Irrigation and Drainage

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Lecture – 44
Drainage System Design

Yes, so this is the lecture number 44 on drainage system design. So, I just said in this we will be talking about the drainages principles and some of the equations will be using in designing of drainages ok. So, the mostly the groundwater flow if you see so the groundwater flow is very slow first of all. So, it takes 10 to 12 meter per day. And if you go even deeper and deeper, it takes years ok. So, the mostly so since so this is entirely different kind of flow compared to the open channel flow because open channel flow is the complete fluid without having any you know interfere with the soil particles that means, it is not a porous you know flow right or flow through porous media.

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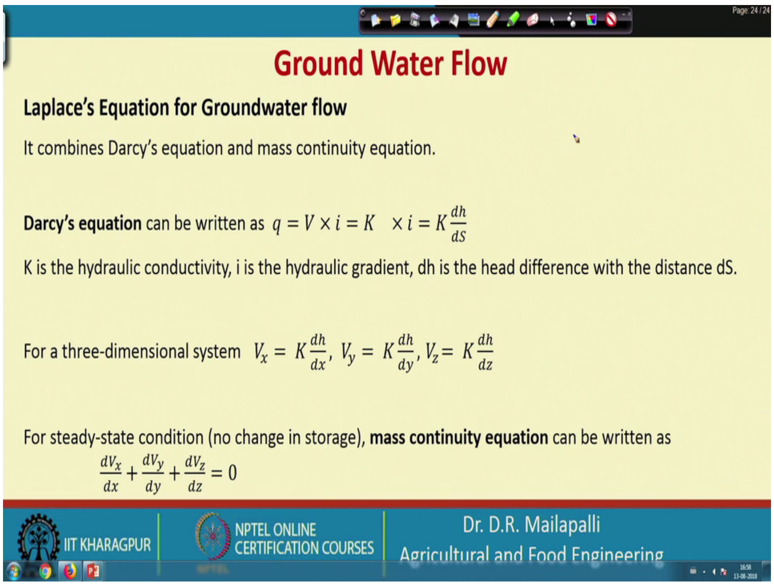

So, flow through porous media is very slow and then basically this Laplace equation is the basic principle used for you know groundwater flow. So, let us see how this been derived. So, this is a combination of both Darcy's equation and mass continuity equation. We were known Darcy's equation which is written as q is equal to velocity V into i ok. So, i is the hydraulic gradient which can be written K hydraulic conductivity into i that is gradient and then the K into dh by ds is the hydraulic gradient ok. And K is the hydraulic conductivity; i is hydraulic gradient, and dh is the head difference with the distance ds ok.

So, this is same thing if you have a saturated soil column which has you know the pressure difference like this is the pressure difference dh, and then you have the dl length or here if it is ds length. And q this is the flow which is taking place. So, the q which is equals and the K is the hydraulic conductivity of the media. So, the q which is equal to K into dh by ds ok, this is what we get this equation.

And then for three-dimensional system the same equation can be written as V x which is equal to K into dh by dx, x direction and y direction and z directions. So, just like this. So, he this one, this one ok, this is V x, V y and V z. So, in three-dimensional case, so the flow which is taking place in x direction is K into ds by dx, it is also says it is a flux. So, V y which is K into dh by dy, and V z K into dh by dz. For steady-state condition that means, no change in storage. So, mass continuity equation can be written as dVx by dx plus dVy by dy plus dVz by dz; in three-dimensional case because these storage is I mean change in storage is 0 in steady-state. So, this can be written I mean and the mass conservation can be written in this way.

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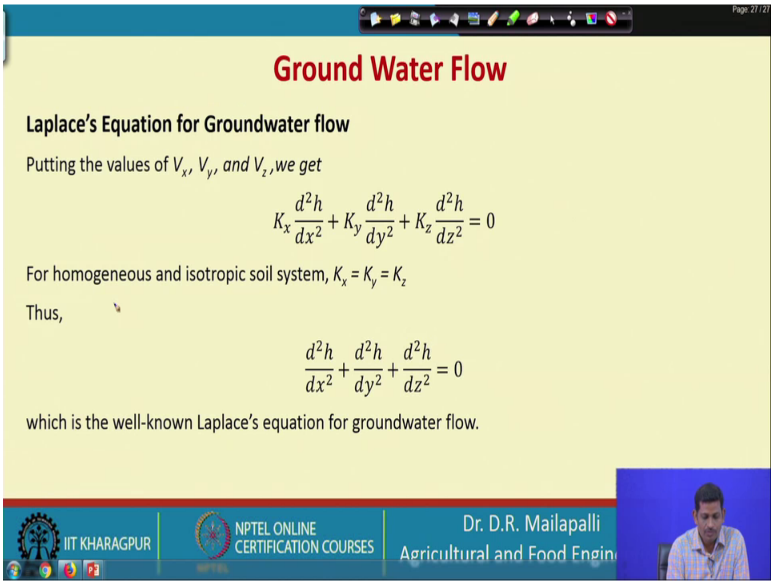

So, combining these two, you get so like K x into d square h by dx square plus K y into d square h by dy square plus K z into d square h by dz square, because we know V x is equal to K into dh by d let us say x this is one. And in mass conservation equation dVx by dx, so that will be d by dx into K into dh by dx, so that will be K into d square h by dx square. So, this is in x direction ok. So, similarly for y direction for z direction you get. And for homogeneous and isotropic soils, so K x, K y, K z are equal, so that K can be eliminated from the previous equation. So, finally, this is the Laplace equation for groundwater flow under steady-state condition ok.

