Availability and Management of Groundwater Resources
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Lecture - 23
Porosity, Permeability, Transmissivity and Storage Coefficient

Welcome to you all, in the part 4 of the module 5 porosity, permeability, transmissivity and storage coefficient.

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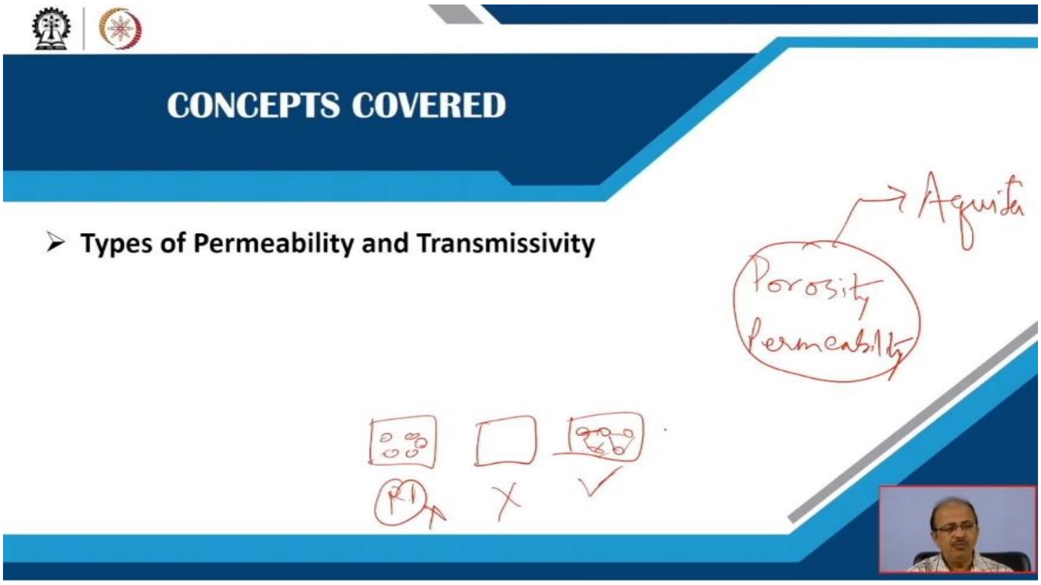

So, in this part we will try to understand about the different types of permeability and concept transmissibility. So, what we have discussed in the last two three lectures that any rock which behaves like an aquifer should have the properties of porosity as well as permeability. So, two important for any aquifer two important properties should be there first is the porosity and second is the permeability.

So, then only we can say that the rock is a very good aquifer. These two are needed for any good aquifer, if suppose we are having some different types of rocks underground in the earth's surface. And in one rock we are having the pore spaces in the other rock we are not having any pore spaces but in one different rock the pore spaces are there but these pore spaces are just in the pores space are here and these pore spaces are interconnected also.

So, there are the interconnection among the different types of pore spaces, so what is happening? This is as per the characteristics of an aquifer; this rock say rock 1, R1, R1 is a very good rock it is not a very good rock. Rather, we can say R1 is not a very good rock; because it is having the pore spaces no doubt, but these pore spaces are not interconnected. So, this is not a very good aquifer.

This is a compact rock solid, rock consolidated rock which are not having any pore spaces since they are not having any pore spaces so it is also not a very good aquifer. Now, this is a rock which is having plenty of pore spaces and all the pore spaces are interconnected among each other. So, this rock will behave like a very good aquifer. So, what we have learned that besides porosity permeability is also one of the very important parameters for considering your characteristics of any aquifer.

