Irrigation and Drainage
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Lecture - 28
Well Hydraulics

Hi, this is lecture number 28 on Well Hydraulics. So, the last class we discussed on you know a Aquifers Properties. So, and this class we are going to see some of the well hydraulics mostly the water flow to well in confined as well as in unconfined aquifers.

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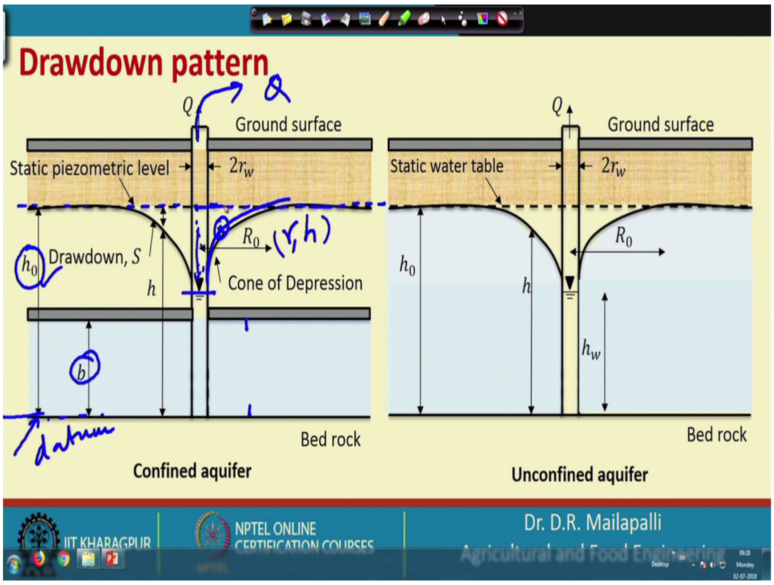

So, before going to the details let us see the draw down pattern in both confined as well as unconfined aquifers. So, in case of confined aquifer, if you see clearly here so, there is a well which is penetrating vertically down and into the you know the confined aquifer. So, this is a confined aquifer.

So here if you observe so, this is a confined aquifer. So, it has a thickness b and so, this is initial water level if you see this is initial water level so, before pumping. And so, if you take this as a datum this is the datum. So, from here to here this is h naught. So, this is initial static water level. So, in case of confined aquifer since it is. So, since the water is under pressure between you know 2 layers right 2 you know impervious layers so, then due to this pressure so, water level rises in the well.

So, the water level is at static piezometric level so, that is h naught. So, and if you see (Refer Time: 02:11) you know if you pump water continuously. So, at a particular time interval so, the water level is going to be you know deplete down so, if you think that this is the water level. So, the patterns this is called the drawdown curve. So, that any point if you take. So, this is a 2 coordinates. So, one is the radial distance so, that is R and then the other is the head. So, the other is head. So, the radial distance from here to here so, from centre well to so, from centre of well to this point and then your h.

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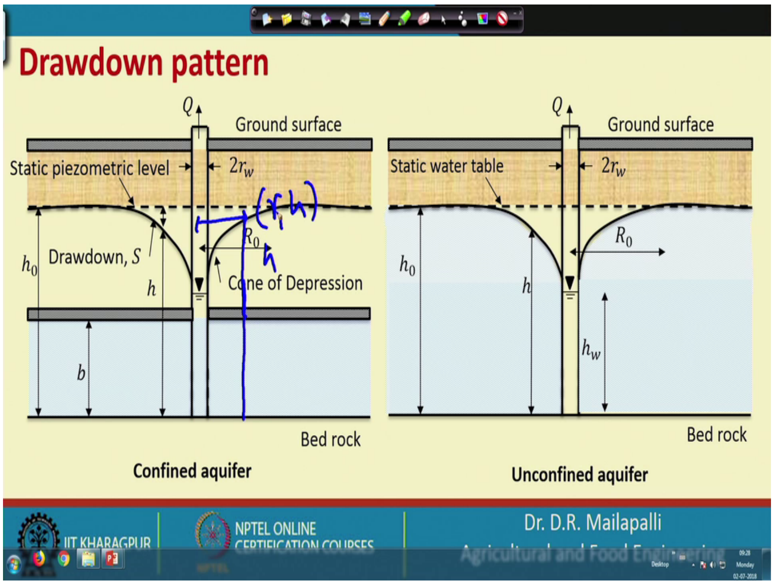

So, this has 2 components R and h. So, this is the drawdown curve. So, this varies with time and also with the distance look at this.

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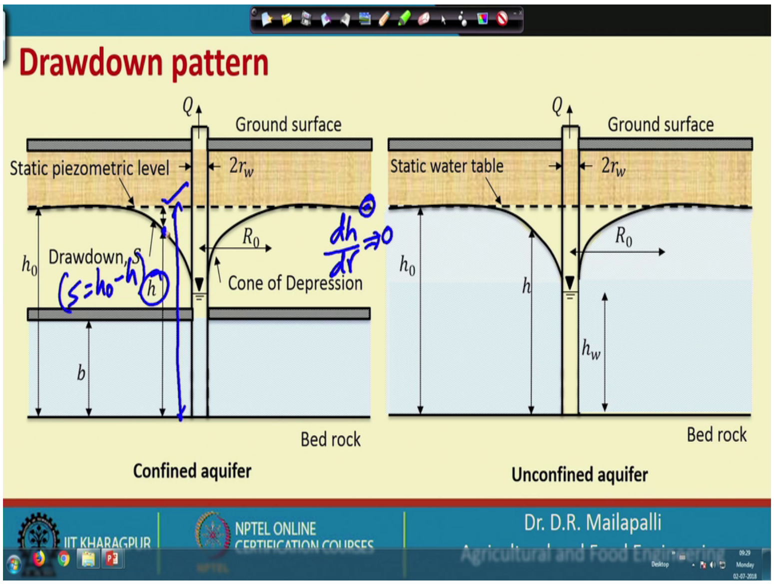

So, at end of these end of this drawdown so, there is a change in the pressure with respected to distance will be 0, because at this point there the curve is tending to the flat like 0 slope. So, d h by d l d r will be 0 at this point. Then so, this drawdown denoted with denoted with S right so, and the drawdown which is the difference between the static water level and the head. So, here the drawdown can be. So, this is h and the drawdown S is equal to so, h naught minus h. So, the initial water level minus the change in water level here h, this difference will give the drawdown. So, and then the cone of depression here.

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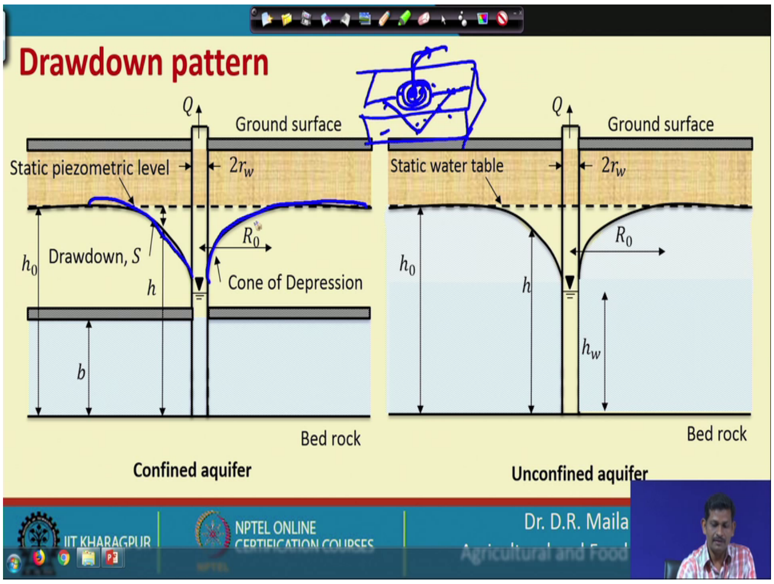

So, this is the pattern the drawdown pattern is like a cone, whereas this is the kind of a cone. So, just like you have you know the spongy material right, this is the spongy material which is initially completely saturated, if you put a straw and take water from here. So, it so, the water which is adjacent to this opening will be first removed, then after that it will be influenced to the extreme points. So, if you see this so, this acts like a cone.

