Availability and Management of Groundwater Resources
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Lecture - 09
Geological Formation as Aquifer (Continued)

Welcome you all in the part 4 of the lecture 2 subject geological formation as aquifers. In this lecture we will discuss about the prominent type of geological formations which in general bears the groundwater inside the earth's surface.

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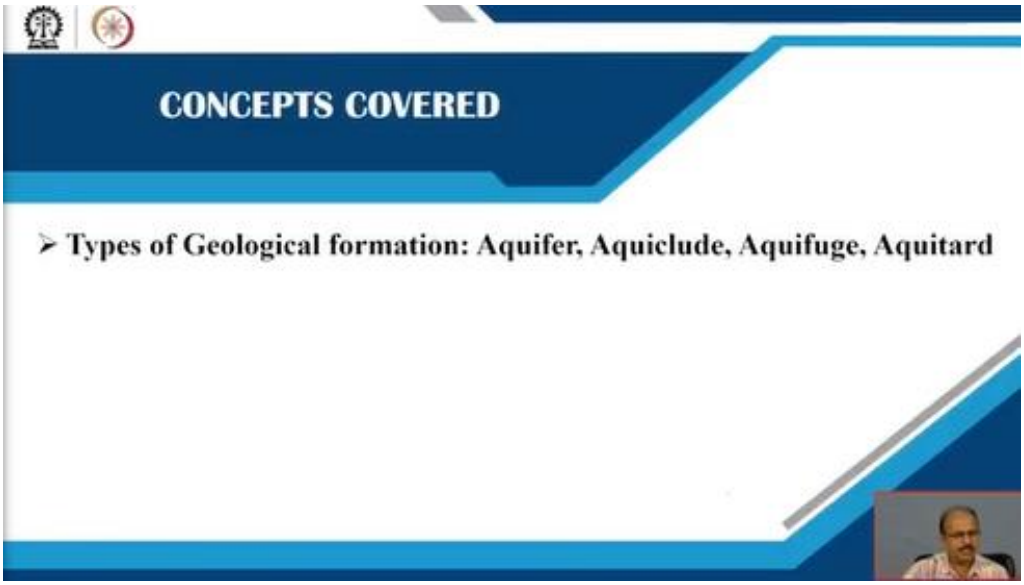

So, what we have discussed we will try to cover the concept in general about the aquifer, aquiclude, aquifuge and aquitard. These four different terms are here in the geological formation and this is the last part of the lecture of the types of geological formations. So, here what concept we have just made regarding the availability of groundwater inside the earth surface. We have seen in the very first lecture that if this is the earth's surface.

So, at the top of the earth surface, we are getting water in the form of rain that is the precipitation. I have already discussed in the first lecture one and the part of lecture 2 also that precipitation is the only source of recharging the groundwater recharging the aquifer.

Precipitation is the only source which is recharging the aquifer and aquifer is nothing but it is a geological formation rocky formation which generally holds the water.

This is holding the water inside the earth's surface. So, this just I am recapping all the important terms regarding the concept about the availability of the groundwater. So, for this rain water just heating the earth surface and then it is just trying to enter into inside the soil layer. Since it is dry so water will come inside and this phenomenon is termed as infiltration. Then first layer of the soil this is suppose this is the first layer of the soil, this is the second layer of the soil, this is third layer of the soil.

So, in this way then we will get some rocks at the top we are getting soil. Soil is nothing but it is the integrated or weather product of the bedrock. So, these are the bedrock. So, in this the again the movement of infiltrated water will be towards the gravity because it will try to reach to the inside the earth’s surface. So, the precipitated water becomes the infiltrated water and then the percolated water and lastly this percolated water is coming inside the rocks which are lying just inside the earth's surface.

We have already read in some lectures that earth interior is composed of crust, mantle and core. So, crust is made up of all the three important types of rocks that is the igneous, sedimentary and metamorphic rocks. So, the concept what we have developed that the rain water is the only source of the recharging of the aquifer means the groundwater what we are telling as a ground water the groundwater is mainly developing mainly living mainly lying in your rocky formation and this rock information is your aquifer.

Now in previous lectures I have also discussed that few formations in different places of our Indian subcontinent is holding the groundwater inside the earth's surface because it is not necessary although I have told you that sedimentary rocks and the metamorphic rocks which has been made by the sedimentary parent. Those two different types of rocks are having the availability to store the water in general.

