Availability and Management of Groundwater Resources

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Lecture - 13
Vadose and Saturated Zone (Continued)

Welcome you all in the fourth part of the third lecture series vadose and saturated zone. So, now from the very beginning from the first part just I am recalling back once again from the very first part we have seen that the earth's interior is having the different layers till we reach to the formations which generally holds the groundwater. So, this concept has built up already in our mind.

Because so many lectures have crossed regarding the subject availability and management of groundwater resources. Always we should keep in mind that we are going to know about the details about the availability of groundwater resources inside the earth's surface. So, this thing we are learning where it is remaining available, what are the factors playing very important role for its availability.

So, these all thing what are the different types of rocks everything's are contributing for this very complicated subject that is the groundwater resource management. So, we have seen from the very beginning that the groundwater resource remains inside the earth's surface in a certain special type of rocks. Special type of rocks I am telling you because these rocks should have some properties. But especially two important properties there should be there.

And that is the one property is named as porosity and other property name that we had permeability. So, two P's are required for becoming a good aquifer, any rock should have two important properties that is first is the porosity and the second is the permeability. Why? Because suppose this rock will only hold the water. So, this water will be of no use yes, this water will remain here this water means remain here means it is an aquifer so it will hold the water.

But for what? Because sometimes, if you are just withdrawing the water from this well or this aquifer then definitely the layer of the water or the volume of the water in this aquifer will

decrease. So, if the level of the water will decrease then there should be chances to have some assess from the different directions of the line this existing rock to have the increase in the level of the water. So, from where the water will increase?

The level of water will increase if there will be some other formations that is the rocky formations. These are the rocky formations these are also holding the water. When we are just by drawing the water from this well so this is also having water this is all the different formations water bearing formations are having certain volume of water, certain amount of water. So, when we are withdrawing this water definitely the water from this may be from this it will try to just balance the level here also inside also the water flows as per their slope as per the topography. So, what is happening? So, this in intake of this water this just you are taking this aquifer is taking the water from this aquifer so intake of this water depends on the property of permeability. Because it should have this aquifer should have ability to receive the water as well as the property to transmit the water then only this is a very good repository of the groundwater resources.

This is a very good formation, rock formations for the availability of the groundwater resources. Otherwise only the aquifer will store the volume of water it is of no use that is what we are seeing also in some passage of our land surface. We are getting some clay soil also clay sealed sand these are the category of the soil. So, clay is a very good porous material, no doubt. Porous material means it will hold the water.

But as far as aquifer point of view if you will just say the details about its volume of water it may volume may be good but it is having one drawback and drawback is that it is impermeable. So, what is happening? The clay can hold maximum volume of water but it is not having the availability either to receive the water or to transmit the water. So, this is the drawback with the clay. But sand is a very good porous material it is having very good volume of water.

So, what it is doing? It is having the ability also to receive the water and to transmit the water. So, that is why sand is a very good aquifer. Wherever we are getting sand definitely we are understanding that here there should be plenty of groundwater resources. So, these factors play

inside the earth's surface. The point what we have discussed in this very special lecture on vadose and saturated zone what we have seen.

That this is the earth's surface and this zone is having a very good water bearing formation. So, this is just the zone of saturation so this is also called as saturated zone. But this zone just the upper layer of the zone of saturation is termed as water table. This we have seen has termed as water table. So, what is happening? Just above the water table to the till the earth's surface or we can see from the earth's surface to the top level of the water table this zone is termed as unsaturated zone or vadose zone.

So, this we have learned already that for the availability of the groundwater resources we should have the idea of the vadose zone also. What is the property of the value zone? And vadose zone is the zone which is generally remains unsaturated, it is remains unsaturated means less amount of water we can say or this only the soil water remains in the zone not this type of water what we are getting in the saturated zone.

So, interestingly the interior of the earth till we are reaching to the any rocky formations which are holding the water that is aquifer it is divided into two important zones. The zone above the water table is known as unsaturated zone, zone of aeration, vadose zone whereas below the water table the zone is termed as zone of saturation, saturated zone. So, this is the basic information's about the interior of our earth in the different part of the land surface generally we are getting vadose zone as well as saturated zone.

One point may be there that by vadose zone the thickness of the vadose zone or the saturated zone will vary from place to place and from season to season. So, this is varying with from place to place and from season to season.

