**Water Management**
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**Lecture 27**
**Furrow Irrigation System**

In the last class we were looking at the relationships which can be used for scientific design of the furrow irrigation system and we had seen started with some of the general defenses which we will have to sort out before you can apply the general relationships to the specific furrow irrigation method. Because of the fact that in the case of furrow is not, the application of water is not similar to what you do in the other two surface irrigation methods, border as well as the basin or the check irrigation method. There are different name given to that.

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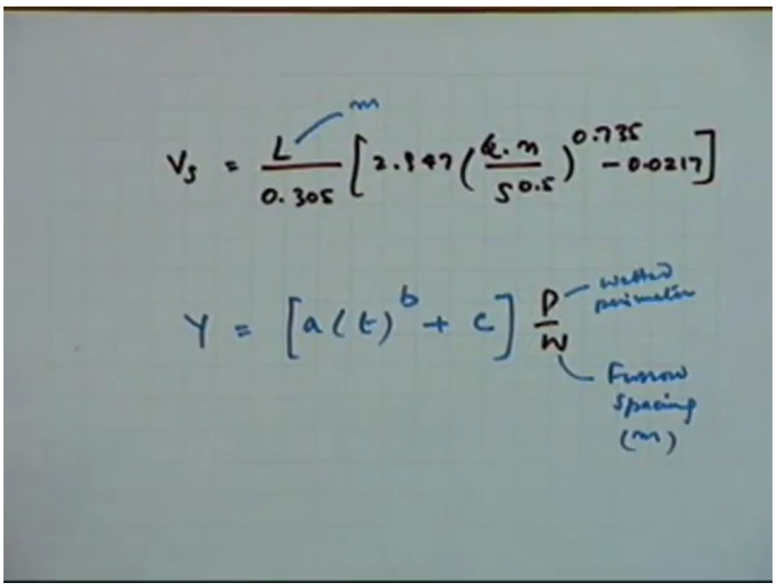


We had seen so far that how we can upgrade the relationship of the general infiltration curve which we had written down and we had incorporated the wetted perimeter and the furrow spacing to upgrade this relationship. Okay.

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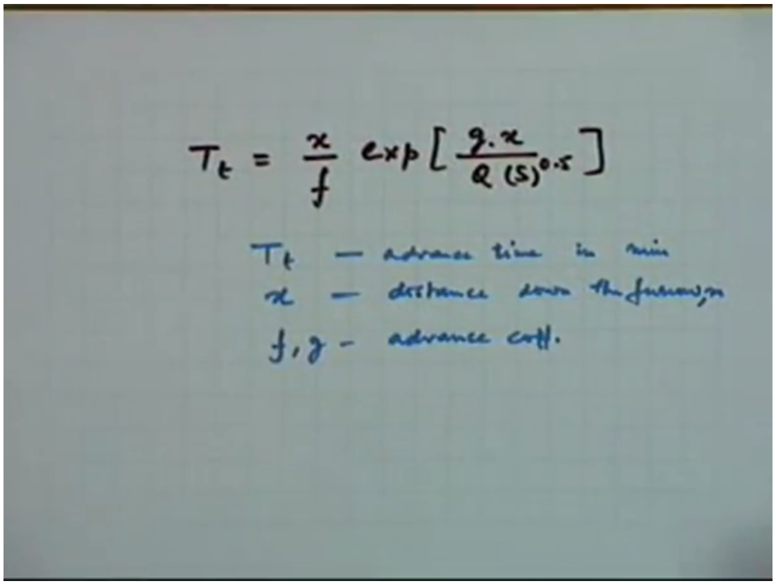


And we had also looked at another relationship which is used for finding out what is the advance time and this relationship we had seen what are the various variables, what do they mean and we had also seen some of the order of magnitude for some family curves.

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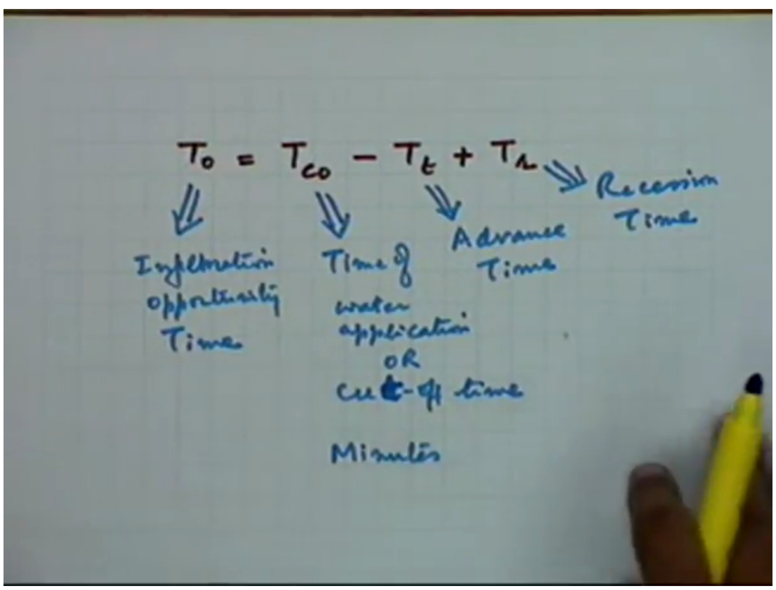


Now today we will start with the most important parameter which is the time of infiltration opportunity. But for how long this relationship between the time of infiltration opportunity, the time of water application and the advance time as well as the recession time? Now here this T0 is the infiltration opportunity time and Tc0 we have looked at all these different variables or layer. Tc0 is the time of water application. You can also call this as the cutoff time.

Now this cutoff time is the time up to which you are supplying the time. This is the advance time, we know it. And Tr is the recession time. All these times are generally expressed in minutes. This general equation, if you look at various components, the Tc0 which is the time of water application, this is the one which is in hand of the management. The farmer makes decisions about this Tc0 for how long he wants to make the water available for the field.

So this is something which dependent on the management of the system. Either the decision is taken by the farmer or it can depend on the availability of water, how the water is made available in the total network. It will be related to that but the ultimate decision is in the hand of the farmer how long he wants to make this water available.