So, the same thing is going to happen here and similarly here unconfined aquifer. So, the aquifer is lying on a bed rock or impervious surface impervious layer here. So, there is no other impervious layer here and top and this is open to the atmosphere. And, the water level here we are seeing so, this is called the static water level and also water table this is called water table. So, in confined case this is water table in. So, sorry in unconfined case it is water table where as confined case it is piezometric surface. So, the similarly if you take water from unconfined aquifer so, same kind of drawdown pattern you can see. So, this is so, the distance between static water level and the pumping water level. So, this is called a pumping water level. So, that is called drawdown.

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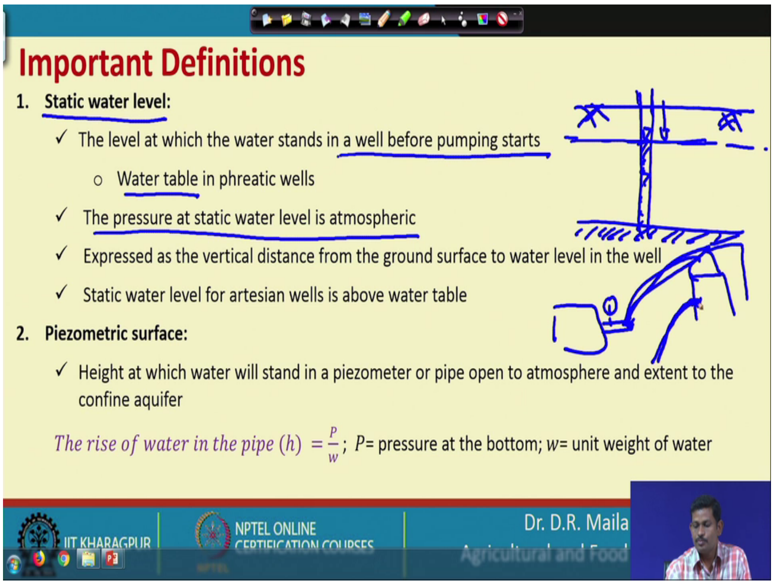

So, and the next is so, some of the definitions are important in order to understand hydraulics of the well. So, first one is static water level so, some of the things we have already discussed just in the previous slide. So, the water level at which water stands in a well before pumping starts. So, that is what so, if you have a well right which is penetrated into the aquifer. So, this is what you call ground level and this is a impervious surface. And so, initially the water level is this. So, this is called static water level.

So, if you see so, before pumping whatever water which is standing in inside the well. So, that level is called the static water level. So, generally this is water table in phreatic wells whereas, piezometric surface in case of confined aquifer or artesian wells.

So, the pressure at static water level is atmosphere. So, static water level generally is atmosphere even in case of piezometric surface. So, the static water at the pressure at water level I mean these water surface is the atmosphere. So, because then that that really equals the pressure equals the pressure the atmosphere pressure. Suppose you have pressurized force just like if you see the fire fighters. So, fire fighting force if you see. So, this is initially under pressure and based on the particular pressure. So, suppose the building is on fire right. So, the water is going to I mean eject or eject to the building. So, the point where the water is reaching at the end it cannot you know further eject.

So, this point at this point so, it will be equal to atmosphere this is a pressure and this point equal to the atmosphere. So, the same thing here the water level rises to the atmosphere equal to atmosphere. So, and the express as the vertical distance from the ground surface to the water level in the well so, this is known and static water level for artesian wells is above water table because of the pressure due to confined layers.

And then piezometric surface so, this is a artesian well. So, the height at which a water will stand in piezometric pipe open to the atmosphere extend to the confine aquifers. So, the piezometric surface we are talking about the water level in the well in confined aquifer. So, or on the water artesian well or the water level in flowing well. So, flowing well the water level in the sense suppose so this is a well so, the is going to flow like this the flowing well right. So, this is your piezometric surface.

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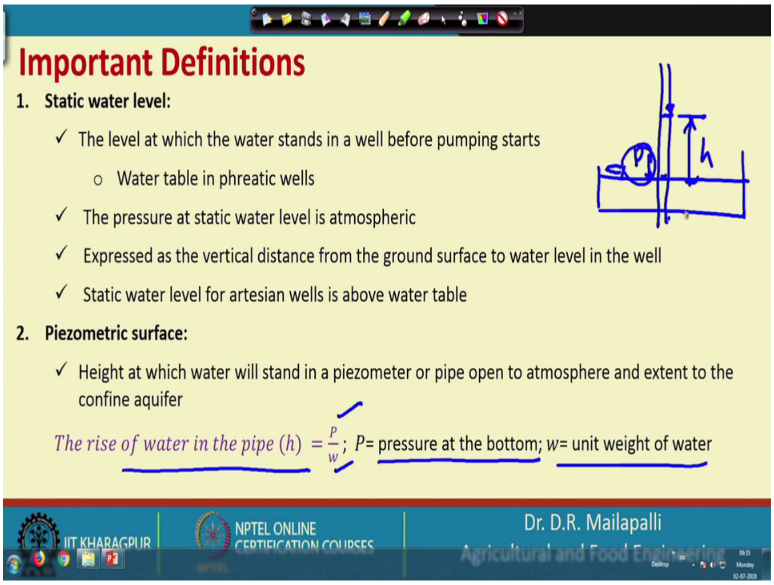

So, the rise in water in a pipe in general h is equal to P by w where the pressure at the bottom and w unit weight of the water. So, suppose this is the water and if you have a pipe in it right. So, the water level definitely rises here so, this is h. So, the water level h so, definitely this is the pressure at this point that this is a pressure, pressure this point. So, at that pressure and then and then divided by unit weight of water will give the rise in the water level in the pipe.

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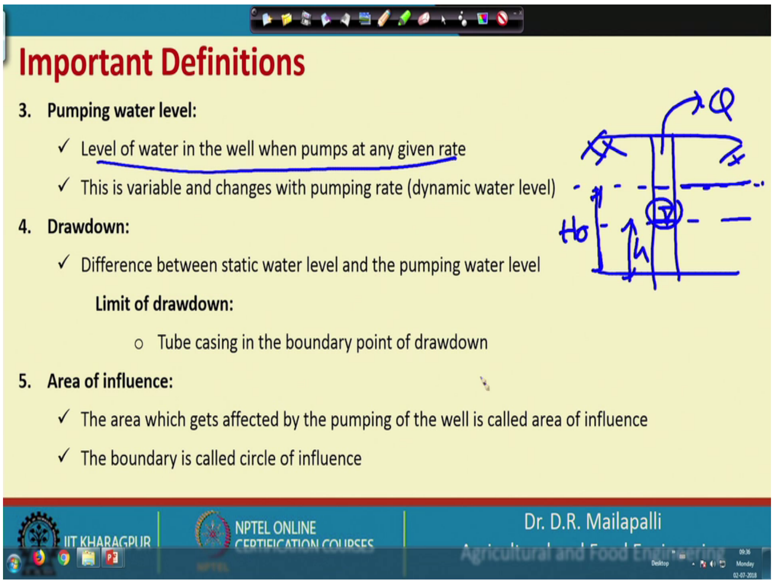

See the pumping water level here so, once you pump water from the well. So, the time at which the water level present in the well is called the pumping water level.

So, the level of water in the well when pump, suppose you have this is the so, this is the well. So, initially this is called static water level. So, then you started pumping it. So, then after that you have seen the water level is depleted down. So, this is called at time t right. So, this is this is called the pumping water level so, this is a static water level h naught let us say, this is pumping water level h.