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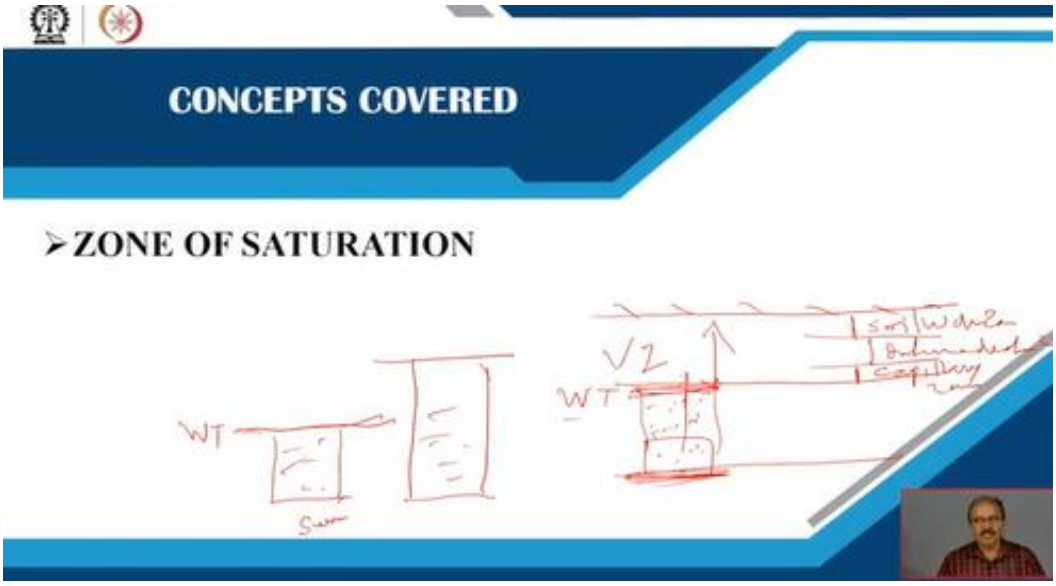

So, we have discussed about the unsaturated zone in a greater detail. Because we have seen that the vadose zone is again subdivided into soil water zone then intermediate zone then capillary zone. What we have seen that vadose zone this is the surface; vadose zone is this one this zone is known as vadose zone and this is the water table. Because it decides the water table is the upper part of any unconfined aquifer.

About unconfined aquifer we will discuss I will discuss it in the later next lecture. But here only one point should be because it has already been dealt earlier lectures just, I am recalling you unconfined means the water bearing formations which are having only one impermeable layer beneath it top remains open. This top remains open with the atmosphere that is why this is the formations which are which is holding the water.

So, this is the upper layer of this water level inside this rock and this upper level of the water level of this rocky formation which is holding the water good amount of water is termed as water table. So, this water table here the water remains direct in contact with the atmospheric pressure. So, what will happen? Suppose this is your area, this is your rocky formations and the water table is at this place. During summer time, during winter, during monsoon what is happening?

This water because this much amount was there but during monsoon season has changed the water table has reached here because of the increase of the level of quantity of the water in this

rocky formation. So, this varies, this water table varies. So, what is happening? This water table is deciding about the zone of saturation as well as the zone of unsaturation. In unsaturated zone which is also called as vadose zone.

We have seen three different layers where there are three subdivisions were there and the top sub subdivision just beneath the surface was the soil water zone if you will recall it soil water zone. Then second subdivision known as intermediate zone whereas third zone is known as capillary zone. This zone is known as capillary zone. So, this whole concept has become clear that we need the earth's surface the water table is deciding at different places the thickness of the vadose zone as well as the thickness of the saturated zone.

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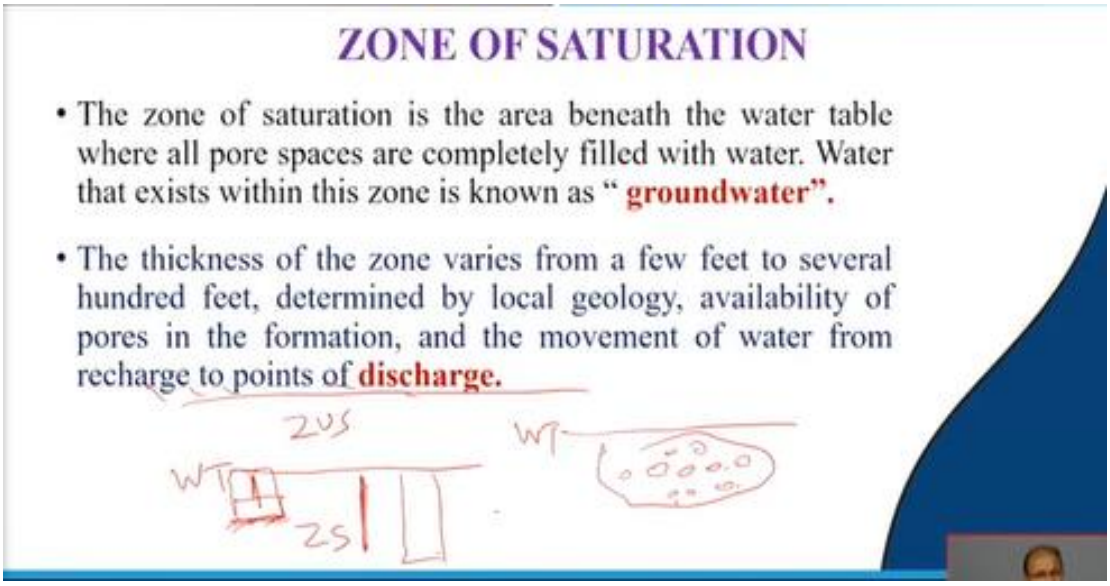

