation and its measurement, equipment that is the rain gauge network. That is the rain gauge is also of two different types recording type non-recording type. Then we have seen the different methods arithmetic mean method and this and polygon method.

To which we can able to know about the different types of the network fixation of the network stations. Then we have seen of the optimum number of rain gauge stations required for any catchment for giving the greater details of the rainfall amount. And also we have seen in the previous parts that if suppose sometimes the any of the rain gauge network is stopped, has stopped working.

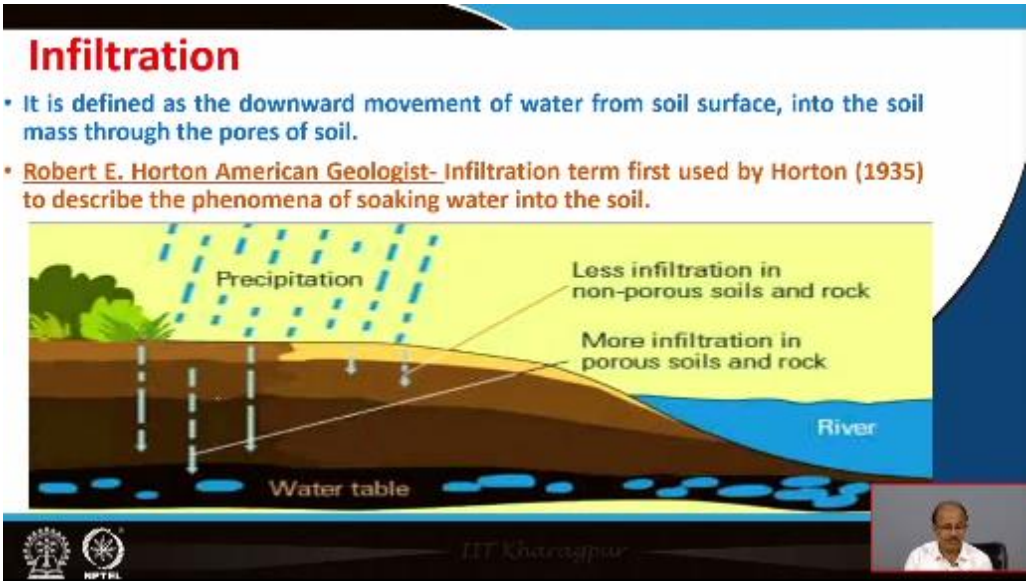
So, in that case the rainfall is not their missing rainfall status claim, so in this situation how to find out the rainfall in the catchment area where we have fixed the different stations network. Now in this part or say in the last part of the lecture of this course, we will learn about the infiltration because we have seen if we will see;

(Refer Slide Time: 01:49)



So in this part generally we will concentrate on the infiltration, infiltration capacity and infiltration indices. So we have seen from the very beginning when we were discussing about the hydrological cycle that precipitation is the only recharge source which is just replenishing the aquifer lying underneath the earth's surface. So this we have seen from the very first slide we have discussed also.

(Refer Slide Time: 02:19)



So here the on the earth surface, no doubt the rain rainfall amount is reaching these rainfall amounts are reaching on the surface. But what is happening we have discussed this thing that this rainfall drop little drops these raindrops will try to reach to the first surface of the first layer of the soil

which is lying just beneath the surface. Because it remains that time before rain it remains in the dry condition.

These remain in the dry conditions so what is happening the raindrop will in will enter into the first layer of the soil. So, this term is generally discussed as the infiltration and then from the first layer of the soil to the second layer of the soil is termed as percolation and ultimately it reaches to the aquifer. So, this we have discussed several times in the past two different discussions now at this present moment we will discuss the infiltration.

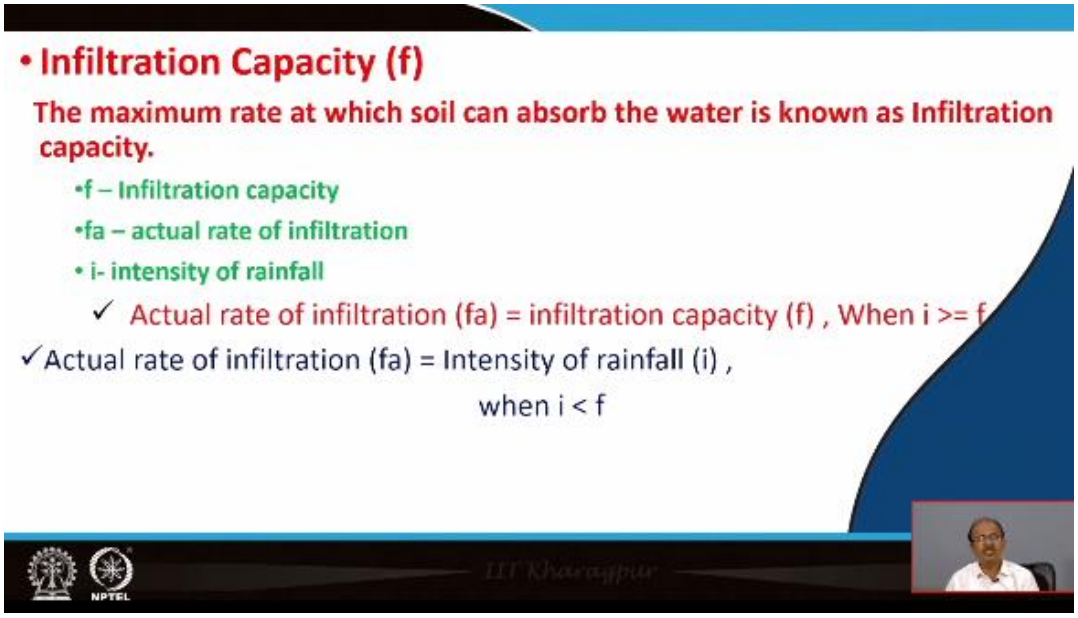
What is infiltration? What is the infiltration capacity and what is the infiltration. So this is very important also for replenishment of any aquifer underneath the surface. So now the infiltration it is defined as the downward movement of water from soil surface into the soil mass through the pores of the soil. So, it the rain drops it moves to the soil surface then into the soil mass where in the soil mass in the soil pores existing pores of the soil.

So, this is generally defined as the downward movement of water from earth's surface to soil surface. One American geologist Robert E Horton, very non-American geologist he actually coined the term infiltration that is in the year 1935 to describe the phenomena of soaking water into the soil. So, this term has come that time by hotel. So, you can see the precipitation is taking place and then the water table is reaching here.

And there are two areas there one area is having more infiltration in porous soil and rock so here porous soil and rock is there, so more concentration is there. But here less bristle infiltration is there because non-polar soil and rock so hard rock suppose hard rock is coming here. So, in the hard rock precipitation is equally taking place at both the places but in this area the hard rocks remain we have discussed in the past also hard rocks remains.

So, no pore spaces are remaining, so it is not accepting the water your rain water whereas this is accepting the rain water because so many poor subspaces are there. So, infiltration wise this is the area having less infiltration and this is the area having high infiltration.