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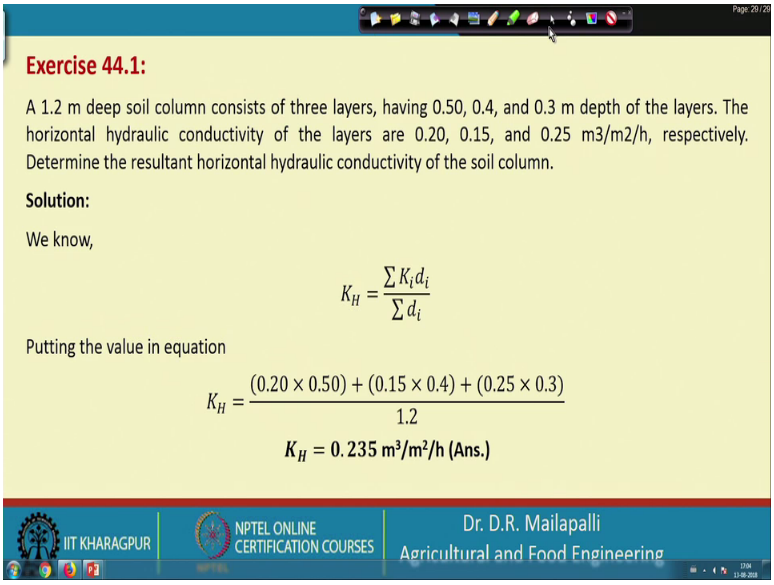

So, here is an example a 1.2 meter deep soil column consist of three layers, one is having 0.5, 0.4, 0.3 meter depth of layers. So, the horizontal hydraulic conductivity of the layers are 0.2, one, 0.15, 0.25 meter cube per metre square per hour respectively. So, determine the resultant hydraulic conductivity of the soil column. So, you have a soil columns like horizontal columns, do which has 0.5, 0.4, 0.3 meter, so 0.5 0.4 0.3 metre depths of layers. And this has 0.2 and 0.15 0.25. So, this is hydraulic conductivity; this is the layers ok.

If this is the case, so what would be your total I mean the average hydraulic conductivity for the whole soil system? So, for horizontal hydraulic connect the K H this is average this is called depth averaged hydraulic conductivity ok. So, the K K i into di by sigma di, so simply just you know put the values 0.2 into 0.5 right and 0.15 into 0.4 0.25 into 0.3 divided by the total is 1.2, and K H is 0.235 meter cube per meter square per hour. So, if this is this is horizontal. So, K V that is the vertical this is also so that will be so that will be divided by d by K ok, so di by K i. So, this will be d divided by di by K i. So, this is the vertical hydraulic conductivity if you have so other things all right.

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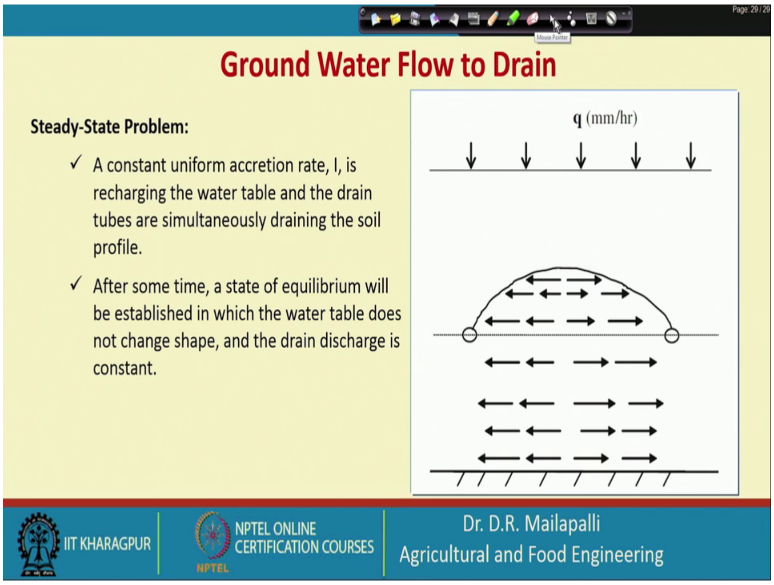

So, next is a groundwater flow to drain. So, we have note the steady-state you know ground water flow using Laplace equation. And this is the steady-state problem. So, you need to assume certain things while as while estimating the water flow or the discharge or drainage to the drain pipe ok. Here if you see the, this is the ground surface; and from the ground surface let us assume the q is accretion rate right so which is accumulate the flow is taking place into the ground. And these are the drains, drain 1 and drain pipe 2 ok, and which is so after sometime it is making an equilibrium with the flow system.

So, then here to assume some of the things like the steady-state problem that means, the q recharges this kind of recharges so which will be equal to the drain discharges, drain discharges. So, then only this will be a steady-state the problem. Then the flow lines are parallel. So, look at this. Here the flow lines which are going parallel to the drains right. So, these two assumptions are very much important for steady-state problem, so here ok.

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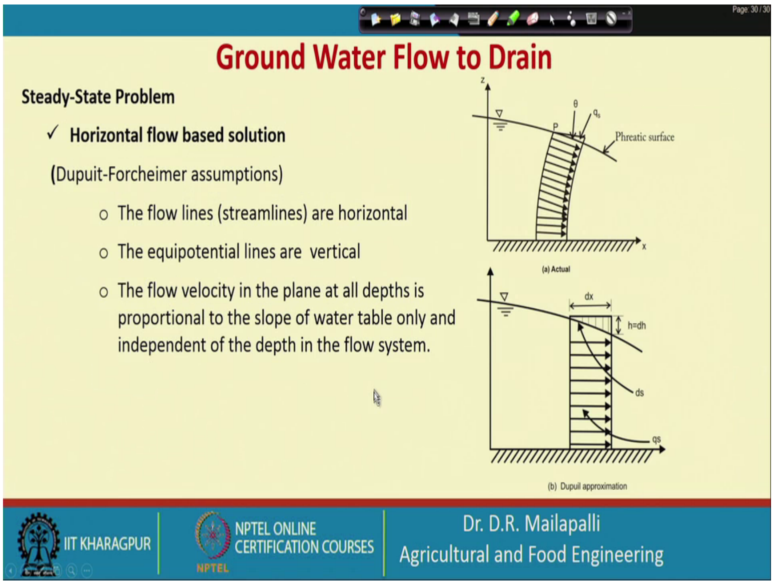

So, then the next is, next is horizontal flow based solutions. So, there are assumption if you see here this is actual, in actual condition for example, this is going to the drain somewhere here ok. So, the phreatic surface this is water table surface right water table surface of the pressure at this point is atmospheric of course. And then if you see here the these re these are the flow lines ok, these are the flow lines and then so in case of horizontal flow based conditions the Dupuit-Forcheimer assumptions need to be considered. So, the flow lines are horizontal.

