

**Irrigation and Drainage**  
**Prof. Damodhara Rao Mailapalli**  
**Department of Agricultural and Food Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture - 50**  
**Tutorial**

Friends, welcome to lecture number 50. This is mostly on the Tutorials. So, we are going to work on some of the problems dealing with you know the drainage, subsurface drainage using Hooghoudt equation and Glover-Dumm equation and finding out the drain spacing and finding out the drain pipe length, pipe diameter and all those things.

(Refer Slide Time: 00:49)

**Example W10.1:**

Tile drains have to be installed in an agricultural land having soil permeability of  $2.3 \times 10^{-3}$  mm/s. An impermeable stratum exists at 3.2 m below the land surface, and it is desired to keep the water level at least 1.0 m below the land surface. The average discharge of the drainage system is  $2.0 \text{ mm day}^{-1}$ . If the tile drains are planned to be placed at 1.5 m below the land surface, the drain spacing in m (assuming the equivalent depth to be the same as the tile depth), is (GATE 2012)

**Solution:**

Given

Soil permeability,  $K = 2.3 \times 10^{-3} \text{ mm/s} = 198.72 \text{ mm/day}$

Average discharge of the drainage system,  $q = 2.0 \text{ mm/day}$

Equivalent depth  $d_e = d = 1.5 \text{ m}$

$h = 0.5 \text{ m}$ .

The diagram illustrates a cross-section of the soil profile. Two tile drains are shown, each 1.5 m deep, spaced 1.5 m apart. The water table is 1.0 m below the surface. The impermeable stratum is at 3.2 m depth. The soil permeability is K. The discharge rate is q = 2.0 mm/day.

So, here example 1 if you see, so is a tile drain is problem. So, the tile drains have to be installed in an agricultural land having soil permeability of 2.3 into 10 power minus 3 mm per second, so that is your hydraulic conductivity. And impermeable stratum exists 3.2 below the land surface, and it is desired to keep the water level at least 1 meter below the land surface. So, this is what we are expecting from the drainage system.

So that means, the root zone we are expecting 1.0, 1 meter below the soil surface. The average discharge of the drainage system is 2 mm per day, ok. So, if the tile drains are planned to be placed at 1.5 meter below the land surface. So, the drain spacing, so assuming the equivalent depth to be the same as the tile depth, so what would be the drain spacing? So, that is the problem here.

So, from the given data; so, the K is given  $2.3 \times 10^{-3}$  mm per second that is the K for this stratum and impermeable layer that is 3.2 meter from the surface here and these are the two tile drains, ok. And, then we are expecting 1 meter below the soil surface the water table, in a day and the drain base depth that is 1.5 meter from the surface, ok. And, then here the other information is given like the drain we are getting the q is equal to 2 mm per day. So, this is we are expecting from the drain tile drains.

(Refer Slide Time: 02:51)

**Example W10.1:**

Tile drains have to be installed in an agricultural land having soil permeability of  $2.3 \times 10^{-3}$  mm/s. An impermeable stratum exists at 3.2 m below the land surface, and it is desired to keep the water level at least 1.0 m below the land surface. The average discharge of the drainage system is  $2.0 \text{ mm day}^{-1}$ . If the tile drains are planned to be placed at 1.5 m below the land surface, the drain spacing in m (assuming the equivalent depth to be the same as the tile depth), is (GATE 2012)

**Solution:**

Given

Soil permeability,  $K = 2.3 \times 10^{-3} \text{ mm/s} = 198.72 \text{ mm/day}$

Average discharge of the drainage system,  $q = 2.0 \text{ mm/day}$

Equivalent depth  $d_e = d = 1.5 \text{ m}$  *W-H*

$h = 0.5 \text{ m}$  *(h = 1.5 - 1)*

The diagram illustrates a cross-section of the soil profile. Two tile drains are shown as circles at a depth of 1.5 m from the surface. The water table is represented by a parabolic curve that rises to a height of H = 1 m at the center between the drains. The impermeable layer is located at a depth of 3.2 m from the surface. The equivalent depth  $d_e$  is indicated as 1.5 m. Handwritten red annotations include a double-headed arrow labeled 'L' for drain spacing, and the calculation  $h = 1.5 - 1$  next to the equivalent depth.

