Water Management
Prof. Dr. A. K. Gosain
Department of Civil Engineering
Indian Institute of Technology Delhi
Lecture 22
Border Irrigation System

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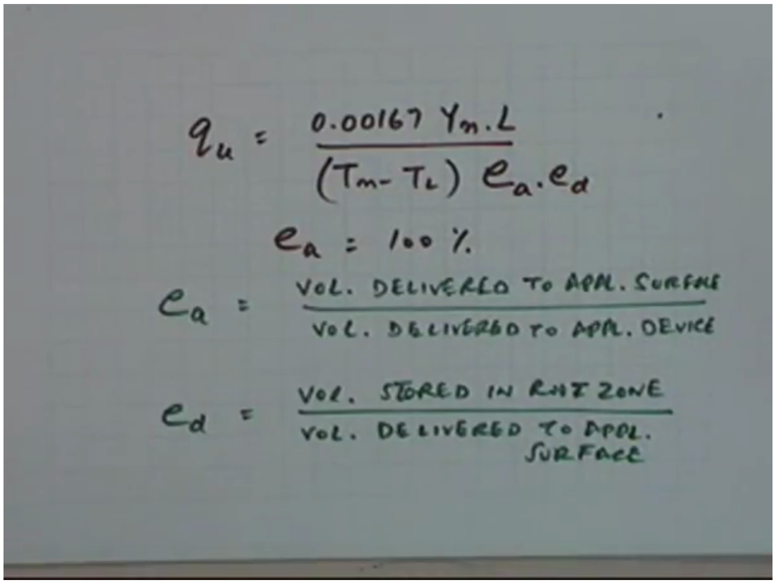

In the last lecture we were discussing the various design parameters of the border irrigation system and I had given you this equation for, this was the equation which we had written for the unit rate of application or the unit stream size. And I had used an efficiency which I had called application efficiency. The way we have defined our application efficiency if we recall, we are defining the application efficiency has two components: one is the application efficiency and the other is distribution pattern efficiency.

So in our case because there is lot of overlap in these areas we had defined an application efficiency which was volume delivered to the applications of surface to the volume of water delivered to application device. That is how we had defined our application efficiency. Remember that. And along with this we had defined another efficiency though this is multiplied by 100. There is another efficiency which was the distribution pattern efficiency. So ed we are calling as distribution pattern efficiency and that was volume of water stored in root zone to the volume delivered to application surface.

That was what the combination of these two we said will give you the application efficiency as is normally defined, is not it? So in this we will rather than using just ea, we can either say is (multi), is combination of ea and ed. But specifically in this particular situation is assumed that ea as defined here ea is 100 percent. That means there is no loss when you are supplying the water from the device onto the application surface.

So we are assuming that there is no loss in real application because this is a general purpose definition which is also used in the context of sprinkler system where you might be losing some water when the water comes out of the sprinkler head or the sprinkler nozzle and is applied onto the surface of the field, the application surface.

When this particular situation when you are using the irrigation methods you might find that this can be easily taken as 100 percent, okay? So your application efficiency is basically confined to the ed value. So instead of using ea as we had used in the last class, I think we will better either use the combination of these two or if we assume that ea is 100 percent as per this definition, we will just use ed which will give you the distribution pattern efficiency which will give you an idea that how much of the water is actually stored in the root zone in comparison to what has been delivered. Okay.

So the, this efficiency ed, what is the level of efficiency which should be used when you are designing a system? You have to have some available values from the experimentation, from the actual data available and that is available in the form of some tables and once such table is available which I will make available to you during the course of your notes or the sport material which I am preparing for you.

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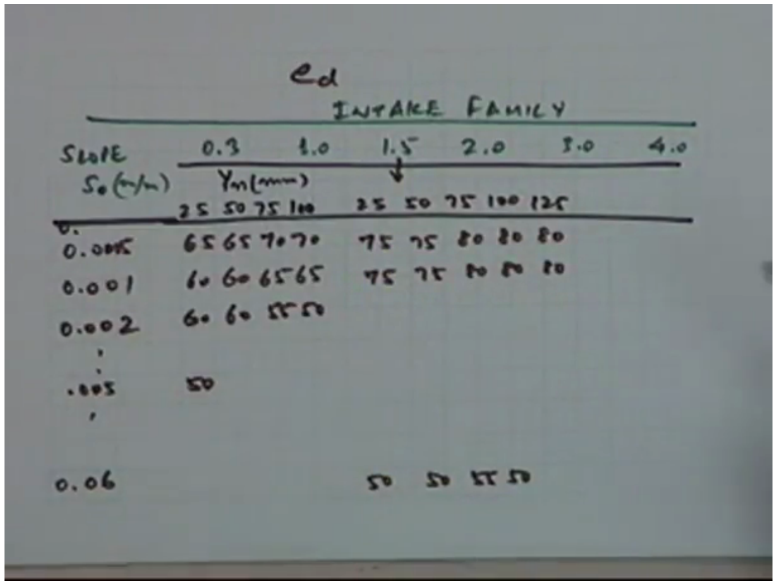

But I will just give you the suggested design, application efficiency or the design distribution that the pattern efficiency which we have just defined. This ed value is given for different intake families and we had discussed what the intake families are. So for different intake families, there are relationships available where you have for different slopes and the slopes are given in meters per meter. For different slopes and for different intake families, let us say that these are the ranges of the intake families which we will in turn suggest what is the type of soil which we are using.