So, here so we consider these flow lines are horizontal right. And then equipotential lines are vertical. So, then this is the I mean the dh, so the vertical equipotential lines and the flow velocity in the plane at all depths is proportional to this slope of the water table only an independent of the depth of the flow system. So, here the flow which is taking place is depends on the dh by dx, so which is the slope of the velocity which is taking place or the flow which is taking place depends on the slope of the I mean the draw down curve we can say here ok.

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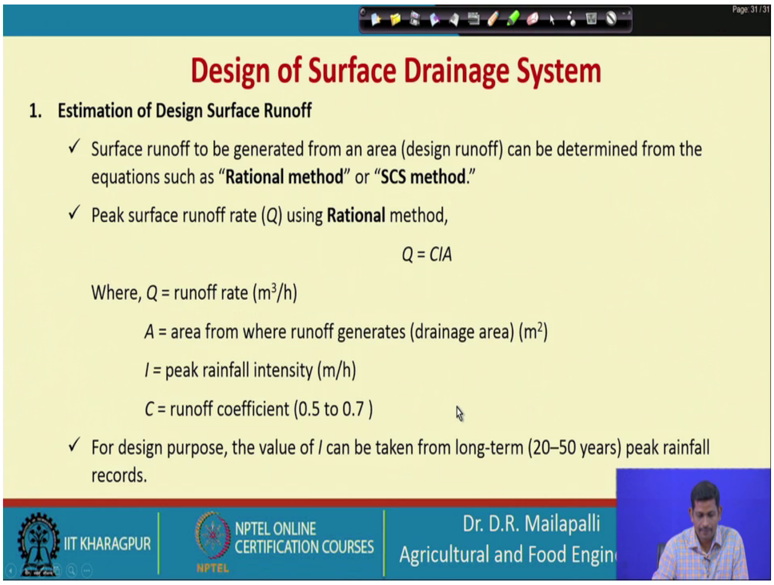

And the next is design of surface drainage system the surface drainage surface drainage is mostly you know plant based on the rational method ok. So, this is basically to use to estimate the design surface runoff. So, the rational method which has the relationship Q is equal to CIA. So, where Q is runoff rate meter cube per hour, and A is the area from where runoff generates ok. So, this is the area, and here you are measuring it, so that Q is equal to CIA this is the area of the particular you know piece of land from where water is draining or running off for a particular storm event ok.

So, i is the peak rainfall intensity, and C is the runoff coefficient usually it taken from 0.5 to 0.7. The i basically can be taken from long term like 20 to 50 years peak rainfall ok. So, this with this you will be knowing how much or what is the maximum runoff this particular land surface can result ok. So, based on that you will be planning for the carrying capacity of the surface drain, so that is the main intension.

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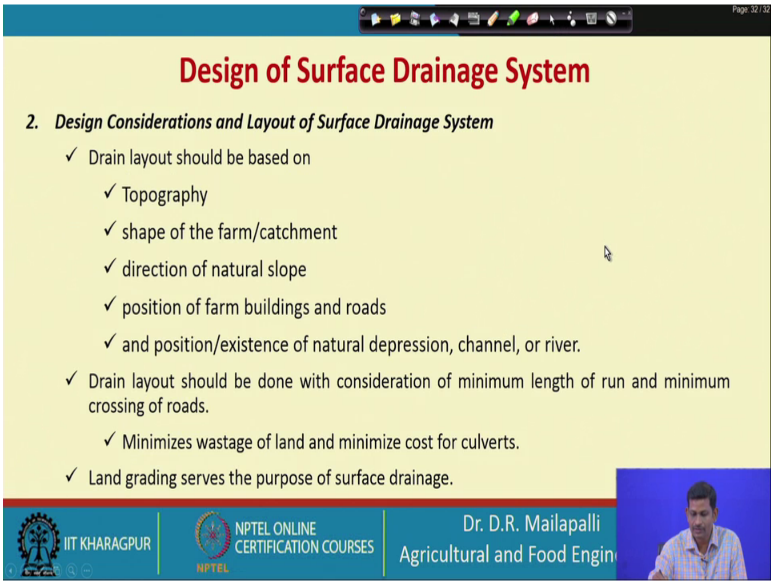

And the second is design considerations and layout surface drainage system. So, the first thing is drain layout should be based on topography ok, shape of the farm and catchment, and direction of the natural slope which way the slope is leading to, and position of the form buildings and roads. So, these are very important your drained I mean the drains or surface drains should not a cross right these buildings or roads. And position existence of natural depressions channels or river. So, this is another important thing, this should be I mean the drain base should be you know little bit higher than the other river or depressions, so, so that this can go into the depression right or the river ok.

And the drain layout should be done with consideration of minimum length of run and minimum crossing of the road. So, this is you have to design the drains in such a way that the length needs to be you know the optimum, so that the construction cost will be reduced, and minimize the wastes of land in minimize the cost of culverts. And land grading serves the purpose of the surface. So, land grading is very important in case of surface drainage construction. So, since the lands or know you know level then they become then the drainage system does not work properly.

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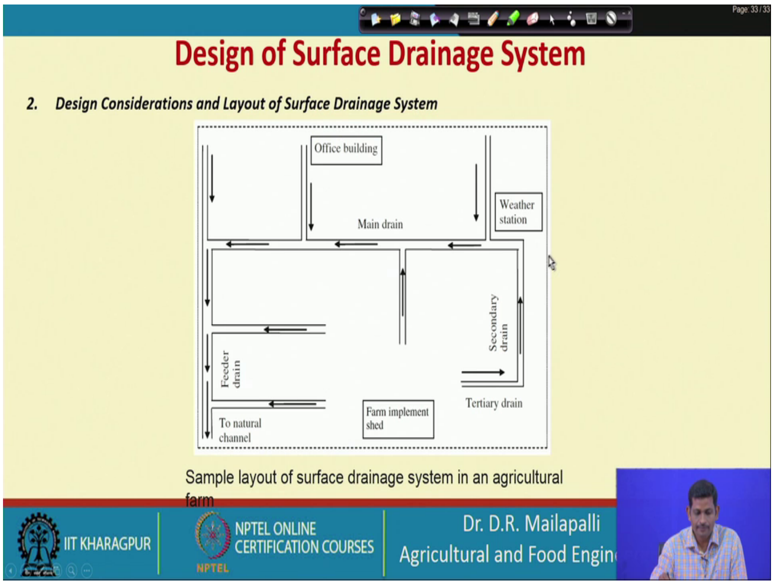

So, here an example how the surface drainages been you know constructed here. So, you have office building here initially is there and farm implement shed right and there is a weather station ok. And if the these this is the thing available, it is already there in the particular you know piece of land you want to make in this you want to construct a surface drain for this. So, considering these three places, so you need to also look at the slope.