(Refer Slide Time: 05:23)

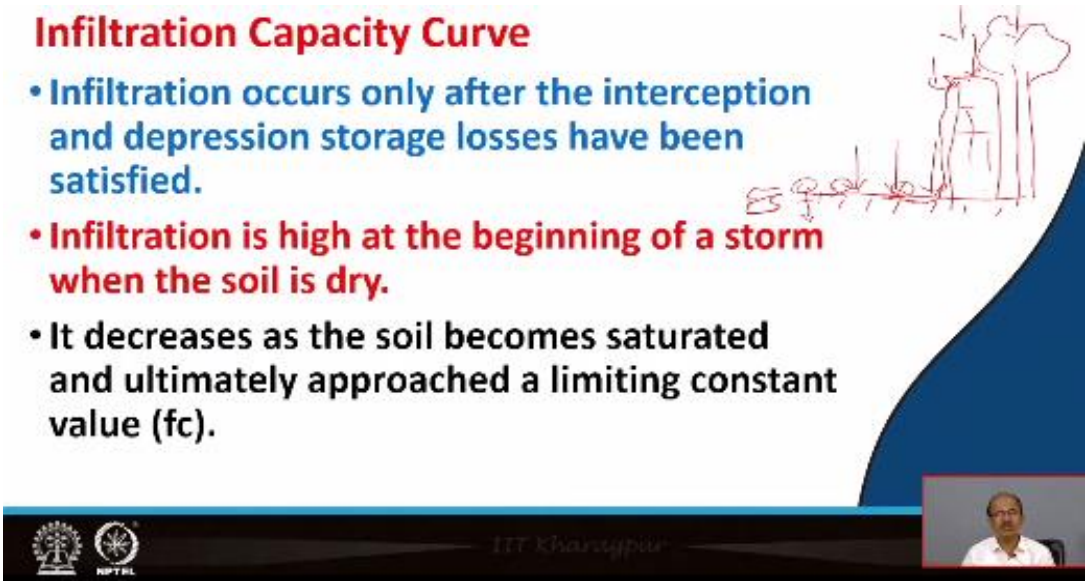


Now infiltration capacity; the maximum rate at which it is called as infiltration capacity is called as the maximum rate at which soil can absorb water is generally known as infiltration quantity. So what is the maximum rate of the soil which can absorb the amount of water is generally known as the infiltration capacity and which is denoted by fa is actual rate of infiltration.

And i is equal to intensity of rainfall. So, the formula will become
Actual rate of infiltration (fa) = infiltration capacity (f) When i >= f means the intensity of rainfall is greater than or equal to f then i is equal to greater than or equal to f. So Actual rate of infiltration (fa) = Intensity of rainfall, When i < f.

Then the actual rate of infiltration is equal to intensity of rainfall so this is very important consideration for the finding your area which is having a good groundwater potential.

(Refer Slide Time: 06:58)



So, now infiltration capacity curve after understanding the infiltration process then the infiltration capacity. Now what is the infiltration capacity curve? So infiltration occurs only after the interception and depression storage losses have been satisfied, we have learned that time also. That when the rainfall starts, suppose that on this is the earth surface and the rainfall started drops are raised to the earth's surface.

So first what is happening we have discussed earlier also that tall trees and tall buildings say this is all buildings and tall trees tall trees and this rainfall will be intercepted by these two, so this will be intercepted. So then from here it will fall to the ground surface towards the ground surface. So it will fall to the ground surface and after reaching to the ground surface, existing if any voids are there they are just fulfilling the water in these voids.

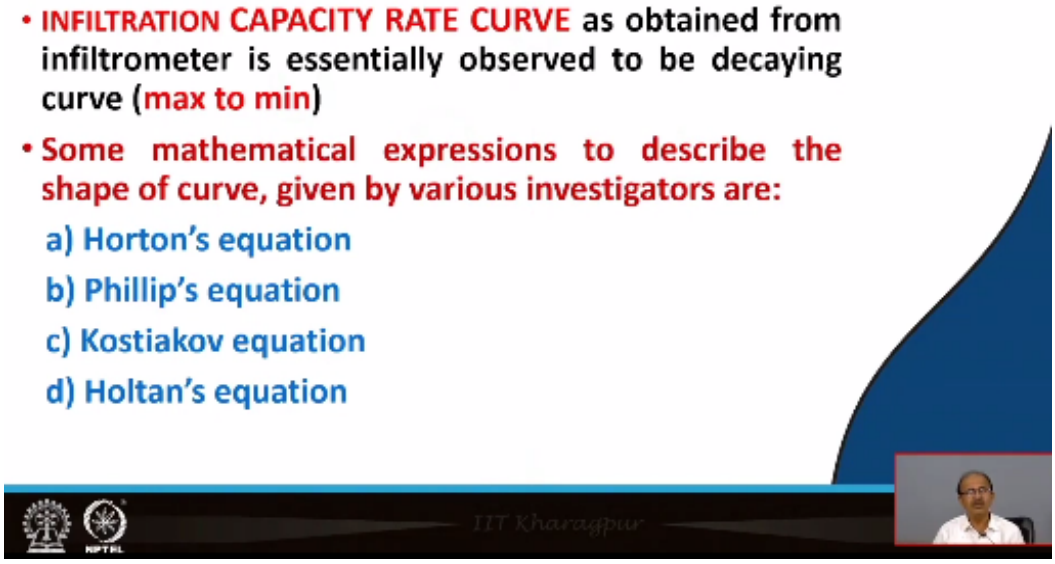
And these voids then only if once it will become saturated this area will become saturated these voids will become saturated then it will start to send water inside means infiltration then only starts. So infiltration occurs only after the interception and depression storage losses have been satisfied and these losses have been satisfied then only the depression infiltration occurs. So infiltration occurs only after the interception and depression storage losses have been satisfied.

Infiltration is high at the beginning of a storm definitely because the soil layer becomes remains dry, so at that time when the rain drop will fall to the earth surface the infiltration will remain high

in the beginning of any rain and when the soil remains dry. It decreases as the soil becomes saturated because then if once the soil becomes saturated then it would not allow water to move down.

So infiltration reduces at that moment when the soil becomes saturated with water and ultimately approached a limiting constant value. Ultimately it will reach to a constant value which is known as fc. So this is very important because for a certain duration the soil will absorb water means the infiltration will be more and a time will come when it will decrease and become saturated means it will not allow even a single drop of water to move inside. Because the; layer has become saturated and this is generally known as the fc.

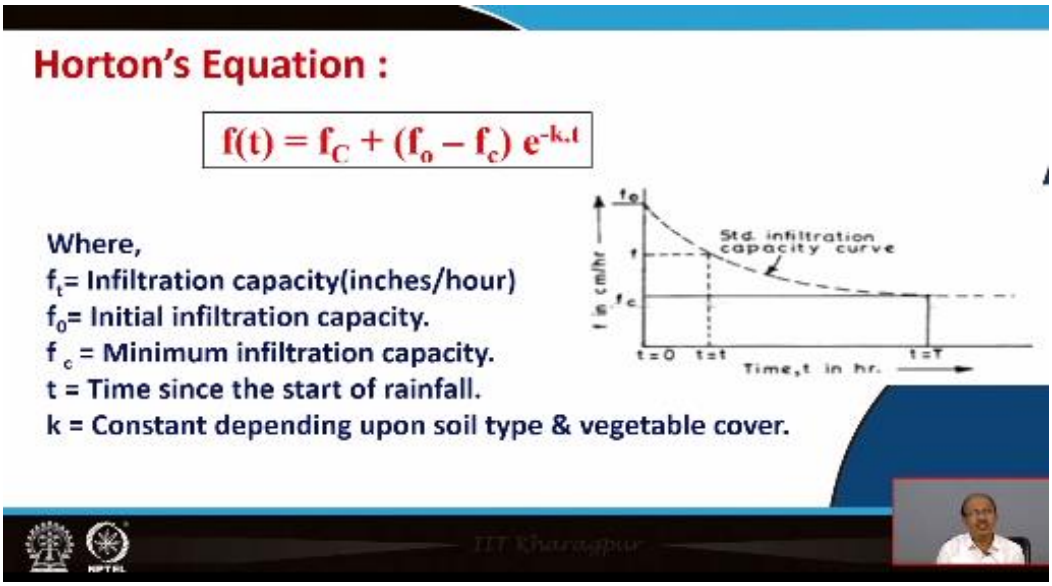
(Refer Slide Time: 09:48)



This is the fc means your infiltration capacity. Then infiltration capacity rate of curve as obtained from the infiltrometer. Infiltrometer instrument is essentially observed to be decaying curve it is generally a decaying curve. Some mathematical expressions to describe the shape of the curve given by various investigators are some investigators have given the your some of the mathematical expressions.