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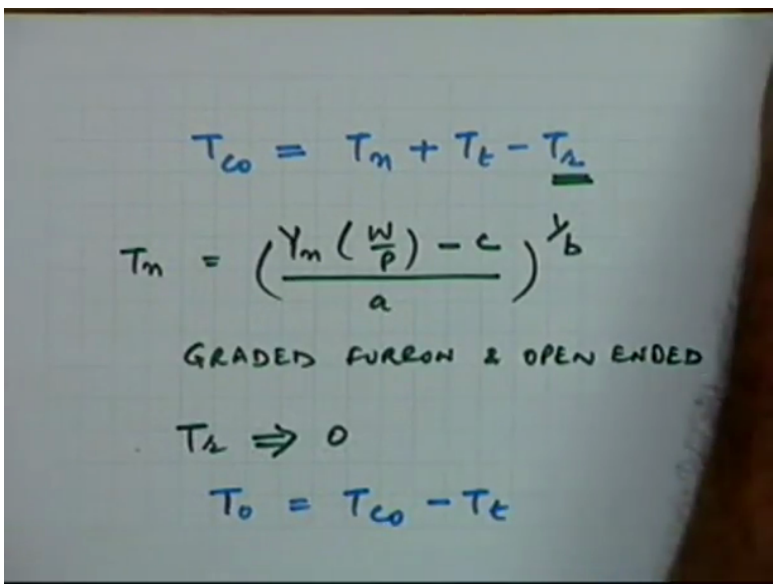


$$T_{co} = T_n + T_t - T_r$$

$$T_n = \left(\frac{Y_m\left(\frac{W}{P}\right) - c}{a}\right)^{1/b}$$

$$T_r \Rightarrow 0$$

$$T_o = T_{co} - T_t$$

So if you try to look at this Tc0, it can be taken to be equal to the net time requirement plus the advance time minus the recession time. So preferably if you want to take care of the net irrigation requirement, this is one indicator which is available to you when you design the system that how much, what should be the order of magnitude of Tc0. It can be known from these three items: the net irrigation time, the advance time and the recession time.

As far as the component of net time is concerned you can use the infiltration, the modified infiltration equation to find out what is the net time requirement. So if you write this equation, this is the net depth which is required. This is the same equation which we had written in the, for Yn that is transformed to get this, obtain the value of Tn. The same equation can be used to find out what is the order of magnitude of the net time requirement to satisfy or to satisfy requirement of Yn which is the net irrigation depth requirement. That is known a priori. That you know when you go in for the design or that irrigation you know that how much is the net depth of irrigation requirement and you can always decide to start the irrigation at that level when the net irrigation requirement is of that order of magnitude.

Then this component of Tr, the recession time can be safely taken as 0 if you consider the graded furrows. And they are open-ended. So if you have open-ended furrows which are having some grade, you will find that the value of Tr, the recession time will approach 0. You can safely assume this to be 0 if you the graded furrows which are open-ended furrows. So you are left with the T0, the previous equation which we had started with. T0 is, can be approximated to Tc0 minus Tt.

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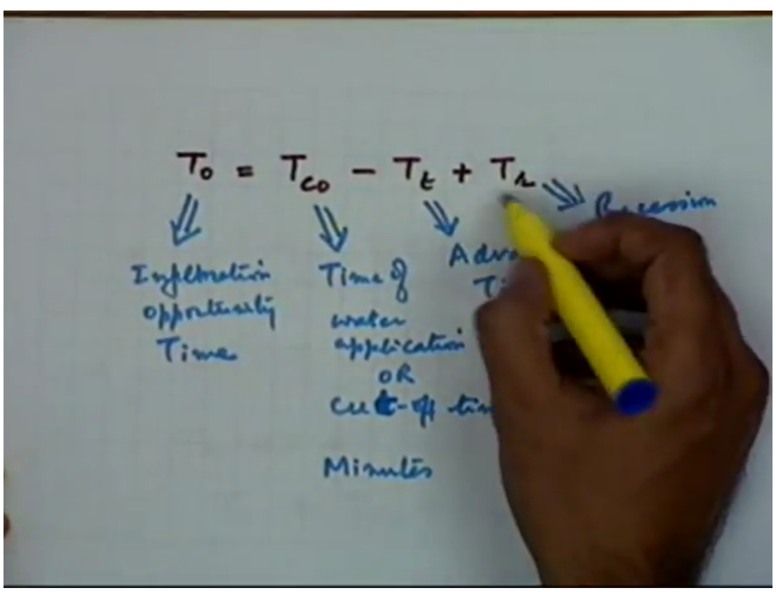


And this equation, this term becomes 0.

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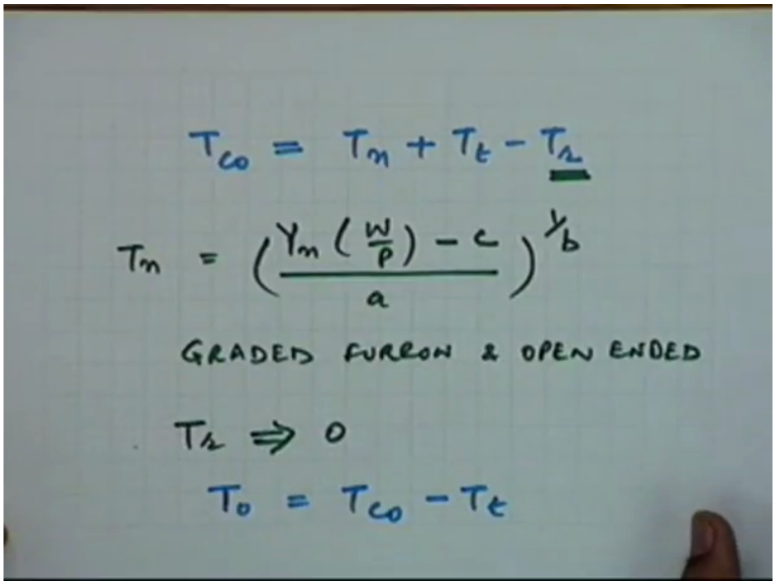


And you are left with this part of the equation. And we have also seen that this Tc0 can be obtained from, the order of magnitude of Tc0 can be obtained from this equation which in turn…..