Now in this fourth part lecture we will discuss in greater detail about the zone of saturation. Zone of unsaturation has already dealt clearly, now zone of saturation. So, the zone of saturation is just the area beneath the water table this is the water table now beneath the water table where all pores the all are rocks this is rocks where all pores and spaces are completely filled with water, these porous species are completely filled with water.

So, this zone is known as the zone of saturation and the water which present here is called as ground. Water which is present in these specific pores in the zone of saturation is called as ground water. Otherwise, we have read several types of water in the vadose zone also pericullar

water, soil water, we have read in the earlier lecture we have read. So, groundwater means the water which remains filled up within the pore spaces of the zone of saturation area only that water is known as groundwater.

And thickness of the zone means thickness of this zone of saturation now we are very clear that this is the water table and this is the zone of saturation and this is the zone of unsaturation and this point is the earth's surface. So, the thickness of this zone of varies from few feet somewhere you will you may get the rock formation at cellular depth. So, when you are getting this one so then here the thickness of the saturated level and very lesser an amount.

But at some places it may goes 100 feet deep down that is why we are getting at some places we are getting shallower aquifer means the formations which are holding the water is lying just at few feet from the earth's surface down below. But at some places we are getting the aquifer that is the formations which is holding the water at a greater depth that is deep aquifer. So, on the surface we are getting the shallow aquifer also as well as the deep aquifer also.

The point is that in the shallow aquifer the water will be at the just ground water table will be just near to the earth's surface. But in the deep aquifer the water table will be at a very greater depth. So, chances of availability of water resources may be there but for its uses you can see that the shallower aquifer can be used very accurately time to time. In the deep aquifer it remains not clear that whether we will get the water if we will just dig a bore well there whether we can get the water or not.

So, this is a very important point because water table always varies from at some places it is just near to the surface at some places it is at a greater depth. Why? Because it depends on factor big factor, the local geology is important. Then ability of the thickness of the zone varies from a few feet to several hundred feet down below and this thickness of your groundwater table is dependent on several other factors.

The other factors are local geology, what is the type of geology in the area? How many available pores in the formations? Number of pores, whether the number of pores are more or not in the

formation and above all the movement of water from recharge to point of discharge, it is also very important, the movement of water from recharge to the points of this discharge. So, this whole factor recharge means just we are supplementing the water to the formations, discharging means we are taking out the water from the formations.

So, what is happening? These whole factors are playing very important role for the availability of the groundwater resources within the earth surface and above all the zone of saturation is very important contributions inside the earth surface which are having the several information's which is holding the groundwater inside the earth surface. So, this zone of saturation is a very important point for the availability of the groundwater resources.

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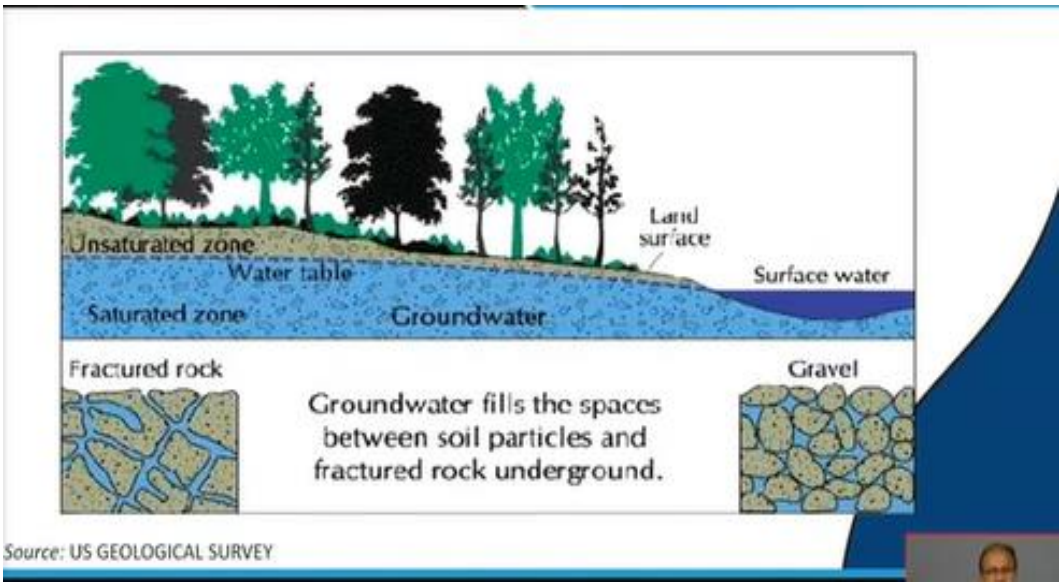

Here we can see what I have told you that in the zone of saturation all the pores will generally remain filled up with the water then only the water is called as the groundwater. Groundwater fills the space between the soil particles. If this is the gravel is just soft rock and this is the hard rock in which fractures are there. So, we can see here that in the gravel there are some areas which are being filled up with the water.

