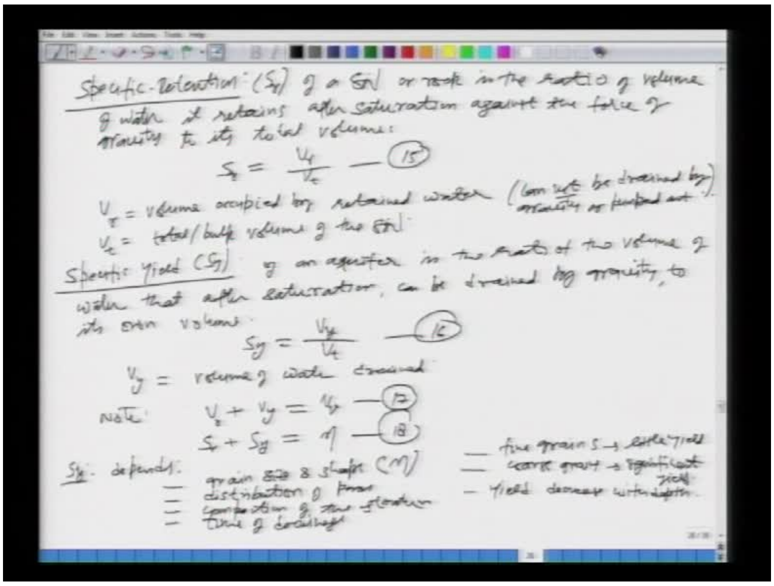
Advanced Hydrology

Prof. Dr. Ashu Jain
Department of Civil Engineering
Indian institute of Technology, Kanpur

Lecture – 38

Good morning and welcome to this post graduate video course on advanced hydrology. We are into the ground water hydrology module, the last lad of this course. Yesterday, we looked at the moment of ground water in the saturated zone and essentially we looked at the Darcy's law, its applicability and validity. And then we also looked at a numerical example in which we saw that how we can calculate the hydraulic conductivity and calculate certain other parameters like Darcy is flux and actual velocity and so on. Today, what I will like to do is; like to go back a little bit, look at some more aquifer property is which we actually skipped.

(Refer Slide Time: 01:07)



So, we will start looking at specific retention and the specific yield, right. So, how we define these parameters for these aquifer properties, which are important to understand as we will move along this course and look at the movement of the ground water in the saturated zone. This specific retention is denoted as S subscript r. And let me give you the definition and then give you the expression of a soil or rock and we are taking aquifer. Here is the ratio of volume of water; it retains after saturation, against the force of gravity to its own volume or to its total volume.

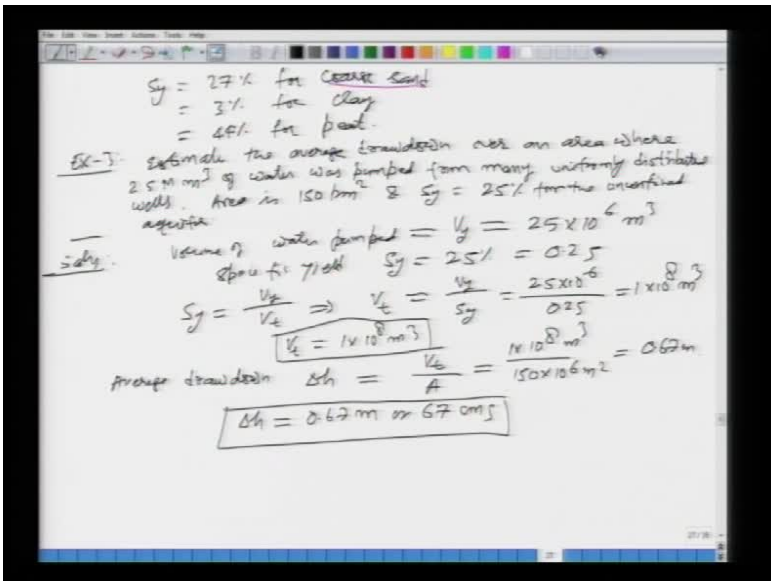
So, what it is this? Basically, what we are seeing is that it is the ratio of the water retained by the soil, against the force of gravity means what? When the gravity forces are not there. So, water being retained by suction or some other forces, right. After these sample has been thoroughly drain due to the gravity forces and to its total volume. So, if we defined it, it will be S subscript r; will be let say V r over V t. And using the equation numbers, let me number this as 15 which we are in following. Where V r is the volume occupied by retained water. And thing to remember is that it cannot be drained by gravity or pumped out even. When we pump out, we cannot pump out the detained water. And V t of course, we had defined earlier it is the total or the bulk volume of the soil. So, this basically, this parameter gives us some idea about how much water cannot be extracted and this retention power or the retention capacity of different types of soils will be different.