Say for Horton's equations are there, Phillip's equations are there, Kostiakov equations are there, Holtan's equations are there. So these equations are given by the various investigators have to describe the shape of the curve.

(Refer Slide Time: 10:38)



Now Horton's equation is f(t) = fc + (fo - fc)$* e^{-kt}$. So what is happening here

fo – initial infiltration capacity

fc – limiting constant value of infiltration

f c = Minimum infiltration capacity.

t = Time since the start of rainfall.

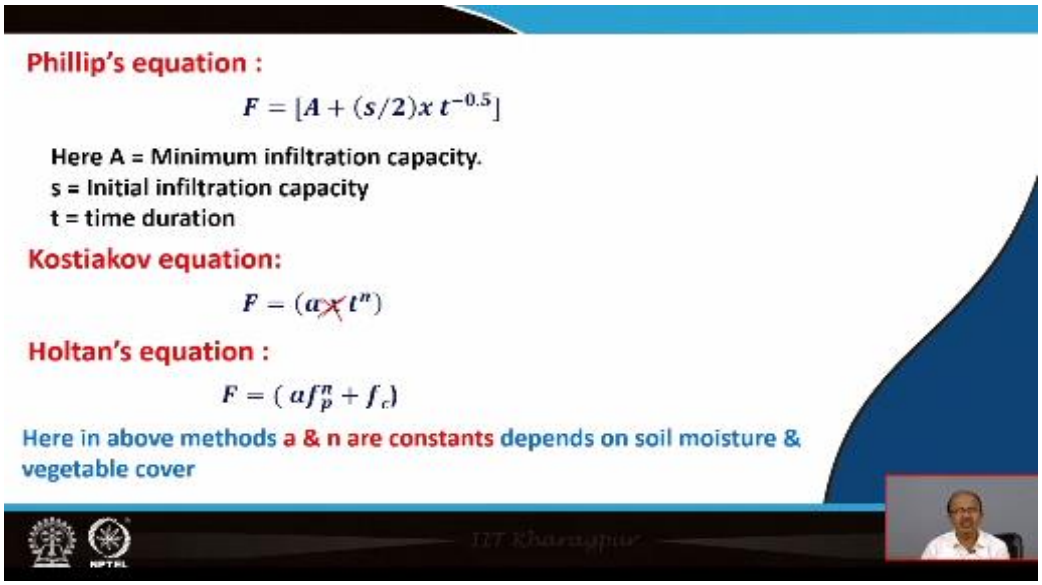
k = Constant depending upon soil type & vegetable cover.

So this is the constant which is dependent upon the soil types and which they will cover.

So through this Holton's equation we can find out the

f(t) = fc + (fo - fc)$* e^{-kt}$. So this generally it is a good equation through which we can find out the infiltration capacities.

(Refer Slide Time: 11:35)



Now next equation is the Phillip's equation, in the Phillip's equation also we can find out the infiltration capacity so

$$F = [A + (s/2)x\, t^{-0.5}]$$

So here A is the minimum infiltration capacity, s is the initial infiltration capacity, t is the time duration. So in this way also with the help of Philip's equation we can find out the infiltration capacity of any event or any area. Now Kostiakov equation and Holtan's equation these two equations are having some constants.

The constants are a and n. So in this case this constant a and n depends on soil moisture and vegetable cover so in the case of Kostiakov equation

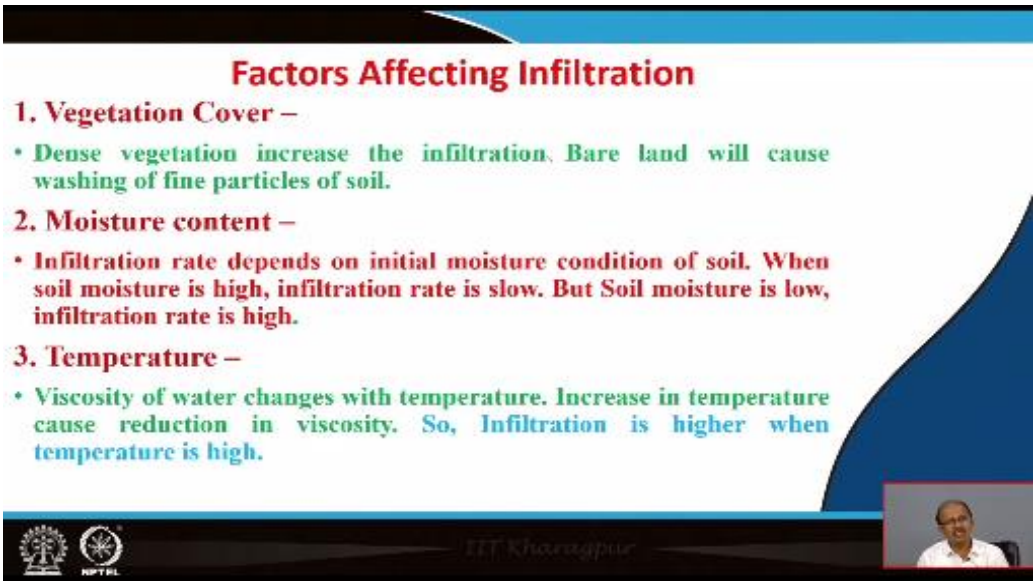
$$F = (a\, x\, t^{n})$$

So here this one is a into t to the power n whereas in Holton's equation

$$F = (\, af_p^n + fc)$$

And here in the above methods a and n are constant and it depends on the soil moisture and vegetable cover. So, these are the different equations to which we can find out the infiltration capacity.