Here also in the fracture rock also we can see the fractured portion where are the fracture portions these are filled up with the water. So, this saturation zone is always having some spaces and, in these spaces, always it remains filled up with the water body. So, that is why this is fully

saturated with the groundwater which we are not getting in the case of unsaturated zone. Unsaturated zones we are not getting there, we are not getting any aquifer in unsaturated zone.

But in saturated zone we are getting aquifer means the formation which is holding the water. So, this is the basic difference between the zone of unsaturation and zone of saturation.

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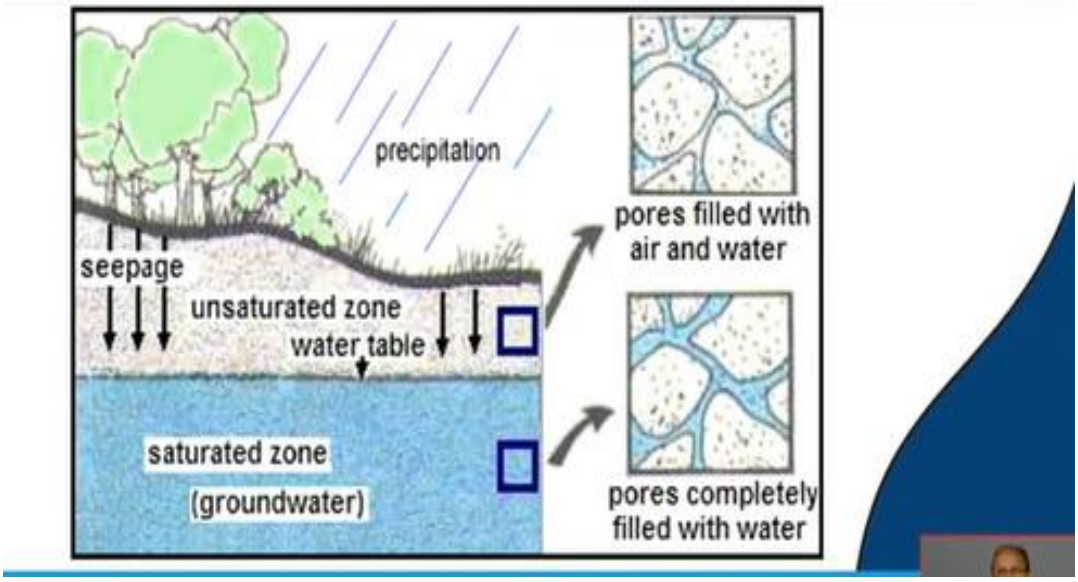

Now this can be also illustrated in this way that pores filled with air and water is from where? From the vadose zone only. In the vadose zone that is in the zone of aeration that is in the unsaturated zone the pore spaces within the soil are generally filled up with the water and air both. Whereas in the zone of saturation the pore spaces within the soil is completely filled up with the water only no air is here, inside the pores of the formations which is holding the groundwater.

So, this is the basic simple definition difference that in the vadose zone. In the zone of unsaturation in the zone of aeration pores filled up with air and water whereas in the zone of saturation the pores are completely filled up with water only.

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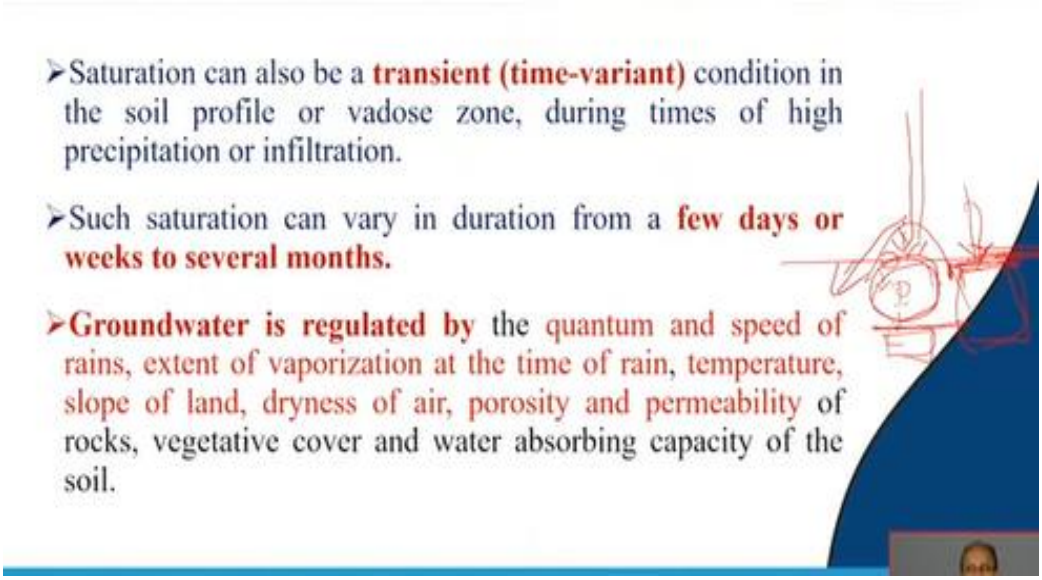