So, depending upon that if we get have some idea, we know how much water we are actually going to play win; if we have an aquifer of certain volume available to us. The next one is the specific yield. This is very important and this is denoted as S subscript y of an aquifer or a soil or rock is the ratio of the volume of water that after saturation that after saturation can be drained by gravity to its own volume; that is the ratio. And, this we can then write as V y over V t that is the ratio; let me number this equation as 16. And then V y is the volume of water drained or pumped out. So, this basically this specific yield gives us an idea about how much water is actually available. There are there is a total force space in the or the porosity, out of this certain fraction actually; you know if it is saturated certain fraction cannot be available for any useful purposes. And, that is your specific retention and the specific yield is something which can be a pumped out or we can use.

Let us see that or note that what will be the sum of this V r and V y; that is the sum of the water retained and the sum of the water drained from a sample or a saturated sample volume of the voids, the total voids. And similarly, because if you divide this equation by V t, then you can say that the specific retention plus the specific yield will be equal to what? This obviously has to be equal to your porosity eta; that is let say 18. Now, this S y is something important. It depends on what? Let me just list a few factors on which it will depend. It will depend on the grained size and shape of the soil on which your eta actually depends, right. And also the distribution of the pores, how the voids or the pores are distributed; distribution of the pores. How they distributed with the specter space? How about the compassion? You may have an undisturbed sample and you may have a compacted sample; there porosity will be different and this specific yield obviously would be different.

So, you have the compassion of the stratum. Also, the time of drainage, if we keep pumping water the specific yield will be changing as a function of time; because the compassion characteristic may be different, as a function of time. The next factor is the course or the fine grains; basically, the soil type or the size of the soil basically. So, if we have the fine grains; means you will have little yield. Just find a points we are looking at an if we have the course grain soil would mean what? You will have significant yield. Now, this yield will decrease with depth as we have said earlier that these specific yield is will depend upon the compassion and as we go down into the ground, the compassion due to the over burden will be increasing and the pores spaces will be decreasing. So, that specific yield also will decrease; so as we go down the yield will be the function of the depth also.

(Refer Slide Time: 09:41)



This S y is about 27 percent for course sent and it is about 3 present for clay type of strata or an aquifer which consists of mainly clay and this is about 44 percent for peat. So, you see that looking at the kind of aquifer, the soil properties; so, we can carry out the whole investigation, we know what kind of soils are present in the aquifer. So, once we have that, we get some pretty good idea about how much water can be taped in the ground. For example, if we find that there is core sand in the aquifer around particular area, then we know the maximum yield we can have is about 25 percent or so. But if it is a clays strata, there is hardly any yield we will have. So, there is no point in spending money in exploring that particular area in which clay is present. So, what I am going to do next is, I would like to look at an example.

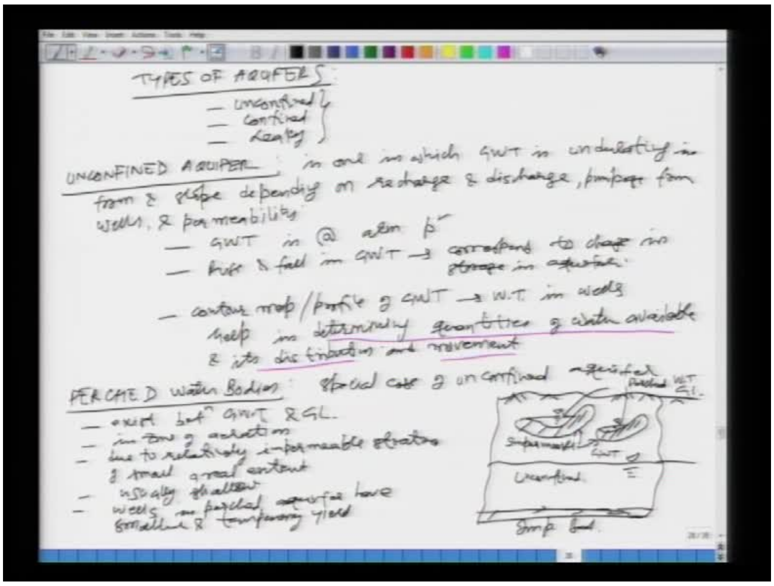
Third example in this chapter, in which we will look at this specific yield, how it can be useful in computing certain important things. And this is how it goes, estimate the average draw down, estimate the average draw down over an area where 25 million meter cube of water was pumped from many uniformly distributed watts, distributed watts. The area which is exacted is about 150 square kilometers and S y the specific yield of that aquifer is given to about 25 percent. So, looking at this what kind of soil is this, in some course sand; from the unconfined aquifer. This is an unconfined aquifer and we are going to look at little bit more closely; what is this unconfined and confined this aquifers. One thing which is you know to be noted here is what is given is a towards is that, we have an area areal extent of the aquifer; the areal extent of the aquifer is about 150 square kilometers. So, it is a large area in which there are many you know tube wells which are dug and we are pumping water.