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So, in this case what would be the spacing, ok? So, that is the problem here, ok. So, given K is given right, q is given like equivalent depth, we have the equivalent depth is same as the tile depth that is 1.5 meter, small h is equal to 0.5 because this is 1.5 minus 1. So, this is small h, this is w minus capital H right, that is the small h is 0.5.

(Refer Slide Time: 03:28)

We know Hooghoudt's equation

$$q = \frac{8Kdh}{L^2} + \frac{4Kh^2}{L^2}$$

Substituting values in Hooghoudt's equation

$$2 = \frac{8 \times 198.72 \times 1.5 \times 0.5}{L^2} + \frac{4 \times 198.72 \times 0.5^2}{L^2}$$
$$2 = \frac{8 \times 198.72 \times 1.5 \times 0.5}{L^2} + \frac{4 \times 198.72 \times 0.5^2}{L^2}$$
$$L^2 = \frac{1192.32 + 198.72}{2} = \frac{1391.04}{2} = 695.52$$
$$L = \sqrt{695.52} = 26.37 \text{ m Ans.}$$

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So, then, so the next thing is so the Hooghoudt equation in both you know the drainage flow above you know drainage base and below the drainage base if you consider. So, this portion will give the drainage flow contribution above the drain and this sorry below the drain and this is above the drain, ok.

So, substituting the values of Hooghoudt equation now, the values are given already is K d is given h is given right. So, then so q also given, so simple substituting the given parameter values; so, you get L is equal to 26.37 meters, ok. So, this is a direct formula based problem right. So, the parameters all parameters are given, now only thing is to find out the spacing in that case, ok.

(Refer Slide Time: 04:28)

**Example W10.2:**

In an irrigation command area, the irrigation interval, gross application in an irrigation and the application efficiency are 20 days, 75 mm and 60%, respectively. The soil is homogeneous with  $K = 0.9 \text{ m day}^{-1}$ . The impermeable layer is at a depth of 7 m from the ground surface. The area is to be tile drain with tiles at a depth of 2 m below the ground surface. The maximum permissible steady state water table height midway between the drains, from the plane of the drain, is 1.2 m. using the steady state approach of Hooghoudt, assuming an equivalent depth of 4.12 m, the drain spacing in m will be (GATE 2010)

$$L^2 = \frac{8Kdh}{q} + \frac{4Kh^2}{q}$$

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So, the next problem here, in a irrigation command area the irrigation interval, ok. So, the gross application in an irrigation and the application efficiencies are 20 days that is irrigation interval, 75 mm this gross application right and 60 percent is the application efficiency.

So, the soil is homogeneous and  $K$  is equal to 0.9 meter per day that is the hydraulic conductivity, the impermeable layer is at a depth of 7 meter from the ground surface, ok. So, like there is impermeable layer from the ground surface. So, this is about 7 meter. The area to be tile drain with tiles at a depth of 2 meter below the ground surface so, there they are at a 2 meter, right. So, you have the tiles installed.

The maximum permissible steady state water table height midway between the drains; so, here, so this one is from the plane of the drain is 1.2 meter right water table height, so this is 1.2 meter, using steady state approach of the Hooghoudt assuming an equivalent depth of 4.12 the drain spacing. So, equivalent depth; so, this will be 4.12 meter. So, the drain spacing will be how much, so what would be the drain spacing, ok?

So, here also the drain spacing formula if you see small  $q$  which is equal to right  $8, K d h$  divided by  $L^2$  plus  $4 K h^2$  by  $L^2$ , right. So, the value, so here  $h$  you can find out like  $2$  minus  $1.2$  you get small  $h$ . So,  $h$  point and  $d$  equivalent depth is given 1 point and  $K$  is given, right. So, the other thing the spacing needs to be find out and you have to estimate the  $q$ . So, this is very important. So, otherwise all parameters are given.

So, this, this value will be estimated using the data given like 20 day, 75 and 60 percent. So, from that you can estimate then once you know q value you can estimate the spacing.