But apart from that few structures few strati graphical positions they also allow to keep some amount of groundwater inside the earth's surface within some formation. So, some of the formations may hold the water but may not transmit the water. I have told you in the previous lecture also that an aquifer is a good aquifer when it is having the two important property. One is the porosity and other is the permeability.

So, these two are very important, porosity is nothing but it is the number of pores divided or volumes more will be the pore more will be the water storage capacity. And permeability is the availability to transmit the water from one aquifer to another aquifer. You can ask why permeability is important because if suppose you are getting a very good aquifer very good amount of groundwater at one place.

But after few years or few months of withdrawal of water from this very place this area will not have water. Then what will your conclusion? Conclusion will be this area is very good. This area is having the availability to store the water but this area is not having the availability to transmit the water from any aquifer or to take the water from any aquifer or to transmit the water to some other aquifer.

This is also very important inside the earth surface your rocks are not lying in the general way, they are lying haphazardly. So, all the rocks inside the earth's surface is lying haphazardly. So, what we are seeing some rocks are here some rocks are here some rocks because different this position of the rocks lying inside the earth's surface. So, the rocks are only the aquifer rocky formation is called as aquifer.

Those rocky formations which is holding the water is called as an aquifer. So, maybe this part of the rock is a very good aquifer. But these part of the rocks are not good aquifer although it is holding the water. Why? Because this part is having the ability to store the water as well as the ability to take the water from some other rock or to transmit the water to some other rock. So, permeability is also good that is why it is a very good aquifer.

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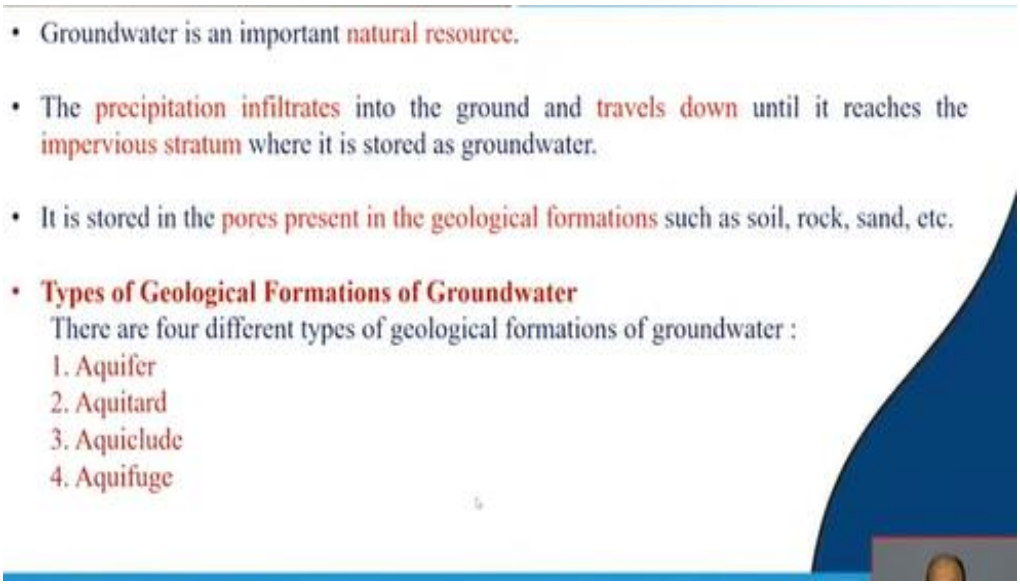

So, what we will discuss here? We will discuss here the important we have already discussed about the different formations of the different places in our country India in the previous slides in the previous lectures I have already discussed. Now I am just concluding to keep these four words in your mind for the availability of groundwater inside the earth and those four words are aquifer, aquiclude, aquifuge, aquitard first point.

Second, all the four terms are related with the rocks and all the four terms means the rocks are holding some amount of water, may not holding some amount of water, may transmit some amount of water, may not transmit some amount of water means all the four different terms of water holding rocks are mainly classified on the basis of two important terminology that is the porosity and permeability which we have discussed from the very beginning.