And what he said is what is given is that these dug wells or the pumping wells are distributed uniformly with the specter space. And this is an important assumption why because we can assume that the draw down is uniform; it is same everywhere. So, that is what we actually try to do; so that we do the pumping the draw down are not very high at a concentrated location. So, these are the data given and what we have to find is the average drawdown. So, if we have pumped out 25 million meter cubed of water, in some certain duration; what will be the lowering of the water table, the ground water table in this unconfined aquifer? Specific yield is given and the amount of water which is a pumped out, that is also given. So, let see how will do that. What is given to us is, the volume of your water pumped out or drained, what is this? This is V y, we have just seen volume of water which is pumped is V y and this is given to us as 25 million meter cube; so I can say 25, 10, 6 meter cube.

What is also given to you is the specific yield. S y is 25 percent; so it is 0.25. What is S y? Well, we have just seen it is V y over V t. So, this will give you the total volume of the aquifer. V t would be what? It will be nothing but your V y over S y, is it not. So, it will be 25, 10, 6 over 0.25, which will be 1, 10, 8 meter cube. So, the total volume of your aquifer is 10 to the power 8 meter cube. Now, the average water drop, average draw down or the average water drop delta h over the whole area, entire area will be equal to what? Will be equal to this total volume divided by the aerial extent, is it not. So, that will be equal to 1, 10 to the power 8 over the area is 150 square kilometers. So, you multiply this by 10 to the power 6, this is meter cube, this is square meters.

So, it will be about 0.67 meters; so you say that the drawdown is about 0.67 meters or 67 centimeters. So, you see that we can calculate the average drawdown but we have to find out first the total volume of the aquifer. So, when we find the drawdown, we have to make sure that we are using the total area, not the volume of water. Because that total volume of water actually is coming out from where? It is coming out of the whole volume. So, water is actually stored only within the pores and where are all those pores? Those pores are in the whole volume. So, you cannot just use the V y, you have to use V t. So, this is an important point in this problem. So, let us move on; the next thing we are going to look at is the concept of these different types of aquifer.

(Refer Slide Time: 16:58)



The types of aquifers. We had very briefly said this, that they mainly two types; basically confined and unconfined aquifers, but will say first we will look at unconfined, un confined; then we will look at confined. And then we will look at what is called leaky aquifers; so we will look at these 3 types.

So, what is an un confined aquifers? I think you are provably aware of these things. What is an unconfined aquifer? Well, it is the one in which the ground water table is free or it is not confined between confining layers. So, you have a bottom layer which is an impermeable layer and then you have the water surface or the ground water table at atmospheric pressure and these are shallow mainly in nature. So, you can defined these as, is one in which the ground water table is undulating; it may vary from one place to the other in the form and slope, depending on recharge. Because an unconfined aquifer can be recharged from the ground; directly through the rain water or the agricultural water or any other type of pond. And discharge and discharge pumpage from wells and permeability. And unconfined aquifer is one in which the ground water table is undulating in form and slope depending on the recharge, the discharge, pumpage etcetera and its permeability. The main thing is ground water table is at atmospheric pressure in an unconfined aquifer, it is an important characteristic.

The other one is that the rise and fall in the ground water table correspond to correspond to change in storage change in storage in the aquifer. This is important; why because when you have a unconfined aquifer, as we said it can be recharge from the top, from the ground. So, if there is any changes in the ground water table, if there is a rise; that means, there is a change in storage or the storage is increasing. And if there is a fall in the ground water table, that is a result of the change in storage. So, the changes in storage are or the rise in fall of the ground water table is corresponding or related to be change in storage in a unconfined aquifer. And we will see later that this is not the case for the confined aquifer; that is why it is important to understand the difference.