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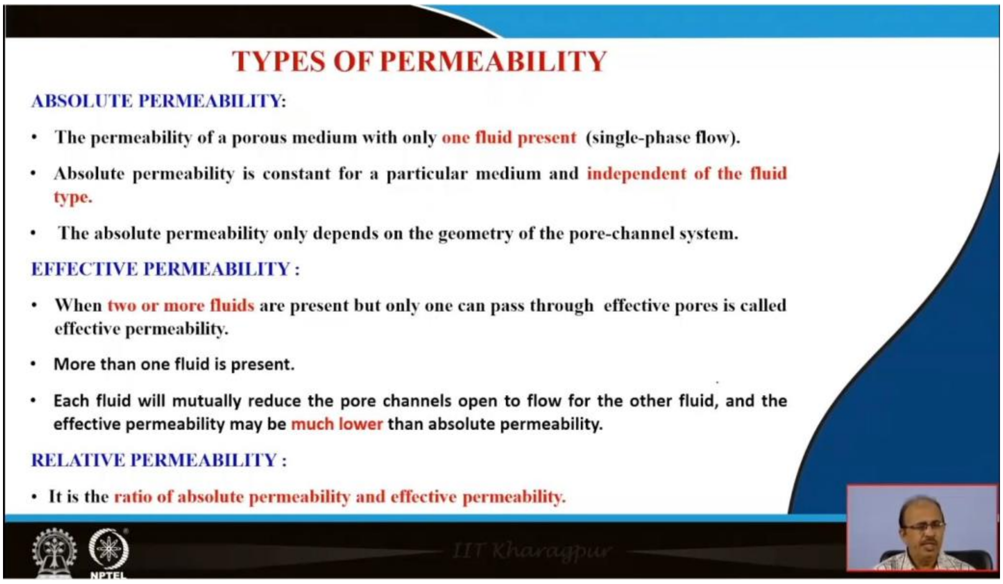

Now, in this context we can see that the different types of permeability are also there, first is the absolute permeability, the permeability of a porous medium with only fluid present. So, this is called as absolute permeability it is a constant for a particular medium and independent of the fluid type. So, it is constant for your specific type of medium and independent as per the fluid type.

The absolute permeability only depends on the geometry of the pore channel system this is about the absolute permeability. Whereas, effective permeability when two or more fluids are present but only one can pass through effective pores, then that type of permeability is termed as effective permeability. We can say it as an effective permeability when two or more fluids are present but only one is passing.

More than one fluid is present this is important for any effective for making effective permeability. Each fluid will mutually reduce the pore channels open to flow for the other fluid. So, for this only the effective permeability has been defined that each fluid will mutually reduce the pore channels, open to flow for the other fluid and the effective permeability may be much lower than the absolute permeability.

Whereas, the; relative permeability is nothing but it is the ratio of the absolute permeability by effective permeability. So, this is these are the three different types of permeability absolute effective and relative permeability. Relatively permanently we have seen that it is just a ratio, ratio of what ratio of absolute permeability as well as effective permeability, so these are the types of permeability.

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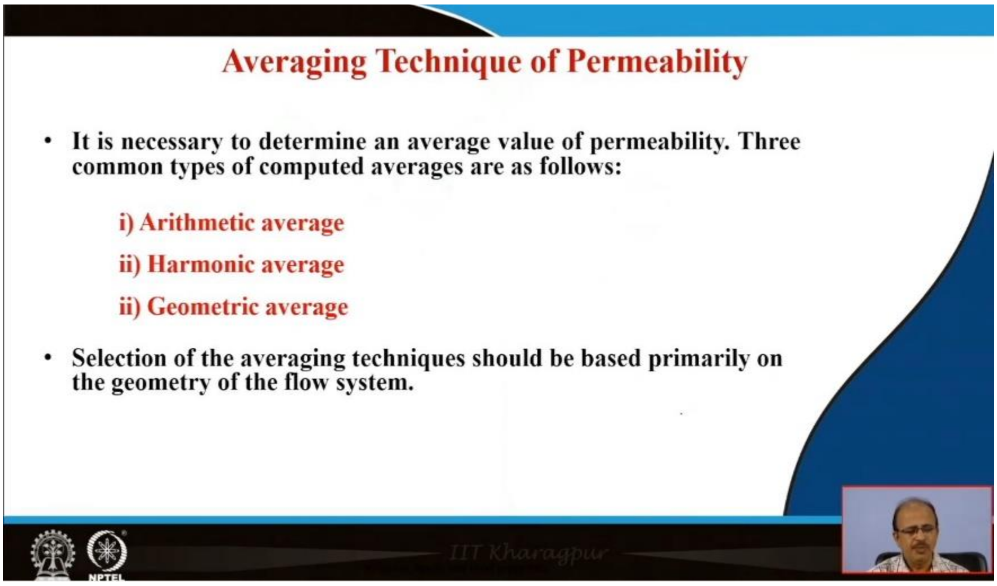

