Ground Water Hydrology
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Module No # 02
Lecture No # 06
Zones of Aeration and Saturation; Aquifers and their characteristics/classification

Welcome to this lecture number 6 on zone of aeration and saturation followed by the aquifers and the characteristics classification.

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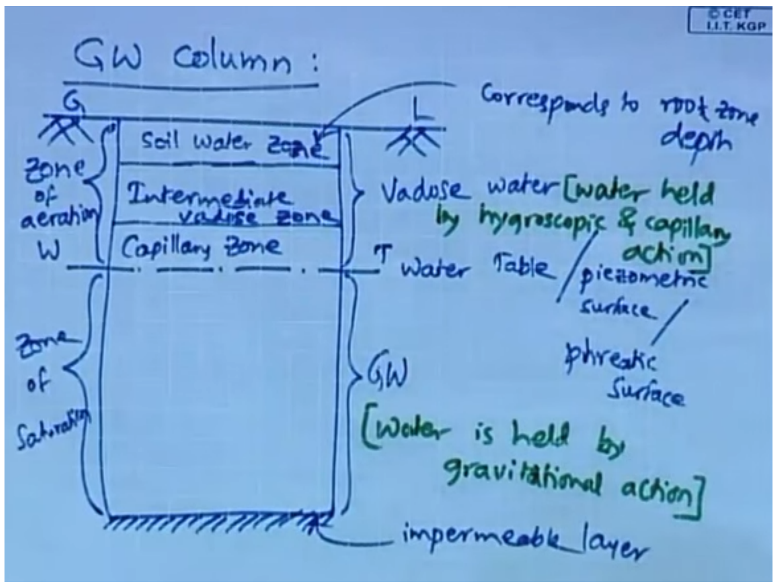

So in the previous lecture we discussed about the ground water column and specifically of course we will briefly dealt about the zone of saturation which is below water table and zone of aeration which is above the water table.

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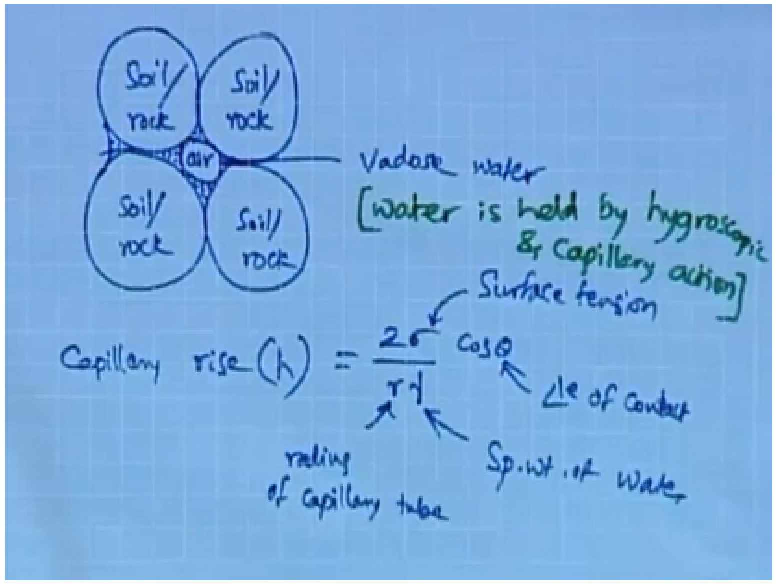

And we also discussed about how in the zone of aeration how the water is held which is basically in the intermediate zone which is vadose water and here so this water is held by hydroscopic and capillary action. So here because of this the attraction between the soil or the rock particles as well as the water so the water is held the water which is not moving is held by these two actions.

And the capillary rise is we also saw the expression for capillary rise which is a given by 2 sigma into Cos theta / R into let it be the specific gravity. So here now let us continue before this one I would like to mention so essentially so this vadose water held by hydroscopic and capillary action and here so in this ground water so water is held by gravitational action okay.