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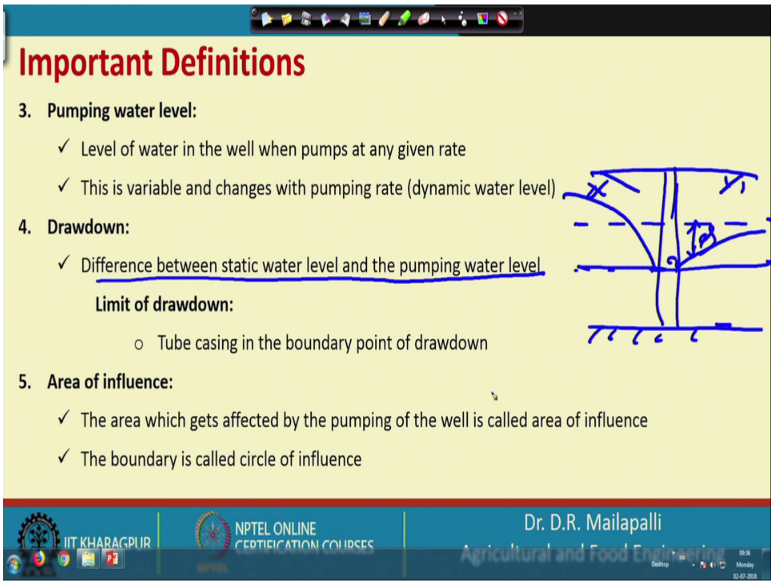

So, then drawdown so, drawdown is difference between static water level and pumping water level. So, the same you see so, this is the bedrock and then have a well. So, static water level and this is the pumping water level right. So, the difference between these 2 will give the sorry so, the difference between these 2 will give the a drawdown. So, that is denoted with S.

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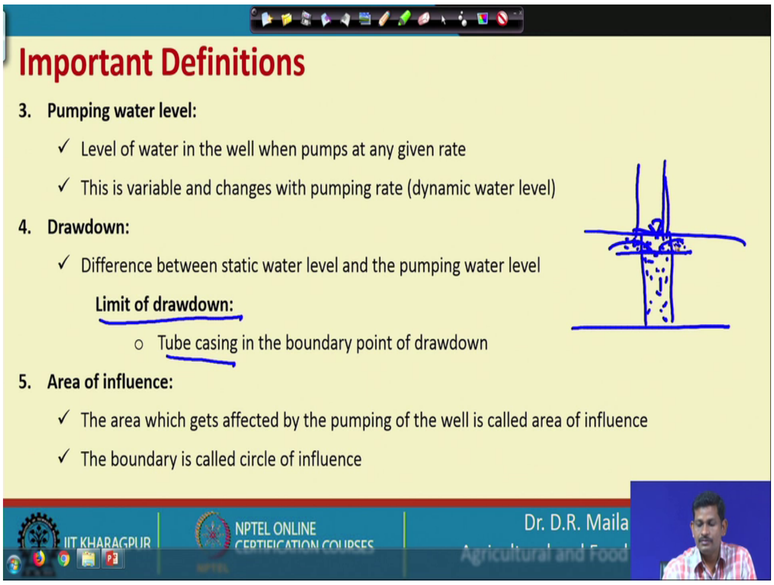

So tube casing in the boundary point of drawdown here, so the limit of drawdown is the tube casing. So, your drawdown should not go beyond the in the tube casing otherwise what happens so, the casing which has perforations right just for say perforations suppose this is the thing right. So, the thing is the pumping water level should not go beyond the casing. So, what happened in that case? So, this will be free right and your yield will be less the first of all and the second there is a chance of sediments enter into the system.

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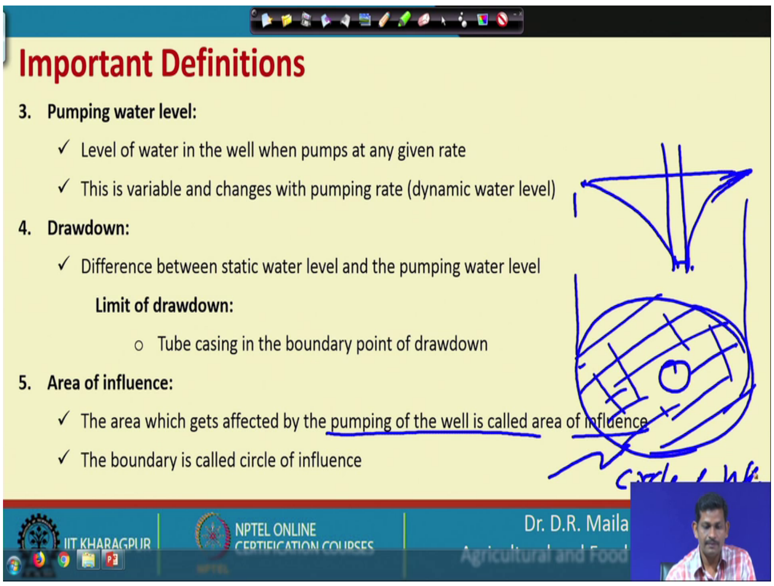

And, area of influence, the area which gets affected by the pumping of well is called area of influence suppose. So, here so, you have a this is a drawdown curve right. So, the area so, the area so, if you take the top loop right. So, this is the well. So, the area which is influenced by this well right is called the pumping of the well is called area of influence. So, this is the area of influence and the boundary is called the circle of influence this is the circle of influence.

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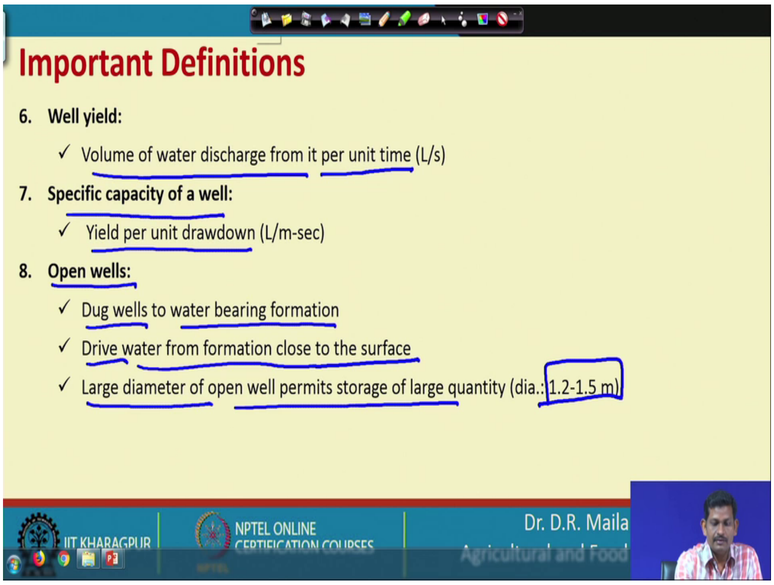

And, then so, next is well yield. So, the well yield is the volume of water discharge from it per unit time. So, in a unit time how much volume of water which is discharged from the well is called well yield.

And, specific capacity of well so, this is yield per unit drawdown. So, for unit drawdown the yield is denoted with specific capacity of the well and they are open wells. So, open wells are also called dug wells and this to the water bearing formation or aquifer. So, this drive water from formation close to the surfaces and large diameter of open well the permits storage of large quantity.

So, generally the diameter of open well varies from 1.2 to 1.5 meter. So, generally these open wells are seen in irrigated fields; nearby irrigated fields where mostly the water being used for irrigations open wells.

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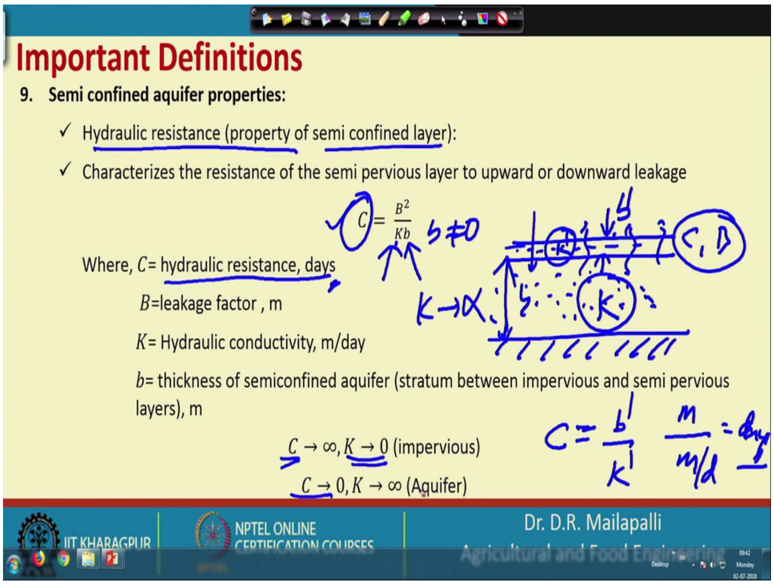

And, then so, the next is so, I in the lasts you know presentation. So, we mentioned 2 properties of leakage aquifers one is the or semi confined aquifer. So, one is hydraulic resistance and the leakage factor. So, here in case of so, I want to repeat those to see some of the properties.