Now, just we will learn the averaging technique of permeability because we have seen two or more fluids can pass and on that basis the types of permeability has also been classified. So, what are the averaging technique of permeability it is necessary to determine an average value of permeability. Three common types of computed averages, first is the arithmetic second is the harmonic and third is the geometric.

We will discuss as per the importance view of the technique few of the technique here. Selection of the averaging techniques should be based primarily on the geometry of the flow system.

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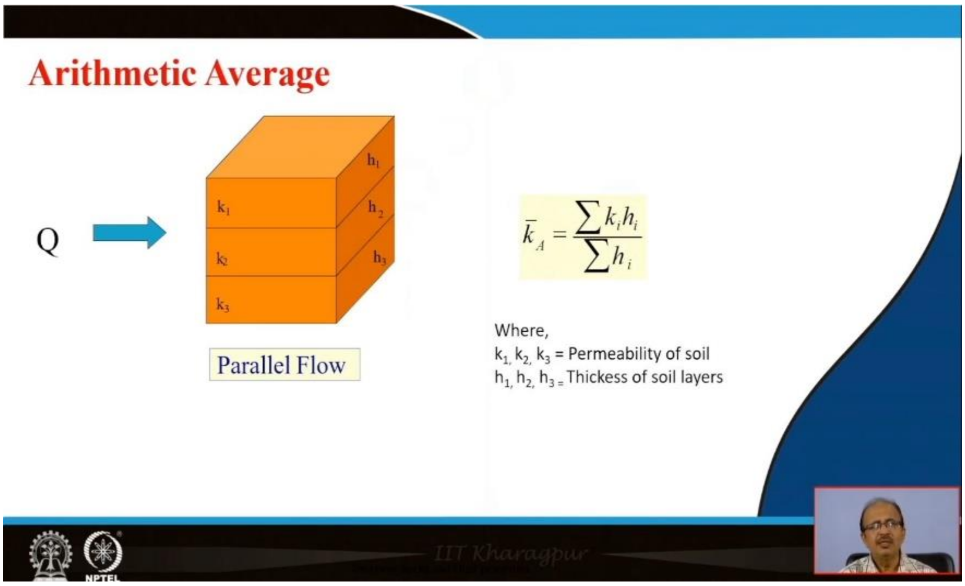

So, now arithmetic average we can see here, here the soil layers are there as per the description flow is horizontal, we are seeing here a parallel flow is there and where k1, k2 and k 3 are the three different permitting of the three different layers of the soil and now h1, h2, and h3 is the thickness of the soil layers we are seeing here. So, for this type of when the situation will remain when the flow will in the horizontal parallel flow will be there of the three different types or some other types of permeability as well as thickness of soil layers.

So, then arithmetic as per the arithmetic average summation of k1, h1 by summation of h1. So, this is the general formula for finding out the permeability and in this case when the soil layers in the soil layers the flow rates remain parallel.