The geological formations which are having a very good porosity, good permeability that will be a best suitable aquifer that will be the best place inside the surface where we can get the groundwater. So, let us discuss in today's lecture let us discuss these four important terms I have told you these are also the rocky formation holding the water. But what is its characteristic? Just we will discuss one by one.

So, see this I have already told you that groundwater is a very important natural resource and precipitated water infiltrates into the ground travels down and then it reaches to the impervious

stratum. Suppose you this and suppose the rain water it is just coming inside the earth's surface rain water is coming inside the surface. So, it can pass through the different types of the soil on rock inside earth then it will reach to a rock which is having good amount of pore spaces to lie here.

If below it will remain the pervious stratum, then what will happen? This stored water groundwater will not store here rather it will move down. So, here also one concept is that there should be some impervious stratum just below the rocky formation which is holding the water. So, this impervious stratum is very important for storing the groundwater. Now this groundwater is stored in pores present in the geological formations maybe soil rocks and etcetera.

And based on these the different four different types of geological formations are noticed. And these geological formations are named as aquifer, aquitard, aquiclude and aquifuge. I have told you all the four terminology is related with the rocky formation which is holding the water. What we have discussed earlier? We have discussed in greater detail. Now just we are concluding ourselves that the precipitated water will remain, where?

Precipitated water will remain in some rock. In which rock? Rock which is having a good pores space and the rock which is having good connection with another for your aquifer. So, two terms should be their porosity and permeability. Now on the basis of this the four different geological formations have been identified and these are the aquifer, aquitard, aquiclude and aquifuge. Now we will discuss one by one.

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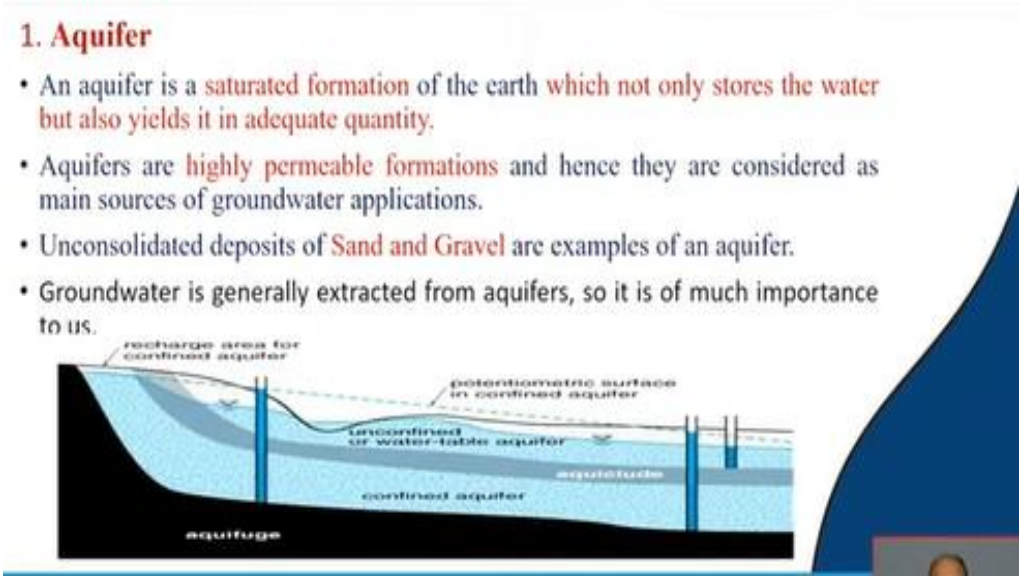

Aquifer, very general term aquifer, whenever a word aquifer is coming it is just a saturated formation of the earth. We can say a saturated formation, saturated formation means fill of water of the earth which not only stores the water but also yields it in adequate quantity. So, only the storage of water is not important. The important is that if you are trying to extract the water from the place means yields will be good.

Yields should be in such a way that the supposed few volume of water you have just extracted after few minutes, hours, day it should be replenished at that level. So, this is the good yield of any aquifer. So, I prefer should store the water as well as it should have availability to withdraw the water to give the water to the users in a proper amount. So, then it is a very good saturated formation.

Now these are highly permeable formation and hence they are considered as main source of groundwater applications. Because permeable it is having the availability to take the water from some other aquifer as well as it is having the availability to send the water from its this aquifer. So, since it is highly permeable formations and aquifer is highly permeable formations so it is having several applications also.