And continuing with this the expressions for this capillary rise so here suppose the this is a capillary tube which is basically a narrow tube this is center line and the diameter of tube which is given by 2R and so this is the surface tension force which is measured as force unit length and this is the angle theta and then this is the water surface this is meniscus and so that is the liquid this case it is the water with specific weight gamma and this theta is the angle of contact which I have mentioned here.

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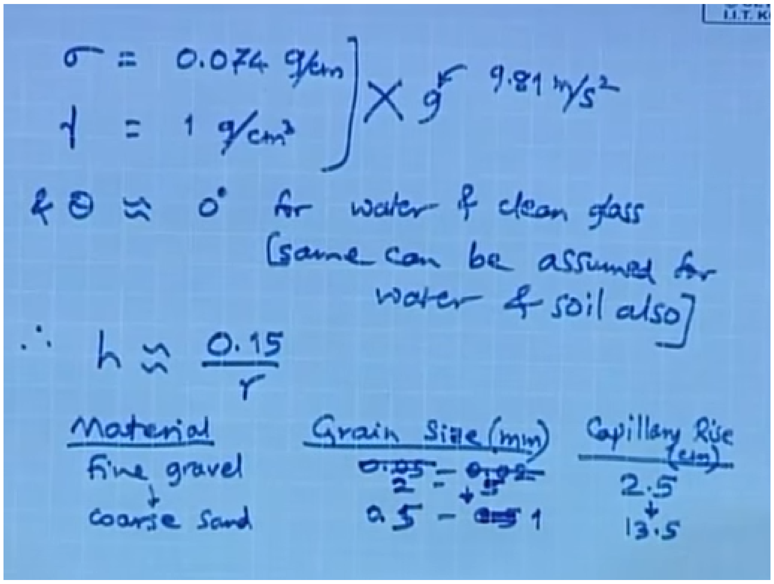

And say for if we further simply so this so surface tension which is mentioned as the force per unit length generally it has a value of say .074. So this is a grams per centimeter of course so this multiplied by the acceleration due to gravity that is 9.81. And then this specific weight of water again this is 1 gram per cubic centimeter again it has to be multiplied by the so this multiplied by G.

So this G is the gravitational acceleration this is 9.81 meter per second square and this theta approximately = 0 degree for water and clean glass same thing can be assumed in there for water in soil also. Same can be assumed for water and soil also therefore the expression for capillary rise H. So it reduces to .5 / R okay so as can see from this one the capillary rise H which determines the height of the capillary zone which inversely proportional to the size of the capillary pores.

That is the radius of the capillary force that is basically here we are approximating the pores in to the requirement circle or shape and then taking its radius. So this H as a this the equivalent the circular pore radius gets reduced the height of the capillary rise increases and here this mentioned that say for different samples that is the say the material grain size in millimeter then the capillary rise in centimeter.

So here on the lowest level were the capillary rise is as low as just 2.5 centimeters we have this fine gravel whose grain size is that is .05 to .02 ok. Further as we go so this is a next is a coarse and of course there are intermediate formations are there. So here coarse and for which it is a one the grain size is one that is a .1 to .5 millimeter and it has a capillary rise of 13.5 centimeter. And then I am sorry I made a mistake here so this says this just like correct this one.

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Material	Grain Size (mm)	Capillary Rise (cm)
Fine gravel	2 - 5	2.5
Very Coarse sand	1 - 2	6.5
Coarse sand	0.5 - 1	13.5
Medium Sand	0.2 - 0.5	24.6
Fine sand	0.1 - 0.2	42.8
Silt	0.05 - 0.1	105.5
Fine Silt	0.02 - 0.05	200

Source: Lohman

So this is grain size is 2 to 5 and coarse and the gain size is .5 to 1 let me re write this again so this is the material grain size in millimeter then capillary rise in centimeter. See on the coarse test we have say find gravel the grain size is said 2 to 5 millimeter when the capillary rise because this is too large grain size. So therefore the pore size is also too large so therefore the capillary rise is also as say 2.5 centimeter followed by vary coarse sand the grain size is 1 to 2 millimeter and the capillary rise is say 6.5 centimeter.