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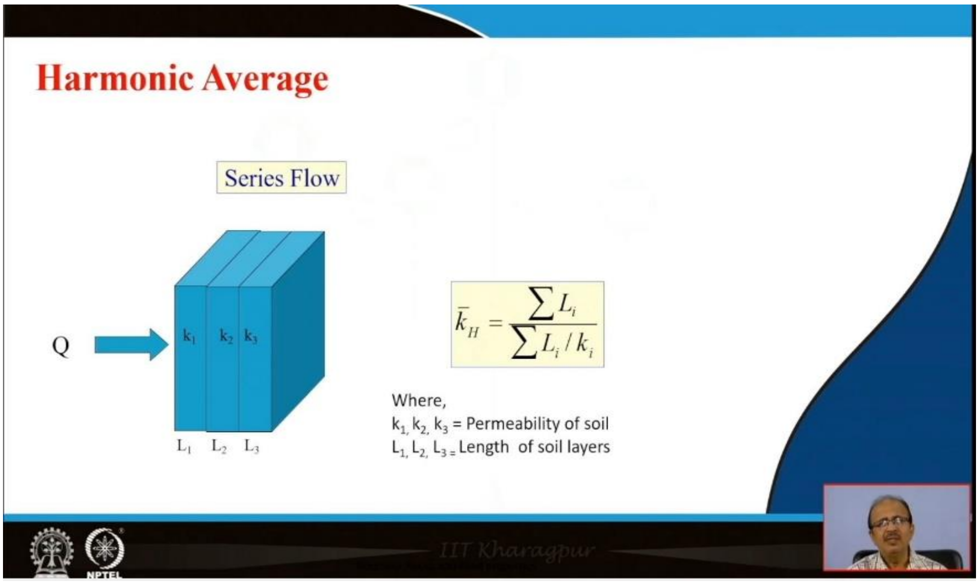

So, now next is the harmony so here, series flow we are seeing here series flow means k1, k2, k3 for three different layers of soil where L1, L2, L3 is the length of the soil layers. So, these are the length of the soil layers, in this case we are seeing that the permeability is your coefficient of permeability is the summation of L1 divided by summation of L1 by k1. So, this is the general formula for finding out the geometric and harmonic average.

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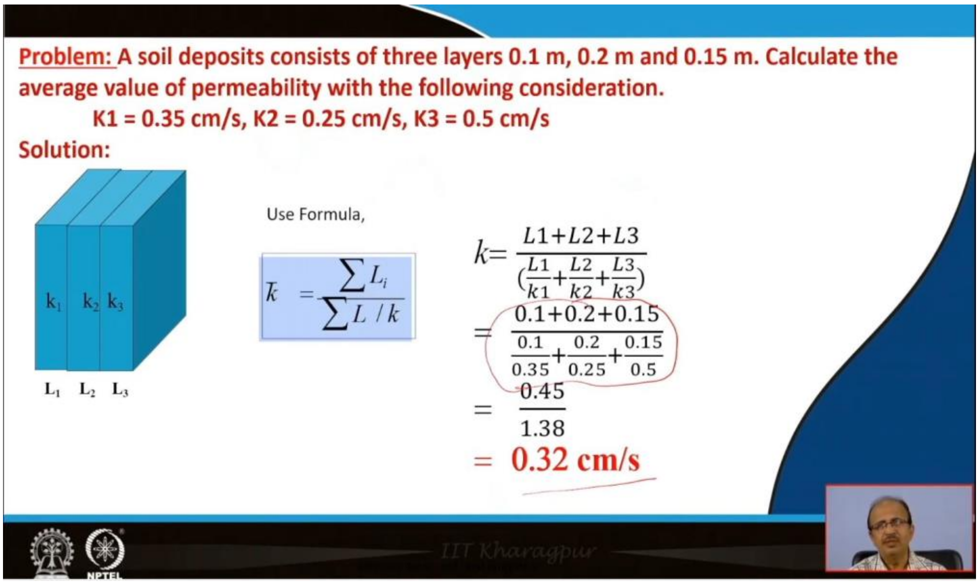

Now, on this basis we will just solve one numerical a soil deposits consist of three layers. So, now we as per the previous your description, A soil deposits consists of three layers 0.1 m, 0.2 m and 0.15 m. Calculate the average value of permeability with the following consideration. k1 = 0.35 cm/s, k2 = 0.25 cm/s, k3 = 0.5 cm/s