So intake family will basically the, this value is a function of what type of soil you are using. And it will also depend on along with the intake family how much is the depth of application, okay? And the depths of application, they are, these are the various possible depths which are frequently in use: 25 millimeters, this will be in millimeters, 25 millimeters, 50 millimeters, 70 millimeters, 100 millimeters.

In some cases you might have 125 millimeters also. These are the most common depths which are prevalent in actual use. So dependent on what is the intake family, what is the value of the slope, the slope variation again they are different prevailing slopes which might be, the range can be quite large and so on. You might go up to around 6 percent, this 6 percent and here we are using it in meters per meter.

In terms of percentage, this will be 6 percent, this will be 0.05 percent. For these slopes, for a specific value of the depth of application and for a specific value of the intake family there are some recommended efficiencies which are the design efficiencies which are achievable efficiencies. Those efficiencies can be used to find out the unit stream size. I will give you idea about, for the case of family of 1.5 and for the values of depth of application of this range.

Just to give you an idea what can be the possible variations of these efficiencies for the slope is again 75, 75, 80 percent, 80 percent, 80 percent. Let us look at the last slope here, 50 percent, 55 percent, 50 percent. So this is the variation. I have just picked up some values from the recommended values from, of the table. You will find that these are some values in this category also for 0.3 intake family. What is the order of magnitude of these?

You will find that in general when the slopes are flatter, you can get the higher values of efficiencies. When the slopes increase, in some cases it might not be feasible anymore to have under specific intake family. You might not be able to use a slope beyond that specific slope. For example, in this case the value of 50 percent efficiency is achievable when you have a slope of 0.5 percent and the depth we applied is 25 millimeters. Okay.

You might not be able to get an efficiency which is even 50 percent if you try to apply a depth which is more than 25 millimeters with such a slope and with such a family of the soil. So they are some recommended efficiencies or the efficiencies which have been seen to be achievable through the experimentation, those values have been, they have been recommended here. You can use them for your design purpose. Okay.

In general you will find that the higher efficiencies can be achieved for moderate soils which have moderate intake. Even the higher values of these intake family numbers will suggest that the again the efficiencies will lower down. But in this range somewhere from 1.5 to 3 intake families you will have quite reasonably good intake the efficiencies which are achieved. But as you increase the slope, these, there will be deterioration of those achievable efficiencies. Okay.

Having selected an appropriate value of ed, you can substitute that in the value of that relationship of the unit stream size and get a value which can be used for your specific conditions. Suppose you have found out the unit discharge, you have adopted some value of the length of the border, you have also picked up the values like how much depth of irrigation is required, that is again known, that is a function of what is the requirement from your crops. The design will also involve in checking these parameters, checking these values, whether these values are in, within the permissible range.

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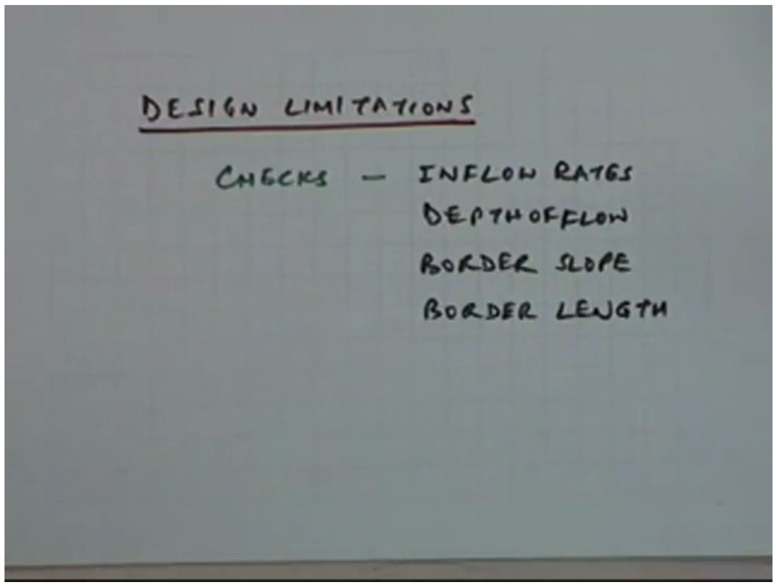

So you should also look at the design limitations. And these limitations are in the form of checks. So once you have come out with the design, once you have selected some parameters, you must check those parameters with respect to the various criteria. And these checks are in the form of, you can check the inflow rates, you can check the depth of flow or the border slope. Remember I had mentioned that there can be different possibilities. You might have some things which are fixed in your conditions. So you can check those items, whether they are within the restricted ranges or they are not within the restricted ranges.

Once you have checked those things and you have satisfied your design parameters, basically what you are checking for is one major thing is that you should not have any erosion problems. They are very detrimental for your total irrigation process. And there are some other conditions which we will see subsequently as we go further. So let us try to look at these items, let us try to check our designs, let us try to look into the relationships which are available for these checks which we have just looked at.