So, look at the here, this is the main drain right which is taking place. So, this is this is kind of a collector. And this is the field drain right and this is the field drain look at this. So, this is not crossing the office building or even this field drain is not passing the weather station. And then these are the feeder drain of course, the field drain feeder drains are same, and this is also feeder drain. And here sometimes what happens; the secondary drain and the tertiary drain, so the tertiary drain I mean drains to the secondary drain, and secondary drains to the main drain ok. So, these are all feeder drain. So, this way we need to check out the drainage plan system plan without crossing the office building and farm implements or weather stations.

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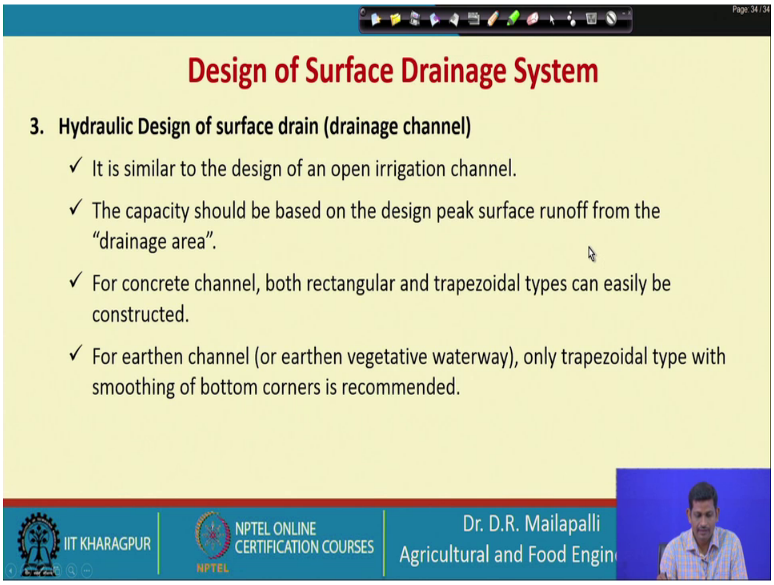

So, then the next is hydraulic design of surface drain. So, so hydraulic design of surface drain, it is similar to the design of an open irrigation channel. In case of open irrigation channel, so we will be looking into the peak run off taking place from the particular area and then design the dimensions right. Similarly, here the capacity should be based on the design peak surface runoff from the drainage area. Using rational formula, you will know what is Q like you peak. And the concrete channel both rectangular and trapezoidal types can be easily constructed ok. So, for concrete channels you can also go ahead with the rectangular trapezoidal, whereas earthen channels safety or the stability is concerned so or waterways, so you will be using the trapezoidal type of channels.

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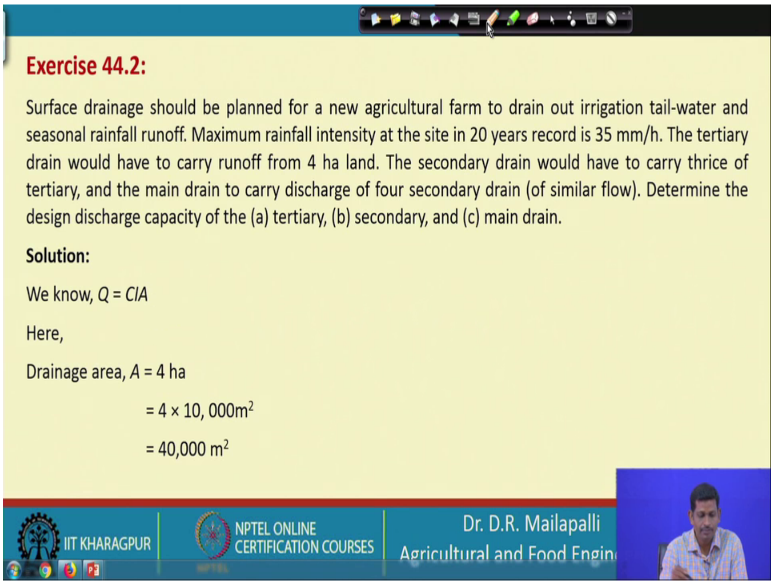

Ok here is an example the surface drainage should be planned for a new agriculture farm to drain out irrigation tail-water and seasonal rainfall runoff. The maximum rainfall intensity at the site in 20 years record is 35 mm per hour. The tertiary drain would have to carry runoff from 4 hectare land. The secondary drain would have to carry thrice of the tertiary and the main drain to carry discharge of force secondary drain of similar flow ok. And determine the design discharges capacity of the tertiary, secondary and main drain.

So, there is an area of the land. You need to design a surface irrigation system sorry surface drainage system. So, it consists of tertiary secondary and main drains ok. So, given the 20 years record period 35 mm per hour; so and also the proportion of the carrying capacity of different channels. So, now, estimate the carrying capacity of tertiary, secondary and main drains ok. This is the example, let us see if the main things here we will be using the Q is equal CIA. So, this is a rational formula. Here area is given 4 hectares, so convert into meter square.