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**Solution:**

Given

Irrigation interval = 20 days ✓

Gross application in an irrigation = 75 mm ✓

Application efficiency are = 60%, ✓

Therefore,  $q = \frac{75}{20} \times 0.6 = 2.25 \frac{\text{mm}}{\text{day}} = 0.00225 \frac{\text{m}}{\text{day}}$

$K = 0.9 \text{ m/day}$ . ✓

Impermeable layer depth from the ground surface = 7 m. ✓

Tile drains depth below the ground surface = 2 m. ✓

$h = 1.2 \text{ m}$ . ✓  $2 - 1.5 :$

Equivalent depth  $d_e = d = 4.12 \text{ m}$

The diagram illustrates a drainage system with two tile drains spaced 4.12 m apart. The ground surface is 7 m above an impermeable layer. The tile drains are 2 m deep. The water table height at the drains is H = 1.5 m. The equivalent depth d\_e is 4.12 m. The diagram shows a parabolic water table profile with a peak height of H = 1.5 m and a height of h = 0.5 m at the midpoint between drains.

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So, let us see how can be solved. So, here the given irrigation interval is given, gross application irrigation the 75 mm, application efficiency 60 percent. So, therefore, small q is equal to 75 divided by 20 days irrigation interval. So, we bellowing the daily water you know requirement gross requirement that is the 75 by 20 that is 0.6 is the efficiency term. So, you get 0.25 mm per day. And if you can convert that in a meter per day, so this 0.00225 meter per day and K is given, right.

So, then the other data like 7 meter and 2 meter is drainage depth. So, h is equal to 1.2 because. So, here so sorry here not done this is not 1.5. So, so this is h is equal to 1.5, ok. So, the small h is equal to, so 2 minus 1 point, sorry 2 minus 1.5 there is the 0.5. So, you supposed to get first, let me will be see the values, right. Let me see: what is capital H. So, the capital H value here it is 1.2 right 1.2. So, this will be. So, H is equal to this will be 1.2 right capital H is equal to 1.2. So, 2 minus 1.2; so capital H is equal to 1.2, so the 2 minus 1.2 will give the point say 0.8, right. So, 0.8 is a small h, and these 4.12.

(Refer Slide Time: 08:46)

**Solution:**

Given

Irrigation interval = 20 days

Gross application in an irrigation = 75 mm

Application efficiency are = 60%,

Therefore,  $q = \frac{75}{20} \times 0.6 = 2.25 \frac{\text{mm}}{\text{day}} = 0.00225 \frac{\text{m}}{\text{day}}$

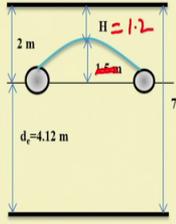
$K = 0.9 \text{ m/day}$ .

Impermeable layer depth from the ground surface = 7 m.

Tile drains depth below the ground surface = 2 m.

$H = 1.2 \text{ m}$ .  $2 - 1.2 = 0.8$

Equivalent depth  $d_e = d = 4.12 \text{ m}$



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Now, if you if you can substitute the values here sorry so, if you substitute these values in this equation, ok. So, the q is given. So, all parameter values are known, right. So, substituting the values so, L value will be 134.63 meters, ok.

(Refer Slide Time: 09:11)

We know Hooghoudt's equation

$$q = \frac{8Kdh}{L^2} + \frac{4Kh^2}{L^2}$$

Substituting values in Hooghoudt's equation

$$0.00225 = \frac{8 \times 0.9 \times 4.12 \times 1.2}{L^2} + \frac{4 \times 0.9 \times 1.2^2}{L^2}$$

$$L^2 = \frac{35.6 + 5.184}{0.00225} = \frac{40.784}{0.00225} = 18126.222$$

$$L = \sqrt{18126.222} = 134.63 \text{ m (Ans.)}$$

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So, this is almost similar to the previous equation sorry seems previous problem only thing is q needs to be you know determined based on the irrigation efficiency, gross water requirement right and also the irrigation interval, ok.

(Refer Slide Time: 09:45)

**Example W10.3:**

The EC of the canal water used for irrigating wheat is 1.2 mmhos/cm while it can tolerate a maximum EC of 6 mmhos/cm. the ET of wheat is 0.8 cm/day and soil hydraulic conductivity is 0.9 cm/h. the area is to be drained by the tile drain laid at a depth of 2.5 m below ground level so as to maintained water table depth at 1.5m the impervious layer is located at a depth of 4 m below the ground surface.