(Refer Slide Time: 13:00)



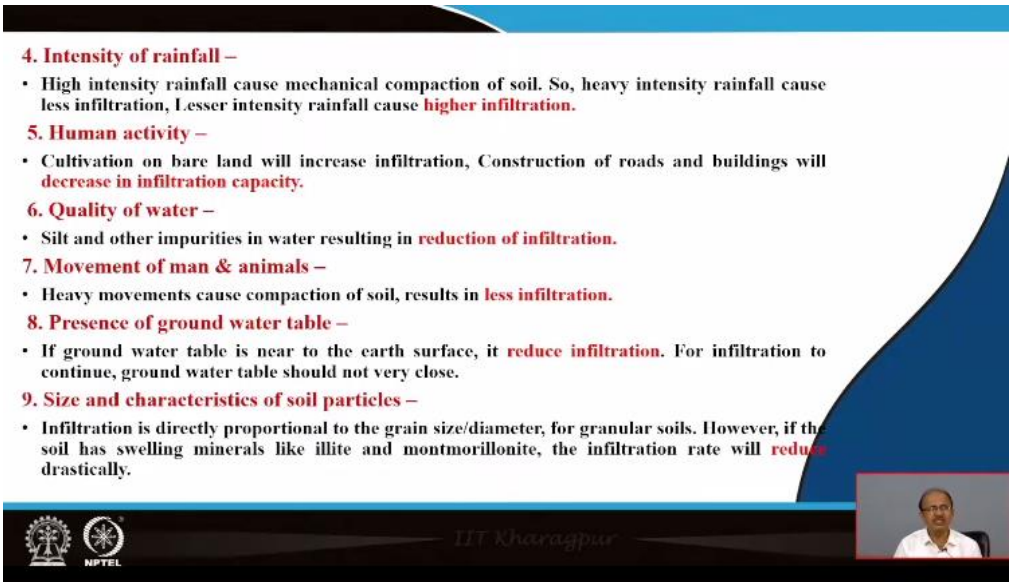
Now what are the factors affecting the infiltration capacity? This is very interesting also because we are knowing that the precipitated water will ultimately reach to the underground layer or through the soil cover only, through the land cover only. So, vegetation covers dense vegetation increase the infiltration bare land will cause washing of fine particles of soil. So, if the dense vegetation will be there it will increase the infiltration.

In inflation will be more, but if there will be barren land so what will happen barren land is there so because of the movement of the air the fine particles of the soil will wash up so there will be if the refined particles will wash off definitely there will be no other media through which the water can move inside. Second factor is the moisture content in filtration rate depends on the initial moisture condition of soil.

When soil moisture is high then definitely the infiltration rate will be slow because inside the water is available definitely from outside it would not take. So, soil moisture is high infiltration rate will be slow but soil moisture is low definitely infiltration rate will be more. So, second factor is the soil moisture content. Third is the temperature viscosity of water changes with temperature. So, if there will be increase in temperature it causes reduction in viscosity.

So, infiltration is higher and when temperature is high so when temperature is infiltration rate is also higher.

(Refer Slide Time: 14:43)



Now next is the intensity of rainfall, so high intensity rainfall causes mechanical compaction of soil because if the intensity will be more definitely the soil layer will become compact mechanically. So, once it will become compact so it will not have the pore spaces to allow water from the earth surface to inside so heavy rainfall intensity rainfall caused less infiltration. So, infiltration will be less lesser intensity and for cause higher infiltrate infiltration.

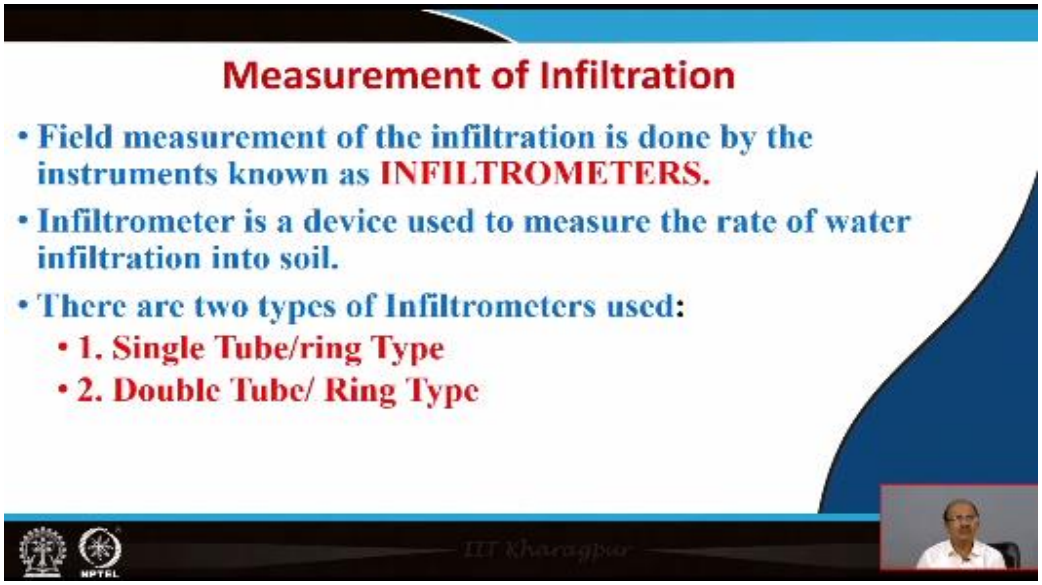
So, if the intensity of rainfall is less then definitely there will be high infiltration but once the intensity of rainfall is high there will be less infiltration. So, human activity cultivation on bare land will increase infiltration if cultivation if going on the bare land and definitely the infiltration will increase. But construction of roads and building will decrease the infiltration capacity because there will be no area of water to move inside.

So, these buildings and roads will decrease the infiltration capacity of the area. Now, quality of water silt and other impurities in water resulting in reduction of infiltration. So if the water is having the silt another impurity, definitely it will not have the media through which it can move inside. So, infiltration capacity will be less now movement of man and animals, heavy movements of man and animals and heavy movements can cause compaction of soil results in less infiltration.

So presence of groundwater table, if groundwater table is near to the earth's surface then definitely it will reduce the infiltration and for infiltration to continue definitely groundwater table should go and should not be very close then only the infiltration will be more. Now size and characteristic of soil particle infiltration is directly proportional to the grain size/diameter for granular size.

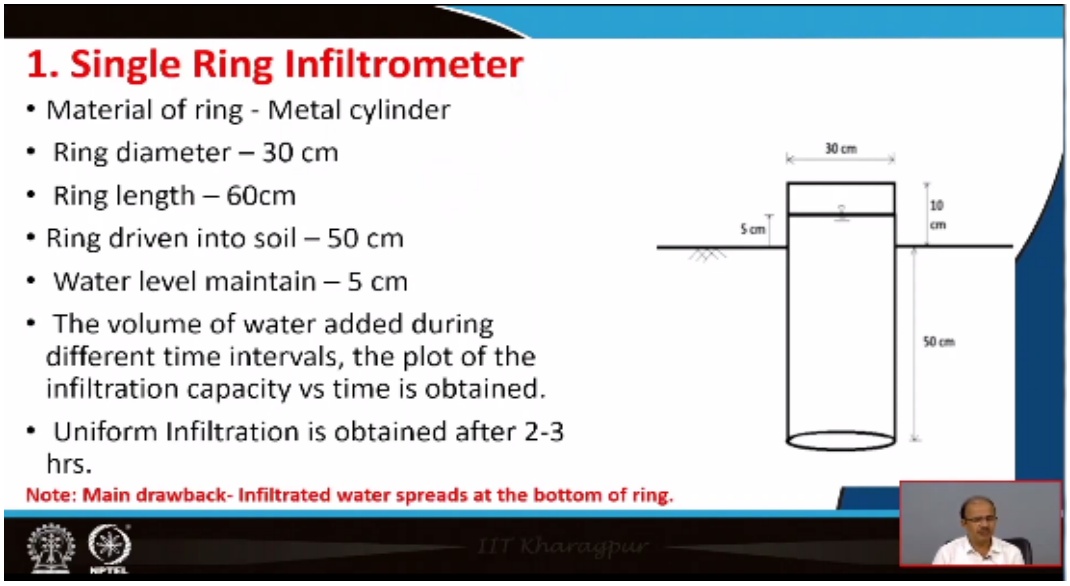
However for granular size in the soil has swelling materials like illite and montmorillonite so, this swelling materials are lying there the infiltration rate will reduce intensity the infiltration rate will reduce very more at this place or at this condition.