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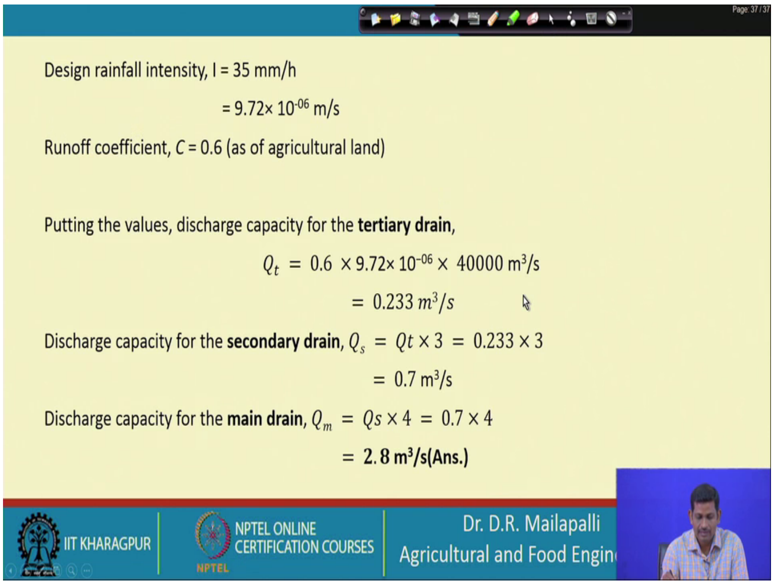

So, the next is and then the next is I 35 mm per hour, so that is in meter per second. And the C is 0.6 for agricultural land and putting all the values for the tertiary drain. So, Q t for their tertiary drain 0.6 9.72 into 10 power minus 6. So, so tertiary drain he carries 0.6 times of that particular area and this will give 0.233 meter cube per second. So, in the discharge capacity secondary drain, so that is 3 times the tertiary drain. So, you get this. And main drain which is 4 times the secondary drain and you will get 2.8 meter per second ok. So, this is the way this problem can be solved.

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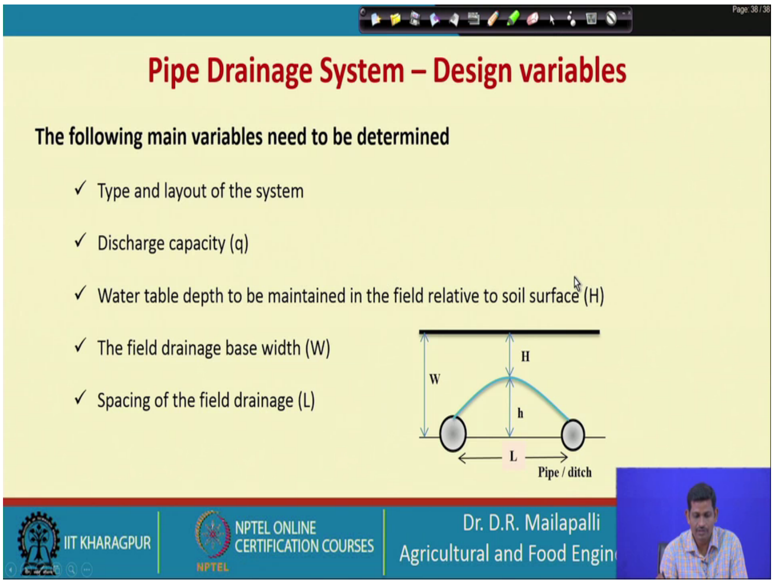

So, the next is the design of pipe drainage systems. Mostly we will be talking about subsurface drainage system that is tail drainage system. So, in this system basically the variables we will be focusing on the discharge capacity q ok. So, this is a discharge capacity let us say q. And water table depth to be maintained in the field relative to soil surface. So, what this is a H, we will be maintained, because this is where we will be we are looking for our root zone basically ok. So, this is H. So, this is H, and the q, 23 need to consider. And then field drain is base width, so the field drain is base width W, and the spacing of the land L. So, these are the main parameters we will be considering in pipe drainage system.

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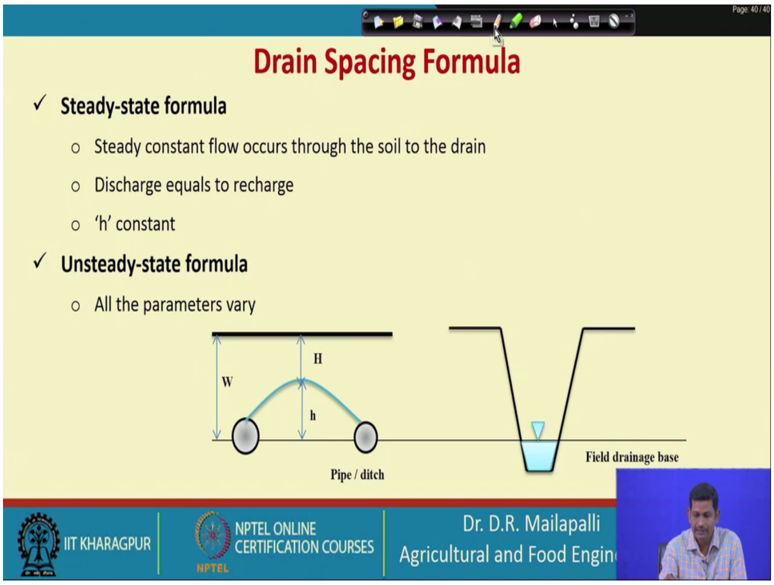

And then, here for steady-state formula, steady constant flow occurs through the soil to the drain and discharge equals to recharges ok, and h is constant. So, as I said after equilibrium, so whatever the q which is taking place, so that will be equal to the drain discharges, so that the h is constant here and this is the steady-state ok. And then unsteady-state formula the all other parameters varying, so the q may not be same as this q ok, and h is not constant, so that will vary ok.