So, if you see the hydraulic resistance, which is a property of semi confined aquifer. So, hydraulic resistance denoted with C, which is equal to b square by K b. So, b is leakage factor here and C hydraulic conductive resistance that is in days and K is hydraulic conductivity of an of the aquifer, b is the thickness of the aquifer. So, here suppose you have a leaky, layer here and this is aquifer let us say this is bedrock this is aquifer, aquifer. In the sense the soil which is completely saturated with water right. So, and there is a leakage. So, water can go up or even during recharge water can go enter in to the aquifer.

So, here K is the aquifer conductivity and b is aquifer thickness. And so, remaining C and B are properties of your semi confined layer. So, in this equation, we are not seeing any property related to semi confined layer. So, here generally so, we are going to see that right so, B so C hydraulic resistance that is in days.

So, C is the generally so, C is equal to. So, b this is in day’s right so, b dash by k dash. So, where b dash is thickness of your I mean semi confined layer this is b dash and k dash is hydraulic conductivity of the semi confined layer. So, that will give the C there is hydraulic resistance. So, days, because this is in metres divided by this is in metre per day you get days.

So, then so, the property here is when C is infinity so; that means, the hydraulic resistance is infinity this is too much hydraulic resistance. So, then the K value is this is K is impervious. So, the K is 0 and that is impervious. So, when this will be infinity; that means K is 0. So, b let us say b is not equal to 0. So, in that case K equal to 0 whereas, when C equal to 0 what happen K should be equal I mean tends to infinity. So; that means, this is an aquifers the perfect aquifer.

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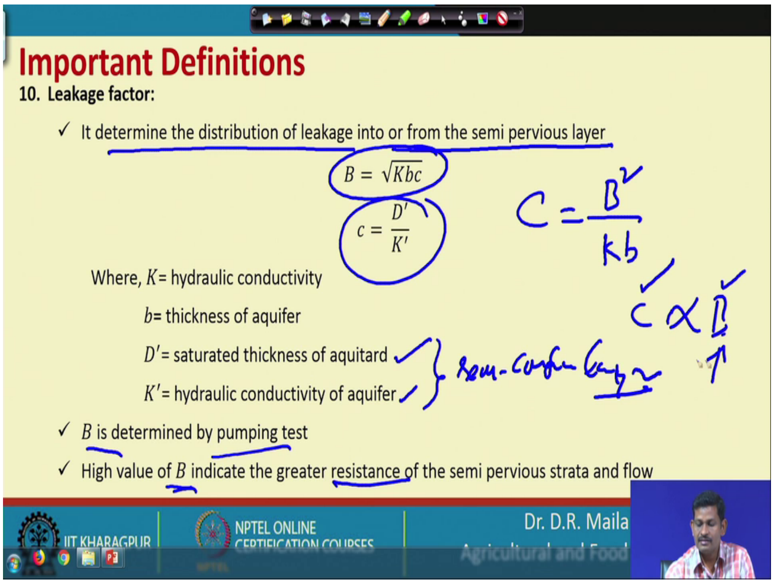

So, and then next property is leakage factor so, in case of leakage factor as I said the determines the distribution of leakage into or from the semi impervious layer. So, are the same equation if we use C is equal to right B square by k b right. So, then B is equal to C k b square root right K b c square root, where c is equal to D dash or b dash by K dash, D dash is saturated thickness of aquifer and K dash is hydraulic conductivity of the aquifer.

So, these this aquifer is the semi confined layer basically and B generally determined with pumping test. So, high value of B indicates the greater resistance because C is proportional to B. So, just we have seen increasing C the hydraulic resistance. So, definitely in a proportional to B; so, B increases means c also increases.

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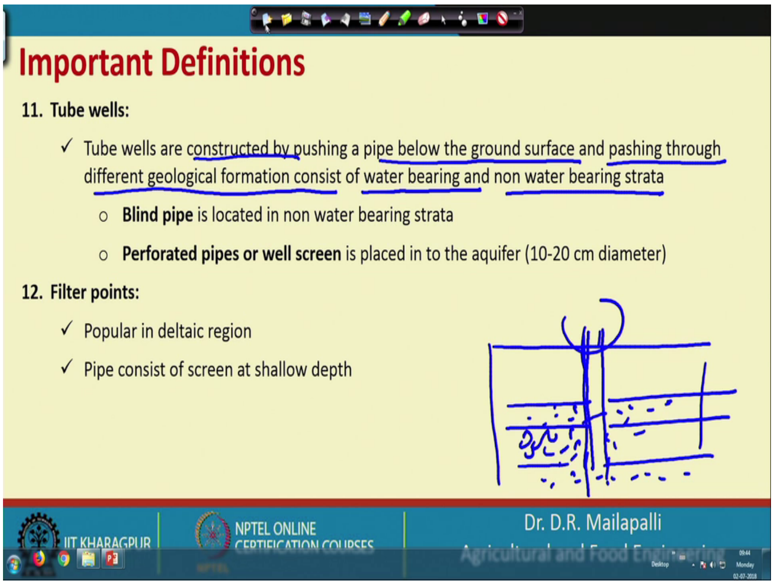

So, then the next is tube wells. So, what is that tube wells? So, tube wells are constructed by pushing a pipe below the ground surface and pushing through the different geological formation, which consists a water bearing and non-water bearing strata. So, this is a tube well is a pipe, which is being pushed down into the into the ground.

So, and also through the different the geological formations sometimes you know this is an aquifer and this is not an aquifer right and again there is another aquifer. So, that that is the definition of tube well. So, it can connect to the single aquifer or multiple aquifers.

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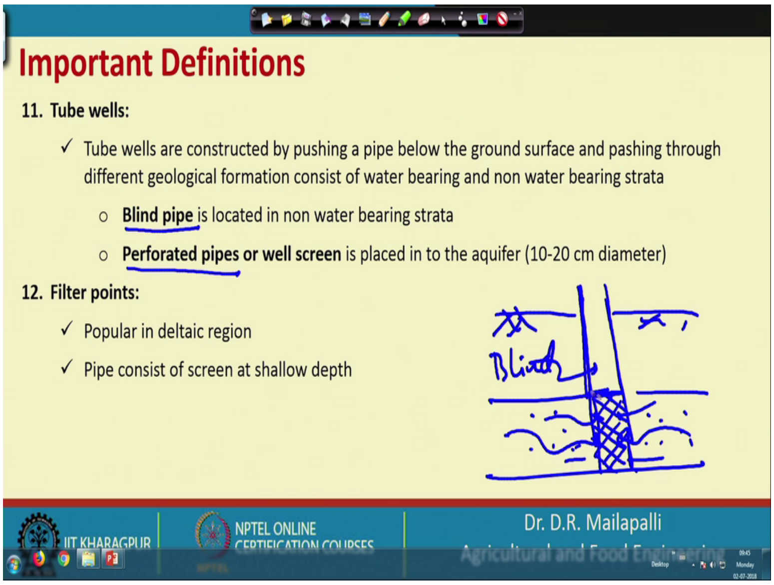

So, here in tube well there are 2 parts; one part one is blind pipe and perforated pipe or well screen. So, this is a pipe if you see ground surface and then there is a aquifer. So, then so this the (Refer Time: 19:26) from top to up to this is called blind pipe, which does not contain any perforation. Otherwise, the next part the below there is a thin pipe. So, which is required because this is the, this is what is that aquifer? So, this collects the water through the perforations.

All right so, the filter points this is popular in deltaic region. So, deltaic region if you see the water table is very shallow.