(Refer Slide Time: 17:07)



Now measurement of infiltration, how the infiltration are measured? So measurement field measurement is generally done by the infiltrometers but the problem is that the rate of water infiltrating into the soil. There are two types of infiltrometers used single tube or ring type or double tube or ring type.

(Refer Slide Time: 17:34)



Now single ring type material ring is the metal cylinder diameter remaining 30 centimeter ring length 60 centimeter, so water level and ring driven into the soil it is important being driven into the soil 50 centimeter. So from here to a driven into the soil it is a water level maintain 5 centimeter whatever 5 centimeter maintained level is required the volume of water added during the time intervals the plot of the infiltration capacity was the time is obtained the and the uniform infiltration rate is obtained after 2 to 3 hours.

So, main drawback is here that the infiltrated water spreads at the bottom of the ring, so it spreads at the bottom of the ring. So this is the main problem with use of single ring infiltrometer.

(Refer Slide Time: 18:28)

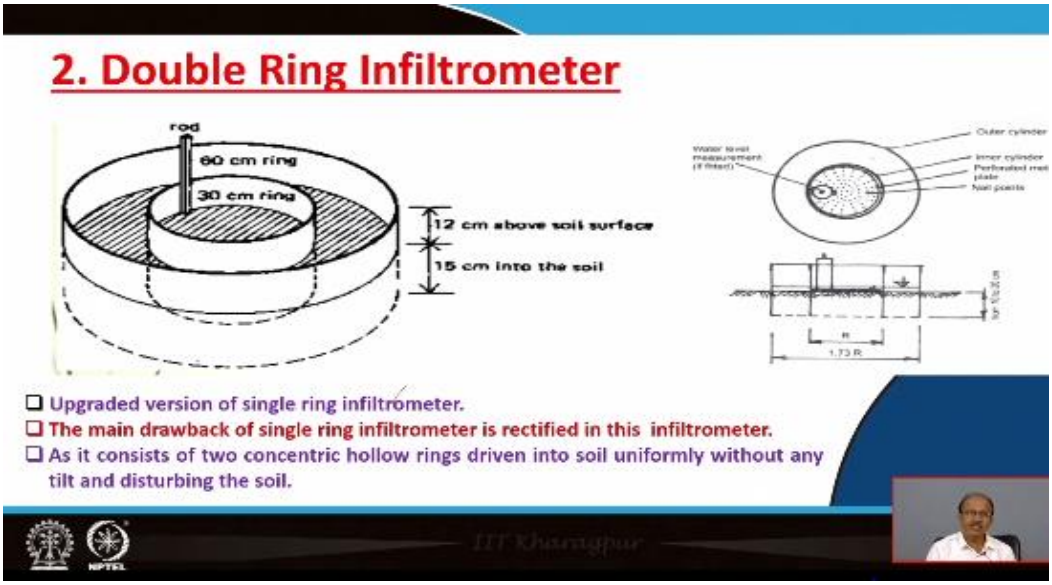
Now single ring infiltrometer it is just again revising the single ring because the this is just a ring into the soil and it is driven into the soil and supplying water in the ring just pouring water either at constant head or falling head condition. Constant head refers to condition where the amount of water in the ring is always held constant, means the level will remain constant that is the rate of water supplied correspond to the infiltration capacity whereas falling head refers to a condition where water is supplied to the ring.

And the water is allowed to drop with time also the operator records how much water goes into the soil for a given time period by any means if it is the operator is receiving the information that how much water is going down into the soil. Then such type of arrangement is all called as falling head whereas in the case of constant head condition the amount of water in the ring will always remain constant.

That means it will remain it will just correspond to the infiltration capacity of the area or soil. So, this is the about the single ring infiltrometer. The disadvantages of single ring advantage are also there the major drawback of the single ring infiltrometer is that the infiltrated water percolates laterally it will percolate laterally. So, if once it will come here then the water will percolate in this way laterally.

So, at the bottom of the ring thus the tube is not truly representing the area through which infiltration is taking place. So, if using the single ring infiltrometer it is very tough to tell that the area is receiving so much amount of water during the infiltration processes because during the single ring infiltrometer study it is found that the water percolates laterally at the bottom of the ring.

(Refer Slide Time: 20:30)



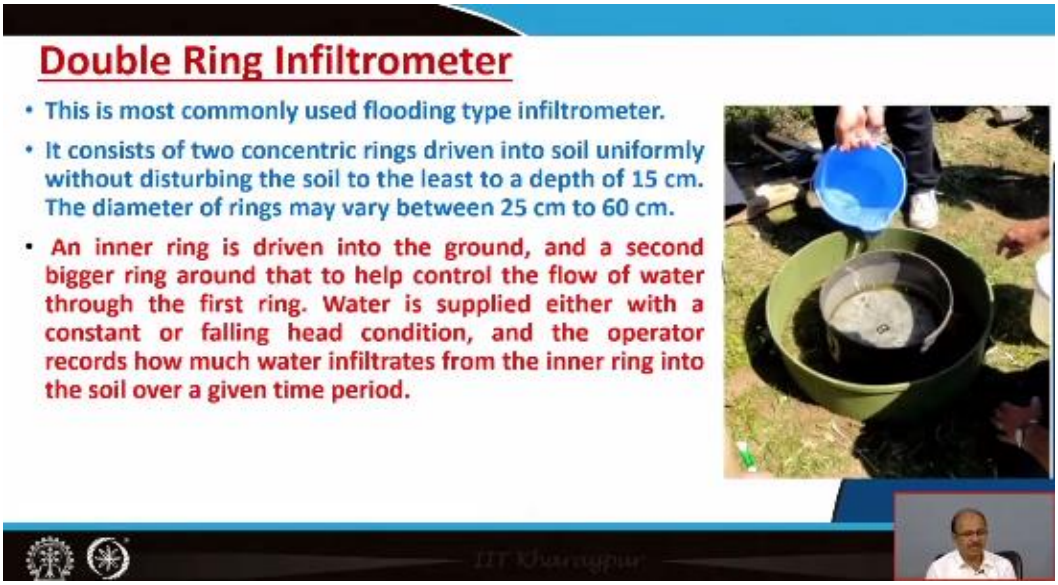
So now second is the double ring infiltrometer. So here two different rings are there you can see here also our ring is 60-centimeter ring and 30-centimeter ring and height is also given 12 centimeter above soil surface 15 centimeter into the soil and 50 centimeter is driven into the soil. It is driven into the soil and then from the earth surface to the above 12 centimeter remains and it is the upgraded portion of the single ring infiltrometer meter.

The main drawback of single ring infiltrator is rectified in this infiltrometer because there is the lateral movement of the water over there here it has been controlled. How it had control? As it consists of two concentric circular hollow rings driven into the soil informally without; any tilt and disturbing the soil. So, this is very important, so the two concentric circular rings and dimension also given just driven into the grounds. And then we are measuring the infiltration rate in the soil of by the developing infiltrometer

(Refer Slide Time: 21:43)

Now in this double ring infiltrometer the material of ring remains of metal cylinder, it remains metal cylinder ring diameter one is 36 centimeter other is 60 centimeter ring length is 25 centimeter ring driven into soil 15 centimeter, water level maintained into 5 centimeter then water in both the rings should be kept the same during the observational period and the measurement is taken only from the inner tube. Measurement is always taken from the inner tube, this is very important.