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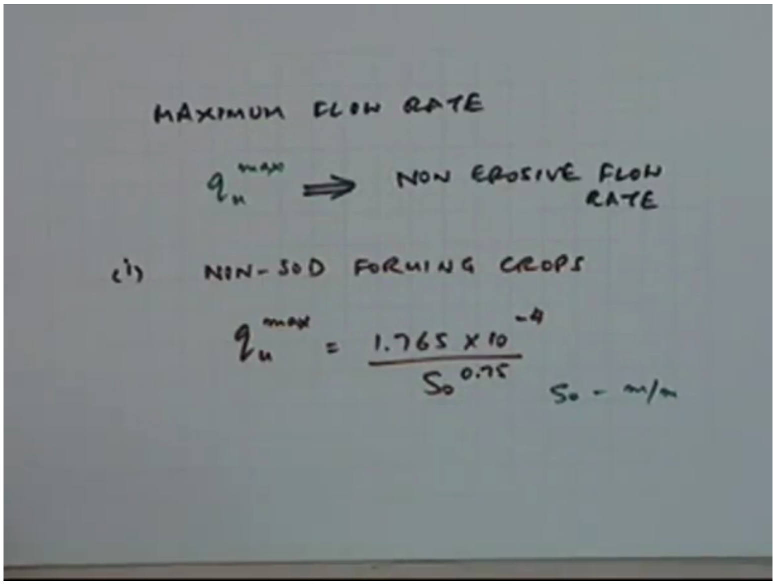

One is the maximum flow rate. In some cases these relationships are based on the hydraulic equations. In some cases there are some empirical relationships also which are put forward and they have been obtained from the actual experimentation. So to find out what is the maximum unit rate which is permissible and this is basically from the point of view of the non-erosive nature of this stream.

What is the stream size under the specific conditions which can remain non-erosive, that is what we are trying to look at because the stream size which you have found that you can check that stream size against this. And this relationship is given for under two conditions. This is basically we are trying to look at from the point of view of non-erosive. And the two conditions are in terms of what type of crop you are having.

The first variety of crops are those crops which are non-sod forming crops which include the crops like alfalfa or small grains crops which are basically, which are not having lot of resistance, their root system is not very well formed. So all those crops if you encounter those crops, then your maximum unit stream size is given by this relationship where S0 is the slope in meters per meter. So S0 is slope in meters per meter.

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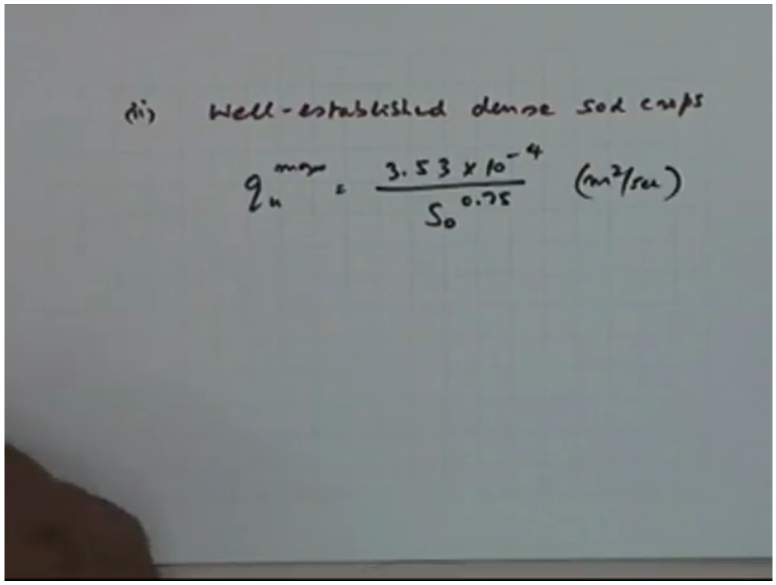

And the second case is the case when you have well-established dense sod crops. So in that situation the erosiveness of the stream size would not affect the field to that extent. You can afford to use maximum stream size which is higher than the previous one. And the relationship which is recommended is similar to the previous one. So almost, you can see here that is almost double than the previous because we had used the coefficient of 1.765 in the previous case, here we are using coefficient of 3.53. And this qu you are getting is in meter square per second. Okay.

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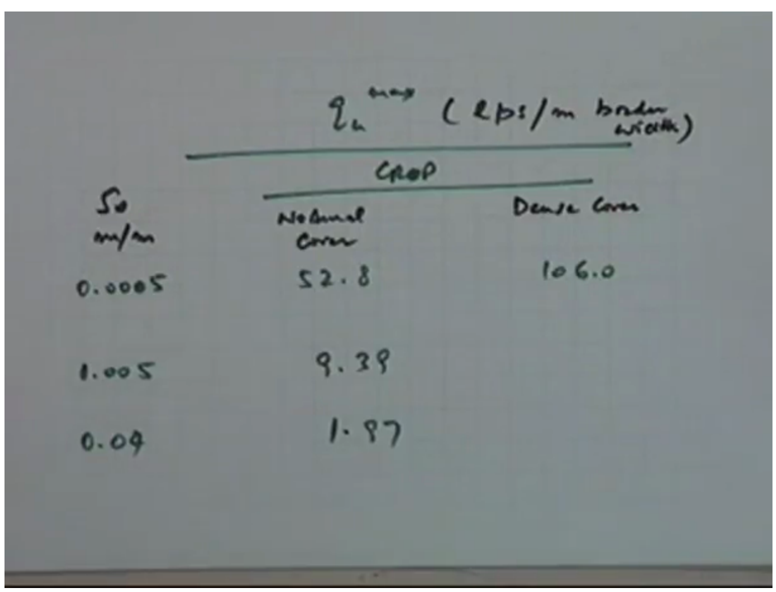