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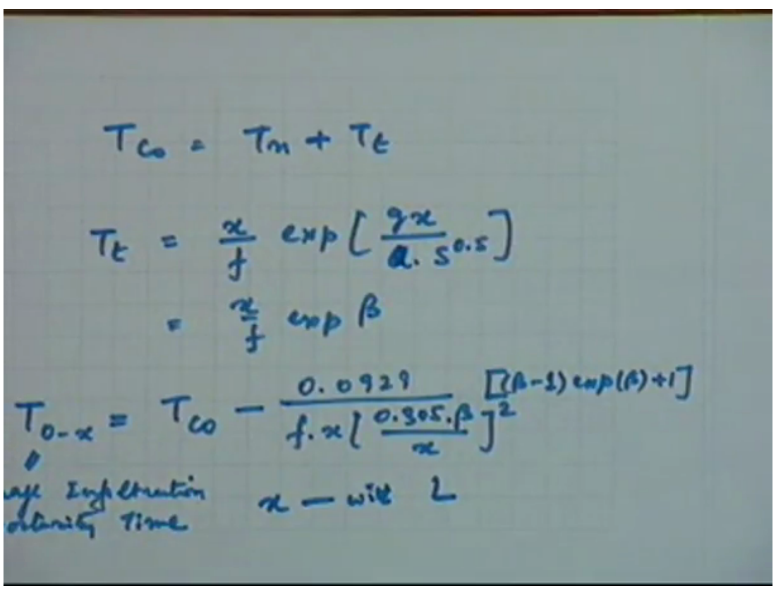


The Tc0 has also modified to Tn minus, Tn plus Tt. This Tt is the time, the advance time taken to reach, for the water to reach the downstream end. Okay. But you can also find out, depends when you start with, either you might be knowing the length of the furrow. In some cases you do not know the length of the furrow. So that case you might have to do some trial and error procedure, you might have to adopt. We will come to that later.

Right now let us assume that this Tt is the advance time with respect to the length of the furrow, the water, how much time water reaches, water takes to reach the downstream end of the furrow that is what Tt is corresponding to. And this Tt, we have also seen that you can predict this Tt depending on the this general equation we had written earlier, that you can use this relationship to find out what is the value of Tt.

And if I put this term equal to beta, I can simplify and write this equation as this. Now this equation we have seen that you are having the, there is a function, this is dependent on the family curve and these variables are available, g and f, these two variables are available for different family curves. So once you know the family curve, once you know the characteristics of the soil, you can find out how much will be the advance time with respect to those.

And here this also incorporates the other characteristics of the furrow, what is the slope, what is the stream size. So having known this, this general equation, this will give you the time for a specific point, for a specific section of the furrow. You can also use this general equation to find out what will happen on the average. To do that, you can take the differential of this and that is what is done in another equation which has been written for any segment of the furrow up to a particular length.

So if we take that, you want to take the average value up to a distance x, then you can write this, the average infiltration opportunity time. This is what is the average infiltration opportunity time up to a distance of x. This is equal to Tc0, is the cutoff time, minus the advance time, the average advance time for the segment. So that is given in the form of this expression, f times x, 0.3905 into beta divided by x square into beta minus 1. This is the total expression which is used for finding out the average infiltration opportunity time for any segment up to any length of the furrow.

So if you want to find out the average infiltration time over the total length of the furrow, you replace x with the length L. Having found this time now let us go to the, those items what we are interested in, is in the design, we are interested in some specifics, some efficiencies and the amount of wastage which we are incurring.

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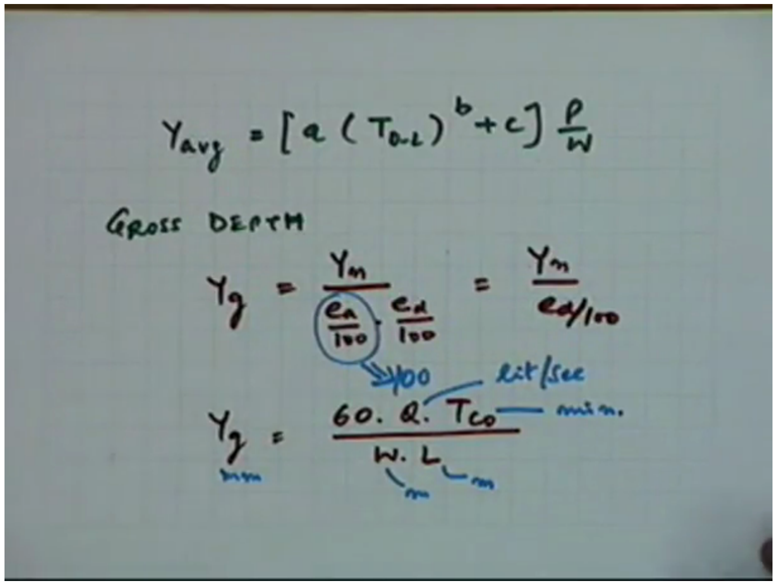


One of the item is the, to find out those wastages you will have to find out what is the average infiltration which has been made available in the stretch of the furrow. This can be obtained using the same equation but replacing the time, the opportunity time which is the time for the length of the furrow, that is what is T0L. So you can use this relationship to find out what will be the average depth of infiltration for the length of the furrow which can also be used for finding out the average depth of infiltration for any length.

In that case you will have to substitute appropriate time here up to that distance. Then you are interested in what is the gross depth. Gross depth can be obtained, let us call it Yg, gross depth can either be obtained by if you know what is the net depth and the efficiency. The efficiency to be used is the application efficiency and the distribution pattern efficiency. But quite this part, the application efficiency for the surface irrigation systems can be approximated to 0 because it is approximated to 100 percent because you are not losing any water from the device. When it comes up to the surface you are not losing any water, the way we had defined this efficiency.

So in other methods this efficiency might be much less. So this will be, this can safely be put as, now this is one way of finding out what is the gross requirement provided you know the distribution efficiency, the distribution pattern efficiency which is not always known because that you will have to, you might have to (evolve) evaluation procedure before you can find out what is the ed.

Or you use a value which is already found out for that particular area under those conditions. This is not necessary that you always know this. You can also find out the equivalent gross depth from the other parameters which is the stream size, the time of cutoff or for how long we have supplied that water and spacing between the furrows and the length of the furrow. This will, the various items, Yg will be in millimeters. If Q is in liters per second and Tc0 is in minutes, this is in meters and this is in meters. Okay.