The coefficient of permeability is given here 0.35 centimetre per second in k2 is the 0.25 centimetre per second it was k1 is 0.35 then k2 is 0.25 and k3 is 0.5 centimetre per second. So, this is given in the question. Now we have to find out the average value of permeability with the following consideration. So, picture will remain there it means we are able to know about which type of formula will be there, so we have seen that this is the series type flow.

$$k = \frac{L1+L2+L3}{(\frac{L1}{k1}+\frac{L2}{k2}+\frac{L3}{k3})}$$

$$k = \frac{0.1+0.2+0.15}{\frac{0.1}{0.35}+\frac{0.2}{0.25}+\frac{0.15}{0.5}}$$

$$k = \frac{0.45}{1.38}$$

$$k = 0.32 \text{ cm/s}$$

so now the answer will be 0.32 centimetre per second. So, in this way we can find out the permeability when the consideration is given whether the series flow is there or horizontal flow is there.

So, we can just put the formula put the value which value is given in the numerical and then we can able to find out the solution also what is the average value of quantity within the different sets of your consideration.

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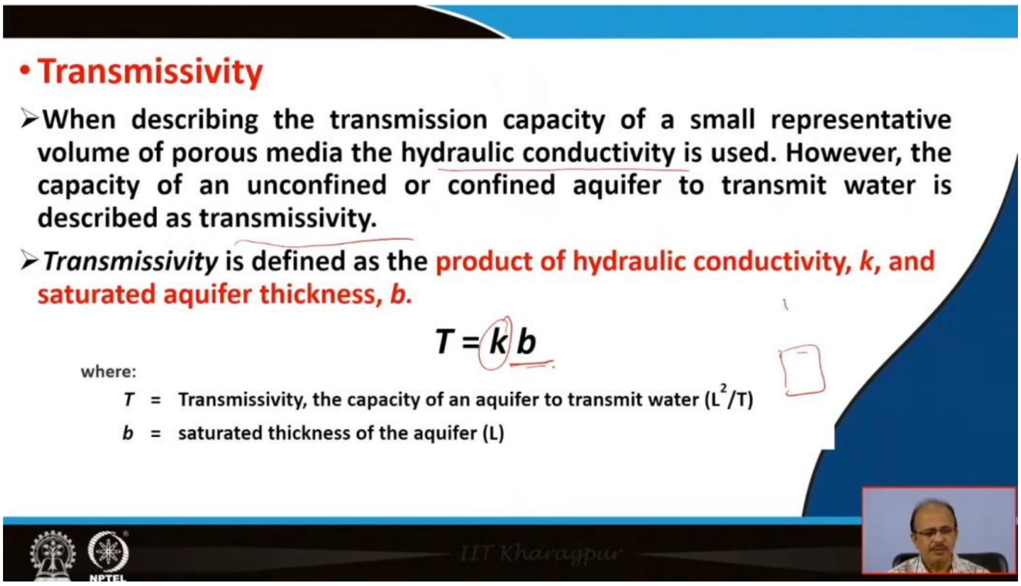

Now, transmissivity, when describing the transmission capacity of a small representative volume of porous media because, aquifer is nothing but this is a porous media it is having the porous process. So, the hydraulic conductivity is used then we are just using the, when we are describing about the transmission capacity of any porous media then hydraulic conductivity this is a very important term is used.

However, the capacity of a unconfined or confined aquifer to transmit water is described as transmissivity. Because this the extent of the aquifer confined aquifer or unconfined aquifer. Extent of the aquifer is a bit more it is having more thickness. So, for general understanding of the porous media what is the transmission capacity we can find that we can know about the hydraulic conductivity generally it is used.

But for the capacity of an unconfined or a confined aquifer to transmit water is generally described by the term transmissivity. It which we can say T = kb which is product of what we are seeing here product of hydraulic conductivity this is hydraulic conductivity and this hydraulic just multiplied by saturated thickness of an aquifer. So, this is the T = kb so, this is very important transmissivity term is very important with relation to the ability of water resources underneath the surface.