Still let us go to still smaller this one that is coarse sand where the grain size is .5 to 1 millimeter and then the capillary size is getting reduced and correspondingly the pore size also gets reduced. So this is 13.5 centimeters then the medium sand as a grain size of .2 to .5 and the capillary rise of say 24.6 millimeter centimeter I am sorry then followed by say fine sand the grain size is say .1 to .2.

And the capillary rise gets further increased to say 42.8 centimeter then it is the silk which has a grain size of .05 to .1 millimeter. The capillary rise increases to 105.5 centimeter and lastly it is fine slit it has a grain size of say .02 to 2.05 and the capillary rise is as high as 200 hundred centimeter. So you can imagine so how the grain size the material gets finer and finer in terms of its grain size. So the capillary rise increases and this has been so sources study by LACHMAN okay.

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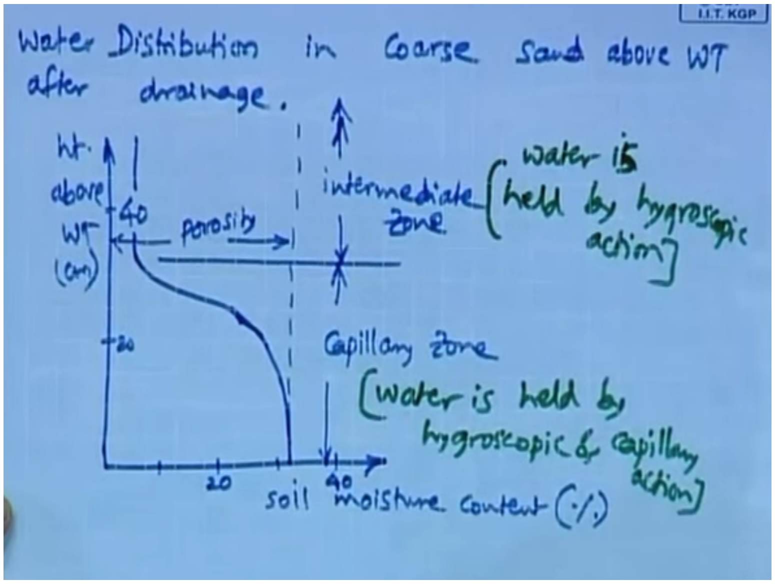

And now let me also represent here the distribution of water in a coarse sand water distribution in coarse sand above water table after draining. So here suppose this is the so this is the moisture so this is the soil moisture content as percentage and this is a height above water table in centimeter and here say let us say this is say this is 20 and this is 40 and here let us say this is 20, 40.

So here this variation is it will be something like this so this is the so this represents porosity and here this represents capillary zone and above this this represents the intermediate zone. So in the capillary zone just at the water table level so the moisture content is exactly equal to porosity and as we go above the water table the moisture content goes on increasing as we can see here and so when we reach this intermediate zone.

So this moisture content it represents only the hydroscopic water so whereas so here we can say this is the hygroscopic component and then this the moisture content held by capillary action and this moisture content help a hygroscopic action. So therefore so in the intermediate zone it is entirely the water is held by water is held by hygroscopic action. Whereas in the capillary zone water is held by hygroscopic and capillary action.

So you can see how it varies and say so we just at the water table level just above the water table so almost all the pores are filled with this soil moisture and then as we go higher and higher it is only those force which is only continuous so they will be filled with as we reach this intermediate zone. So it is only the hydroscopic water which is the water held by the force of attraction between the in the spaces the void spaces as well as the air, as well as the rock particle and then the water.

So this is how for in the zone of saturation the water is held entirely by gravity and that is for all the zone below the water table and as we go above at the water table. So this is held by hydroscopic as well as capillary action and as we reach the intermediate zone so the number of force which contains soil moisture gets reduced only those continuous pores ah they first of all for the capillary action they must have a very small size and then so through which the capillary rise takes place.