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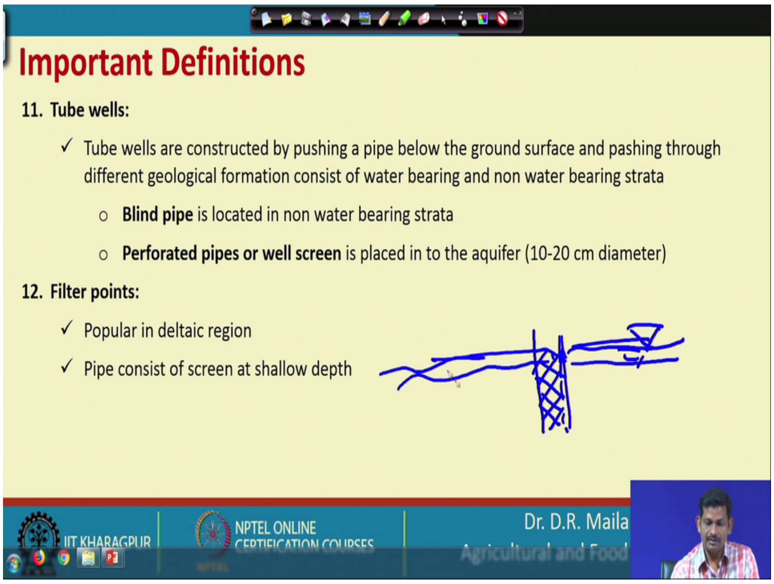

So, water table is shallow you do not require any blind by here. So, directly you can use a screen pipe right the whole screen pipe can be used right. So, because the water table is up here so, all maybe even will be less, but since the water table is shallow you do not require any blind pipe in case of the so, those are filter points.

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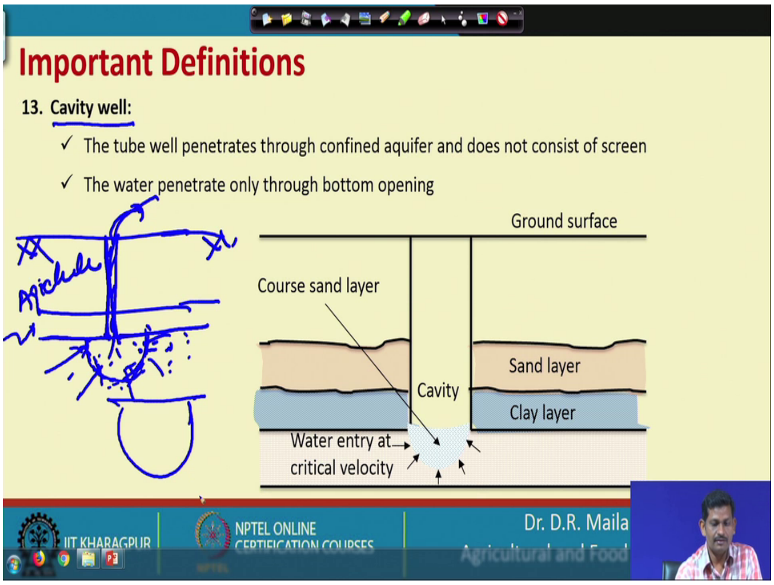

So, then what is the cavity well. So, the cavity well is a tube well. So, opposite to the filter point so, this consists of blind pipe in does not contains any contain any screen pipe. So, here the cavity wells are generally used in clay soils. So, like if you have a clay layer, if you have a clay layer. So, this is a ground surface right and this is a clay layer. So, that is aquiclude right aquiclude.

So, then the only thing for this so, the clay layer will act as and the support right. So, only the blind pipe is required up to these and since this is an aquifer it does not require any screen point right. So, this really have a stability right, it creates stability to the pipe and also does not allow to sinking of well.

So, then if you see, if you take water from here so, it forms a nice you know you know spherical bulb through 3 D view if you see. So, it is like a like a bulb. So, water which is nearby is extracted by this one.

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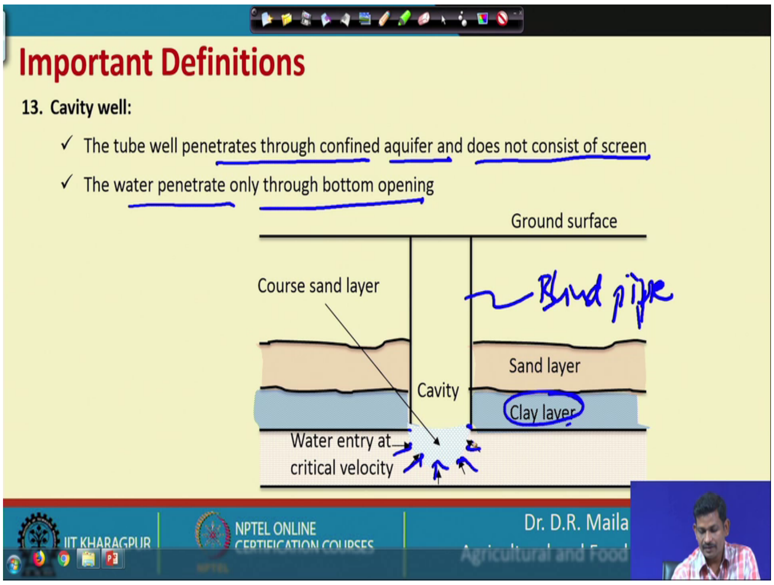

So, cavity well is a tube well penetrates through confined aquifer and does not consist of a screen and the water penetrates only through bottom opening. So, here so, this is a blind pipe and is the ground surface this is a course sand is here and this is clay layer and also sandy layer. So, we are looking for the clay layer. So, once it hits the clay layer and that is it so, water enters the critical velocity just like it clears a bulb here.

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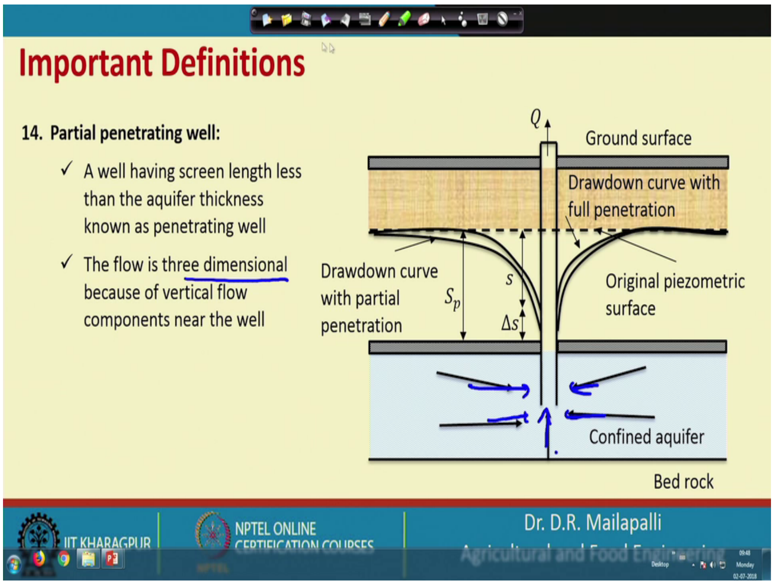

And, the next is partial penetrating well. So, here if you see in previous case, the well was here up to this is a fully penetrating well right. So, in case of partially penetrating well, so the water is flowing through well in 3 dimensional basically.

So, 3 dimensional why because the bottom since the bottom is open partially I mean it is kept at partially, it is not fully pass through the confined aquifer. So, there is a possibility of vertical flow down. So, this is a horizontal flow, horizontal vertical flow. So, this all combines your 3 dimensional flow, a well having screen length less than the aquifer thickness. So, this screen length is not equal to the aquifer thickness. So, then that is called the partially penetrating well.

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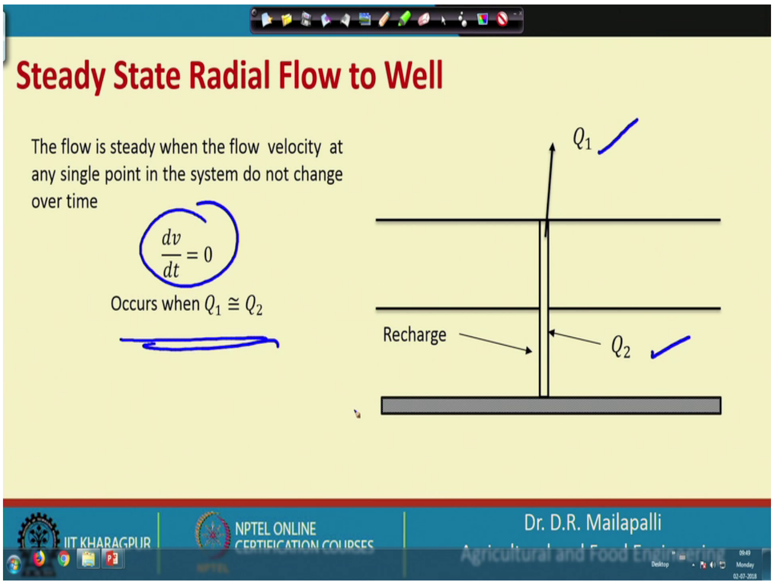

So, then what is the steady state flow to well. So, in this case of studies steady state so, the pumping water level will be equal to the recharge Q right Q 2. So, recharge Q 2. So, the pumping if the pumping water level Q 1 is equal to Q 2, which is recharge or the well water flow to well. So, then the d v by d t is. So, the change in velocity will be 0. So, then this will be to Q 1 is equal to Q 2 and we say the flow is steady state in the well.