Generally, hydraulic conductivity transmissivity is the easier referred to the same view that it should have some sort of transmission capacity. Then if the transmission capacity will be there then definitely there will be the consideration of your thickness saturated thickness of the aquifer as well as the constant that is hydraulic conductivity for a particular type of soil.

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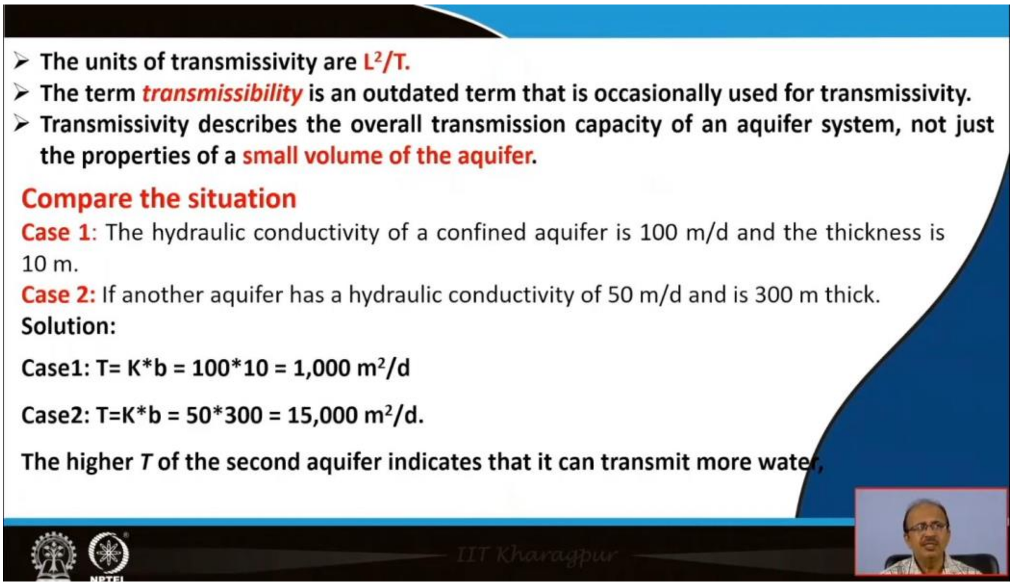

Now, we can see the unit of transmittivity are L^2/T this is the dimension L^2/T m^2/s then this the unit. The term transmissibility is an outdated term that is occasionally used for transmissivity. The transmitter describes the overall transmission capacity of an aquifer system, not just the property of a small volume of the aquifer. We cannot just refer for a very small volume of water within a rock or within an aquifer.

Just compare the situation this may come in our earth surface that hydraulic conductivity of a confined aquifer is 100 m/d and thickness is 10 m. So, for any confined aquifer the hydraulic conductivity is 100 m/d and the confined aquifer thickness is your 10 m and second condition is if another aquifer has a hydraulic connectivity of 50 m/d and the thickness of an aquifer is 300 m thick.

So, these two situations may come in your study of the groundwater resources underneath the surface. So, just we will see what is happening, so just when we are seeing here, we are finding that first solve case one in the case of Case1: T= K*b = 100*10 = 1,000 m^2/d

Case2: T=K*b = 50*300 = 15,000 m^2/d.

The higher T of the second aquifer indicates that it can transmit more water, thus if all else is equal, it would be a better target for a water supply well

So, a more amount of water will be transmitted to the when the transmissivity will be higher, so this is the concept. So, this is almost related to the permeability their permeability is also there. So, in which we have seen that the ability to transmit or receive water from one aquifer to another aquifer. So, in the two different condition we have seen how the hydraulic conductivity and saturated thickness.

When we are multiplying these two different terminologies, we are getting the transmissivity of any aquifer.