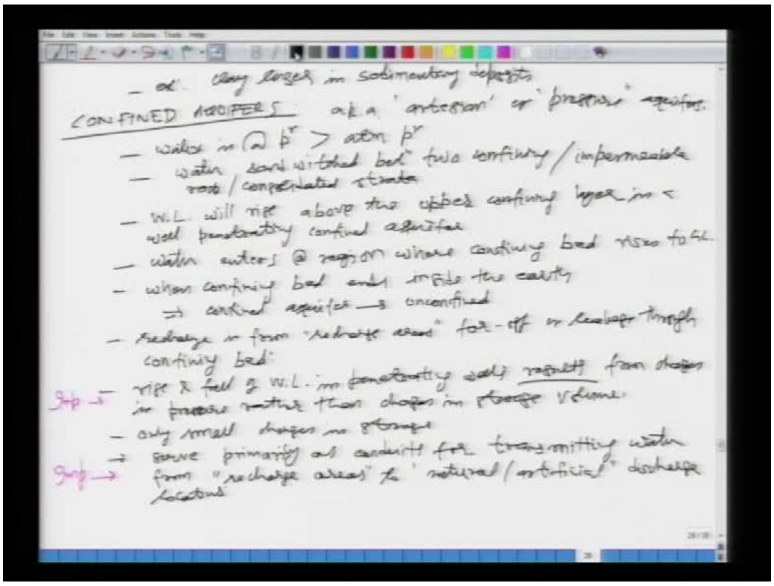
Now, the other thing is the contour maps or profile of the ground water table in the whole aquifer which is basically your water table in the wells, observed wells. We can find such maps; so these maps actually help in determining the quantities of water available and its distribution and movement and its distribution and movement. So, the important thing here, what we are seeing is that; the contour map. If you want to develop a contour map in a unconfined aquifer or the profile of the ground water table, then what do we do? Well, we just put some observation wells, we dig some wells in you know at some spacing and then we observe the water table. So, if you note down that water table the elevation and we develop some contour, what is a contour? Contour is basically line joining the equal elevation. So, once we do this exercise then that contour map is very useful in what? In, let me see in determine the quantities of water available because that will tell us how much water is available in certain area and its distribution, where it is concentrated and how it can move.

So, let say if you are a develop a contour map, it may have a certain contour interval; 1 meter here 2 meters here and so on. So, if you see the concentration of those contour lines which are very close in one area, means it is steeply sloping down. So, the movement will be very faster there and if you have a very flat radiant, then that is where we want to tap the water. Anyways, so this contour map is nothing but the water table in the observation wells, in a unconfined aquifer; which actually will not be the case. In the confined aquifer it is a piezometric surface, it is slightly different, will come to that little later. Before we move to that I would like to briefly give you a concept of what is a called a perched water bodies or perched aquifer. What is it? It is a special case of an unconfined aquifer. What I will do is I will just give you schematic of this, before I give you the details of this. So, this is the impervious bed town at the bottom; impervious rocks eta and then you have the ground water table somewhere here. So, this is your unconfined aquifer and this is your ground water table.

So, what may happen is you may have some material which is impervious and there may be some water at a shallow depth lying in here. And these are called the perched water table, this one and this one. This we say is the perched water table and these are some clay lances, some impervious material which is lying above the groundwater table. And, these are I would say impermeable strata, this one and this one. So, this perched water body is basically, they exist between what? The ground water table and the ground level, this is the ground level. So, this is your ground level. So, it exit between ground water table and the ground level in zone of aeration. What is the zone of aeration? It is basically the unsaturated zone above the ground water table.

Due to relatively, how it is occurring? Due to relatively impermeable strata, impermeable strata of small areal extend. So, it is very small, you see that you know some water may be may be available here; but it will not be much. It will usually shallow as I said the perched water body and if you dig a well or the wells in a perched water body or aquifer; such wells will have what? Will have very small and temporary yields. You know some times what happens is, we start digging a pumping well; we start digging a pumping well. And then what happen is we encounter certain water; so we feel that we reached the ground water table and then we start pumping the water out. But after few months may be or after some time, there is no water because this for the perched water bodies and it is not the actual ground water table. And if you dig deep it is very difficult to go through that clays strata; so, that is when we realize. So, whenever we are doing any investigation for water we have to go sufficiently deep.