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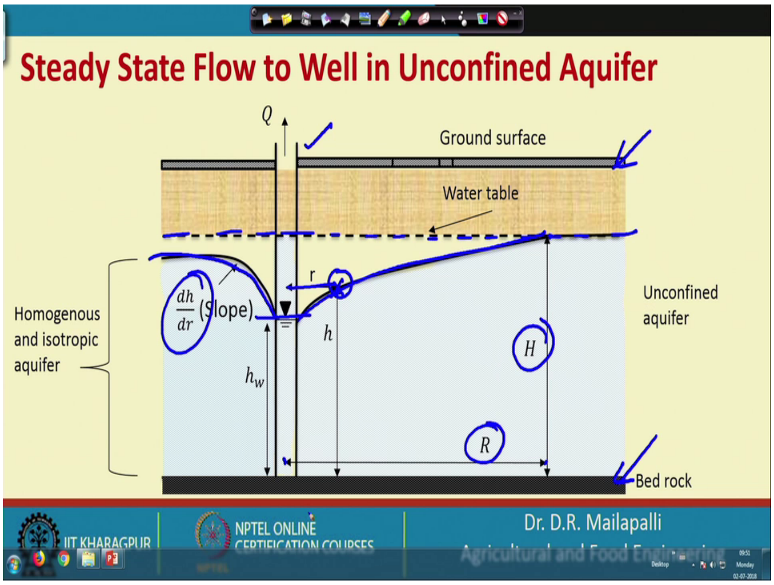

So, then how to find out the study state flow to well in confined unconfined aquifer? So, in case of unconfined aquifer so, this is this is the bed rock right. And, this is the ground surface and this is the static water level or static this is water table and, this is the well, and of course, after sometime after pumping for you know at time t. So, the water level reached to this point is called pumping water level, and the corresponding drawdown curve is like this and this is d h by d r represented with and at any point here this is r right.

This is a distance from the centre of well and then the corresponding head at this point. And, H is the head at the extreme point or it is called static water level table and R is the radius of influence R. So, these with these parameters so, let us derive an equation to find out a flow into the well.

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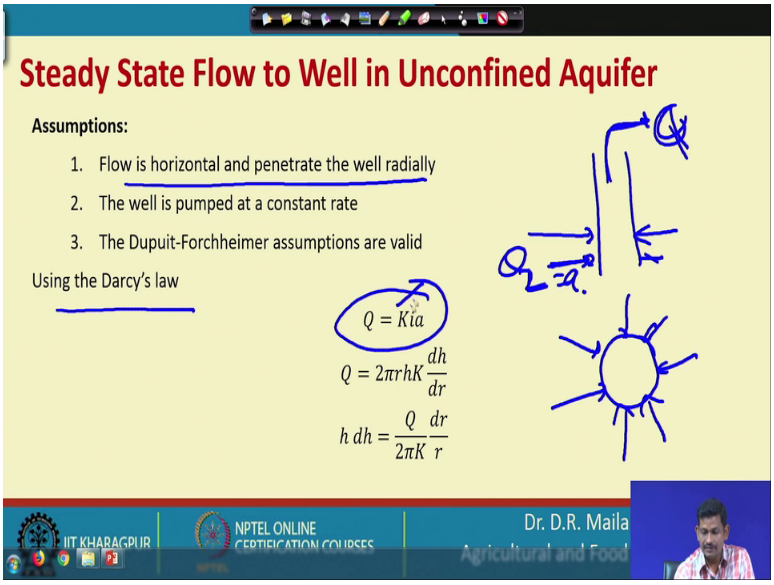

So, here in case of steady state so, there are assumptions that flow is horizontal and penetrating the well radially. So, the flow which is taking place this is horizontal right and also this is horizontal, but radially it is doing it. And, then well is pumped at a constant rate, this Q is constant here right so, then the Q 2, which is also equal to Q 1.

And, Dupuit Forchheimer assumptions are valid in this case. So, using the Darcy's law because the Q, which is going in is equal to going out so, Darcy's law is well valid. So, Q is equal to K i a right. So, then the K is hydraulic conductivity.

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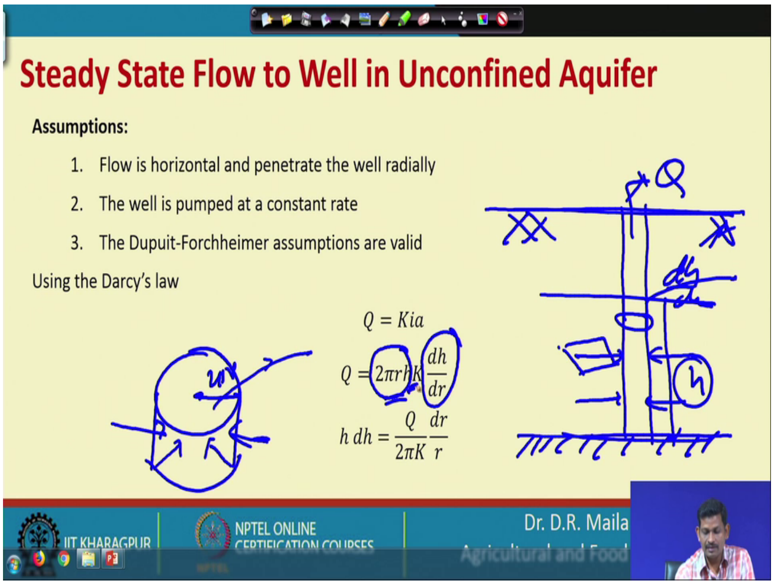

So, if you have this is a well right so, this is a bedrock and this is a surface water and salt surface and this is a well going Q right. So, then at this point if you so, see water is flowing horizontally into the system so; that means, if you take any you know point here right so, any so well point here so radially going.

So, this is the well. So, water is going horizontally so, then so, d h by d r will give the your what you call this drawdown curve d h by d r and 2 pi r h 2 pi r h because the what this is h for example, right. So, water is really flowing to the surface right. So, we have to take the surface area. So, that is 2 pi r so, this is 2 pi r into h. So, that is surface area of cross section and k is hydraulic conductivity. So, then if you just re shuffle that h d h is equal to Q by 2 pi r 2 pi k into d r by d r. So, then the next we are going to integrate that with the boundary condition.

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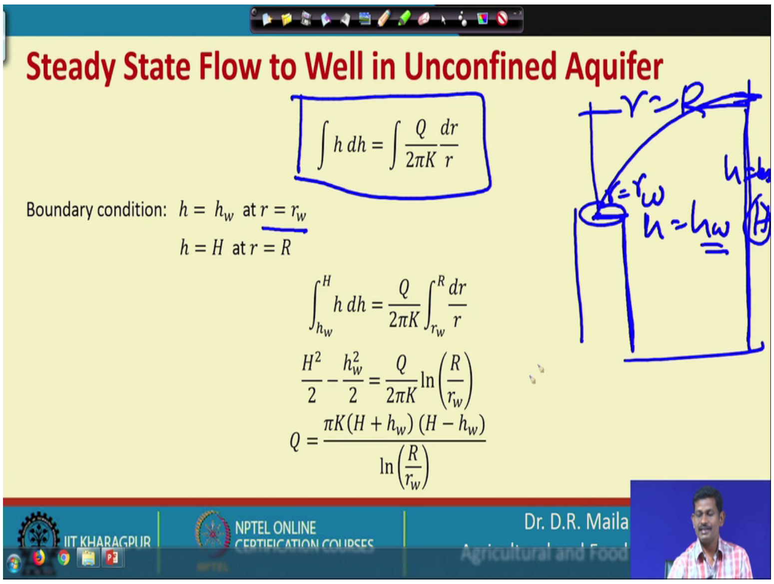

So, then you can get the solution so, h d h is equal to integration Q by 2 pi k into d r by d r. So, this and boundary conditions are when r equal to r w so; that means, exactly at the radius, radius of the well. So, r is equal to r w r w is the well radius. So, h is equal to n h w. So, h at this point h is h w. Then, h is equal to h 8 suppose this is a drawdown curve. So, when h is equal to h. So, when h is equal to h. So, that will be possible only when r is equal to capital R. So; that means, that extreme point so, in extreme point r equal to capital R.