The order of magnitude, the maximum flow rate which we have just written the two equations for two different cases with respect to the crop type, we have said that in one case we have normal cover and the other case is the dense cover. This is non-sod type, is sod type. And for the slope, let us have look at some values maybe. This is the slope, 0.05 percent. You get, you can afford to use a stream size.

Now this stream size is not in meter square per second, this is in liters per second per meter width of the border. Okay, the units are different. So you can use 52.8 liters per second per meter width of the border when you have such a flat slope. But if the dense cover is there, you can still use the higher stream size. If the slope is 0.5 percent, then it reduces to 9.3 and this will be around 18.8 or so. Similarly let us say that if this is 4 percent, you might not be able to use a very stream size. This will be as low as 1.97. So you have to have, you have to look at what are the prevailing conditions and the other parameters will be, will have to be decided by those conditions.

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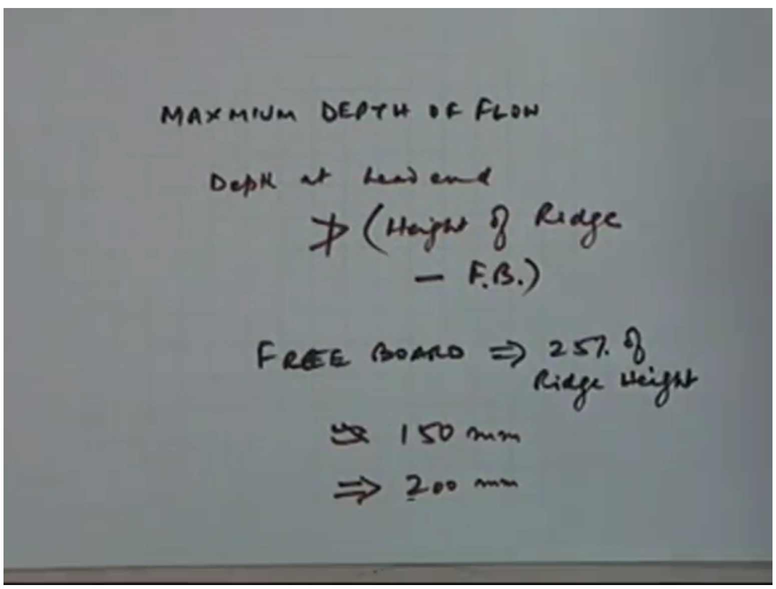

Similarly the when you look at the depth of flow, in general the depth of flow will be a function of how much is the ridge, what is the ridge size you have. When you are constructing the borders you will have to enclose it with the ridges. All these borders which we are considering so far, we are not looking at the length in that manner. We are assuming that we are, we can use the borders in two manners.

One, you can have open ended borders where you do not have the ridge at the downstream end. So the border is not blocked. We will come to that later stage at a later stage where we can see that how we can look at those borders where you have the end blocks in place and positioned because in the case of borders without any end blocks you might have some surface runoff. Some runoff can take place. So that runoff if you want to avoid, you can use the borders with the end blocks.

When you are looking at the maximum depth of flow, the depth of flow let us say at the head end, it should not exceed the height of ridge. And you cannot allow the water depth to get accumulated up to the height of the ridge because once the ridge is toppled, it might get washed away. So you have to have, you have to keep some free board. It should not exceed the height of the ridge, minus some free board.

And this free board is normally around 25 percent of the ridge height. There is a general criteria which is used that one-fourth of the ridge height you keep it as free board. So your maximum depth should be basically around three-fourth of the ridge height. In terms of the actual quantities the value which is normally used is around 150 millimeters. The depth does not exceed around 150 millimeters in most of the cases. But in some cases if you have a soil which does not have much erosion problems, then you might use some value which is approaching around 200 millimeters.

This is to be used only in those cases where you have non-erosive soils. The soils are not as erosive as in the cases where you are using smaller depth. But the recommended depth is around 150 millimeters. This also, these were the approximate ranges but you can also find out, you have the relationships which can give you the depth of flow, the maximum depth of flow at the upstream end.