(Refer Slide Time: 27:17)



Then, continuing further the example of such perched water bodies is the basically your clay lances, as I just mentioned; clay lances in the sedimentary deposits. So, this was about the unconfined aquifer. Now, we will move on and look at confined aquifers. They are also known as artesian wells; I am sure you may have heard these terms or pressure aquifers. These confined aquifers are, you know called in many different names. Few of them is artesian wells; artesian is basically coming from France, some French. Hydraulic engineers they carried out many investigation in the earlier 19 century and they found or they after they went very deep in to the ground, they found the water. And the deep well there are called Artois and origin of this word is from that Artois, which is a very deep well; so it is an artesian wells. And, also it is known as the pressure well. Why because the water which is there in the confined aquifers is at higher pressure than atmospheric; it is at a very high pressure. That is why if you deep, you know dig into it water can come out very easily.

So, let us look at this the characteristic of a confined aquifer. As I said the water is at pressure greater than atmospheric pressure. Second one is the water is sandwiched, sandwiched between two confining or impermeable rock or consolidated strata. The water level in any well which is dig into it, will rise above the upper confining layer. Try to understand this. If we dig a well into a confined aquifer, the water level will rise above the upper confining layer. Why because water is at higher pressure than atmospheric; it is just that this confined, alright in a well penetrating a confined aquifer.

There are few properties we are looking at of the confined aquifers. The water in the confines aquifers enters at regions, where does the water come from in this confined aquifers? Well, it comes or it enters the regions where the confining bed that the confining bed rises to the ground level. Because the water is sandwiched between two layers; so how does it enter into it? So, this confining layer some, somewhere have to meet the ground. So, when you have these two confining layers, the some you know very far distances in certain region it has to you know meet the ground and that is where the recharge area will come from. Normally, may be the hill area also. Many of the confined aquifers in Uttar Pradesh and the planes, the recharge area is coming from the Himalayas for Indian conditions. So, this is an important characteristic.

When the confining that ends inside the earth. The earlier point what we said is the confining bed is going all the way up to the ground level. In the second one we are saying, we confining that when it ends within the earth; then what happens? That means, the confined aquifer actually becomes what? Unconfined. Try to understand this you have these two confining layers, the recharge area we are seeing is very far of the regions where this confining layer will meet the ground. However, if you have this upper confining layer, let say it goes and then it disappears. There is no strata or the confining strata end here. After that what happens? Well it becomes the unconfined aquifers so there can be all different types of possibilities.

The recharge is from the recharge areas which are for off or leakage through, leakage through the confining bed as we have just said the recharge in the confined aquifer is where from very far of areas as compare to the unconfined aquifers because in the unconfined aquifers the recharge can be from the top. Now, the important point I would like to make here is rise and fall the rise and fall of the water level in penetrating wells in the penetrating wells results in a confined aquifers we are taking about from changes in pressure rather than rather than changes in storage volume.

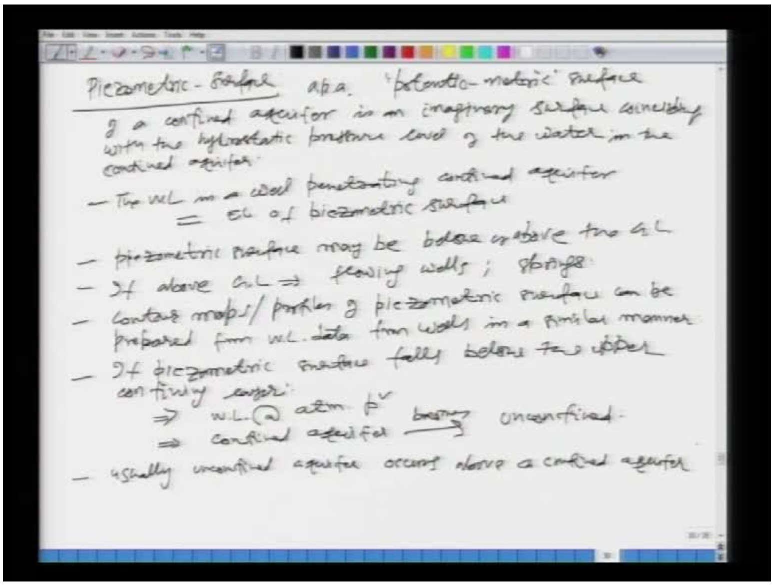
So, you have a confined aquifer, if you tap into it if you have a well inside the confined aquifers you are drawing the water out. Where is this water coming out from it is actually not the storage you have a recharge which is a continuous conduit so this changes in the pressure which will take place. So, they will be very little changes in the storage volume in a confined aquifer so if there is a rise in fall in the piezometric surface then they correspond to not the change in storage in the confine aquifers, but what change the change in the pressure the pressure will go down. So, let me reiterate that only small very small changes in storage and that basically means, that this confined aquifers serve primarily as primarily as conduits for transmitting conduits for transmitting the water from the recharge areas the recharge areas to natural or artificial discharge location discharge locations.