(Refer Slide Time: 22:18)



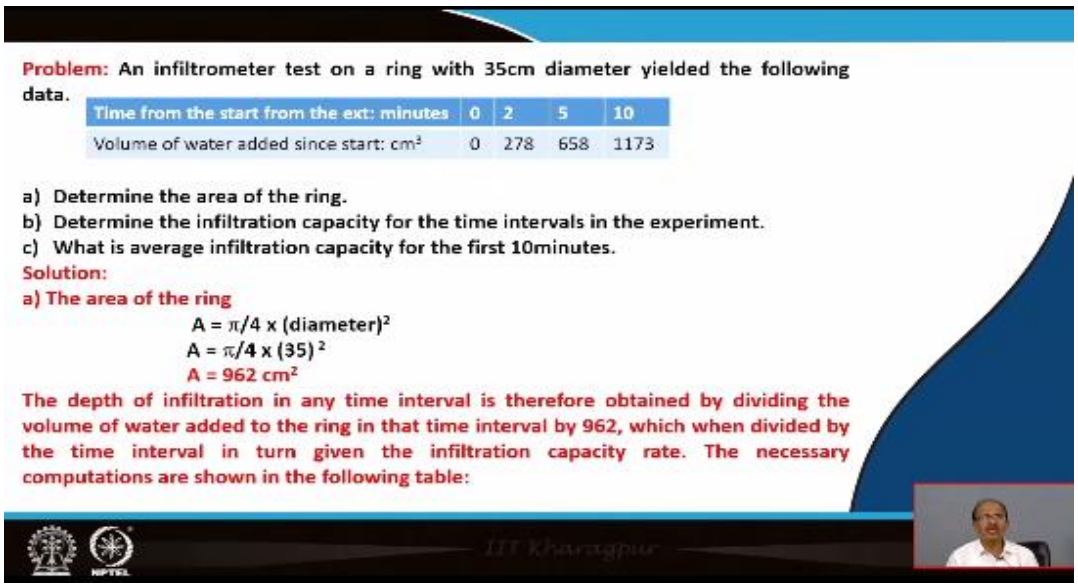
Now here in the double ring infiltrometer which is also known as the flooding type infiltrometer, it consists of two wings driven into the soil and without disturbing the soil to at least a depth of 15 centimeter. So depth remains 50 centimeter diameter of the rings vary from 25 to 60 centimeter

and inner ring is driven into the ground and a second bigger ring around that help to control the flow of water through the first ring.

So, first of all the second inner ring is driven into the ground and then the second ring is also driven to the ground and water is supplied either to constant or falling in condition. And the operator records how much water is infiltrating from the inner ring of the soil over a given time period. So, this is very important and that the flow of water will be first through the your outer ring and then the inner ring.

So the point behind it is that, if we will put the water inside out inside first then the chances will be that the surrounding layer will become saturated. But once you are putting the water in outside first and then in the inside then you can able to measure the infiltration rate of the area very correctly.

(Refer Slide Time: 23:51)



Now based on this one small numerical we can go through this small numerical An infiltrometer test on a ring with 35cm diameter yielded the following data.

Time from the start from the ext: minutes	0	2	5	10
Volume of water added since start: cm^3	0	278	658	1173

a) Determine the area of the ring.

b) Determine the infiltration capacity for the time intervals in the experiment.

c) What is average infiltration capacity for the first 10minutes.

Solution:

a) The area of the ring

$$A = \pi/4 \times (\text{diameter})^2$$

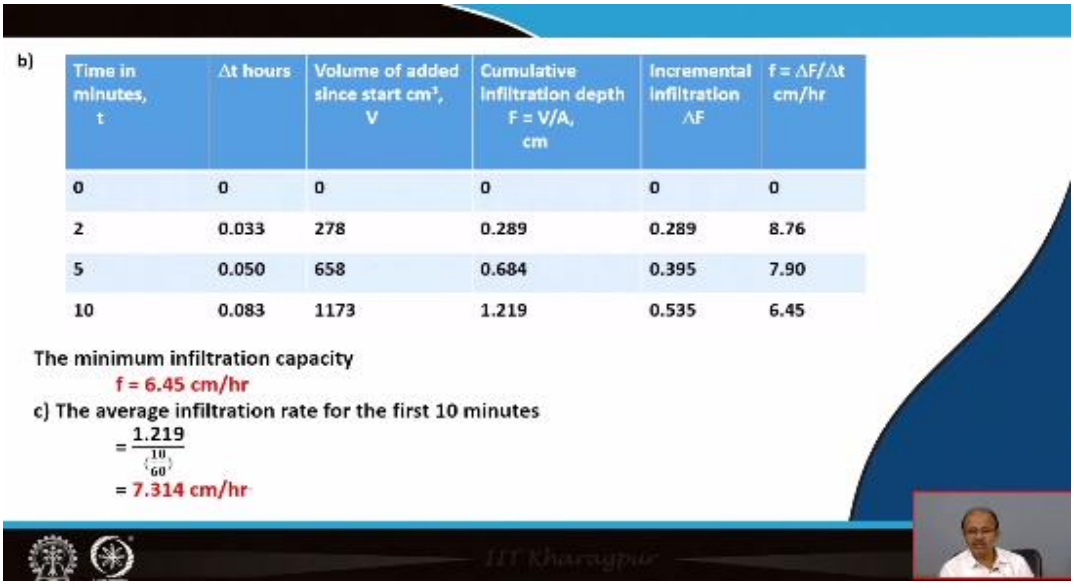
$$A = \pi/4 \times (35)^2$$

$$A = 962 \text{ cm}^2$$

The depth of infiltration in any time interval is therefore obtained by dividing the volume of water added to the ring in that time interval by 962, which when divided by the time interval in turn given the infiltration capacity rate. The necessary computations are shown in the following table:

The first question we have seen the depth of infiltration in any interval is therefore obtained by dividing the volume of water added to the ring in that interval by 962 which when divided by the time interval in turn given the infiltration capacity rate. The necessary computations are shown in the following table. We can see the computations in the next table.

(Refer Slide Time: 25:33)



Now here just we have further computed the data

Time in minutes, t	Δt hours	Volume of added since start cm^3, V	Cumulative infiltration depth F = V/A, cm	Incremental infiltration ΔF	f = ΔF/Δt cm/hr
0	0	0	0	0	0
2	0.033	278	0.289	0.289	8.76
5	0.050	658	0.684	0.395	7.90
10	0.083	1173	1.219	0.535	6.45