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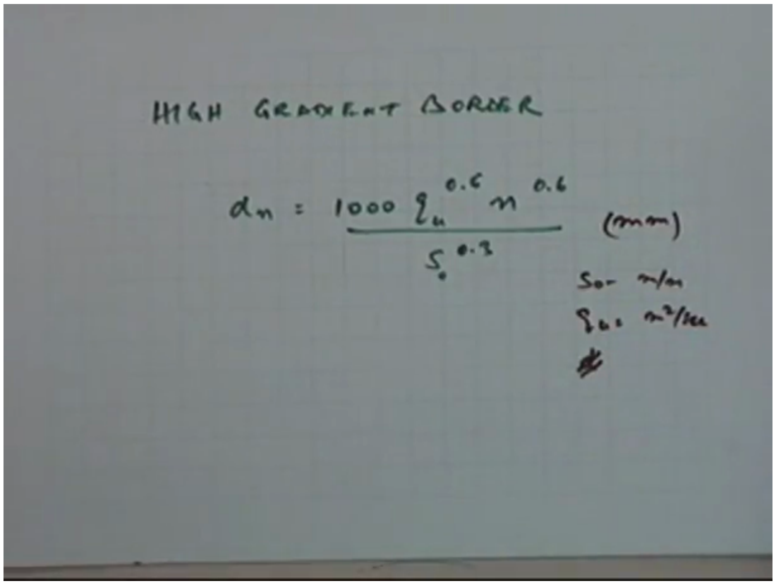

There are two cases which have been considered. We have already seen that the gradient of the border will make lot of difference in terms of what is the normal depth which is getting established. And we had said that the if the slope is more than 0.4 percent, then we will call it as the high gradient border, otherwise we will call it low gradient border. So if you have high gradient border, then you will achieve, at the upstream end you will achieve normal depth.

And that normal depth you can find out using this relationship. And this relationship, all these quantities we have already defined the units are all same, this is in meter square per second, and the dn which you are getting this is in millimeters. Okay?

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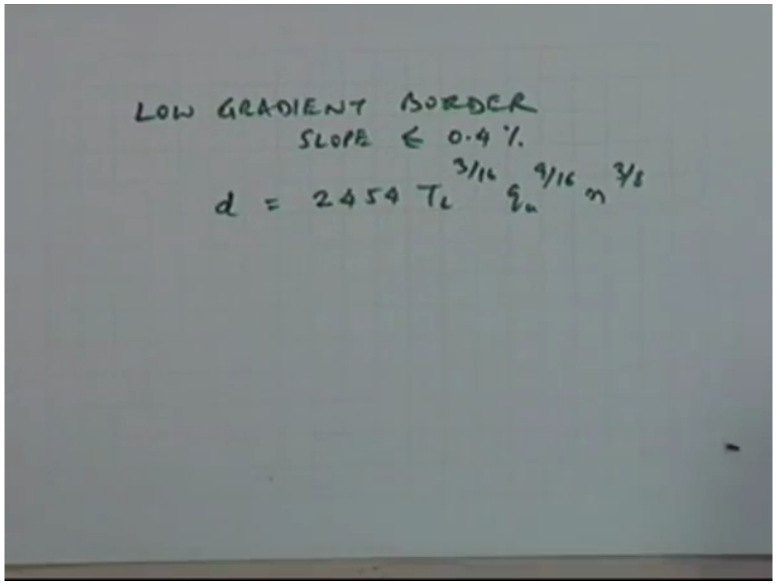

And for the other case when you have low gradient border, on this case you might not be able to achieve the normal depth. Depth at the upstream end is given by this relationship, so this is the case when the slope is less than equal to 0.4 percent. Now you can find out the actual d and then you can see whether is it within the permissible range or not. Okay? You can also see whether your the ridges which you have provided will they be able to take care of the depth which will get accumulated with respect to the other variable because this will be now dependent on what is the TL, what is qu and the n value.

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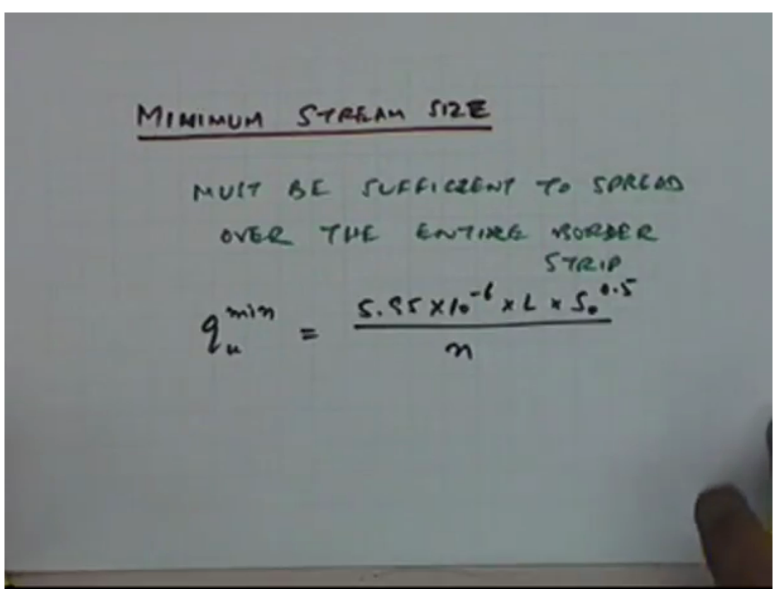

That was the maximum depth of flow. Let us look at the minimum stream size, what minimum stream size you can afford to use. This is a condition which is the other extreme. You are using the, you are trying to find out the maximum possible stream size with the condition that there should not be any erosion whereas in most of the cases you might find that is not the maximum, maximum is constrained by the other restrictions: the availability, what the worst stream size is being made available to the farmer.