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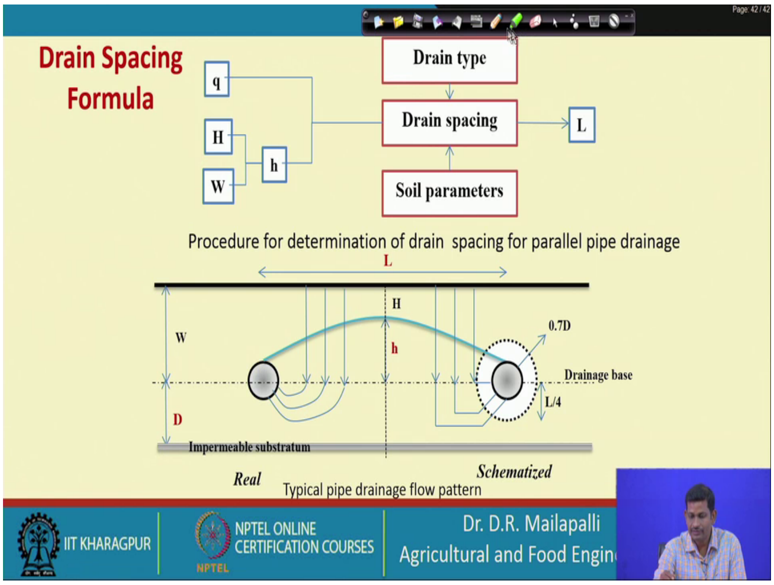

And then drain spacing, the drain spacing formula it has the input so you should know the q right H and W. From H and W, you can estimate h. So, you know H minus W sorry W minus H, W is the base width, so W minus H will be h ok, so that h will be known. And q and h, from q and h knowing the drain type and soil parameters, you can estimate you can use the drain spacing formula and then estimate L that is the drain space. So, this is the simple way to remember how to estimate drain spacing by knowing the q, H and W ok, and also drain spacing formula and other parameters. So, here so as I mentioned previously this is the real case and schematized case in case of your tail drain.

So, in the real case, so this is W is the base width, and D is depth to your base from the impermeable stratum ok. So, and if you see here the flow lines which are going vertical then after that this is going radial ok, going vertical and radial, vertical and radial. But in case of schematized ok, so because it is a difficult to you know formulate in this way. So, in case of a formulations, it is easier to is a vertical and then horizontal, then the radial ok; vertical, horizontal, radial. So, the flow is taking place in three you know modes, one is vertical, horizontal and radial place ok.

So, the mostly here for radial flow for radial flow the diameter is 0.7 D ok. So, this is the flow let us a radial flow of influence and also which will be I mean I mean the horizontal flow will be taking place about L by 4 right at the depth of L by 4 ok. So, here the horizontal flow will be taking place L by 4 that is the from drain base to L by 4 below the horizontal flow will be taking place. So, these are the assumptions where we need to make a to schematized or to model the drain spacing or to model the drain or to find out the drain spacing formula ok.

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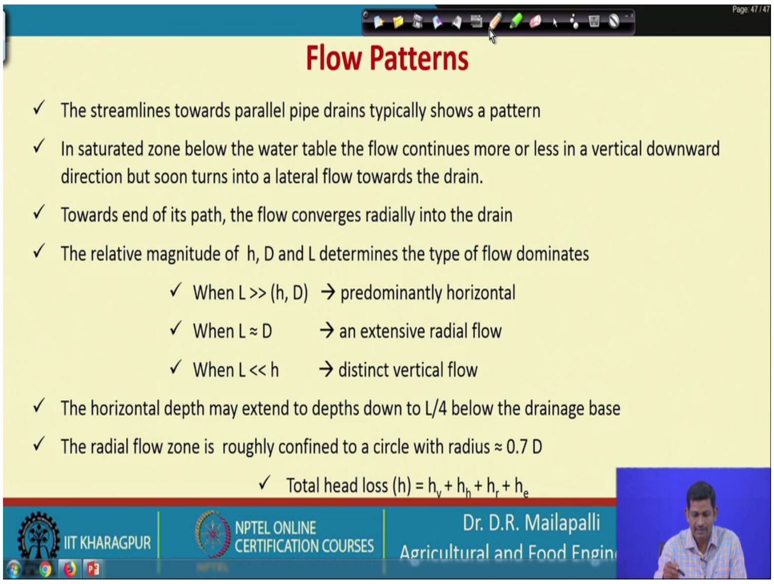

So, the flow patterns if you just go back and refer. So, here the streamlines towards parallel pipe drains typically shown as a pattern. So, we have seen previously. So, if you see, so this is a drain ok, so first it is going vertically down and then horizontal and then radial. So, this shows a particular pattern. In saturated zone below the water table the water continuous more or less vertical downward, this is what we see and direction but soon turns into lateral flow towards the drain. Towards end of its path, the flow converges radially, so laterally and then radially.

So, here the relative magnitude of h, and D and L determines the type of flow this is very important. So, the basically the flow type of flow is the vertical lateral or radial that will be deter[mined]- that will be determined by knowing h small h, and capital D and l. So, when L, it is very very larger than h and D right, h and D, then this is predominantly horizontal flow when the spacing which is equal to the distance between the you know drain base and the (Refer Time: 24:15) layer, then an extensive radial flow. So, when L is very very less than h right, h is the head at the middle of two drains, so that is a distinct vertical flow ok, so that means, the h is very very high then the spacing then it is a vertical flow.

So, the horizontal depth may extend to depth down to L by 4, below the drain waste base we have seen previously. The radial flow zone is roughly confined to a circle with radius 0.7D, there also we have seen the previously. And total head loss will be the total head loss h like a drain the total head loss suppose this one and this is a root zone and this is at H, and this is small h, and this is capital W and then impervious layer, so that is at D ok. So, here at any point h, at any point h, which is which is equal to h v, head due to vertical, head due to horizontal, head due to radial and the head due to entrance, entrance losses, because the water when you are flowing here this is the envelope material right so I mean the head definitely influence the head loss due to entrance.

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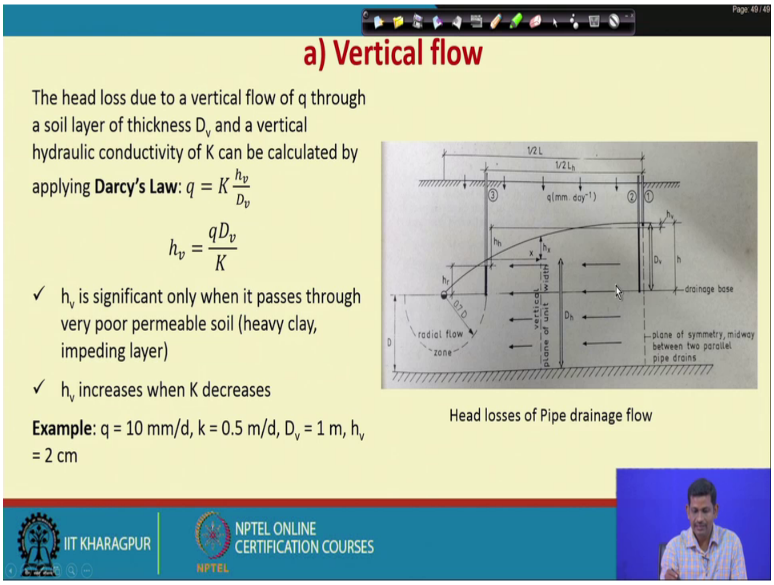

So, with this theory let us find out the different heads right; vertical, horizontal, radial and then entrance so then that comprises the total head ok. So, if you see here, this is a whole schematic; so let us say this is one drain right and there is a another drain somewhere outside this you know slide, but see here this is the middle point right, this is the middle of the drain. And let us say the distance between these two right; L by 2, this is L by 2.