So, this tells that saturation can also be a time variant. This saturation in the formation is a time variant condition. In the soil profile of vadose zone during times of high precipitation or infiltration. So, when there will be high precipitation say a heavy shower is there or high infiltration is there then what will happen? There will be the variation in the depth of the water table also. The variation of the depth of the water table will decide the zone of saturation also.

So, such saturation can vary in duration from a few days or weeks to several months that can remain for few days only that can remain for a week also and for months also. So, but it is not quite certain that this saturation will last for this much period only. The variation is for few days also, for few weeks also, for several months also groundwater is regulated. Now we have understood already that groundwater remains in the formations and the unsaturated zone are also very important.

Without unsaturated zone it is impossible to have groundwater in the zone of saturation. Why? Because we have seen the concept that when the raindrops fall on the earth's surface first thing is happening what is that is infiltration so just sending the raindrops inside the earth's surface. Then percolation this infiltrated water will then percolated down and then towards the gravity it will reach to the aquifer.

So, when it reaches to the aquifer this is the water table but this area is total the zone of unsaturation. Suppose a very good aquifer is inside the earth's surface but it is not having any unsaturated zone. Then how the water will move inside the zone of saturation? It will become since it is saturated with water so raindrop will never come to this point, it will just flow with the topography.

So, that is why the zone of unsaturation is equally important than the zone of saturation and at the present day lots of research are going on for the zone of unsaturation that is the vadose zone. Vadose zone hydrology is a very important topic, vadose zone. So, this groundwater what we are just studying about the ability of the groundwater resource. This groundwater resource is dependent on several factors that is the speed of the rains.

What is the intensity of the rain of any area? What is the extent of vaporization? Evaporation we have read evaporation from the open surface transpiration from the leaf surface so this we have read. Temperature, what is the temperature of the area, slope of the land. Suppose good rainfall is there but this rainfall is on the hills so what will happen? There will be no scope for infiltration, no scope or percolation straight forward this rain water will just have the surface flow and ultimately reaches to certain streams.

So, that is why these are few factors. Another factor is the dryness of air then the porosity and permeability of rocks, vegetative cover and water absorbing capacity of the soil all the factors are equally important for having the groundwater resource availability inside the earth's surface. If the factors favourable factors are remaining definitely, we are getting very good ground water resource.

Otherwise, we may get lesser number of aquifers good aquifers in the area from where we can extract the water for our general use. So, that is why for the availability and management of groundwater resources we should have the total concept starting from the hydrological cycle to the down below then only we can understand how the groundwater remains. And this thing also we have read earlier that very few quantities of rain water out of 100 only 10% water that is coming down to the earth's surface or transforming into the groundwater.

Otherwise, rest 90% rain water is being lost or becomes remain unused. Why? Because most of the content most of the percent of the rain water they just evaporate back. Evaporation and transpiration, evapotranspiration then remaining amount is a just wasting away just like a runoff. So, only few percent out of 100% say only 10% of the rain water which is only recharge source is entering into the earth's surface.

And that is just converting and just making a path through the zone of unsaturation then reaches to the zone of saturation that is the aquifer and making and remaining as a groundwater. So, and several factors are also very important for making the groundwater inside any repository rocks that is aquifer. So, these factors are there.