So he might not be able to achieve the maximum stream size which we are talking about but minimum is more important from his consideration because minimum stream size is achievable. He might have the control to supply, to apply a stream size or use a stream size which is as low as possible. By the same time he must know what is the minimum stream size which is practicable, which is suitable. So that has to be seen from the angle of what is the, what will give a sufficient spread, what stream size can give a sufficient spread over the border length.

So from that angle the minimum stream size we must, this must be sufficient to spread over the entire border strip. Okay. Minimum stream size, if we designate it as qu minimum, this is given as into L into S0 by n. So you can, you check your minimum stream size, whether is below this. If it is below this, then you will have to revise that minimum stream size because that will give you a very low efficiency which will not be acceptable. This is another check which you must apply on your design parameters, on the stream size which you have computed from the previous expression.

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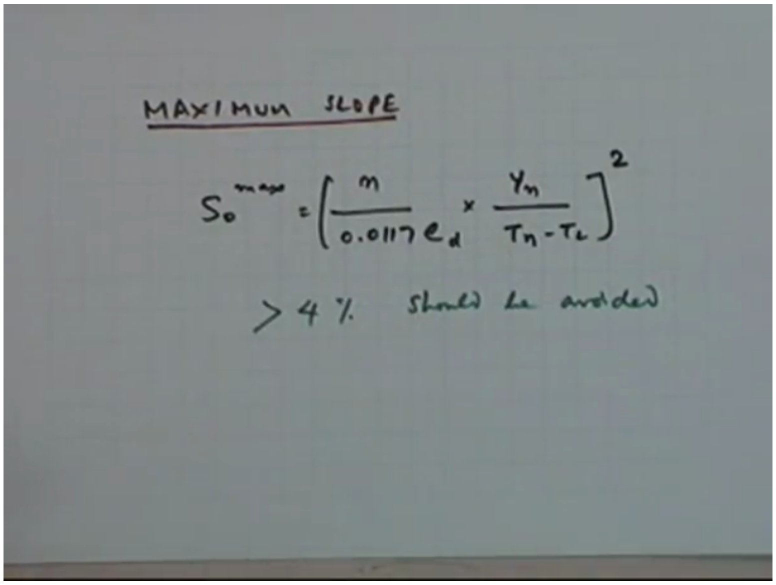

Now let us talk in terms of the other important parameter which is the slope. If you are, if you want to change the slope, the prevailing slope, that is a parameter in your hand. You might, if you are farming your areas, if you want to relay your areas, you might like to change the existing slope to another slope. In that case you can even think of providing a slope. Now what slope should be provided, what slope is reasonable slope, that is what you have to know the limits, what is the maximum slope.

If that is the situation where you are interested in knowing what is the maximum possible slope which can be used, you can use this relationship, into, square. All these terms, the Tn is the net time, n is the lag time which we have already seen in the previous class, we had explained. This is basically the application time, Tn minus TL is the time of application which will be required and Yn is the depth, ed, we have seen is distribution pattern efficiency and n is the Manning's coefficient. Normally the slope, any slope which is more than 4 percent should be avoided.

So if you get a slope which is more than this, it should be restricted below this. But in general you can, for the prevailing conditions you can find out what is the maximum possible slope which can be used and you can check your slope against that.

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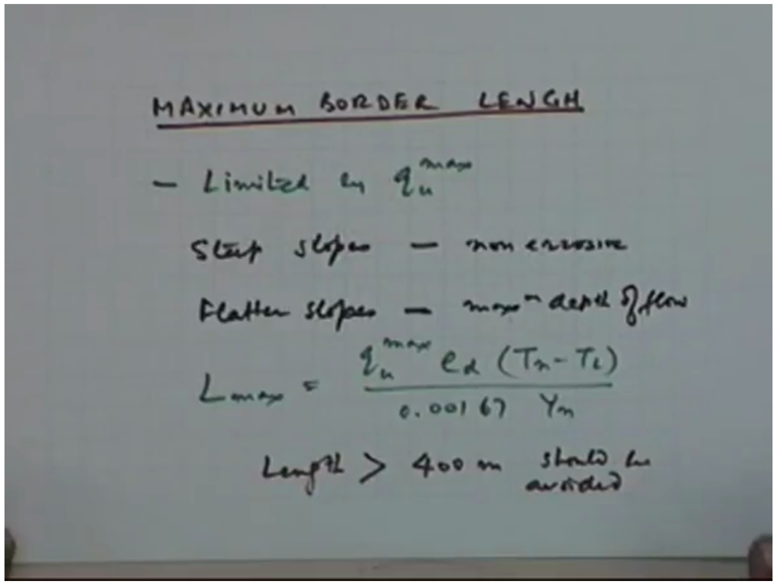

Let us come to the border length, maximum border length, this is usually limited by the maximum unit inflow rate. But again it depends which slopes you are using. If you are using steep slopes, then the non-erosive stream size has to be the limiting factor. And if you are using the flatter slopes, then the maximum depth of flow will be the governing criteria. But the maximum length, you can this expression to find out the maximum length. This is basically the same equation which you had used in the beginning.