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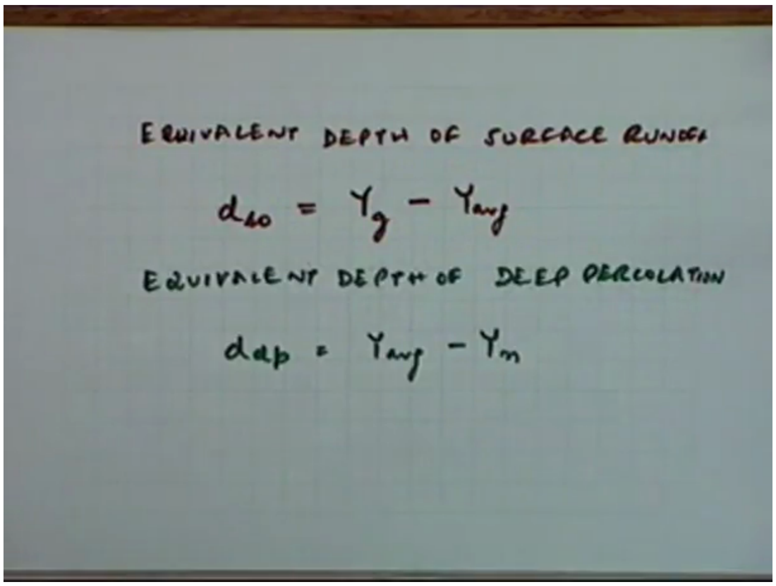


So once you have found out the equivalent gross depth of application, you are basically now interested in knowing what is the equivalent depth of surface runoff. If we call it as dr0, depth of runoff, surface runoff, that will be equal to the gross depth minus the average depth. Okay. Then you are also interested in another item that how much, there is one form of loss which would be prevalent in the furrows. The other form of loss is the deep percolation.

The equivalent depth of deep percolation, let us call it, this is Y average minus the net depth of irrigation. So once, you can find out these two items, you can also find out all the other efficiencies which you are interested in, which you have dealt with. That is how you can evaluate specific system which you have evolved and you can change some of the parameters, see how these values change. It is not always necessary, they all, they are also graphical procedures, the graphical they are some charts which have been formulated, they are available, you can directly use those charts.

And they, all these charts are based on these relationships. So once you use those charts, you can arrive at some of the preferable parameters and you can use those parameters. To make this more clear let us take one more actual data and see that what, we will just go through the one example program, example data and show you that how you actually perform, how you actually use these relationships to arrive at a the specific values.

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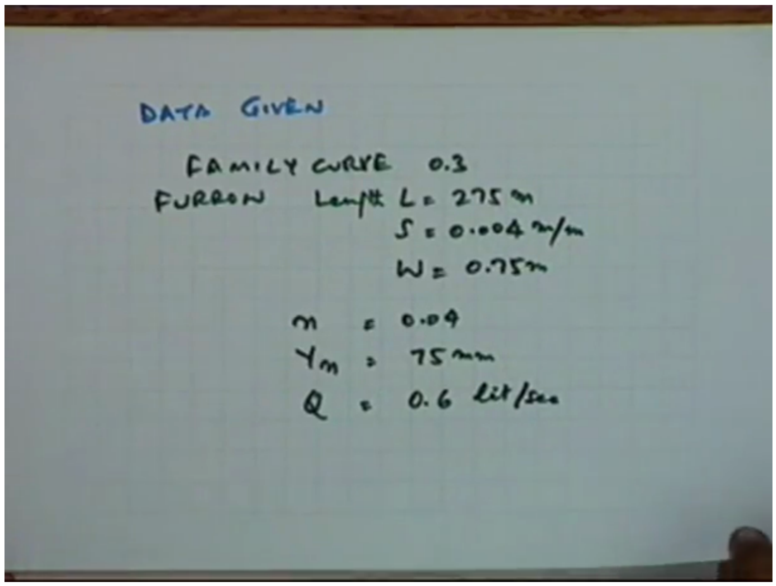


I will quickly go through this. The data given in this, you have the data available on what is the family curve. It has value of 0.3, then the data on furrows. The various data on furrow, one is the length, length is 275 meters which is the given length available. Then slope is 0.004 meters per meter, the width or the spacing between the furrows is 0.7 meter. The other characteristics of the soil are given in the form of n value, 0.04. And the requirement, the net irrigation depth is given as 75 millimeters.

So that is the requirement and another parameter which is available is a stream size. The stream size which is available is 0.6 liters per second. So with this data now you want to design the system or at least check the system for the various type of efficiencies and losses which you are incurring. But if you have this, these parameters fixed to these values, will be the end result.

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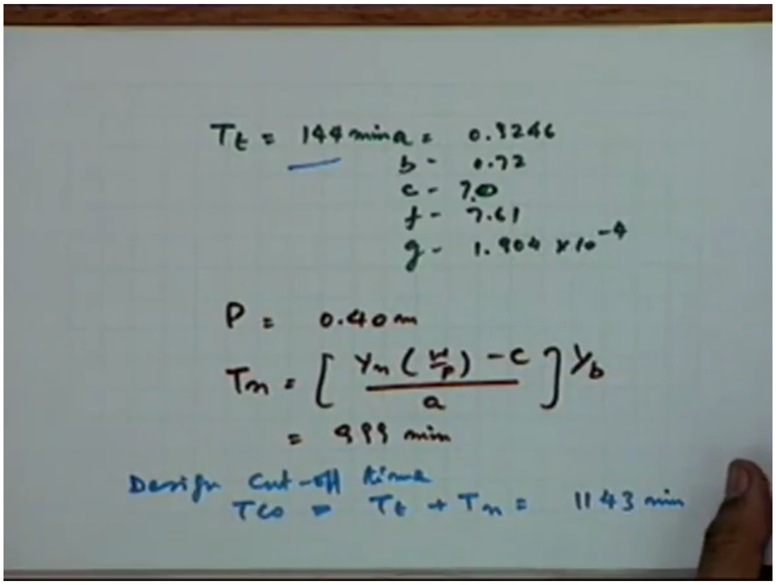


Now the first thing you should, which you will like to know is that what is the advance time for this family curve. And to do that, you know the family curve. The corresponding values of a, b, c and f and g parameters, they are known. a is 0.9246, b is 0.72, c is 7.0 and f is 7.61, this is 1.904 into is for minus 4. Having known this you can find out what will be the value of Tt for the length of 275 meters and that Tt is, comes to 144 minutes.

Having known this, this is a parameter which is now available to you with respect to the characteristics of the soil and the furrow characteristics because while evaluating the beta you have used the Q and S also, as well as the other parameters of f and g. Then you can find out the adjusted weighted parameter, this P and this adjusted weighted parameter is 0.4 meters. You can also find out the net infiltration time, Tn. You have the relationship for that which is based on the modified infiltration opportunity curve which is we have already written this, minus c and this gives time requirement, the net for this net infiltration time.

To get a depth of Yn you need 999 minutes. Then you can find out the design cutoff time which is Tc0 which was Tt plus the net time. And this is the summation of 999 and the advance time which was found to be 144 minutes. So this is the total design cutoff time. That means you should cut off the water only after this time.