So, I am going to say that this rise in fall this point is important to understand also this last one. So, what we have said is that this confined aquifers basically serve as a conduit for transmitting the waters how they have a recharge area which is very far of. So, there water enters if you pump the water out there is hardly any change in storage, but you have the water getting started to move from the recharge area and what is a discharge area discharge locations are what either it is artificial in which we are pumping the water out or it may be natural.

From the confine aquifers we have the phenomena what is called the springs or springs and so on. So, the confined aquifers are very much different as compare to the unconfined aquifers as for as there operation is concerned because water is at a pressure which is higher than atmosphere. So, we have seen that the unconfined aquifer we the ground water table at the atmospheric pressure now in the case of the confined aquifers if you dig a well observation well into a confined aquifers water will rise quite high. And if you join the if you have many such observation wells and if you join the points of the water levels in different observation well what is that surface called what is that line called the potential meter surface or the piezometric surface rather.

So, that is what we will look at the characteristic of a piezometric surface in a confine aquifer.

(Refer Slide Time: 37:59)



Piezometric surface we do not call it down water table we call it is not as atmospheric pressure. It is also known as potentio-metric, potentio-metric is a one word and they separating it surface of a confined aquifer of a confined aquifer is an imaginary surface. Remember, it is an imaginary surface does not exists coinciding with coinciding with the hydrostatic pressure the hydrostatic pressure level of the water in the confined aquifer. So, it is an imaginary surface which confined with the hydrostatic pressure as we said in a confined aquifer the water is at a higher pressure so the hydrostatic pressure may be higher that the atmosphere atmospheric pressure so whatever it is if you dig a observation well the water will rise quite high and if you join that surface that is called the piezometric surface.

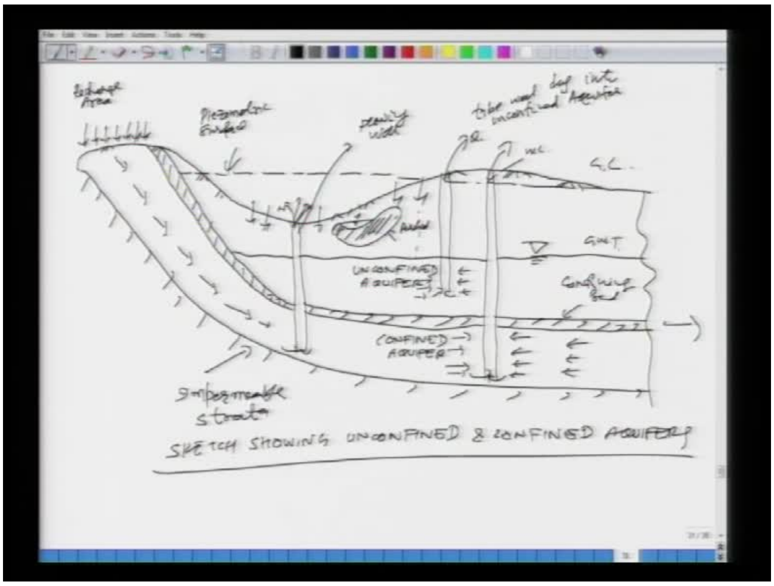
The water level in a well penetrating confined aquifer confined aquifer is what is equal to the elevation of your piezometric surface that is what we are saying. The piezometric surface the piezometric surface may be below or above the below or above the ground level can you imagine that you have a confined aquifer in which the water is at a high pressure if you dig a well what may happen is that the water may rise above the ground. Water will actually just huge out it is called a flowing well and we will look at these phenomena in a schematic diagram very shortly. If it is above the ground level means what do we have the phenomena is called the flowing wells we do not have to actually pump the water if your piezometric surface is above the ground level, and we have springs the contour maps slash profiles of the piezometric surface can be prepared from what water level data from the wells in a similar manner as I just said.

Because the water level in the well represent the pressure conditions so if we can join them we can develop what is called contour maps in terms of the piezometer surface. If the piezometric surface falls below the upper confining layer would mean what would mean that the water level will be at what at atmospheric pressure, because it is connected to the recharge area that would mean you confined aquifer actually becomes unconfined.