And then, there are 3piezometer install; this is the piezometer 1, piezometer 2 and piezometer 3. So, these three piezometers are installed in such a way that, that captures both vertical horizontal and radial probes. For example, here so piezometer 1 is installed exactly half of the distance ok, so that means this is the maximum h, where you can see this. So, near to that there is another piezometer which is installed right; so that captures I mean here if you see the difference between, the head difference between 1 and 2 will give h v, so that is the head due to vertical flow.

And let us if the D v is the distance or D v is let us say the maximum h here ok. I mean through which the vertical flow will be taking place for examples ok. So, vertical flow is taking place like this, so take this is the D v and here that is the piezometer 1, and there is another piezometer 2 here. So, the head difference delta h, delta h will be here, and D v this is saturated media. So, the vertical flow which is taking place from this column will be estimated using Darcy's law ok. So, the Darcy's equation so this will give the Darcy's equation h v is equal to q which is taking place, that is a q right the same thing same here.

And then q into D v into k that is h v. So, in other ways q is equal to k into h v by D v ok. So, this is Darcy's law and you can write down h v as q D v by k v, so that is where the vertical head will be estimated. So, the same thing can be observed by difference, but taking the difference of water levels in one and two that is vertical ok. So, and similarly there is another piezometer installed at a distance of 0.7 D right, 0.7 D so that will capture the radius I mean, I mean the head due to head due to radial flow ok. So, now let us this is a vertical flow you can estimate using Darcy's equation.

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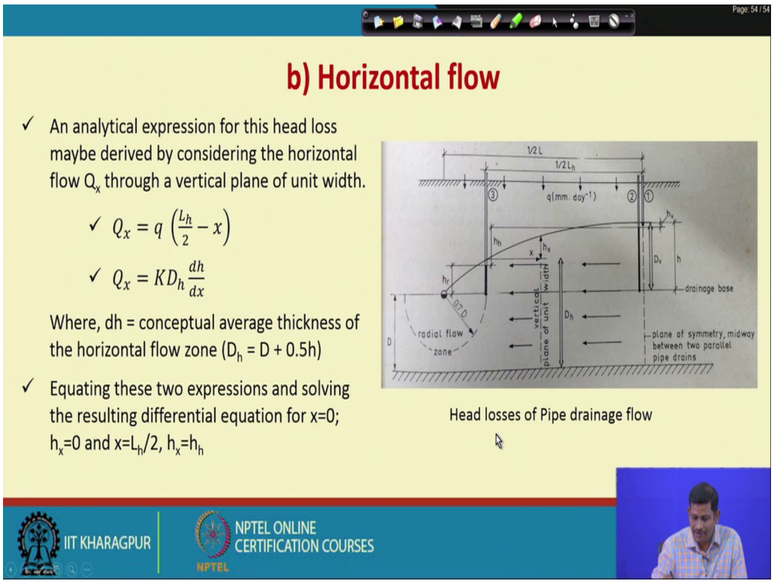

Similarly, there is a horizontal flow horizontal flow which can be estimated. So, this is little if you see here, so the horizontal flow is taking place from 3 to 2 ok; so between 3 and 2. So, so let us say from this point this is going in x direction and this is going in y direction, x and y is h. So, x and from this point x towards this direction, and h in the upper side, this is h and x ok, so then this is a linear interpolation.

So, the q h that is a horizontal flow which is taking place, so that will be is equal to q into L h by 2 minus x. So, L h by 2 is the distance between the 1 and 2 1 and 2, so that is q into L h by 2 minus x. And from Darcy's law, you can also estimate K into D h dh by dx, because this is the layer thickness and through which the horizontal flow is taking place and hydraulic conductivity and D h and dh by dx. So, D h into let us say unit width unit width, so that will be so basically this is cross sectional area, when there is a unit width and D h is the unit thickness ok. So, D h can be written as D plus 0.5 h. So, the D h it is identified as the D here plus 0.5 of d 0.5 of h.

So, and also you have equating these two expressions for solving the result differential equation for x is equal to 0, h x equal to 0, x equal to L h by 2, h x equal to h h. So, here so as I said, this is x and this is h. So, when x is equal to 0, h is equal to 0 when x is equal to L h by 2 at the extreme point right, and h x equal to h s. So, this is h s.

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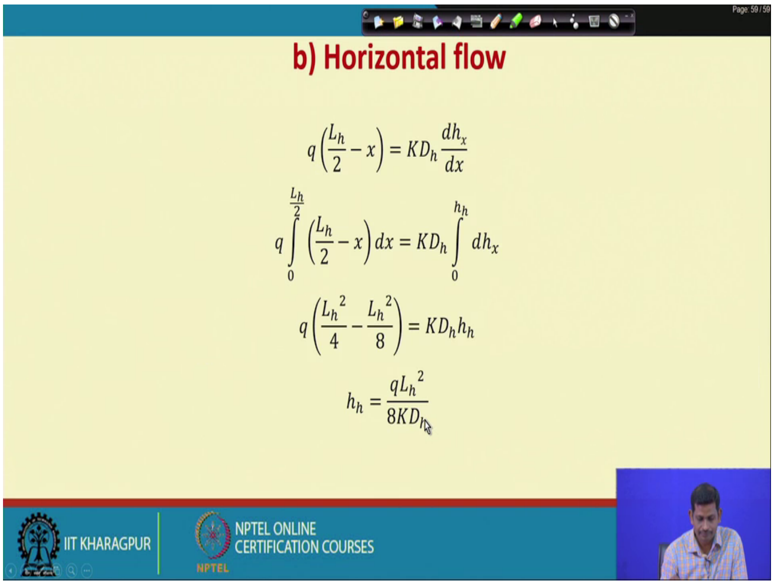

So, with this boundary conditions and then equating these, integrating this, you get the solution as so first of all equating this, and then these are the limits and L 0 and L h by 2, L h by 2 minus x dx K into D h by dx. And finally, if you integrate it, you get h h the horizontal head, head due to horizontal flow is equal to q L h square divided by 8 K into D h.