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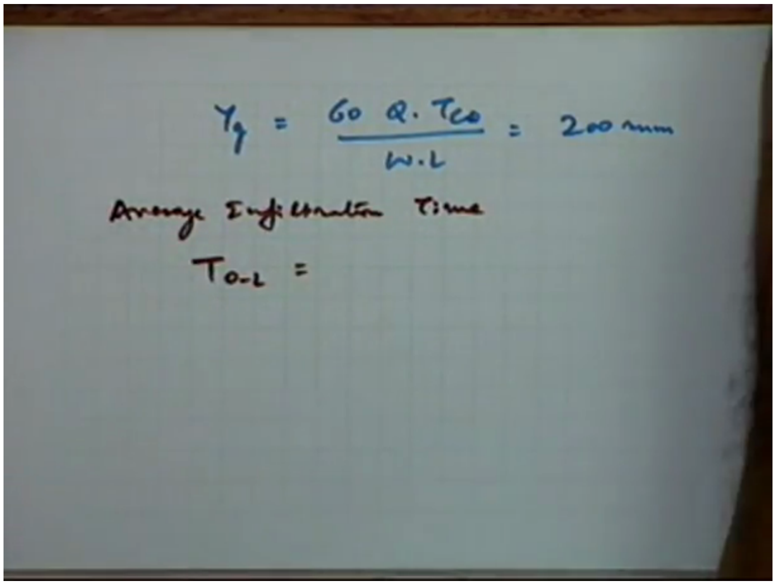


You can also find out the gross depth from the this equation where Q is known, Tc0 is known, W is known, L is known. And this comes to be 200 millimeters. Now you can see here that with respect to the other parameters, the gross depth is way above the net irrigation depth. Net irrigation depth is only 75 millimeters whereas you are required to apply 200 millimeters of depth. So now you can also find out the average infiltration time and we have seen that this relationship you can, we have seen the relationship which is written earlier.

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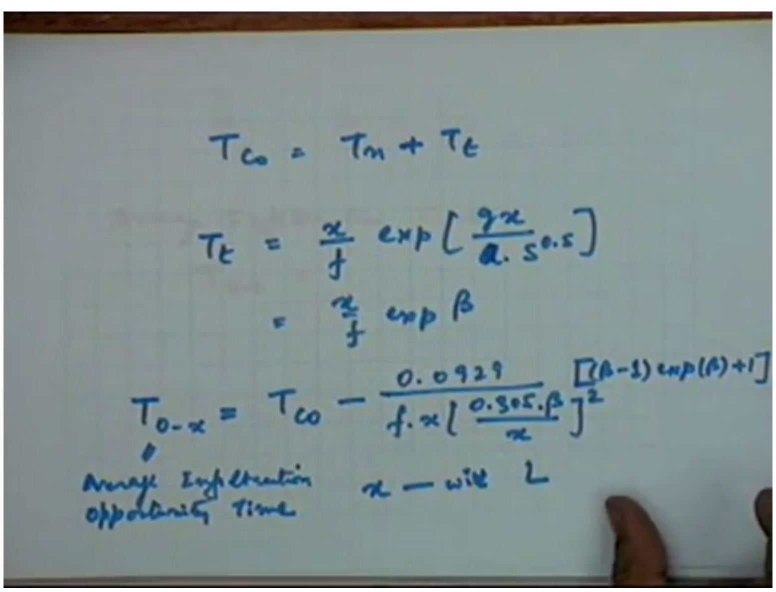

And this relationship you can substitute the value of x as L and all the other values are known. And you can find out what is the average infiltration opportunity time for the whole length.

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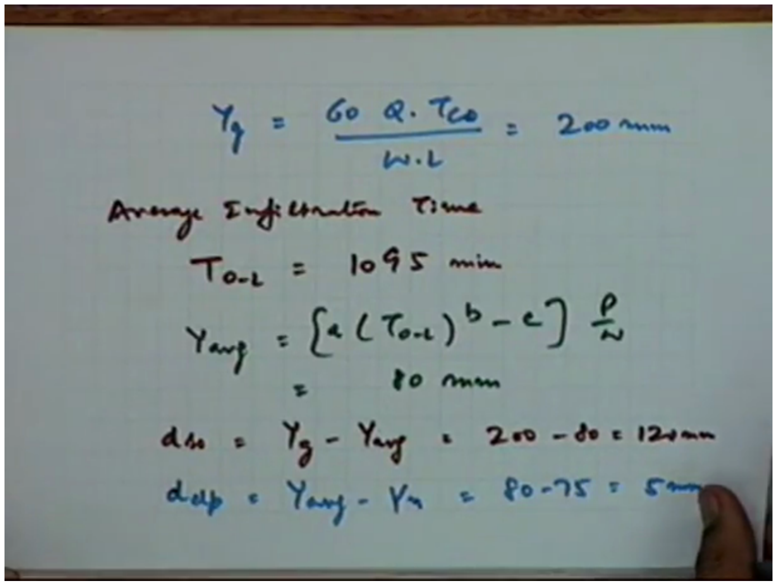


And it works out to be 1,095 minutes. Okay. Now the average infiltration depth can also be found out using this relationship and this works to be 80 millimeters. And now having obtained all these different values, you can compute what is the surface runoff, dro which is the variation between Yg and Y average. Yg is 200 millimeters, and Y average is (100) 80. So you are losing 122, 120 millimeters of water through the surface runoff. And deep percolation is only 5 millimeters. This is average infiltration depth, this is the net infiltration depth. So on the average we are losing around 5 millimeters of deep percolation.

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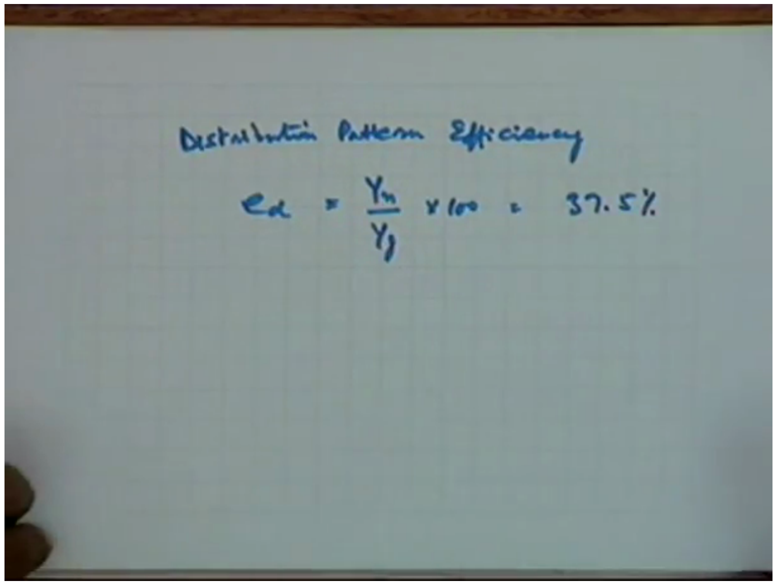


Similarly you can also find out the distribution pattern efficiency which is nothing but the Yn by Yg into 100 which works out to be 37.5 percent only. Okay. Now these details have given you insight into what is the level of efficiency which we have obtained if you fix these parameters or if you adopt these parameters and how much losses you are incurring in. Basically the efficiency is also dependent on the losses only. So looking at these values, you can decide whether this is acceptable to you or not. If it is not acceptable, then you can change some of the parameters depending on what is with the newer reach.