You can find out for the maximum possible stream size what is the maximum possible length. And in some situations if your intake rates are very low, you might find that you get a very big value. In general any length which is greater than 400 meters should be avoided. Okay. Length in general should not go beyond 400 meters, it will become unmanageable.

In all these situations one more thing that we are using, at every place we are using ed. In case you find that the ea is not 100 percent, if you are certain that ea some value which is less than 100 percent, then you must use, along with ed you must use ea also. Okay. That is very essential, unless you are certain that ea is close to 100 percent. So you can improve upon all these relationship, wherever you have used ed you can substitute ea into ed. If ea is not, if it is not known to be 100 percent, if it is less than that, it can be seen that yes, it might be less than that, so you can use that actual value.

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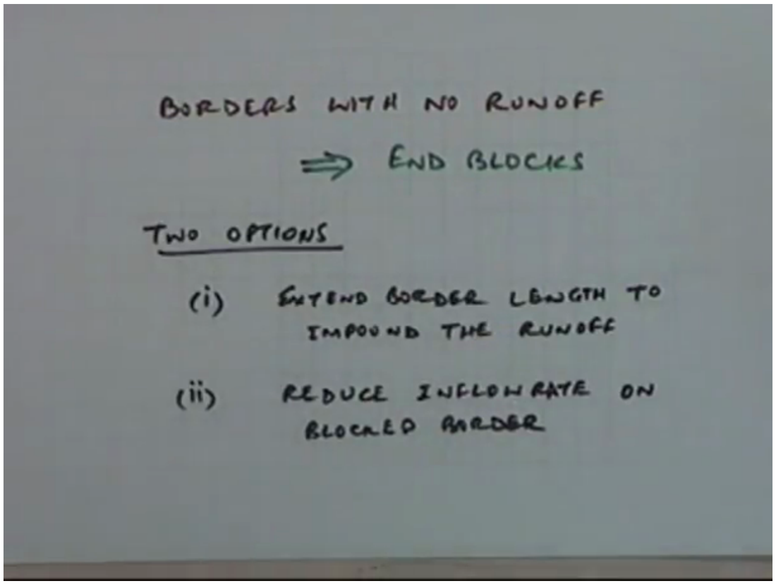

Let us consider the cases where you want to use the borders with no runoff. That means you are using the end blocks, you are trying to restrict if there is any surface runoff, you are trying to restrict that surface runoff by putting a blockage at the end or by constructing another ridge at end. Now then when that happens, basically let us first look into that why you should think of that because any surface runoff which taking place is going as a waste, so is reducing your overall efficiencies and you can think of using the surface runoff in some manner.

There are two possible options available. What those two possible options are? The first option is that extend the border length to impound the runoff onto this extended length. So all that surface runoff which was taking place earlier, if you find out how much length of the border has to be extended to accommodate that additional runoff which was available. So you can afford to extend your border length and consume the surface runoff in that extended border length, is one way of handling this problem.

The second possible manner can be to reduce the stream size. So in the second case you can reduce inflow rate. In this case you have not changed the length of the border, is the same as the original length. But in turn you had, you have reduced the inflow rate to such an extent that there will not be any surface runoff. Fine?

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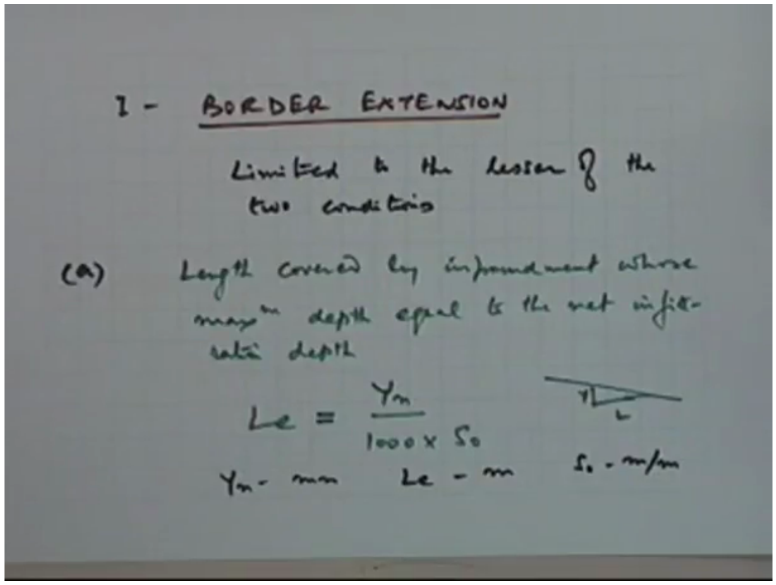

Let us look at the first case and the first case when you are extending the border. When you think of extending the border, the length up to which the border can be extended is limited to the lesser of the following two conditions:

Condition a is, in this condition what we are saying is that the length covered by an (impound) impoundment whose maximum depth is equal to the net infiltration depth. What we are saying is that the equivalent length or the length which has to be increased, in that case will be equal to Yn by, basically what we are saying is that if there is the slope, this is the slope of the area, if we know what is the Yn, up to which length, what will be the equivalent length up to which it can be absorbed. So this is a very simple formulation and Yn is, the units which are used, Yn is in millimeters. L is in meters and S0 is in meter per meter. This is one condition.