Unconsolidated deposits of sand and gravels we have already discussed the unconsolidated, consolidated and semi-consolidated. So, unconsolidated deposits of sand and gravel are

examples of an aquifer. It is a good aquifer. Wherever we are getting the sand and gravel inside the surface it is having good number of pores also and it is having the availability to take and transmit the water from one aquifer to another aquifer.

So, groundwater is generally extracted from aquifers. So, it is of much importance to us also because we have to take water for drinking, bathing and other purposes. So, the place where the water is fully saturated means a very good aquifer is there then we can utilize the groundwater resources in a better way. That is why an aquifer is very important for the availability of the groundwater resources inside the earth's surface.

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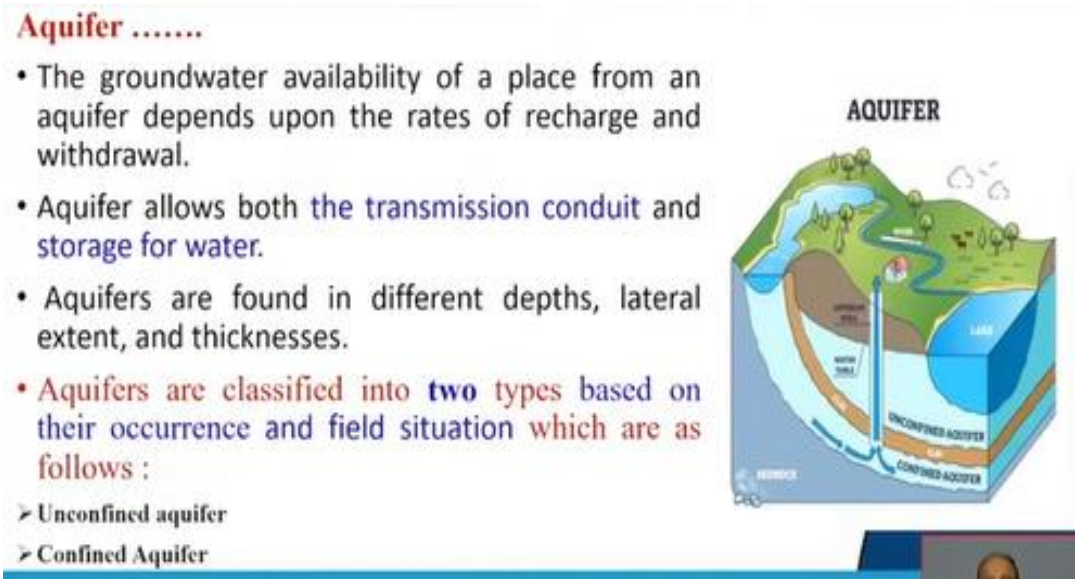

Now just continuing the points of the aquifer the groundwater availability of a place from an aquifer depends upon the rates of recharge and withdrawal. You can ask why not at every place we are getting the groundwater. Because we cannot get the groundwater in similar amount at ever places because the rate of recharging may differ from place to place. Amount of precipitation may differ from place to place, not only the amount of precipitation other factors are also there.

Suppose the one area is agriculture area, this is the agriculture area one other is your constructed area. So, constructed place is having no earth surface whereas agriculture area is having plenty of earth surface. Then what is happening? If the rain will fall here, it will have the chance to

infiltrate and percolate it and percolate and move to your aquifer. But here there is lesser less chance because all the area has become cemented, where it will infiltrate?

It will not infiltrate neither it, will infiltrate nor it, will percolate. So, what will happen? That will surplus rain water will move to some other places and which is called as runoff just you recall the first lecture runoff, this is surface runoff. So, those amounts of rain are falling at the same place. But at the same locality one area is agriculture area other area in your building area, settlement area where there are no space for infiltrating and percolating the rain water.

Then what is happening? The rate of recharge in this area is good but rate of recharge in those area is not good. So, this is also one of the very important factors with respect to aquifer. Aquifer allows both the transmission conduit and storage for water. What we have discussed? It should have availability to transfer from one aquifer to another aquifer and aquifers are found in different depths also its thickness and extents are also varying.

Somewhere inside the earth's surface you may get a big very good aquifer in a greater length but at somewhere you may get some patches of aquifer. So, sometimes we are getting aquifers at shallower depths say 20, 30, 8, 10 meter depth but sometimes aquifers are lying at 100, 200 meter depths. So, the point is the location of the aquifers are not fixed, the extent of the aquifers are not fixed.