For example, you might not be able to change the grade if you do not want to incur any more money. You might be able to only change the length which is again is not very difficult to take into consideration or the stream size which is again within your command. You cannot possibly change the soil type, it is not possible. Once you have a soil type of known nature, it will behave in the same manner. Okay.

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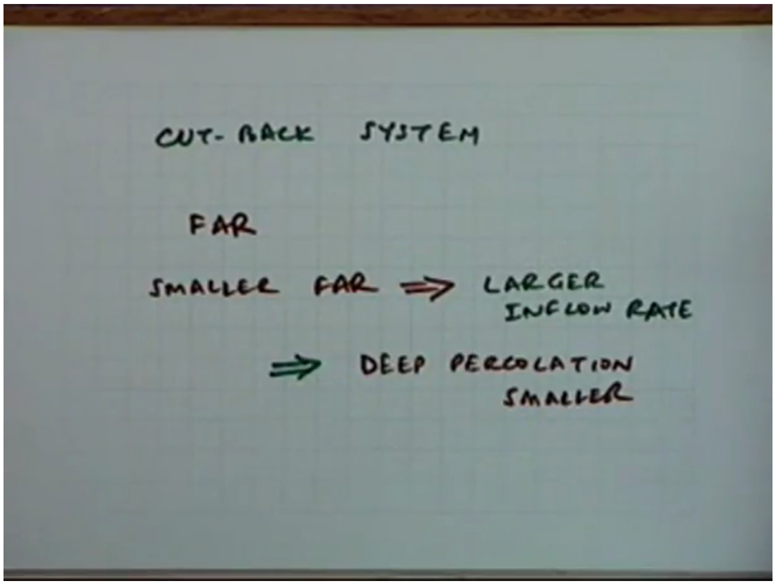


Let us go to the another important feature which has come out from experience and this is technique which is used in the furrow irrigation system, is only a technique of managing the water, the operation. During the operation you use the water in such a manner that you enhance the efficiency. And this procedure is called the cutback system. In this system what you do is that you try to choose a higher stream size to start with.

When we say higher, it has to be non-erosive. So you choose high stream size so that you can wet the whole length of the furrow in some short period. And then you reduce the stream size. By doing so it has been found that you enhance the efficiencies. Why it is so? You must have observed earlier that we had defined. Let us try to look at the system with respect to the FAR, the fractional advance ratio.

If you remember we had, I had given you some values of the FAR table. In the FAR table, you must have noticed that the smaller the FAR, lesser is the amount of losses. And when the FAR will be smaller? When you are spreading the water throughout the total length in a relatively shorter period which means for smaller FAR ratio, this corresponds to the larger inflow rates. And when the inflow rate are larger for smaller FAR ratios we have seen that your deep percolation losses are, they are also smaller. We have relatively lesser deep percolation losses when you reduce the FAR ratio. That is what has been adopted in this particular cutback system. That you try to use FAR which is very small and you try to wet the whole furrow. Once you have done that, then you reduce the stream size and you ensure that the net irrigation requirement is taken care of.

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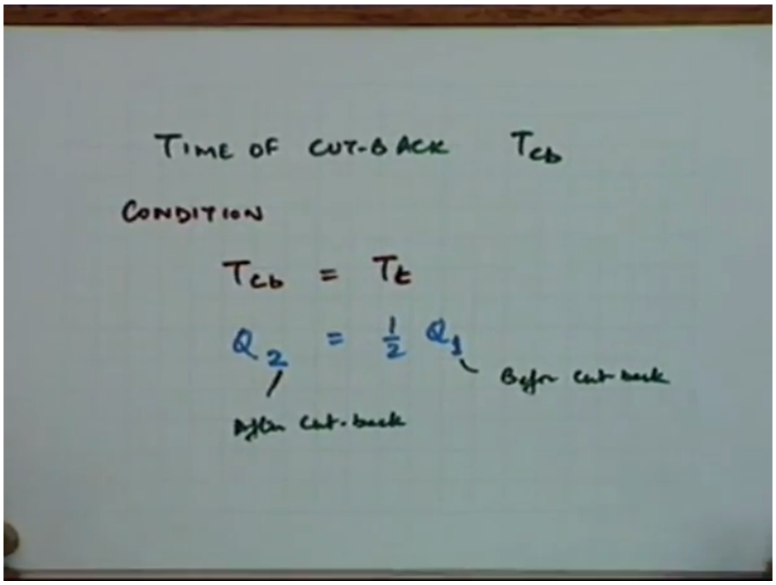


So there are some equations which have been modified from the previous equations to account for this cutback system. Let us look at those relationships, how they have been changed to account for all this procedure of cutback system. But before we do that, let us define some additional parameters which are relevant with the cutback system. These parameters are time of cutback which is you can define as Tcb.

The equations which we are going to introduce, they are with the condition that Tcb is equal to the time of advance Tt. That you cut back the stream size once the water reaches the downstream end. Okay. And the other condition is that the final flow, final stream size, the cutback size which let me call it Q2 is equal to half the initial stream size which is Q1. So 1 belongs to conditions, the suffix 1 belongs to conditions before the cutback and 2 after cutback. Okay.