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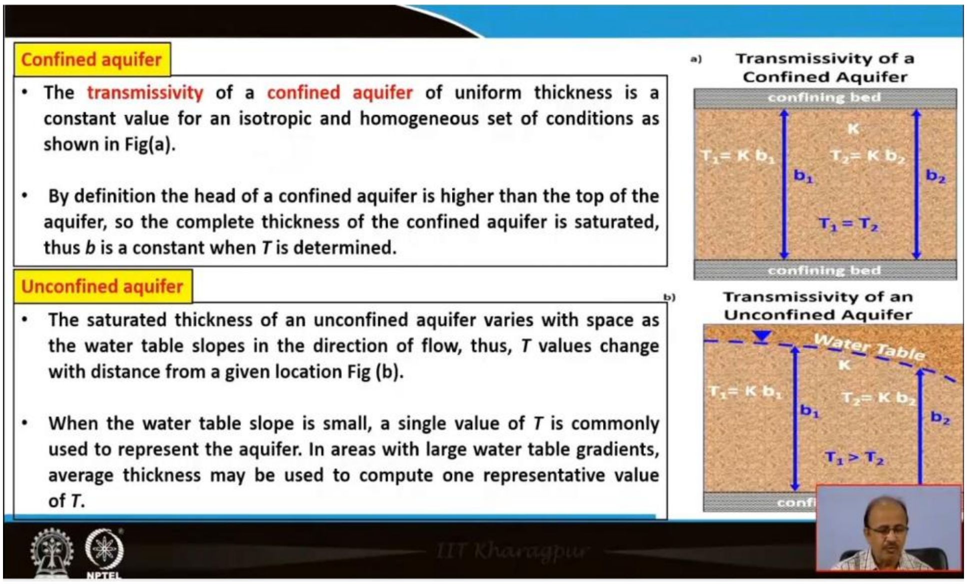

So, now the transmissivity we have discussed in greater detail, now for the confined aquifer and unconfined aquifer we will see how it is varying under two different sets of conditions. So, with this just you see right side is your diagram the transmissivity of confined aquifer this is confined aquifer. Why confined aquifer? Because this formation is having confining beds at the bottom as well as at the top.

So, the confining beds we are knowing are generally impermeable beds which does not allow water to move up or down. So, in this case this is a rock formation underneath the earth surface in which we are having the confining beds at the bottom as well as we are just seeing the confining beds at the top. So, the your definitely the formation the rock is confined in nature so what will be the transmissivity of an confined aquifer.

So, we have seen the transmissibility is nothing but it is T is the T = kb where k is the hydraulic conductivity and b is the saturated thickness of an aquifer. So, this is generally the general definition of the transmissivity which we have seen just now and I have discussed in the formula also. Now just seeing by the change of the depth thickness of an aquifer what is happening with the T value that is the transmissivity value.

So, in the case of confined aquifer it is having uniform thickness, since it is confined. So, at the top and bottom it is confining beds, so it is the thickness is uniform and it is having the constant value for an isotropic and homogeneous set of conditions. In this case we can see isotropic and homogeneous set of conditions are lying. So, the two confining beds at the top at the bottom is there.

So, this is definitely the condition of a confined aquifer and here we can see that the head of a confined aquifer this is higher than the top of the aquifer here, what is we are seeing that the thickness saturated the complete thickness of the confiner was saturated so, b is a constant when T is determined. So, one more thing we can see that here b1 and b2 is the almost equal. So, T1 and T2 is also equal here.

So, in this case because it is a case of confined aquifer having two different confining beds at the top and the bottom. So, thickness aquifer thickness is same near about equal because it is a isotropic and homogeneous set of conditions aligned here. So, as per the formula the T1 = T2. So, in this case it is the just the equal. Whereas in the case of unconfined aquifer, unconfined aquifer we have seen that unconfined aquifer is an aquifer which is only underlined by a confining bed.

And the upper level of the water in an unconfined aquifer is termed as water table. So, just with this concept we can just see the interpretation of the transmissivity which is a very important parameter of an aquifer. The saturated thickness of unconfined aquifer varies with the space as the water table slopes in the direction of flow. So, definitely the water table will slope in the direction of the flow.