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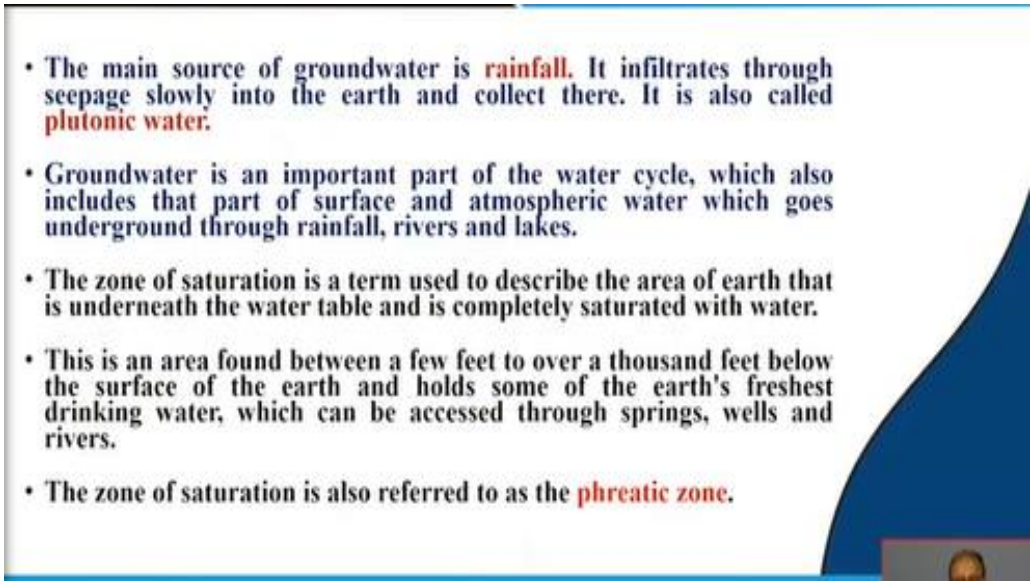

So, what the point is that the main source of groundwater is rainfall. It infiltrates through seepage slowly into earth in the terms of infiltration, percolation and remains inside any formations also sometimes called like plutonic water. Groundwater is an important part of the water cycle, which also includes the part of surface and atmospheric water which goes underground through rainfall, rivers and lakes.

Sometimes from the rivers, lakes which are the source of surface water the seepage may take place and ultimately reaching to the aquifer underlying aquifer. So, the zone of saturation is a

term used to describe the area of the earth that is underneath the water table and is completely saturated with water that is completely saturated water. This is an area found between a few feet to over thousand feet below the surface of the earth.

So, the variations are there at some place near to just earth's surface at just at other place just at greater depth. So, this zone is also termed as phreatic zone.

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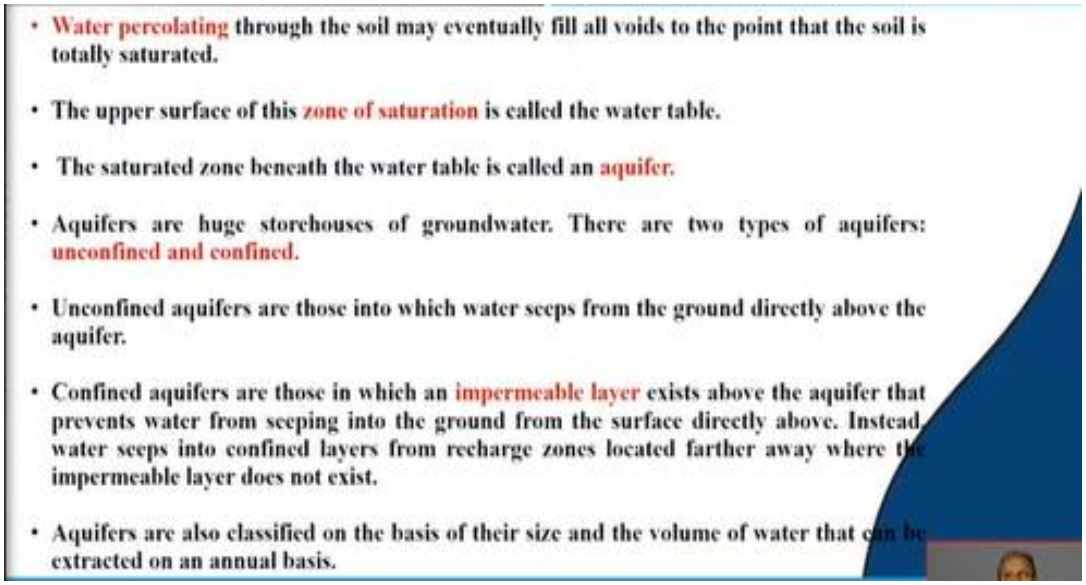

Now what is happening? Water percolating through the soil may eventually fill all voids in the point that the soil is totally saturated, just water percolating down through the soil will eventually fill all the voids. And the upper surface of this because if once the voids have been filled with water, then the upper surface of this which term does water table only. This is the aquifer so this aquifer is primarily divided into two types unconfined and confined.

So, two types of aquifers are there, we will discuss just in the coming lectures. Unconfined just in brief I am telling unconfined aquifers are those in which we are getting only one confining beds underneath the rocky formations only one confining beds. Suppose if this is one aquifer and this aquifer is having the water table here so here some bed rock formation is there which is impermeable that is why it is holding the water here.