Due to the force of attraction between the soil or rock particle and water due to surface tension force and above that in the intermediate zone it is entirely by the molecular the inter molecular attraction between the soil moisture the air void as well as or rock particles. Now let us consider and this water content which is held by various actions whether it is the hygroscopic action in the intermediate vadose zone or hygroscopic as well as capillary action.

In the capillary zone both in the zone of aeration and further below in the zone of saturation by gravitational actually acceleration. So this moisture can be measured by various methods which is a gravimetric method as well as the other the tensiometers and so on. And the same thing here we can mention here by a tensiometer basically it made it just pulls.

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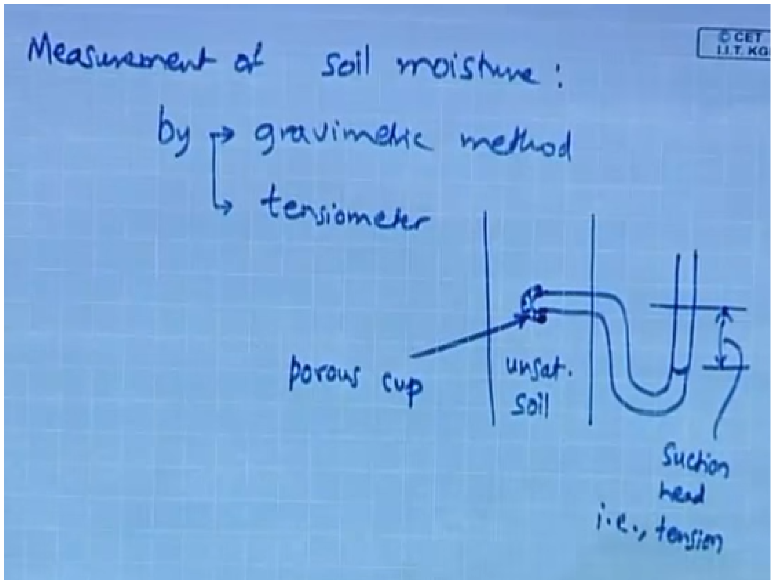

So this water which is held in that is the measurement of soil moisture so this is by gravimetric method and which we take the weight measurement and also say by tensiometer. So in this tensiometer suppose this is the soil column and here so this is the tensiometer so this is the poros cup and this is the unsaturated soil and here so this is the suction head which is essentially water held by the molecular attraction between water air particles as well as soil particle.

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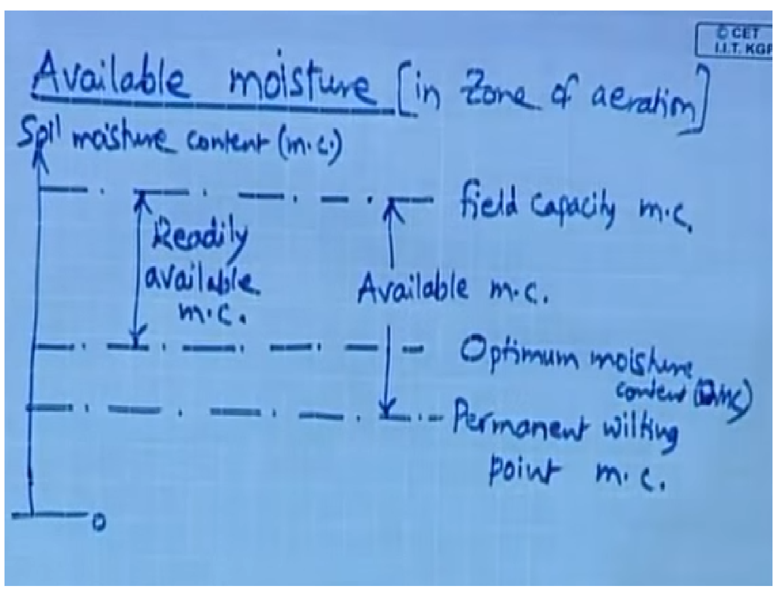

So now let us come to what is known as the available water or available moisture content so here suppose I represent so this is the soil moisture and here so this is 0. So the maximum soil moisture so this is the soil moisture content which can be which is possible is which is denoted as field capacity. So this moisture content let me represent this as MC. So this is field capacity moisture content so this field capacity is essentially the maximum possible water which can be held in this zone of aeration.