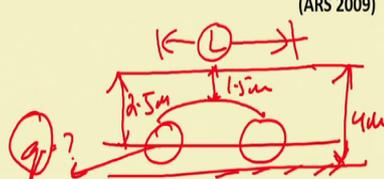
- Compute the drain spacing using Hooghoudt,s equation. X
- Calculate the drainage flow rate out of a 400 ha field ✓
- What is the size of drain pipe laid out on a gradient of 0.001 m/m, assuring that drain is running full and Manning is 0.01? (ARS 2009)

**Solution:**

Given,

$EC_{iw} = 1.2$  mmhos/cm

$EC_{dw} = 6$  mmhos/cm



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And then the example 3 here; so, this is the leachate requirement problem. So, the EC of the canal water used for irrigation irrigating wheat crop is 1.2 millimhos per centimeter. So, this is the electrical conductivity of the irrigation water, while it can tolerate a maximum EC of 6 millimhos per centimeter this is regarding the soil.

So, then ET of wheat is 0.8 centimeter per day and the soil hydraulic conductivity 0.9 centimeter per hour, the area is to be drained by the tile drain laid at 2.5 meter below the ground level. So, the tiles are laid at 2.5 meter below the ground, and maintain water tables at 1.5 meter, the impervious layer is located at a depth of 1.4 meter. So, if this is impervious layer. So, this is about 4 meter below the ground surface; and the area and 2.5 meter below the ground level below the ground level, ok.

So, as to maintain the water table depth at 1.5 meter, water table depth at 1.5 meter, and the impervious layer is located 4 meter below the ground surface. This is the compute the drain spacing using Hooghoudt equation. So, what would be the drain spacing, and calculate the drainage flow out of 400 hector field? So, then, so what is q from 400 hector field? And what is the size of the drain pipe laid out in a gradient of 0.001 meter per meter assuming that drain is running full and Manning's n is 0.01? So, this is a Manning's n so that is 0.01.

So, in this problem, so the first thing is you need to find out what is irrigation I mean leachate requirement using the EC values of water as well as the crop tolerance level, ok.

So, with these knowing the leaching requirement now you have to find out the irrigation requirement, ok. So, then from there you will be finding out what is q, ok. So, that is the first question. And the next, sorry that this is the; so knowing q value so you can find out L, then drainage flow rate for 400 hecter field can be estimated. And then knowing the q right knowing the q and Manning's equation so, you can find out the diameter of the pipe and the tile pipe, ok. So, now, the given values are here EC iw irrigation water, EC dw that is the drainage water the 6 millimhos per centimeter and then with these we are going to find out leachate requirement.

(Refer Slide Time: 13:09)

ET = 0.8 cm/day ✓  
 Soil hydraulic conductivity = 0.9 cm/h. ✓  
 Tile drain depth = 2.5 m ✓  
 water table depth = 1.5m ✓  
 impervious layer = 4 m ✓  
 Area = 400 ha ✓  
 Gradient = 0.001 m/m, ✓  
 n = 0.01 ✓

Diagram showing a cross-section of the soil profile with a water table, tile drains, and an impermeable substratum. The water table depth is 1.5 m, tile drain depth is 2.5 m, and the impervious layer is 4 m. The water table is shown as a curve between two tile drains, with a height of 1.5 m at the center and 1 m at the drains. The distance between drains is L.

Impermeable substratum

$LR = \frac{EC_{iw}}{EC_{dw}}$   
 $LR = \frac{1.2}{6} = 0.2$

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So, ET is given 0.8 centimeter per day soil hydraulic conductivity point 9 centimeter per hour, tile drain depth is 2.5 meter water table 1.5 meter and impervious layer 4 meter and area 400 hecters, gradient that is the slope 0.01 meter per meter, and then Manning's roughness coefficient that is n which is equal to 0.01.

So, we know the leachate requirement formula LR is equal EC iw by EC dw. So, substituting the values here EC iw 1.2 and EC dw 6. So, you get leachate requirement is 0.2.

(Refer Slide Time: 13:57)

As we know that

$$\text{Depth of water drained} = \text{depth of water applied} - \text{depth of irrigation requirement}$$

$$\text{Depth of water drained} = D_i - LR \times D_i = D_i - 0.2 \times D_i = 0.8D_i$$

$$ET = 0.8D_i$$

$$0.8 = 0.8D_i$$

$$D_i = 1$$

$$LR = \frac{D_d}{D_i}$$

$$D_d = 0.2 \times 1 = 0.2$$

Drainage flow rate = 0.2 cm/day

Hooghoudt's equation

$$L^2 = \frac{4Kh^2}{a} + \frac{8dkh}{a}$$

So, using this leachate requirement, so you are going to find out the depth of water drained. So, that will be the depth of water applied minus depth of irrigation requirement, ok. So, or in other word depth of water applied is equal to depth of water for irrigation and depth of water for drainage that is for leachate requirement, ok.