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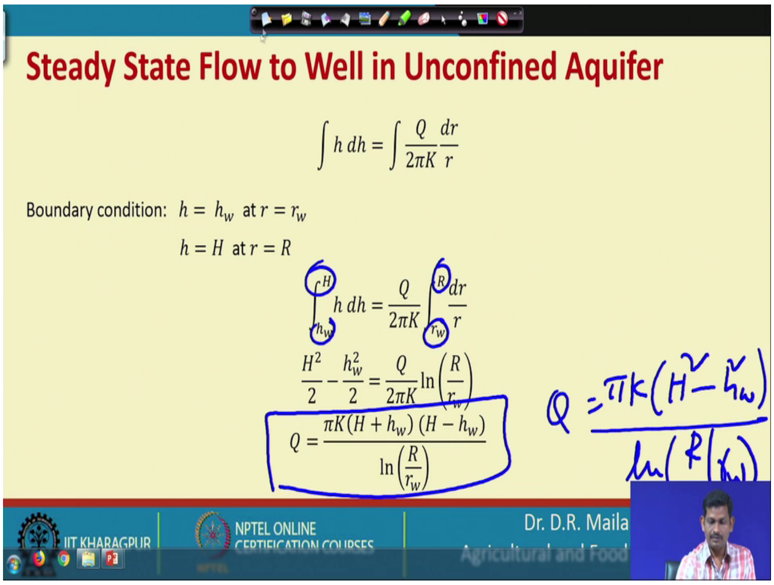

So, put these limits right r w R and if you can integrate this finally, get the equation Q where Q to pi K H plus h w h w into H minus h w. Q is equal to pi k into H square minus h w square divided by l n of R by r w.

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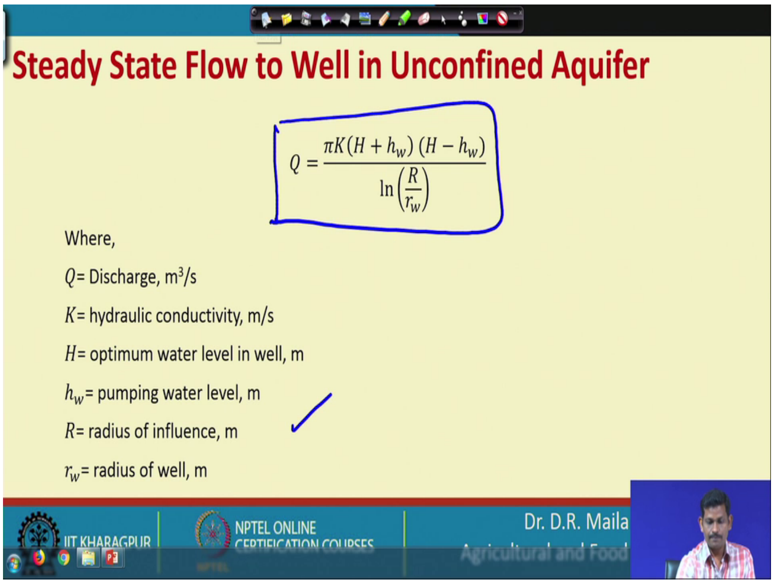

So, and the this is the same equation, the same equation will are talking and these are the definitions.

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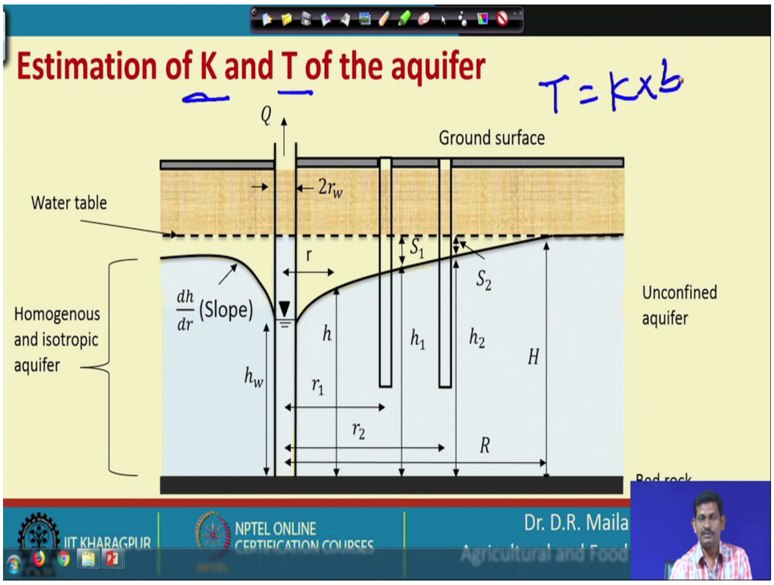

And, in the next so how to estimate the aquifer properties like hydraulic conductivity and transmissivity. So, hydraulic conductivity transmissivity so, K once you have one parameter the other parameter can be estimated because T equal to k into aquifer thickness b. So, here in order to do that so, install a 2 observation wells observation well, one and observation well 2 nearby the pumping well. So, this is a pumping well.

And, then so, in each observation well we are going to find out the draw down S 1 and draw down S 2. So, that is the use of this using 2 data draw down points. So, you can find out the K value and T value. So, let us see how we can do that.

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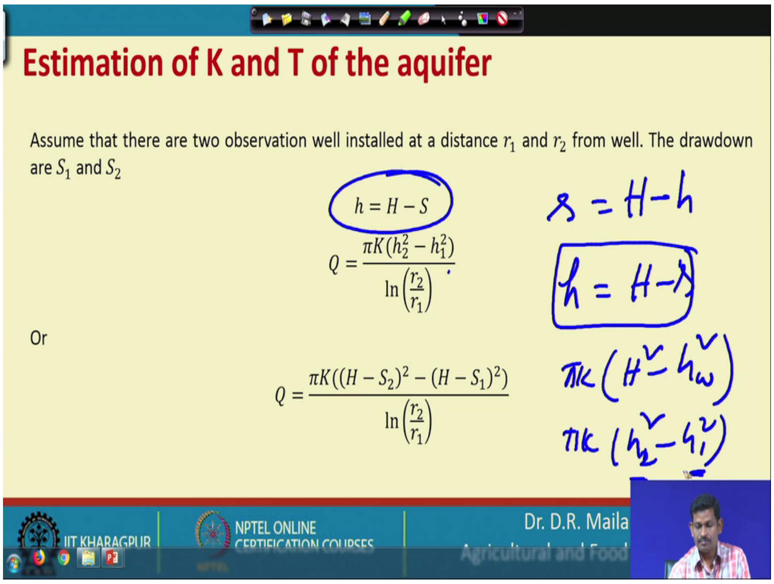

So, here in this so, assume that there are 2 observations wells. So, then in if you have an observation well nearby knowing so, draw down is equal to s is equal to capital H, which is static water level minus small h which is the pumping water level. So, then just a substitute for you know h small h, which is equal to capital H minus s.

In this in the previous equation Q is equal to 5 h then h 2 square minus h 1 square because if you remember 5 k into H square minus h w square right. So, let us this is also known as pi k into h 1 h 2 square minus h 1 square. So, the same thing so, this is h 2 the second observation point h 1, the first observation point.

So, now, substitute these values, the h 2 and h 1 right. So, pi k into H minus H 2 square minus H minus S 1 square by l n by r 2 by r 1.