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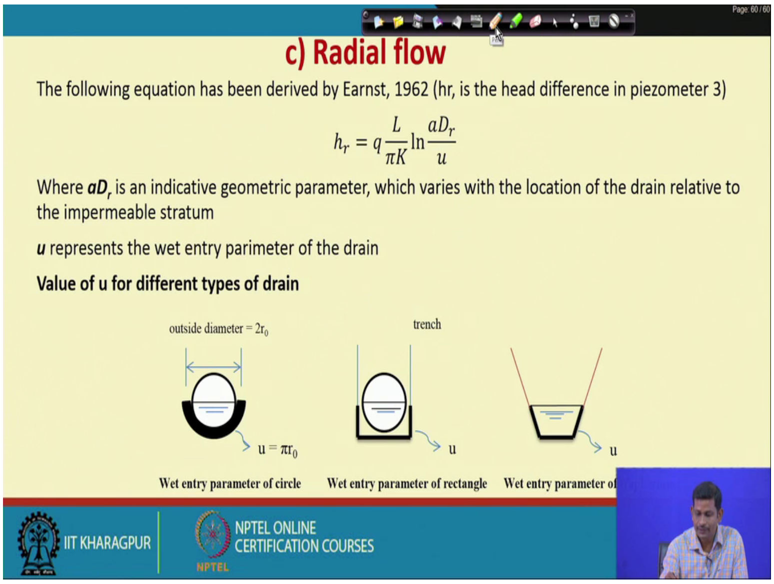

And then radial flow, for the radial flow there is a Earnst, 1962; he has suggested the equation. So, h r is equal to q in to L by pi K into ln of a D r by u. So, where a D r is the indicative geometric parameter, which varies with the location of the drain related to impermeable stratum ok.

And then, u represents the wet entry parimeter of the drain. So, here for example, if it is a circular, so u is equal to pi r naught, because circular the only wetted is have right. So, pi r naught. And in case of trench, so u is the rectangular and in case of rect trapezoid and the u is the trapezoid a perimeter is basically the parameters.

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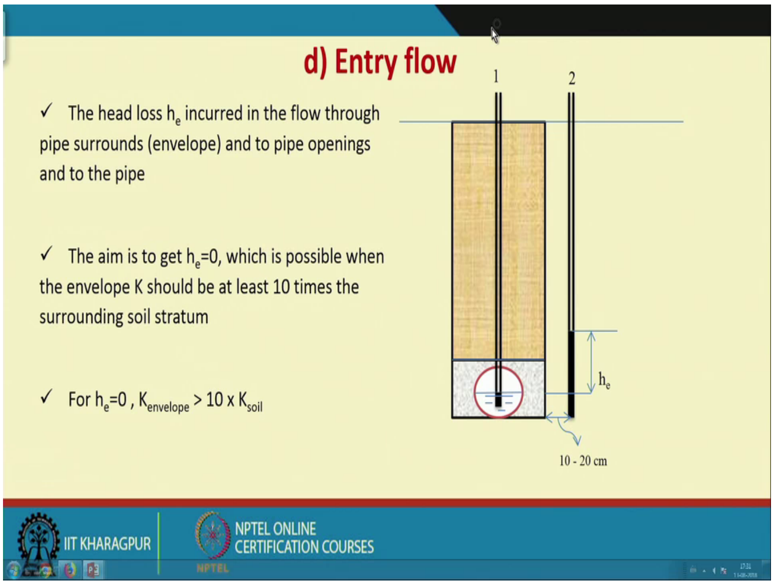

And then yeah; so, the next is entry flow h e for entry flow basically, so h e we need to minimize. For h e needs to be 0; K envelope greater than 10 times the K soil. So, hydraulic conductivity of the envelop material should be greater than 10 times of the soil hydraulic conductivity. So, here in you can also measure the entry flow by installing a piezometer nearer to the piezometer, which she is directly connected to the well. So, for example the piezometer is installed into the drain, and there is the second piezometer which is installed at 10 to 20 centimetres nearer to the drain, which has the envelope material ok. So, here the drain it h e, so that will be so like this ok.

So, this is h e we need to find out or minimize ok. So, so if you install the a piezometer nearer to 10 to 20 centimetre nearer to the drain, the water level which is present right ah. The difference in two water level will give the h e ok, so that that way we can estimate h e or h e I mean, you can also minimise h e by I mean by knowing the hydraulic conductivity of the soil, and the estimating the K envelope by multiplying with the 10.

So, this is all about this lecture, in which we will be talking about the drainages, the flow ok, hydraulics. So, the basically in the real sense, so the fluid I mean the drainage which is taking place in the top two drain pipe will be leading to the vertical and then all ups and it goes to the radial. And whereas, in schematic lay in order to make the flow; you know simulations easier. So, what we do? So, first vertical flow and then, the lateral flow, and then radial flow. So, these three flows will be considering in drainages.

So, the other thing is so the drainages head which is taking place in between two drain points, it can be considered by summing up the you know vertical head, horizontal head, a radial head and the entry head ok. So, combining all these three heads, we will get the total head ok. So, mostly in order to find out these heads we will be using Darcy's equation; and also linear interpretation in case of horizontal head.

And in case of radial Earnst equation, whereas in case of entry losses, so you will be you know using, you will be installing you know piezometer nearer to 10 to 20 centimetres, nearer to the main drain ok. And then and the head difference or the water level difference in both drains you will both piezometers will give the h e.

Thank you so much.