And also the minimum this is amount of soil moisture corresponds to so this is the permanent wilting point moisture content. And of course there is also an intermediate this is known as the optimum moisture content or say OMC. So here essentially so this field capacity is the amount of water which is held in a soil after wetting and after drainage as become negligible. So generally it is after say 2 days of drainage.

So the after 2 days of keeping it for draining so all the water which is generally goes out through drainage that gets drained out and then the moisture content which remains in that soil sample or soil or rock sample is the one which represents the field capacity moisture content. And the total amount of moisture is the volume for that is the known as field capacity similarly so this welting point is the moisture content it represents the moisture content wherein the plants start welting.

That means say below this welting point all the water all the moisture it is held by only molecular attraction between moisture or water particles as well as air and soil or rock particles. So it is not given away by the soil so therefore plants cannot extract any water by capillary action. So the plant welting or drying so this drying plants so further so they die so this difference between the field capacity moisture content and then the permanent welting.

So this is known as available moisture content and similarly the difference between the field capacity and optimum moisture content which is slightly higher than the permanent welting point. So this is known as the readily available moisture content. So essentially so they all the irrigation so they depend upon readily available moisture which can be easily extracted by the plants through capillary action.

So therefore in this irrigation what is done so as soon as this soil moisture gets depleted to this optimum moisture content level. So the one irrigation supply is given so then the moisture content increase to field capacity moisture content level and then further again by the due to a plant metabolic activity due to evapo-transporation as well as evaporation the soil moisture gets gradually decreased and again when it reaches this the optimum moisture content then the next irrigation is given.

So like this so this is how the process of irrigation continues now let us come to the moisture content in the zone of this one. So this available moisture so here so this is in the zone of aeration ok.

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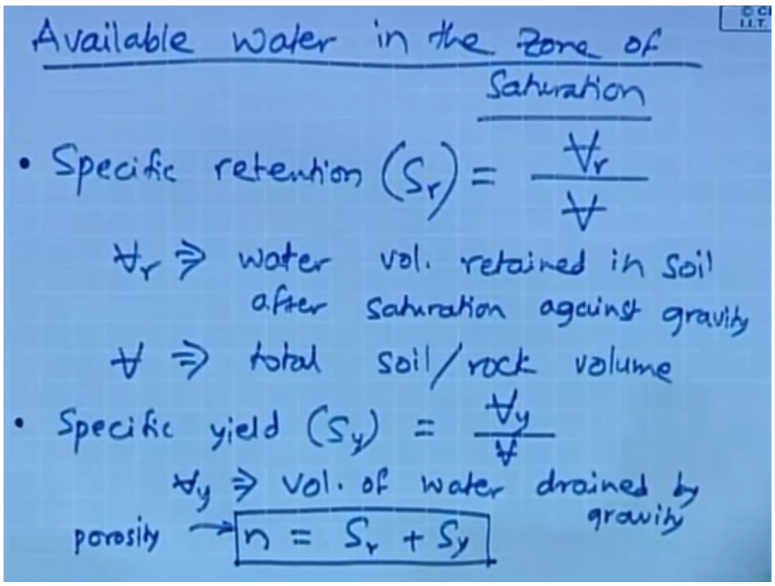

So now let us come to the zone of saturation which is the now let us come to available water in the zone of saturation again here so in the zone of saturation. So most of the water is held by is this zone of this is a gravity action of course very small amount is held by hygroscopic action. So here let us define say two terms which is the specific retention so if we denote this as SR.