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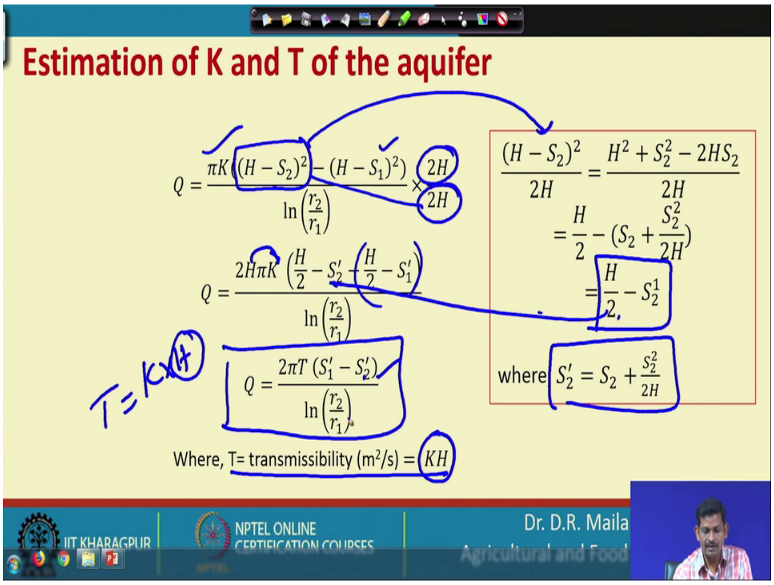

So, the next so, and once that is done. So, the pi K H minus S 2 square, H minus S 1 square into just multiply by 2 H and divide by 2 H. So, take one here and see how it how we can transform. So, H minus H 2 square by 2 H right by 2 H is equal to H square plus H 2 square minus 2 H S 2 by 2 H.

So, the finally, if you simplify that this will be equal to H by 2 into S 2 dash S 2 dash. So, where S 2 dash is equal to S 2 plus S 2 dash square by 2 H. Now, substitute this into here right into here. So, 2 pi 2 h pi K H by 2 so, minus S S 2 dash minus H by 2 minus S 1 dash.

So because this will be H minus S 2 2 H is equal to so, H by 2 right minus S 1 S 2 dash similarly for S 1. So, then simplifying that you get 2 pi T by S 1 dash minus S 2 dash l n by r 2 by r 1. So, where so, here T is equal to so, pi not pi H into K. So, T is equal to K into H; H is the thickness. So, that is the static water level so, substituting T in place of K H you get Q is equal to 2 pi T into S 1 dash minus S 2 dash by l n by r 2 by r 1.

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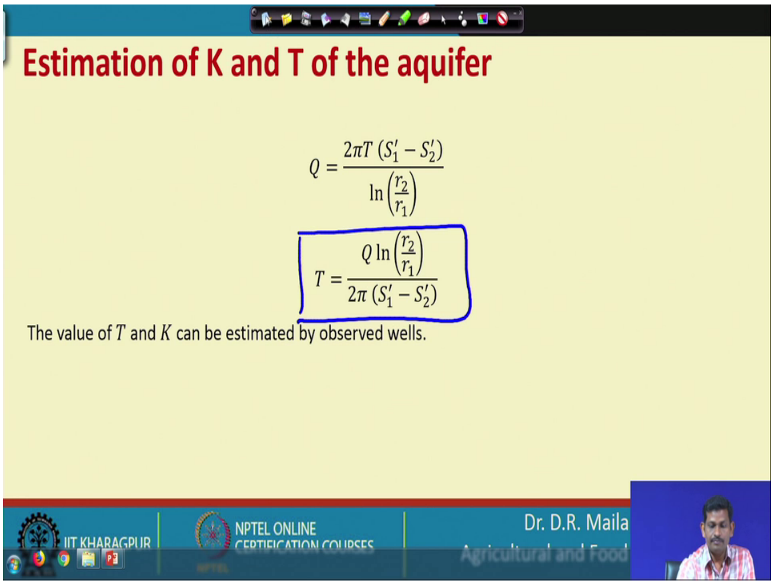

So, this way so, the final so, finally, you get a T is equal to Q into l n r 2 by r 1 2 pi into S 1 dash by S 2 dash. So, let us see an example here.

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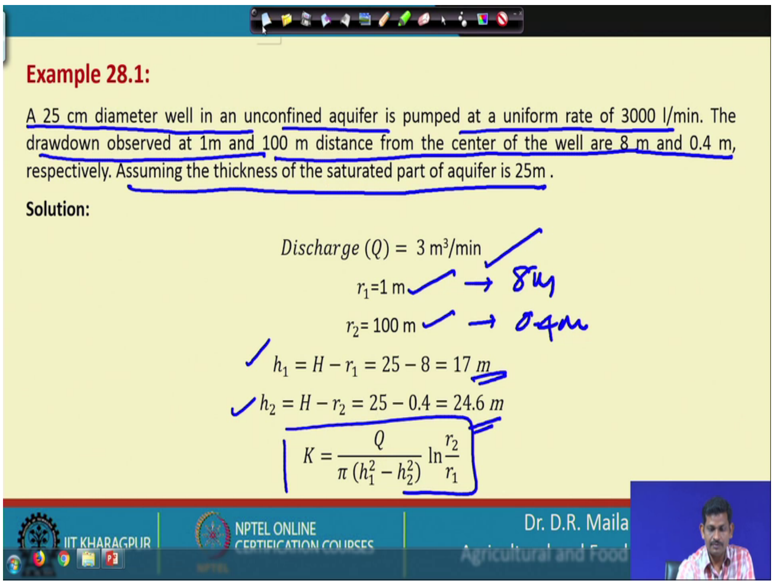

So, the example so, you have a you have a 25 centimetre diameter well in an unconfined aquifer pumped at uniform rate Q is equal to given. So, the drawdown observed at 1 meter and 100 metre distance, are 8 meter and 0.4 meter respectively, assume the thickness of the saturated aquifer is 25 meter.

So, the values given Q is given r 1 r 2 and the corresponding S 1 S 2 also given. So, at r 1 1 meter this is 8 metre S 1 and 100 metre it is a 0.4 metre. So, then h 1 is equal to H minus r 1 sorry, draw down observed at 1 metre, 100 metre distance from the centre of the well are 8 metre and 0.4 metre.

So, then so, h 1 is equal to H minus r 1 h 2 is equal to H minus r 2. So, this will be 17 metre and this will be 24.6 meter and substitute in the unconfined aquifer (Refer Time: 35:15) r 2 by r 1 right. So, then so, substitute in this equation.

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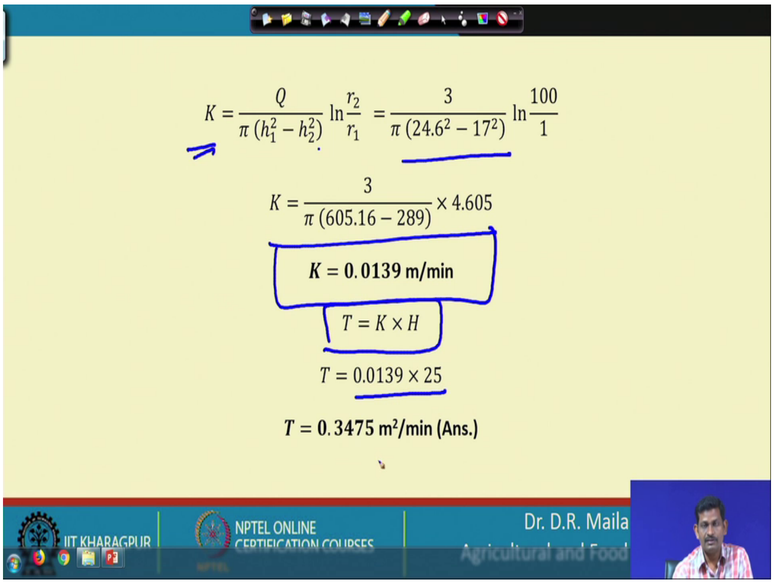

So, you will get the K value, which is Q by pi h 1 square by h 2 square, l n r 2 by r 1. And, substitute the values and K value you get 0.0139 and multiplying with H you get T is equal to 0.3475 metre square per minute.

So, in this lecture, what we focussed is some of the important definitions in case of well hydraulics. And, then how to determine the flow to well during study state and unconfined aquifer and we also solved the problem on unconfined case so, and using knowing the draw down at 2 observation points. So, we would be able to estimate the aquifer parameters such as K and T. So, that is hydraulic conductivity and transmissivity.

Thank you.