So, then what is happening the T value changes with distance from a given location. So, T value will always change as the water table will drop definitely the T volume value will change. We can see here also this is the case of the unconfined aquifer. Here, you can see the thickness of a saturated aquifer is this much whereas here as the slow water table slopes down. So, the thickness b2 is only this much.

So, here what is happening that b2 is less than b1, so if b2 is less than 1 then definitely T1 is greater than T2. So, this is the concept of the two different types of aquifers regarding transmissibility. We can see in the case of unconfined aquifer when the water table slope is small but a single value of T is commonly used to represent the aquifer. In areas with large water table gradients average thickness may be used to compute one representative value of T.

So, this is very much clear from this diagram that here the b1, b2 is the same so T1 = T2 whereas, in this case generally the thickness of the saturated varies so T1 is greater than T2. So, this is about the transmissivity in case of confined and unconfined aquifer.

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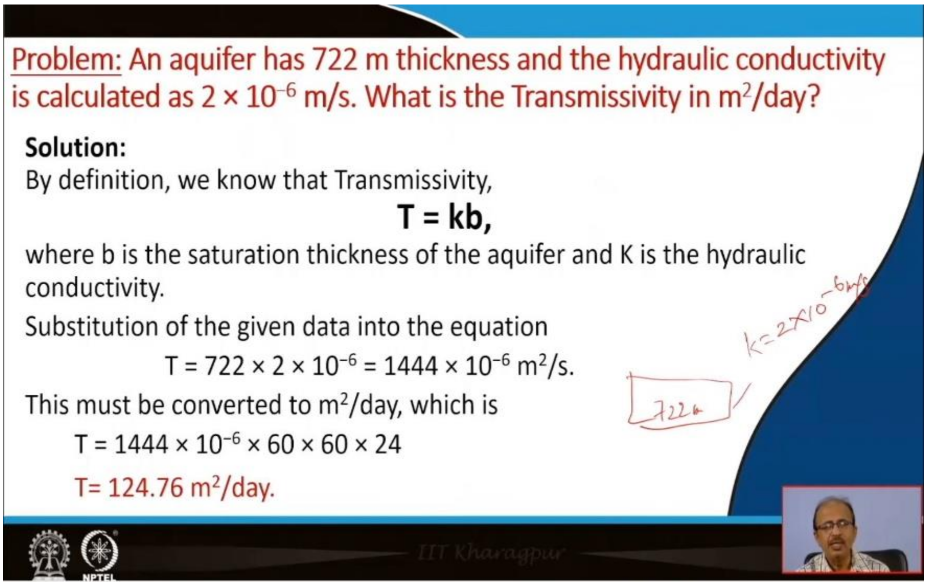

Now, just based on this, just a small numerically here that an aquifer has 722 m thickness and the hydraulic conductivity is calculated as 2×10^{-6} m/s. What is the Transmissivity in m^2/day?.

So, find out the transmissivity in meter square per day. So, this is a very important numerical because generally we are in practical mode, we are searching such type of findings also. So, By definition, we know that Transmissivity,

T = kb

where m is the saturation thickness of the aquifer and K is the hydraulic conductivity.

Substitution of the given data into the equation

$$T = 722 \times 2 \times 10^{-6} = 1444 \times 10^{-6}\ m^2/s.$$

This must be converted to m^2/day, which is

$$T = 1444 \times 10^{-6} \times 60 \times 60 \times 24$$

$$T = 124.76\ m^2/day.$$

So, what we have seen? We have seen that the aquifer is having thickness any aquifer is having thickness and the same aquifer whose thickness is there separately the hydraulic conductivity varying from place to place. Because this will decide the type of a preferred which type of a preferred is there.

Whether the; aquifer is productive or not whether the aquifer is good or not. So, suppose a used thickness is there but it is yield is very poor. So, that aquifer is not considered as a best aquifer. So, we should put in the mind the concept of transmissivity is nothing but it is the multiplication of the saturated thickness of the aquifer as well as the hydraulic conductivity of the formation. So, this we have understood in this lecture. So, the more concepts we will learn in the next lecture. So, we thank you very much to you all.