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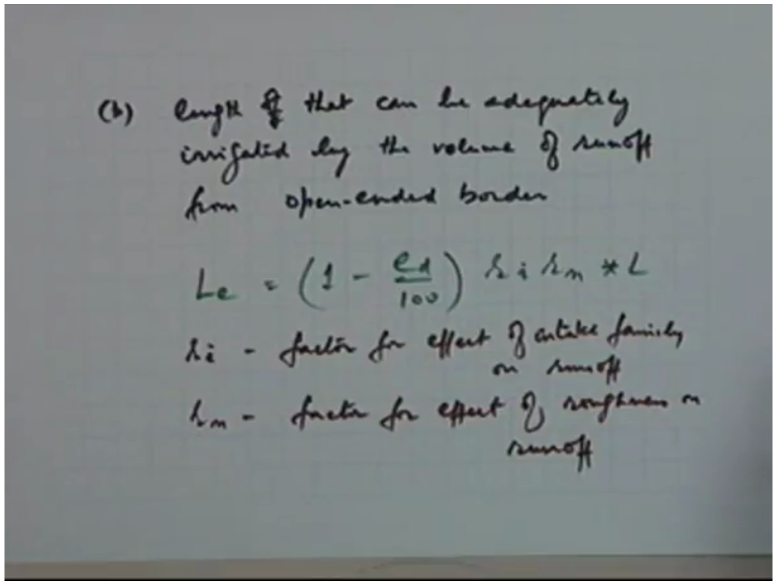

And the second condition is that length which can be adequately irrigated by the volume of runoff from open-ended border. What we are checking is that what we are, we are interested that any extended length which we are trying to make use of it should have sufficient depth and it should also be in a position to take care of this requirement which is in this extended length properly.

So that, from that angle, from the requirement point of view, this extended length is given in this form, into the original length. Otherwise there is no point if you try to extend the length without looking at what is the requirement, what is the chances of getting this length taken, chances of getting this length satisfy its own requirement, there is no point in extending. So that is what we are trying to look at both the conditions.

One, there is should be sufficient length and second, that length whether is it taking care of its own requirement or not. If it is not taking care of its requirement, then we will reduce the length to that limit where it can take care of its requirement. So we are, out of the two conditions we are choosing the minimum and only that much length is extended. Now this, in this equation ed is same as before, is the efficiency. But ri is the factor for effect of intake family.

So there is a factor which is dependent on the intake family, was the, and that takes care of the effect of the intake family on the runoff. And rn is another factor which is dependent on roughness of the area. So this factor is used for the effect of roughness on runoff. And L is the original length of the border.

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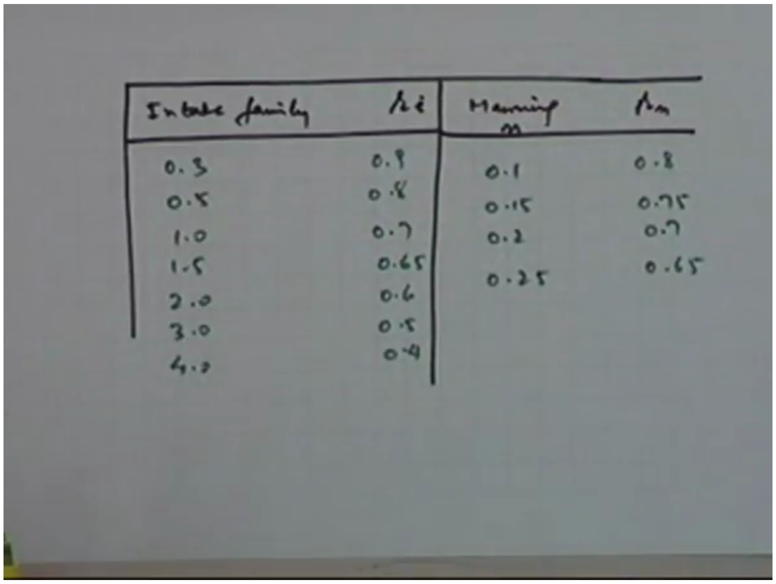

Intake family	ri	Manning n	rn
0.3	0.9	0.1	0.8
0.5	0.8	0.15	0.75
1.0	0.7	0.2	0.7
1.5	0.65	0.25	0.65
2.0	0.6		
3.0	0.5		
4.0	0.4		

Now these, they are values which are made available for different intake families. For different intake families, ri is given. I can give you the values. This is 0.9, 0.8; 1.0, 1.5, 2.0, 3.0, 4.0. These are the factors which are recommended factors for different intake families. And similarly the other is between Manning's n and the rn value. These are the values for, recommended for different Manning's n.

So the impact of different roughness and the intake families have been taken care of, and finding out what will be the equivalent length or what will be the length which is, which can be extended to account for that surface runoff which is being produced. I think we will stop here. I can take on any questions if there.