The depth its lateral extent and thickness all varies from place to place with respect to the variation of rate of recharging and withdrawal. So, aquifers are further classified into two types based on their occurrence and field situation. In short, I will discuss because this I have to discuss in greater detail in the later chapters, unconfined aquifer and confined aquifer. So, these two important types of aquifers have been classified on the basis of its position inside the earth's surface. So, we will discuss this thing in greater detail later on but in brief.

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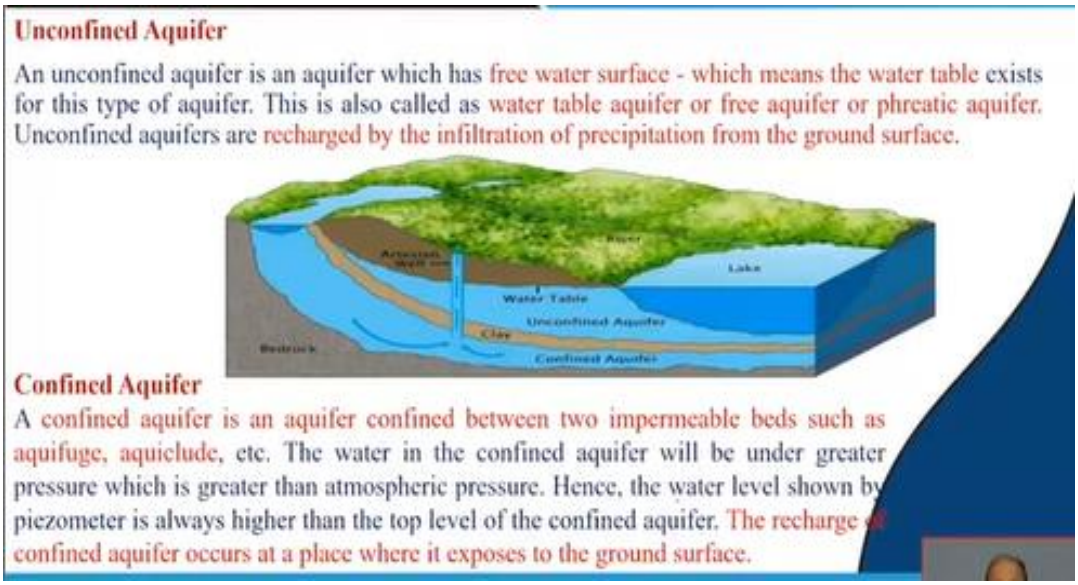

Just I am telling you in this lecture also that the word unconfined means the rock is having no upper and lower boundary. It is remaining a free surface with the atmosphere the water saturated aquifer saturated required means the water will aquifer which is containing the water is remaining in direct contact with the atmospheric pressure. Maybe over lying or underlying by some your rocky formations.

So, based on this the two different types of aquifers have been classified. Unconfined type of aquifer is an aquifer which has free water surface what I have told you just now, free water surface. So, it is having the free water surface you can see this portion of the aquifer is known as unconfined aquifer and here this unconfined aquifer is having the free water surface what we are seeing in the well the upper level of the water is called as water table.

Because those level of water is just remaining in direct contact with the atmospheric pressure. So, this unconfined aquifer is also sometimes called as water table aquifer or free aquifer. So, unconfined aquifers are the charged by the infiltration of precipitation from the ground surface. We will discuss in greater detail, just here we can think it that unconfined aquifer is only underlying by some rock because that rock is essential which will not transmit the though this water because your water is here.

So, some sort of control should be here so at the bottom control is there. This is also a rock and this rock is having that property to store more amount of water but it is having the property that it should remain impermeable. It will not allow the water to move down. So, that is why this when the any saturated formation say aquifer is having only one rocky layer in just below it which is impermeable and above layer is free from the atmosphere then such type of aquifer is called as unconfined aquifer. We will discuss in greater detail in the later chapter. Confined aquifer, the word itself telling that it is remaining confined. Confined under which? Confined between some rocks but again here the same point is the rocks should be impermeable in nature then only the water can remain stored there.