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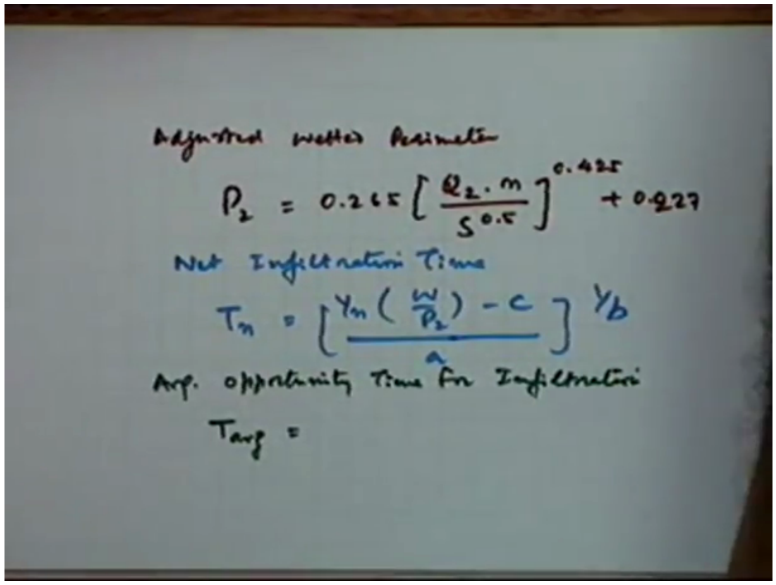


Now the equations which are modified, first is the relationship of adjusted weighted parameter. Adjusted weighted parameter is now for the condition of perimeter after the cutback, is designated as P2. And instead of using Q here, we will use Q2 which is the cutback stream size. Otherwise the equation is same. Okay. Similarly the other equation which will need change will be the equation of required net infiltration time which will now will be, only difference is that the adjusted weighted perimeter, appropriate perimeter will have to be introduced. Similarly the average opportunity time for infiltration, this parameter will be, only the second term, the equation which we had written earlier, we will pick up the second term of that only.

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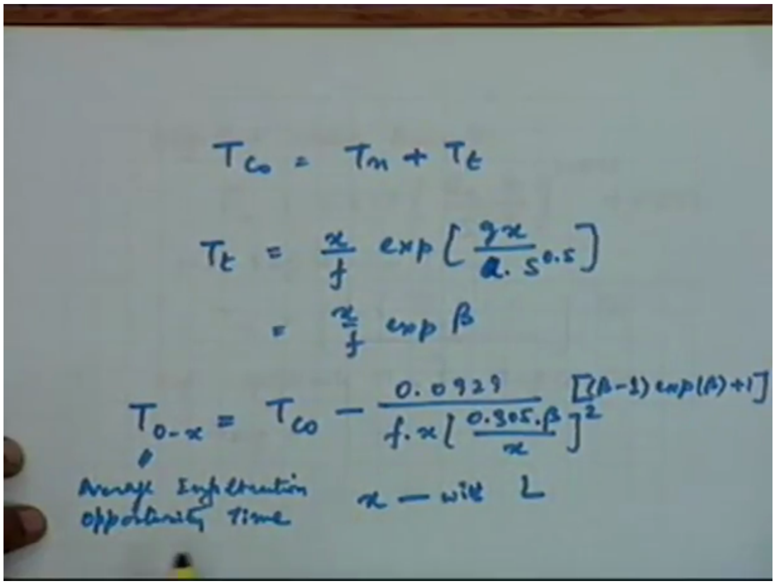


And take the this equation. Now Tc0 we are not concerned with because that has been taken care of before the cutoff period. Okay. We are only concerned with this part which is giving the average infiltration opportunity time after the period after the cutoff.

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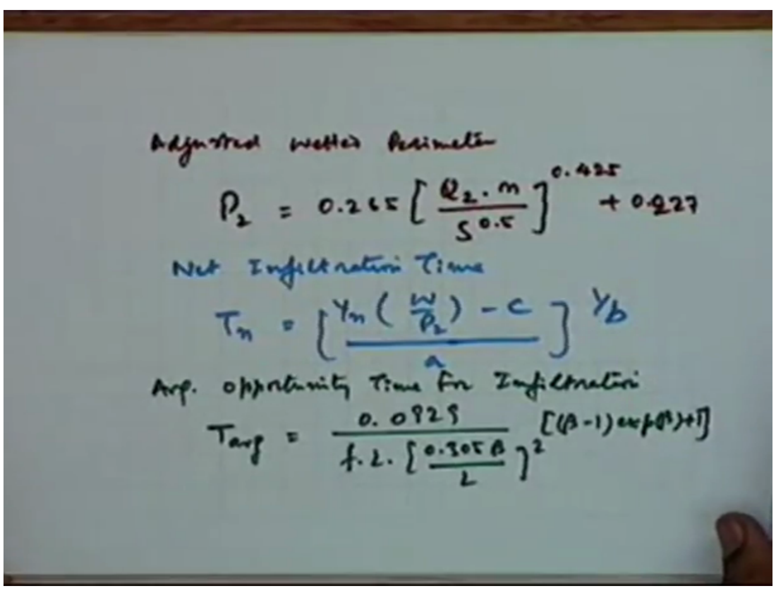


That will be only represented by the second component or the second term of the equation which is now can be written as, okay.

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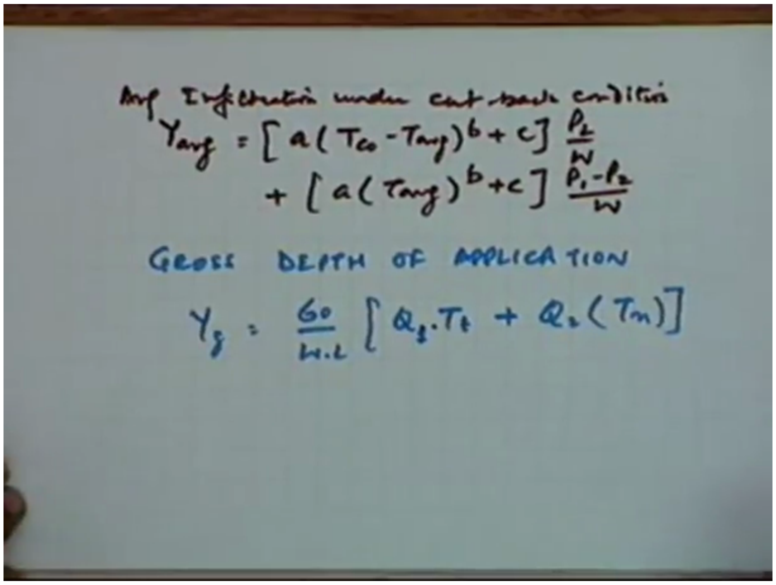


And similarly the equation for average infiltration under cutback conditions which is, which will be now transformed to, you have two components and one before the cutback and one after the cutback. This will be the relationship which will give you the average infiltration under cutback condition. And similarly the relationship for the gross depth of application will also be modified, is Q1 into the time Tt, plus Q2 will be prevailing during time Tn.