So this is the ratio of the volume of water which is retained in soil against gravity after saturation divided by total volume. So this VR is the water volume retained in soil after saturation against gravity and this V is the total soil or rock volume and let us also define another terminology here that is the specific yield which is denoted by SY. So here this is equal to VY / V where again V is the total soil or rock volume.

And this VY is the volume of water drained and obviously this is by gravity okay and so this N which is the porosity. Of course few hours in the previous class I think I represent this by alpha and few authors they use the notation N. So this is equal to the specific retention plus specific yield so this is a very important relationship between porosity and specific yield as well as specific retention.

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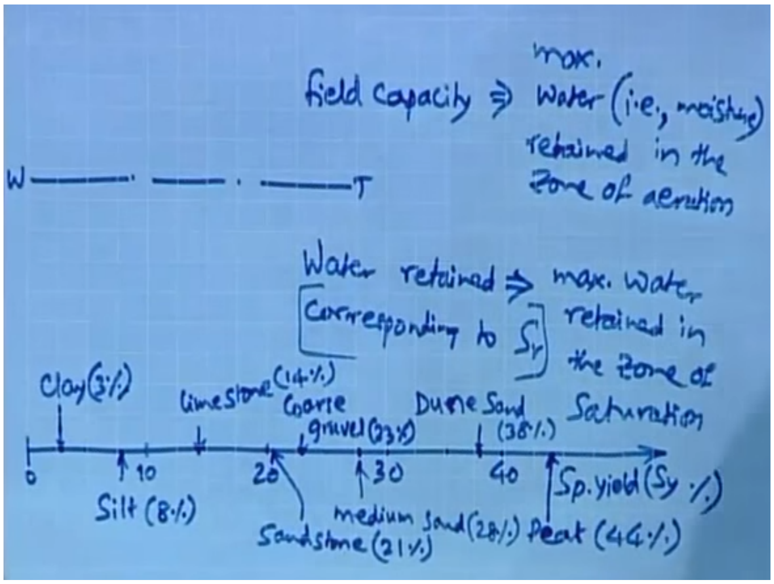

And here so essentially so if we if I represent so this is the water table so water retain above water table is known as the field capacity. Water here you can say it is moisture retained in the zone of aeration here you can say let me the maximum water and here so this is the and below this it is the water retained so this is what I retain corresponding to the specific retention water SR maximum water retained in the zone of saturation.

So essentially this field capacity as well as the water retained so they represent the same water content while the field capacity represents the water the maximum water retained in the zone of aeration wherein all the pores are saturated well the water retained represent the maximum water retained in the zone of saturation and obviously so this is corresponding to SR. So this here we can say this is and both are against gravity.

So like this so the essentially this field capacity as well as water retain so they represent the water which is which can be retained maximum extent in the zone of aeration as well as zone of saturation. So now let me also represent here so the and as this ground water this one so our objective is to harness or extract ground water as much as possible. So therefore this specific yield is more important to us and here suppose I represent on a scale the specific yield express as percentage.

So here from the lowest level say this a 10, 20, 30, 40 and in the highest this one say 44 we have peat which is basically in the vegetative matter which is decomposed and then the lowest specific yield is observed in clay. Which is so peat as 44% and this clay which is as minimum which is 3% and in between we have say the dune sand 38% and we have say medium sand which is say 28% and we have say coarse gravel 23% and we have sand stone 21% and we have lime stone 14% and we have silk here with generally the this one okay.

So these are some of the typical values of the specific yield in different materials ranging from the minimum 3% in found in clays and maximum of 44% found in around 44% found in peat. So in between we have silk, limestone, sand stone, coarse gravel, medium sand, dune sand okay and of course few more. So this is the variation of specific yield in different soil or rock furnishing.