Try to understand this what we are saying is that if you have a confined aquifer in which the piezometric surface if it is above the ground level you have a flowing well or the springs. But if the piezometric surface drops below the upper confining layer this is the upper confining layer and if the piezometric surface drops below that. Then what happens? Then this confined aquifers is no longer confined because the water here is at the atmospheric pressure, because it is related to the atmosphere somewhere from the recharge area.

So, then the confined aquifers actually becomes unconfined if the piezometric surface falls below the upper confining layer. The last point about them is that usually the unconfined aquifer occurs above a confined we have a confined aquifer which are deep at the bottom and then on top of that you will have an unconfined aquifer. The next thing I am what I am going to look at is I look at overall system which I will show you all of these things.

(Refer Slide Time: 44:43)



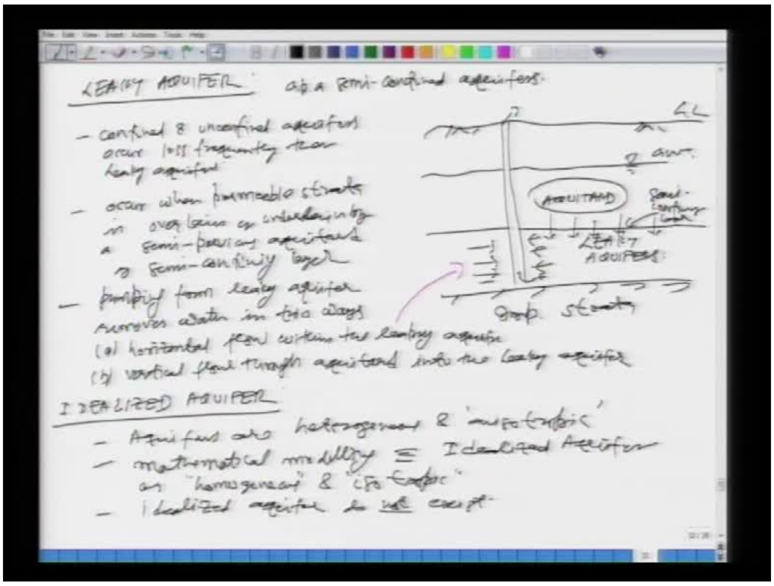
So, let say this is your bottom confining layer, this is your impermeable strata and then you have this is your ground this is your ground level and then you have let say well very deep into this confined aquifer there may be another one down here and then you have some upper confining layer like this, so this is your some confining layer at the top. And I am not drawing this above this is continuing here. So, this is your upper confining layer and let me say that this is your confining bed, so what is this is your confined aquifer so if your pumping water out from this we have dig this well from the top then what will happen the water will travel towards it further distances.

And then you say that you have the ground water table there is a unconfined aquifer somewhere down there this is your ground water table so what is this? This is unconfined aquifer this is unconfined aquifer what is this is obviously your recharge area very far of which is open to atmosphere. So, water can actually infiltrate into this and travel from long distances into these confined aquifer. And then it will go into this tube well and then if I draw the piezometric surface let say it is somewhere down here it will be let say horizontal here I am saying it will cut here like this. So, this is your piezometric surface what is a piezometric surface if we have dig this well into the confined aquifer so water level will rise up to this piezometric surface. So, this is your water level in this pumping well now this piezometric surface at this location in this particular well is higher than the ground this is the ground you see.

So, what will happen here because there is higher pressure then water will naturally start coming out, so this is your what is called the flowing well for a spring. It may be natural it may be artificial this is the way I have shown this is artificial then I dug a well there and then water will start boozing continuously we can also tap into the unconfined aquifer. So, this is a tube well dug into unconfined aquifer water will travel into this you may also have some perched water bodies here some clay lances this is our perched. So, this way you see that we have a looked at a schematic diagram in which we have try to demonstrate.

How the confined aquifer will occur what could be the possible ways of that recharge area? We can dig wells into a confined aquifer and then we may have either a flowing well in which water may be coming out automatically because the piezometric surface is higher. And then also we may have a penetration well in which the water table is not above the ground rise in that case we will have to pump the water out. None the less, if the observation well or the pumping well is deep enough than the water will come from the confined aquifers we can also pump water from the unconfined aquifers. So, this is the different ways of looking at let me say that this speaker is basically as catch which is showing what unconfined and confined aquifers.