So you have taken into consideration the effect of the timing corresponding to the corresponding discharges or stream sizes. Now once you have this particular change in the relationships, you can again find out what will be the various quantities. And just to show how much variation it makes taking the same data which we have taken for the previous example, let us find out that if you cut back, use the cutback system in a way that you cut back the stream size after two half the original stream size after the water has reached the downstream end of the furrow, then what will happen?

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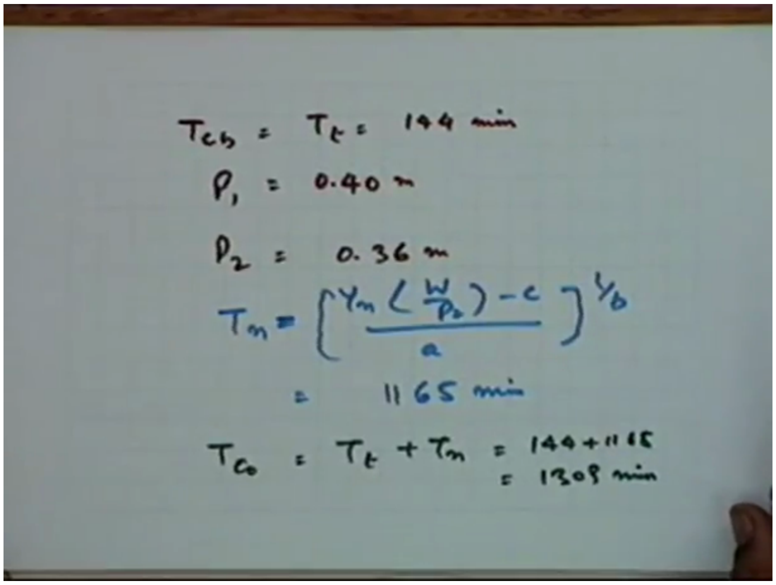


To do that the, we now that the cutback time is equal to the time of advance which was, which we have found out in the previous case as 144 minutes. The adjusted weighted perimeter during the condition before the cutback we had found out to be 0.4 meter. That we will, we are calling it as P1 now. And you can find out P2, P2 works out to be 0.36 meters. This is the adjusted weighted perimeter after the cutback.

And similarly you can find out the Tn and Tn is basically, will be equal to now, and it is 1,165 minutes. So the time of cutoff works out to be 1,309 minutes. In comparison to the previous case, the time of cutoff has increased slightly. That means you are supplying water for a longer period by the same time, is not at the same rate, is much less in terms of volume.

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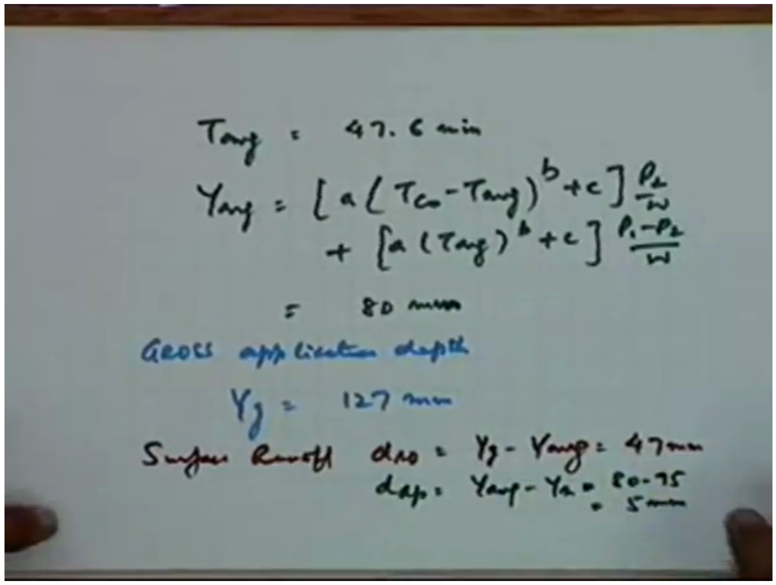

You find out the other quantities, the average infiltration time during advance period, works out to be 47.6 minutes and the average infiltration correspondingly which you have, we have given expression that it will be dependent on, plus the other term, and this works out to be 80 millimeters which is same as before. But the gross application depth, this is 127 millimeters. Earlier we had found out the gross application depth as 200 millimeters. So this is drastically reduced.

And thereby the surface runoff which is dro, is only 47 millimeters instead of 120 millimeters the previous case. The deep percolation has also reduced. Deep percolation was the quite minimum, is not reduced, is the same. The major difference has been made by the surface runoff component.

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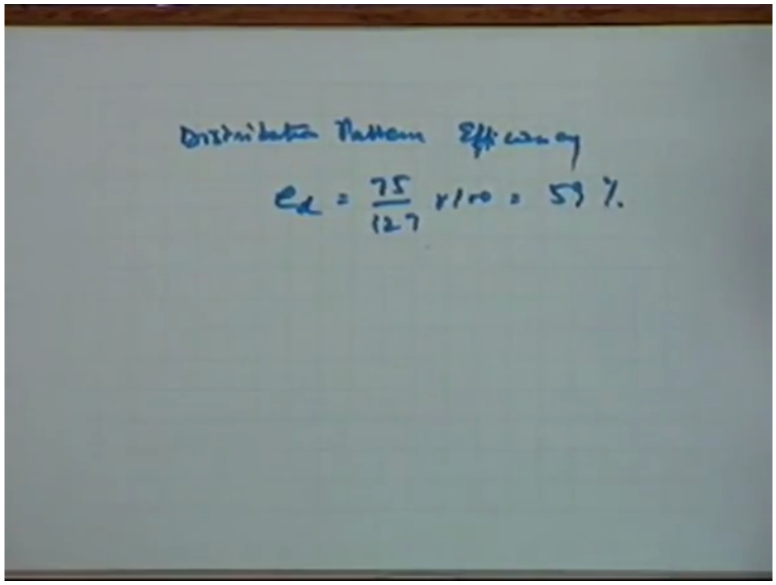


And with the result, the distribution pattern efficiency now will be 75 by 127 into 100. So now this is increased considerably. In the earlier case it had around 36 percent or so, now we have 59 percent distribution pattern efficiency. So you can see that by just, everything else is same, by just changing the way you apply the water, by introducing a procedure by which you can reduce the supply, the first stream size which has been used that has ensured that the whole surface is wet.

And if you keep the same stream size, then you are wasting lot of water through the surface runoff because the infiltration rates keep on reducing as we have seen the infiltration capacity curve show that the infiltration rates, they reduce with time. So to account for that and to take advantage of that, the system of cutback is very beneficial in the case of furrow systems. Okay. Any question? We will stop here today.