If it will become permeable this then this formation will be up to this place. So, this thickness of the aquifer that is why varying from place to place because underneath the formations there should be some impermeable layer. This impermeable layer will remain then only it can store or hold the water at this place. So, in case of unconfined aquifers one impermeable bed is required just below it and the top portion remains in contact with the open atmosphere.

Or an example, a very simple example of unconfined equity dug well. You have seen in a well just we are seeing from the top also our level of water is clearly seen there and the top level of the water is termed as groundwater table and this very aquifer is termed as unconfined aquifer. Because here the; water table remains directly in contact with the atmospheric pressure. This is the just about the brief know how about the unconfined aquifer.

And for confined aquifers this is also one of the formations which is holding the water. But what is happening here? At the top as well as at the bottom both side there should be impermeable formations. It is holding the water it is having very good formations, very good formation means it is holding the water also means porosity is good, it is having the ability to transmit the and take the water also. So, having the; ability to transmit the water also so very good permeability also.

So, in this way what we have seen that here the water remains in confined positions. It is not remaining direct in contact with the atmosphere then what is happening? Here the water remains in contact with the hydrostatic pressure, here the water remains not with the atmospheric pressure but in the hydrostatic pressure. The confined situation in the confined case of aquifer what is happening?

The confined aquifer is having overlain as well as underlain by some confining beds then only the water will remain in confined position. So, some rocks should be there which is having the characteristics of impermeable nature that will just keep the water in confined positions. If you will puncture it all on a sudden the water level will go at the top move at the top and this, we have seen in the case of artesian well condition also.

This is the artesian well condition also. So, the point is that the zone of saturation we will further discuss this thing, the zone of saturation is further known as the unconfined aquifer and the confined aquifers. So, this we will discuss in greater detail in the coming lecture and these aquifers are classified on the basis of their size and the volume of water that can be extracted in the annual basis, which type of aquifer is good for its use.

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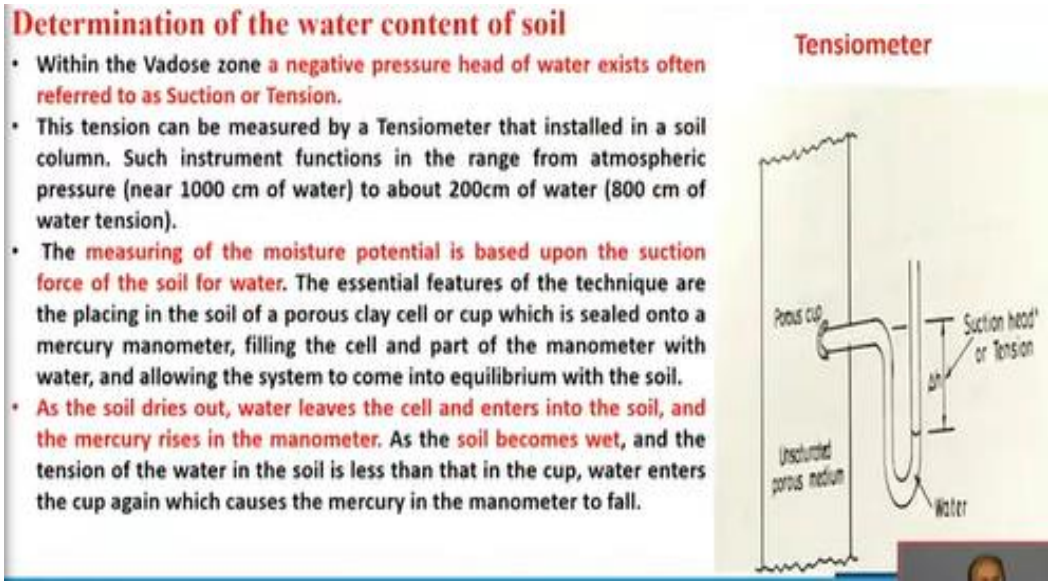

Now one important just tense they are methodology to determine the water content of the soil. Generally, in vadose zone, I have told you vadose zone hydrology is very important. Within the vadose zone a negative pressure head of water exists often referred to as suction or tension. The instrument name I have told tensiometer earlier also I have told you. Here what is happening? This is the soil layer; this is the unsaturated porous medium.

And within the vadose zone a negative pressure head of water exists often which is referred as suction or tension. So, this tension can be measured by your instrument known as tensiometer that installed in a soil column. So, this is a soil column or a soil column, such instrument function in the range from atmospheric pressure 1000 centimetre of water to about 200 centimetres of water. So, what is happening?

The measuring of the moisture potential is based upon the suction force of the soil for water. The essential feature of this technique are the placing in the soil of a porous clay cell, this is the

porous clay cell. So, this is being placed in the soil column which is sealed onto a mercury manometer, this is a mercury manometer. So, it has been sealed here the soil column then filling the cell and part of the manometer with water.