So, the depth of water drained is equal to, so irrigation depth minus leachate requirement into irrigation depth, this is extra amount you need to apply as irrigation so that the salts can be leached out, ok. So, the  $D_i$  minus leachate requirement 0.2 and  $D_i$ , so the total will be  $0.8 D_i$ . So, and this will be equal to depth of water drained. So, we are equating that  $0.8 D_i$ , right, we are expecting if that much drain water is taken by the crop right. So, ET is here the drainage water, because that is that means, water is taken up by the plants.

So, then substituting these values  $D_i$  is equal to 1 and leachate requirement is  $D_d$  minus  $D_i$  and  $D_d$  the drainage depth will be 0.2 into 1 that is 0.2 centimetre per day, ok. So, this is in a day see drainage flow rate is equal to 0.2 centimeter per day. And now, using Hooghoudt equation so, this is contribution of drainage water just above the drain flow above the drain base depth and below the drain base depth, ok.

(Refer Slide Time: 15:53)

The slide contains the following content:

$$L^2 = \frac{4 \times 0.009 \times 24 \times 1 \times 1}{0.002} + \frac{8 \times 0.009 \times 24 \times 1 \times 1.5}{0.002}$$
$$L^2 = 432 + 1296$$
$$L = \underline{41.57 \text{ m (Ans.)}}$$

Drainage flow rate (Q) =  $q \times A$

$$\text{Drainage flow rate (Q)} = \frac{0.2}{100} \times 400 \times 10000$$
$$= 8000 \text{ m}^3/\text{day}$$
$$= \underline{0.092 \text{ m}^3/\text{s (Ans.)}}$$

As we know that

$$Q = A \times V$$
$$V = \frac{1}{n} \times R^{2/3} \times S^{0.5}$$

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And then so all values are known except L, so you can easily find out the value of spacing, like substituting the values you get 41.47 meter and drainage flow rate Q is equal to small q multiplied by capital area I mean A, A that is area so that will be 0.2 by 100 because this is unit conversion and 400 that is hectares and again convert into meter square. So, the total will be now 8000 meter cube per day of drain drainage water which is resulting from the area 400 hectares and you can convert 0.092 meter cube per second.

So, and then now q is equal to A into V. So, this is to estimate the diameter of the tile pipe, or the tile pipe q is equal to A into V. So, V is equal to 1 by n this is the Manning's roughness equation.

(Refer Slide Time: 17:09)

$$Q = A \times \frac{1}{n} \times R^{2/3} \times S^{0.5}$$
$$Q = \frac{\pi}{4} \times d^2 \times \frac{1}{n} \times \left( \frac{\pi d^2}{4 \pi d} \right)^{2/3} \times S^{0.5}$$
$$Q = \frac{\pi}{4^{5/3}} \times d^2 \times d^{2/3} \times \frac{1}{n} \times S^{0.5}$$
$$0.092 = 0.31 \times d^{8/3} \times \frac{1}{0.01} \times 0.001^{0.5}$$
$$0.092 = 0.98 \times d^{8/3}$$
$$d = 0.411 \text{ m}$$
$$d = 41.1 \text{ cm (Ans.)}$$

*Handwritten notes:*  
 $L = A/p$   
 $= \frac{\pi d^2}{4 \times \pi d}$

So, Manning's equation if you substitute for V, then V is then q is equal to A into this is the velocity, ok. So, q is equal to, so A can be substitute as pi by 4 d square into 1 by n. So, n r pi d square by 4 pi d, right. So, because r is equal to A by p since it is a circular so this is pi d square by 4 into perimeter. So, that is so perimeter is pi d so you get the pi d square by 4 pi d, ok.

And substituting the values here for q and for other values you end up with you know d is the unknown parameter. So, now, finding out the d you get 41.1 centimeter. So, that is the diameter of the pi which can accommodate the drainage flow rate, ok.