The minimum infiltration capacity

f = 6.45 cm/hr

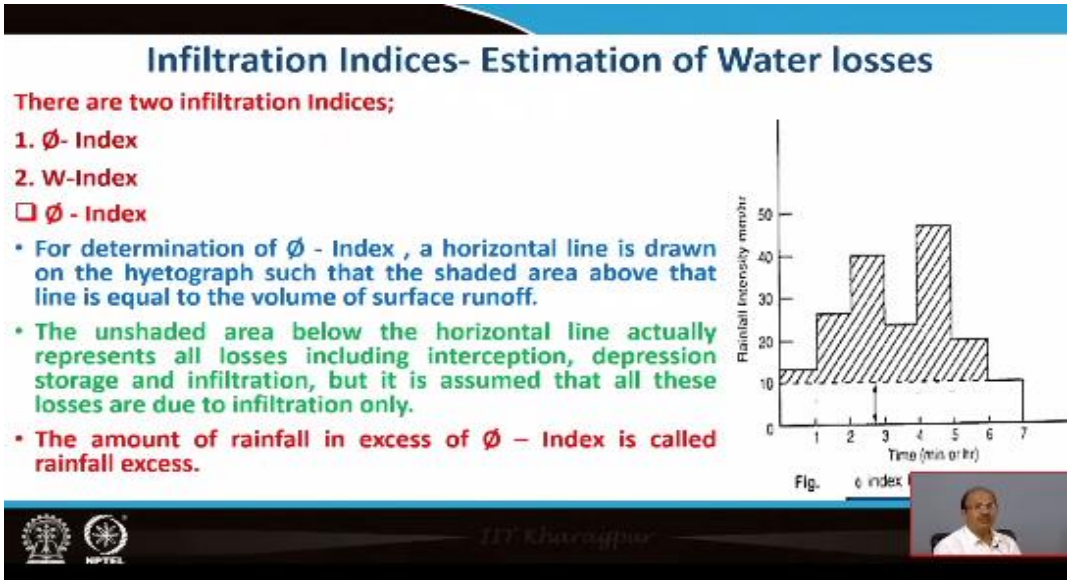
c) The average infiltration rate for the first 10 minutes

$$= \frac{1.219}{(\frac{10}{60})}$$

= 7.314 cm/hr

So this thing we have to think over and then just for 10 minutes 15 minutes we can find out the infiltration rate.

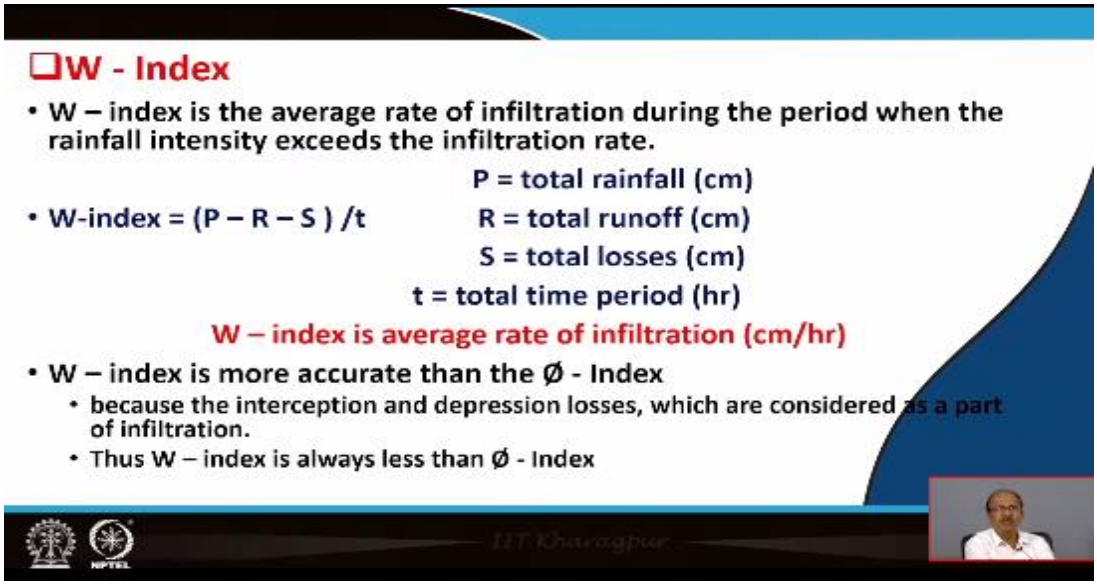
(Refer Slide Time: 27:53)



Now indices, some indices are also very important for finding the estimation of water losses the two increases are there Ø- index and W-index. Ø-index the determination of phi-index the horizontal line is drawn on the hydrograph. And such that the stated area above the time line is equal to the volume of surface runoff. So here it is the volume of surface runoff. Now unshaded area below the horizontal line you can see here these are the horizontal line unshaded area the actually represent all losses including interception, depression storage and infiltration.

But it assured that all these losses are due to the infiltration only. So the amount of rainfall in excess of high index is usually involved rainfall excess. So Ø- index is called as the rainfall excess. So, this is the Ø-index and W-index is very important in filtration indices through which we can find out the different types of losses in terms of interception, depression, storage and infiltration. So, through this we can find out the different types of losses.

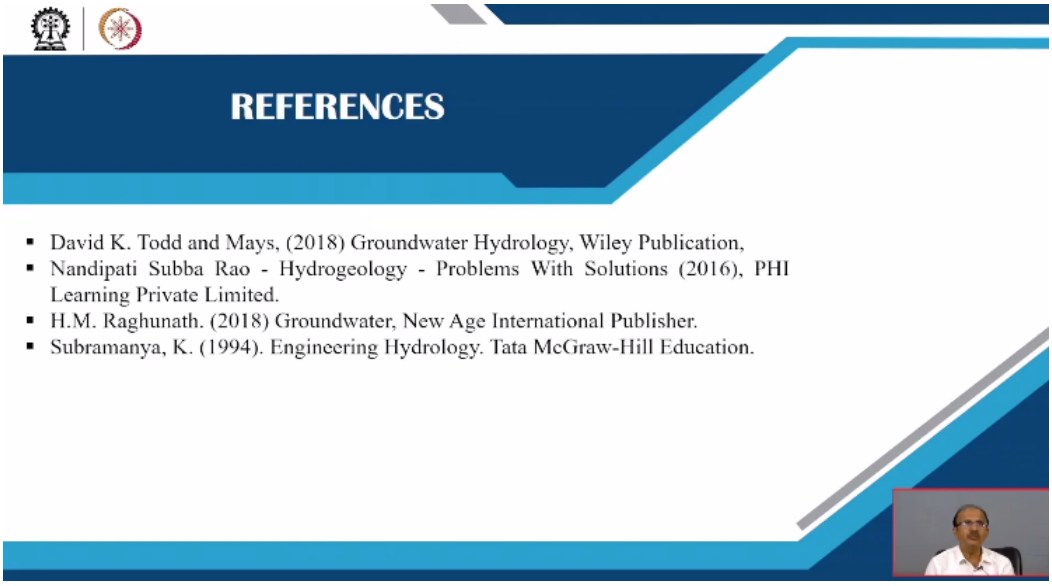
(Refer Slide Time: 29:01)



Now W-index is the average rate of infiltration during the period when the rainfall intensity exceeds the infiltration rate. So, W-index is the average the rate of infiltration. So, W-index can be written as W-index = (P – R – S) / t that P the total rainfall in centimeter, R is the total runoff in centimeter, S is the total losses in centimeter and t is the total time period in hours. So, W-index is average rate of independent infiltration in cm/hr.