So, a confined aquifer is an aquifer confined between two impermeable beds what I have told you that the top as well as at the bottom. And the name here is given aquifuge and aquiclude which just I have discussed that these are the four important formations. So, for a moment you please keep this in your memory that aquifuge and aquiclude they are just the impermeable beds impermeable rocks which are lying just up and below of any saturated formations which is holding the water.

So, the water in the confined aquifer will be under great pressure, this water will remain under great pressure. Because at the top also one rock is there, at the bottom also one rock is there but this rock may hold water because may be porosity is good but may not transmit water from this place to this place or this place to this place. So, then what will happen? This portion of the water will remain in confined pressure.

If you will puncture it all on a sudden the water will move up and artesian condition you are understanding it here the same confined aquifer is sometimes called as artesian aquifer also. Here the water levels shown because this water level what is being shown by piezometer. Piezometer is one your artificially made instrument through which we are just measuring the level of water inside any confined aquifer.

So, this level is remaining at the top but that top portion is not showing actually the level of the water in the confined aquifer. So, the point is that the recharge in the confined aquifer always

occur but from where? Not from the infiltration but through some seepage which is occurring just from the side where you are having no rock impermeable rock from there it is just recharging the area.

In the unconfined aquifer the recharging were from directly from precipitation, infiltration percolation. But here the recharging since the two impervious rocks lying up and below down in the aquifer. So, here the precipitated, infiltrated and percolated water is not recharging this very aquifer, confined aquifer rather water from other sources I have told you in the just a few minutes before that the constructed area, the settlement area rain water is not entering inside there rather it is moving to some other place.

So, some other place water will then move inside and recharge the confined types of aquifers. So, this we will discuss in the later class.

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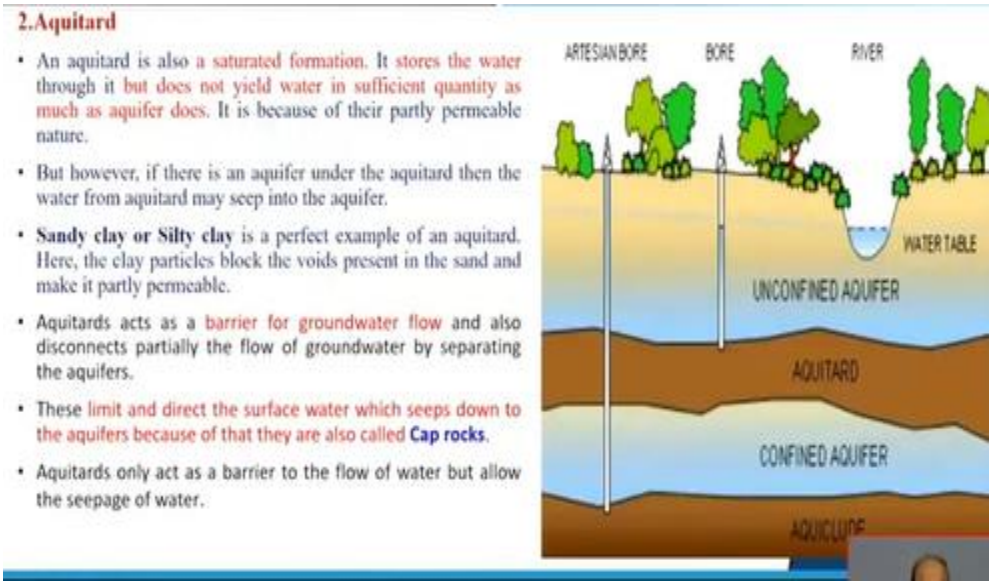

Now second important formation is aquitard. Aquitard is a saturated formation saturated the word has come saturated means it is having the water. So, it stores the water, this is the aquitard it stores the water but does not yield water in sufficient quantity. But if you wish to extract water from it you may not get water from here. So, why? Because it is partially permeable not fully permeable, it is partially from permeable.

However, if there is an aquifer under the aquitard see here one aquifer is under the aquitard then the water from aquitard may seep into the aquifer. So, just I have discussed that aquifer confined aquifer is getting recharging from the seepage water. So, aquitard acts at just the barrier for groundwater flow. It is just a barrier it is also a rock and this rock is having the availability to just stop the groundwater flow.