(Refer Slide Time: 51:32)



And how they occur, how they recharge and so on and obviously this unconfined aquifer how can it be recharge through rain fall water will go down and then recharge that area.

Let us quickly move on and look at the what is called the leaky aquifer? They are also known as semi confined aquifers. The confined and unconfined aquifers actually occurs less frequently then the leakier so leaky aquifers are in fact more frequent so this is important to understand. When do they occur well they occur when a permeable strata permeable strata is over length or under length either above or below under length by a what by a semi pervious aquitard or semi confining layer.

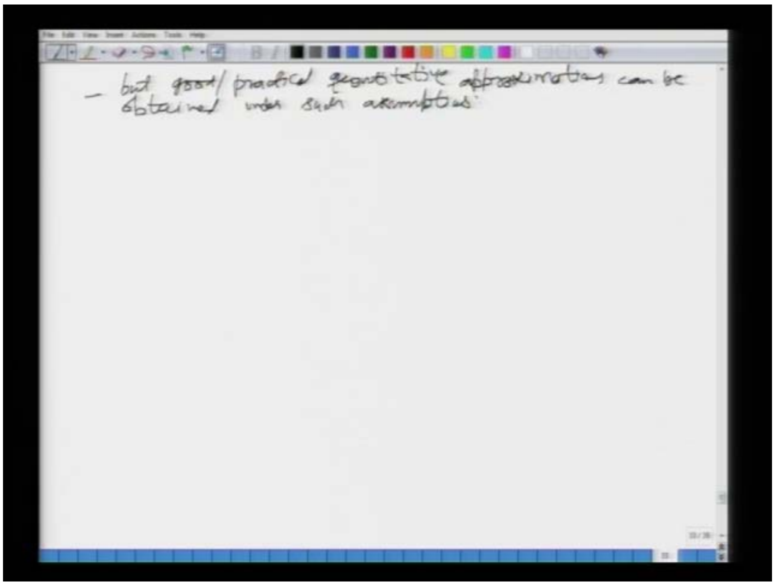
So, let us look at that so you have let say this is your impervious strata down at the bottom and then this is your ground level, let say you have a well very deep inside this confining layer. And then you have this is there is a semi confining layer it is not exactly confining semi confining layer so this is what is called your leaky aquifer. Because it is leaking at the upper confining layer so it may receive water from the aquitard above. So, you have an aquitard that say sitting above this there is the water table which is down here this is your ground water table so it can receive water from the aquitard like this. And one can tap into the leaky aquifer and then you will have water flowing like this now this is important to understand that the pumping from a leaky aquifer pumping from leaky aquifer removes water in two ways. How? One horizontal flow asIhave shown within the leaky aquifer which is what which is actually this one?

And two or b the vertical flow through aquitard vertical flow through aquitard into the leaky I have said here aquitard, but there can be an unconfined aquifer here also which will contribute water vertically down into the leaky aquifer because of this existence of this semi confining layer. These are the three different types of aquifers. Now, what we will do is we will look at what is called an idealized aquifers so these are aquifers which actually occurs naturally in the nature, but when we are doing the modeling when we want to model this it is extremely compact so what we do is we try to idealize this or we assume that here homogeneous isotropic and so on their lots of type of you know words I am going to through actually.

So, let us look at how we are actually or how we actually handle this situation? How we actually model this? Because it is a very yeah heterogeneous system it will be very difficult to model so let us look at what is called the idealized aquifer. So, we assign aquifers are heterogeneous and anisotropic what is anisotropic? An anisotropic aquifer is one in which the aquifer property is bearing in different direction. So, the mathematical modeling its difficult so what we do is we idealize or we use the idealized aquifer.

As what as homogeneous and isotropic so we are kind this regarding those in most of the time it is important to note that this such idealized aquifers that is homogeneous isotropic etcetera do not exists there nothing like a idealized aquifer which will find in nature. However, good or practical a quantitative approximations quantitative approximation can be obtained under such assumptions.

(Refer Slide Time: 58:03)



So, we see that what we have done today is we have looked at some other aquifer properties in terms of the specific yield and the specific retention and then we looked up at an example. And then we looked at different types of aquifers and mainly confined and unconfined there various entry cases the properties you know and how they behave when they are subjected to either pumping or different types of force in functions? So, all of this is important to understand and towards the end we have seen what is an idealize aquifer. So, I think I will like to stop at this point of time and in the next class we will look at how we can actually handle this anisotropic aquifer in which we may have different layer and how we can bought it that I would like to stop at this point of time.