(Refer Slide Time: 18:10)

**Example W10.4:**  
The following data were obtained from an agriculture land requiring a pipe drainage system for groundwater control:  
Hydraulic conductivity = 8.3 cm/h, drainable porosity = 5%, reaction factor = 0.31 per day and equivalent depth to the impermeable layer = 2.8 m  
The drain spacing computed by the Glover-Dumm formula will be ? (GATE 2008)

**Solution:**  
Given,  
$$\text{Hydraulic conductivity} = 8.3 \text{ cm/h} = \frac{8.3}{100} \times 24 = 1.992 \text{ m/day}$$
$$\text{Drainable porosity} = 5\%$$
$$\text{Reaction factor} = 0.31 \text{ per day}$$
$$\text{Equivalent depth to the impermeable layer} = 2.8 \text{ m}$$

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And then this is example number 4. So, here the following data were obtained from an agriculture land requiring a pipe drainage system for groundwater control, ok. So, hydraulic conductivity is given 8.3 centimeter per hour, drainable porosity that is a 5 percent, reaction factor that is alpha V discuss the 0.31 per day an equivalent depth to the impermeable layer that is d 2.8 meter.

So, the drain spacing computed by Glover-Dumm formula will be, so that we need to find out - what would be the drain spacing from Glover-Dumm equation. So, you remember the Glover-Dumm equation for unsteady state flow used. So, hydraulic conductivity is given 8.3 centimeter per hour so that is 1.992 meter per day. And drainable porosity it is a 5 percent, reaction factor alpha which is the 0.31 per day and equivalent depth to the impermeable layer that is 2.8 meter.

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Glover-Dumm equation

$$L^2 = \frac{10Kd}{\mu\alpha}$$
$$L^2 = \frac{10 \times 1.992 \times 2.8}{0.05 \times 0.31}$$
$$L^2 = \frac{55.776}{0.0155}$$
$$L^2 = 3598.45$$
$$L = 59.98$$
$$\cong 60 \text{ m (Ans.)}$$

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So, with this data and from Glover-Dumm equation you get L square is equal to this is the simple Glover-Dumm equation  $10 Kd$  by  $\mu\alpha$  and  $r$  square sorry L square is equal to  $10 K$  is given,  $d$  equivalent depth is given, and  $\mu$  and  $\alpha$  is given, this is the 5 percent.

Now, L square, this is the drainable porosity right and this one is reaction factor. So, now, L is equal to 59.98, 60 meter that is spacing, ok.

(Refer Slide Time: 20:08)

**Example W10.5:**  
A subsurface drainage system is installed in an agricultural area to control the water table. The design discharge rate of the drain is 2 mm/day. The depth of water table midway between the drain is 1.5 m below the soil surface. Drain pipe with a radius of 0.10 m is installed at a depth of 2 m. There is an impervious layer at a depth of 7 m below the soil surface. The hydraulic conductivity of the homogeneous soil above the impervious layer is 1m/day.

a. If the flow rate takes place only below the drain level the equivalent depth for a drain spacing of 90 m is  $L_e$

b. If the flow rate water takes place only above the drain level, the drain spacing is (GATE 2004)

**Solution:**  
Given,  
Discharge rate of the drain ( $q$ ) = 2 mm/day = 0.002 m/day  
hydraulic conductivity ( $K$ ) = 1 m/day

The diagram shows a cross-section of the soil. A drain pipe is located at a depth  $d$  from the soil surface. The water table is shown as a curve that is 1.5 m below the surface midway between drains. The soil has a hydraulic conductivity  $K = 1 \text{ m/day}$ . An impervious layer is located at a depth  $D = 7 \text{ m}$  from the surface. The discharge rate of the drain is  $q = 2 \text{ mm/day}$ .

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And then, so the next in the next example this is the subsurface drainage system right

installed in an agricultural area to control the water table. So, that is the purpose and the design discharge rate of the drain is 2 mm per day that is small  $q$ , the depth of water table midway between the drains is 1.5 meter below the soil surface. So, that you have this is the drain base depth, and this is impervious layer, right.

So, we are expecting here exactly, so in the midway between the drains. So, the depth of water table we are expecting is 1.5 meter this 1, right and  $q$  from here the  $q$  is equal to 2 mm per day, 2 mm per day, and drain pipe with the radius of 0.1 meter is installed at a depth of 2 meter. So, this is installed at the 0.2 meter there is an impervious layer. So, impervious layer is 7 meter. Then hydraulic conductivity of the homogeneous soil about the impervious layer is 1 meter per day. So, the  $K$  which is equal to 1 meter per day, ok.