So, it is just a barrier for groundwater flow and it also disconnecting the flow of groundwater, separating flow of groundwater from one aquifer to another people. We can say it is the rock which is just separating the two different types of aquifers. Good example of the aquitard is your sandy clay and silty clay. Since the sandy and silty can hold the water but clay can also hold the water but clay is very impervious in nature.

So, that is why aquitard may hold the water but may not yield give good yield to the place where it is remaining. So, sometimes it is also called as cap rocks because it is just stopping the groundwater flow just it is just separating the different types of aquifers. So, this is the second important type's geological formation which is holding the water. We can call it as an aquifer we can call it as a saturated formation.

But the point is that it is not having the availability to give proper yield for against the requirements. So, it is not a very good rocky formation from the groundwater point of view.

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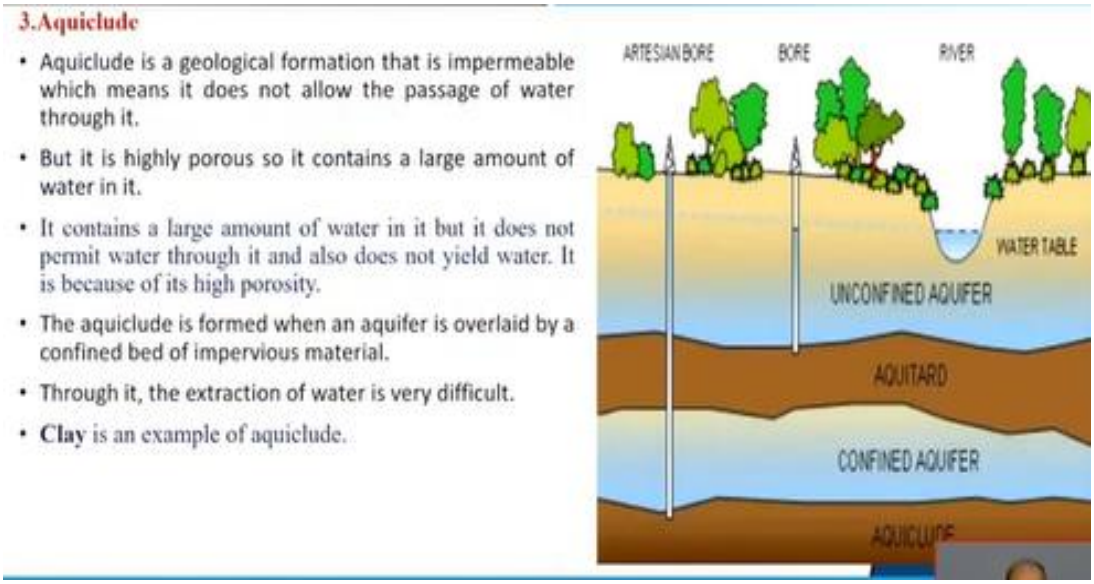

Next is the aquiclude. So, first we have discussed the aquifer then discuss the aquitard now aquiclude. Aquiclude is also a geological formation but it is impermeable means it will not allow the passage of water movement of water through it but it is highly porous. So, it contains a large amount of water in it. Aquitard, aquiclude is highly porous, if it is porous so it may contain large amount of water in it.

It contains a large amount of water in it but it does not permit water through it to move and it also not permit a good yield from the area. So, may be water storage capacity is more there in the rock but yield is very poor. So, the Aquiclude is formed when the aquifer is overlaid by confined bed of impervious material. You can see confined aquifer is lying just at the top of this rock which is aquiclude. So, here the extraction of water is very difficult.

Since from here if you wish to extract the water, it is very difficult. So, the good example of this aquiclude is the clay. I have several times discussed that clay is not a very good formations which regarding your groundwater availability point of view, it is not a very good formation. Although it is a saturated formation holding the water but it is not having the availability to take the water from some other aquifer nor it, is having the availability to transmit the water from one aquifer to another aquifer. So, clay is a very good example of aquiclude.