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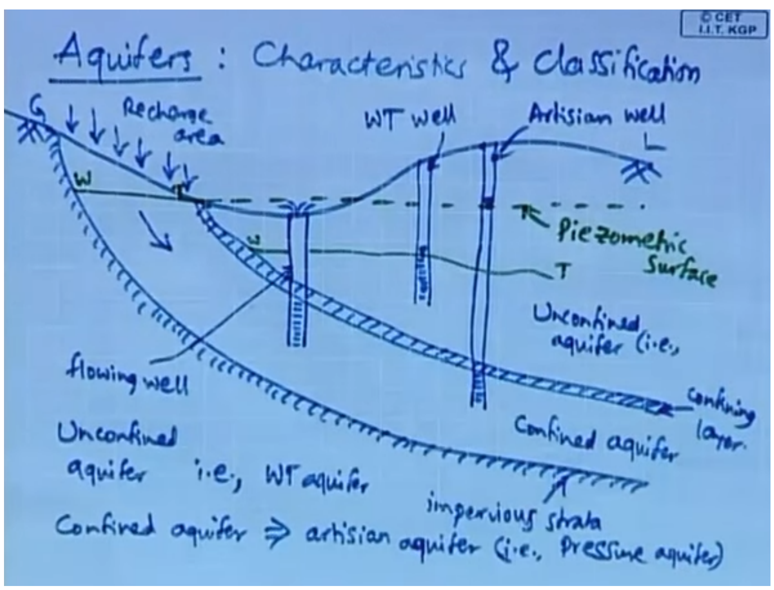

Now let us come to the aquifers their classification characteristics and classification. So this aquifers are essentially there is a water bearing layers so here you can say in this so typically we can say this above this lime stone all this rock or soil formation they represent aquifers below this limestone all this soil or rock formations they represent either aqui tards, aqui tudes and aqui fuges which we discussed in the previous class in the previous lectures.

So here I would like to draw you attention to a schematic cross section representing the various aquifers. So this are the impervious so this is the impervious strata so this is the recharge area so this is the ground level and here I would like to represent the water table or piezometric surface so this is the water table and this is and this is peizometric surface which represent the basically the energy and here up to this recharge through different forms of precipitation.

So this soil moisture the water moves and this this is known as the confined aquifer which is essentially confined at top or as well as bottom confining layer. So this is the confining layer and here suppose we drill a well here which penetrates all the way up to confined aquifer and here this one we may find we may so this is water table so this well is penetrating through the all the way and here this is the confined aquifer and then this is the unconfined aquifer also known as water.

Let me write here so this unconfined aquifer that is water table aquifer so this unconfined aquifer represents top most aquifer which has only the one confining layer at the bottom whereas its top surface represents the water which is subject to which is undulating and it is depending upon the slope the areas of recharge, discharge and pumping and other factors and in this case.

So now let us come to this well which has been dug in the which has been drilled in the in the area and the land area which is below the peziometric surface and it penetrates all the way up to the confined aquifer. And here the total s this peziometric surface represents the energy the total energy at that level for this depth all the way for confined aquifer. So therefore here the well starts oozing out water that is corresponding up to peziometric surface and such a well is known as a flowing well.

So here the water gushed out of the well on its own so now artificial pumping is required and on the other hand suppose we drill a well which penetrates only the unconfined aquifer in this case the surface the water surface corresponding to the water surface at that location and so therefore this well which penetrates only the unconfined aquifer is known as the water table well and on the other hand suppose we drill another well which penetrates through the unconfined as well as unconfined aquifer.

So here water table corresponds to this one and the peziometric surface and this well is known as artesian well. So this confined aquifer is also refers to as artesian aquifer which is also known as pressure aquifer okay. So there are three types of well the flowing well the water table well as well as artesian well. When the flowing well the water is gushes out on this naturally by because of the ground surface below the peziometric surface is there whereas in the water table well as well as the artesian well.

So the water surface will be below the corresponding to the water table or the peziometric surface and this artesian well it draws from both the confined as well as unconfined aquifer at the bottom as well unconfined aquifer at the top so we will stop here and we will continue further our we will continue discussion in the next lecture thank you.