And allowing the system to come into equilibrium within the soil and leave it for certain time and just see how when it is reaching to the equilibrium condition. As the soil reaches as the soil dries out water leaves the cell, water will leave this water will be just go moves out from the cell and enters into the soil and the mercury then rises in the manometer. As the soil becomes wet and the tension of water in the soil is less then what is happening? Water enters the cup again which causes the mercury in the manometer to fall. So, in this way generally we are measuring the water content of the soil of the vadose zone area. Now with the help of instrument known as tensiometer.

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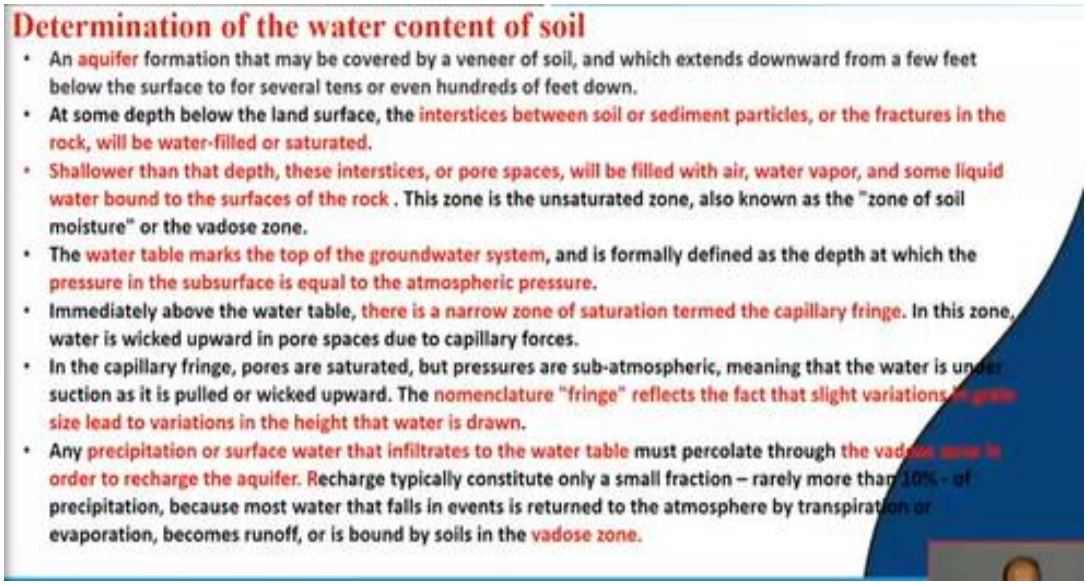

So, what we have seen that an aquifer formation may be covered by a veneer of soil and which extends downward from few feet below to the surface to several tens or even thousands of hundreds of feet down. This generally happens at one place you may get aquifer at a certain depth shallower depth but other place you will get the aquifer at greater depth. So, what is happening? At some depth below the land surface the interstices between soil or sediment particles or the fractures in the rock will be totally water filled and this water filled area is generally known as the saturated area actually known as the saturation of saturation. Whereas

shallower than that depth these interstices are pore spaces will be filled with air water vapour and some liquid water bound to the surface of the rock. This is the condition of zone of unsaturation. This zone is unsaturated zone and also known as the soil moisture zone or the vadose zone.

So, the water table marks up the top of the groundwater system and it formally defined as the depth at which the pressure at in the subsurface is equal to the atmospheric pressure what I have discussed just now. The water table will always remain in contact with the atmospheric pressure. Immediately above the water table there is a narrow zone of saturation that is generally we are knowing that the water table.

This is the water table; this is the zone of saturation zone of saturation whereas this is a zone of unsaturation. But in the zone of unsaturation where the pore spaces are filled up with air, water a few liquids but in the zone of saturation the pore spaces are filled up with water only. But just few inches above the water table very narrow height few inches above the water table there is a formation known as narrow capillary fringe which also some upward movement of water remains there. In capillary fringe pores are saturated, because it is just a few inches above your water table. So, this narrower area is generally known as the capillary fringe area and the word fringe reflects the fact that slide variation in grain size leads to variation in the heights that water is drawn. So, that is why the term fringe is applied here.

Any precipitation or surface water that infiltrates the water table must percolate through the vadose zone. In order to recharge the aquifer without the help of vadose zone we cannot recharge the aquifer. Recharge typically constitutes only a small fraction I have told you only 10% of the rain amount is entering into the earth surface. More than we have seen that the other factor that is the evaporation, transpiration, runoff, generally these all process the rainwater are being wasted. So, what is happening?

In order to get a good precipitation so what we have seen that or already we are getting very lesser amount of precipitation throughout our land surface and in that few amounts are only just entering into the earth's surface and converting it into the ground water which is being used. So, with this we have already understood about the different layers inside the earth surface consisting of zone of unsaturation, water table and zone of saturation. Thank you very much.