So, the questions here are, so if the flow rate takes place only below the drain level the equivalent depth for drain spacing of 90 meter is. So, what would be the, what would the, what would below that level the equivalent depth for what is the equivalent depth? What is the  $d_e$  you have to estimate. So, this is the we have to find out what is  $d_e$ . And then if the flow rate water takes place only above the drain level the drain spacing is, ok. So, it is like a in both cases you are going to find out what would be the drain spacing as well as the  $d_e$ , ok. So, let us just see these values given the discharge rate of the drain small  $q$  which is the 2 mm per day, hydraulic conductivity 1 meter per day.

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As we know Hooghoudt's equation for water below the drain level,

$$L^2 = \frac{8dKh}{q}$$

$$90^2 = \frac{8 \times d \times 1 \times 0.5}{0.002}$$

$$8100 = 2000 d$$

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We are going to list out the other known parameters, ok. So, the first thing is, so here this

is 7 meter below, as the measuring 2 meters are drain base depth, and 1.5 meter we are expecting from I mean the water table to be down at 1.5 meter below the ground, ok, so all right.

And then as we know Hooghoudt equation for water, so this is equation of water flow or water contribution or drainage contribution above the drain base depth. So, that is L square is equal to 8 d K h by q and 90, L is given right only thing is d is you need to calculate. So, from this so, d can be estimated as, ok; so, from here so d can be estimated as 4.05 meter.

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As we know Hooghoudt,s equation for water below the drain level,

$$L^2 = \frac{8dKh}{q}$$

$$90^2 = \frac{8 \times d \times 1 \times 0.5}{0.002}$$

$$8100 = 2000 d$$

$$d = 4.05 \text{ m (Ans.)}$$

Hooghoudt,s equation for water above the drain level,

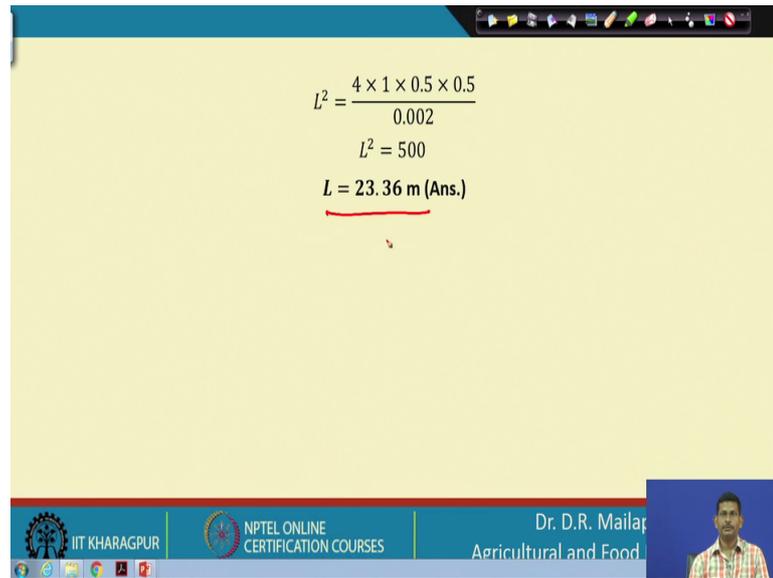
$$L^2 = \frac{4Kh^2}{q}$$

$$L^2 = \frac{4 \times 1 \times 0.5 \times 0.5}{0.002}$$

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And the above drain level. So, this is the equation L square is equal to 4 K and h square by q. So, substituting the values here you get L is equal to 23.36 meters, ok.

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$$L^2 = \frac{4 \times 1 \times 0.5 \times 0.5}{0.002}$$
$$L^2 = 500$$
$$L = 23.36 \text{ m (Ans.)}$$

So, here in this example, so we found out the contribution if you know the contribution of  $q$  above the drain base depth and below the drain base depth. So, you can find out the corresponding you know the drain spacing as well as the depth to, I mean from the impervious layer to or equivalent depth, impervious layer to drain base depth, ok.

So, this is all the tutorial. So, in this basically we were talking about the steady state problems, as well as one problem on unsteady state problem using Glover-Dumm equation. Otherwise most of you know problems are related to the Hooghoudt equation. And we have seen the variety of equations, finding out spacing, finding out the drain flow rate, and contributions flow above and below the drain base depth, ok. So, I mean I think the this variety of problems differently will help in understanding the problems right related to surface as well as subsurface drainage systems design, ok.

Thank you so much.