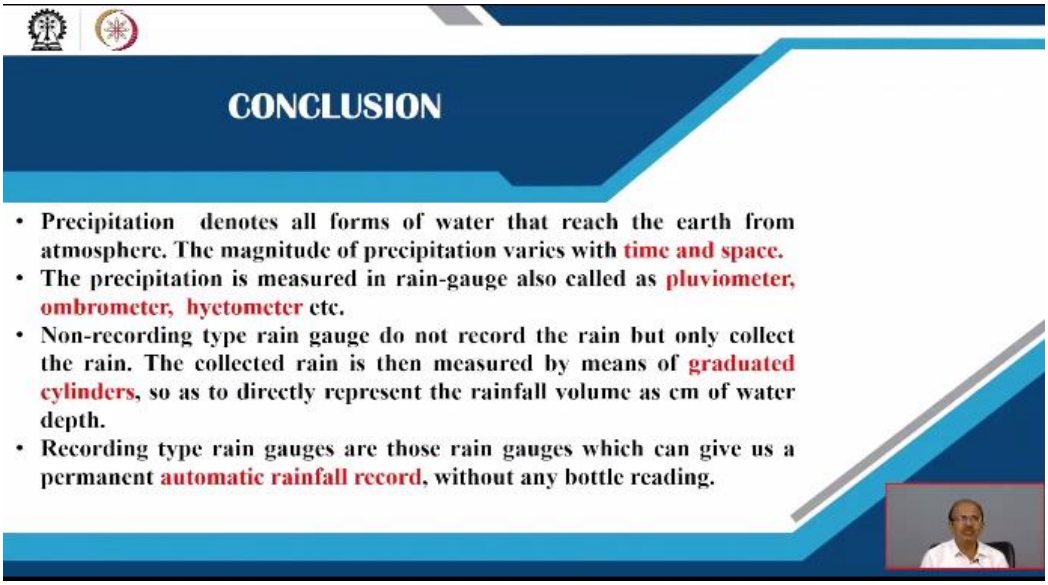
Where, W-index is more accurate than the phi-index. So W-index is the more accurate than the fine index because the interception and depression stop losses which are considered as a part of infiltration and thus W-index is always less than phi-index and because index is more accurate than the pi index because the interception and depression losses which are considered as a part of infiltration in the phi-index. So, W-index is always less than the phi-index

(Refer Slide Time: 30:11)



These references I have taken for making the lecture notes that is David Todd and Mays, Subba Rao and Raghunath and the Subramanya some of the eminent hydrology books is here.

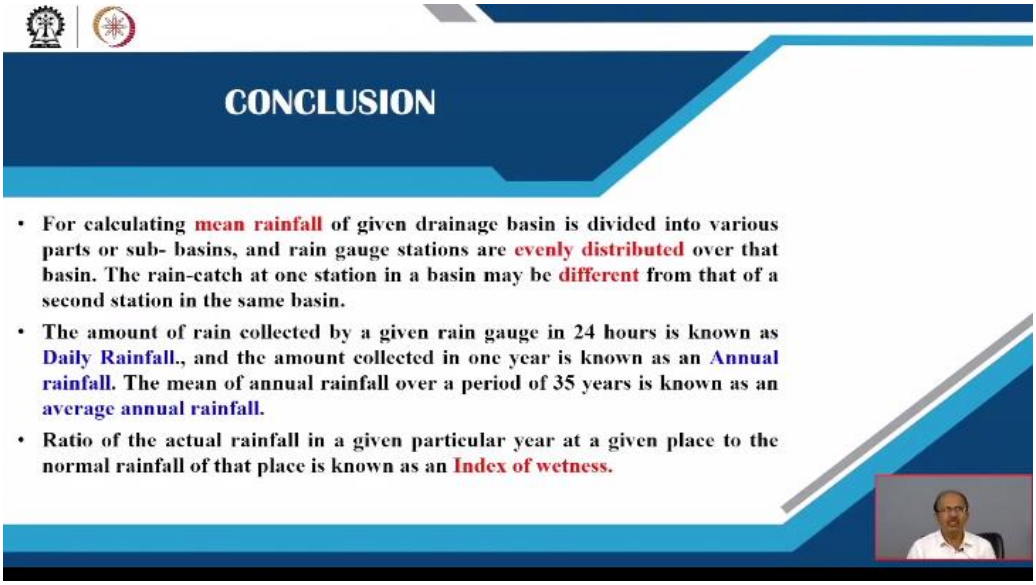
(Refer Slide Time: 30:29)



Now conclusion of this chapter that is the, your rainfall then the index of wetness, then the your infiltration is that in this module 8 we have discussed in details about the precipitation you know which denotes all forms of water that reach the earth from the atmosphere. The magnitude of precipitation varies with time and space the precipitation is measured in rain gauge also called as pluviometer, ombrometer and hyetometer.

The different types of rain gauges are there we have seen the non-recording type rain gauge do not record the rain but only collect the rain. Whereas the collected rain is then measured by means of graduated cylinder. So as to directly represent the rainfall as centimeter of water whereas the recording type rain gauges are those ranges which can give us a permanent automatic reinforced record without any bottle reading.

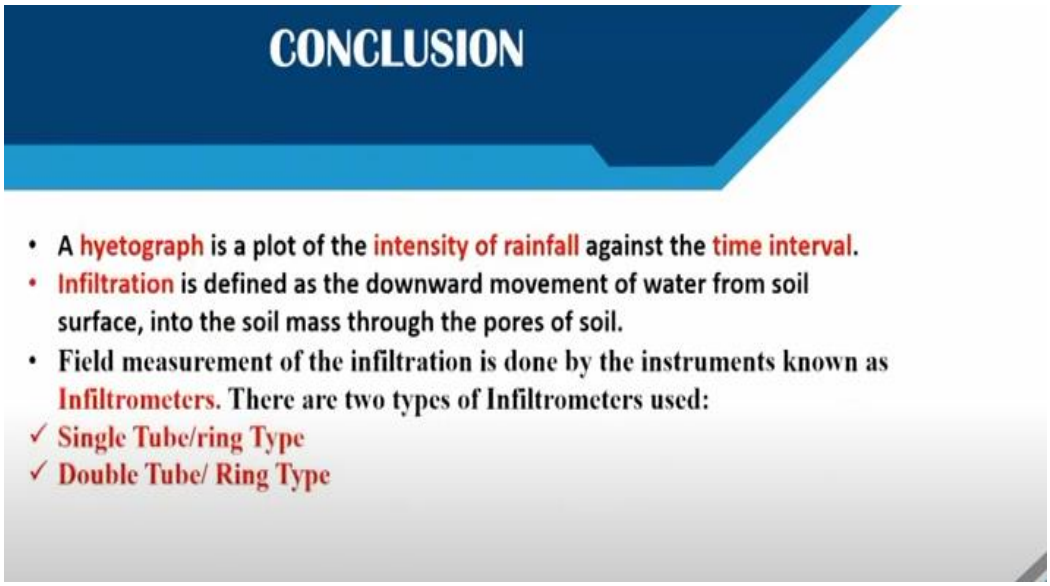
(Refer Slide Time: 31:28)



For calculation of the mean rainfall of any drainage basin generally the basin is divided into parts or sub-basin and the rain energy stations are evenly distributed over the basin area thus rainfall stations in one basin may be different from that of a second station in the same basin. So this way we can find out the main rainfall. The amount of rain collected by a given rain gauge in 24 hour is generally known as the rainfall and in one year it is known as annual rainfall.

In India it is considered about 35 years which is generally considered as the average annual rainfall. The ratio of the actual rainfall in a given particular year at a given place to the normal rainfall of that place is generally known as the index of wetness.

(Refer Slide Time: 32:18)



Now a hydrograph is a just a graph of the through which we can find out the intensity of rainfall against the time interval. And infiltration is defined as the downward movement of water from soil source into the soil mass through the pores of the soil. And for measurement of the infiltration is done by the instrument known as infiltrometers which are of two different types single ring infiltrometer and double ring infiltrometer.

So many discussions about the rainfall, index of wetness and infiltration. So now we have discussed in greater detail about the rainfall in this module. Thank you very much to all.