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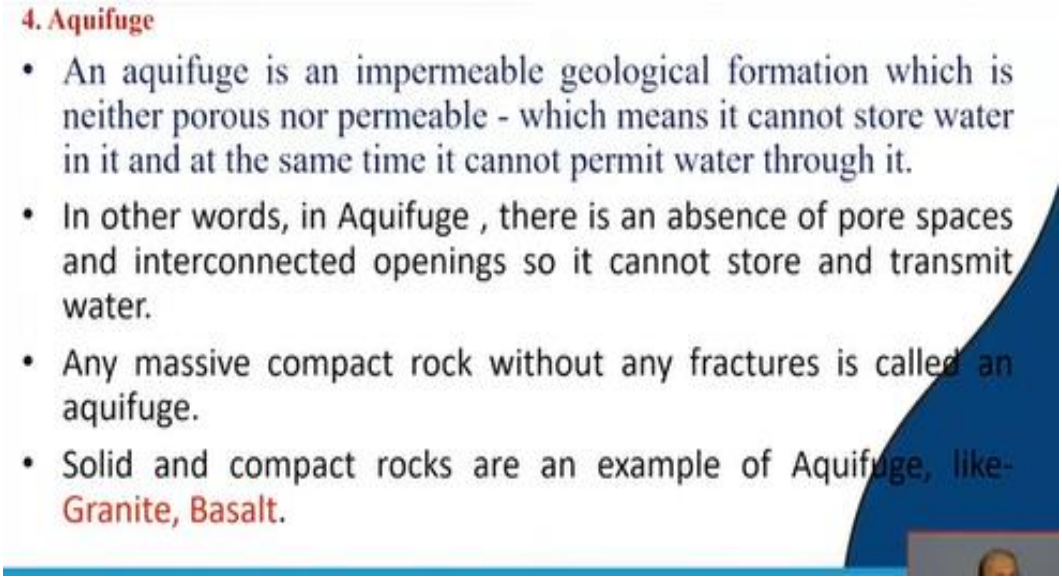

Now the last geological formation is your aquifuge. It is also an impermeable geological formation it is neither porous nor permeable. So, which means it cannot store water in it and at the same time it cannot permit water through it. So, see from the very beginning the at least the rock were holding the water but aquifuge is neither storing the water not allowing the water to move to some other aquifers.

So, what is there aquifuge there is an absence of pore spaces as well as the interconnected openings. So, it cannot store and transmit the water, it cannot store. Now just I have also given you the idea that we are having three important types of rocks igneous, sedimentary and metamorphic rocks. Just if we will guess which type of rocks will be the good example of aquifuge. The answer will be the igneous rock.

Even metamorphic rock is also coming sometimes but igneous rock is a very good example and your granite, basalt these all are very good example because it is just forming by the consolidation of the molten magma. So, it is neither having the pores nor any cracks through which it can allow to move the water or to allow to, store the water. So, aquifuge is another rocky formations geological formations which is inside the earth.

But it is important because it is it is playing a role for making the space the area where a very good aquifer lie impervious. Because imperviousness is also very important term then only the

water will remain placed there otherwise the water will move flow somewhere else. So, the last geological formations which we discussed are the aquifuge.

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Comparison of Groundwater formations

Geological formations/ Properties	Aquifer	Aquitard	Aquiclude	Aquifuge
Water storage	Yes	Yes	Yes	No
Permeability of water	Permeable	Partly permeable	Impermeable	Impermeable
Yield of water	Yes	Yes, but slow yielding	Do not yield	Do not yield
Examples	Sand, Gravel	Sandy clay	Clay, Shale	Compact rocks such as

So, what we have discussed in the different types of geological formations because from the very beginning the stress is about the geological formation. Geological formations are nothing but these are the rocky formations and these rocky formations are holding the groundwater inside the surface. This concept already has been discussed. Now just we have summarizing these four different formations what we have discussed just now aquifer, aquitard, aquiclude and aquifuge.

In terms of water storage properties, in terms of permeability behaviour, in terms of yield of water from specific formations and what are the examples. Just a comparative discussion about these four formations are in terms of water storage you can see and we have made our concept also that aquifer is having the availability to store the water as well as it is having the availability to transmit the water. So, since it is having the; transmit the water or storage of water.

So, it is a best place for the storage of groundwater. So, in terms of water storage we can just compare the aquifer, aquitard, aquifuge, aquiclude see in the case of aquifer. Yes, it is storing the water. In case of aquitard, it is also storing the water, it is having some pore spaces in which it is storing the water, it is having some cracks pieces in which it is storing the water. Aquiclude also it is having the availability to store the water.

But aquifuge is not having the availability to store the water, it is not having any spaces pore spaces, fractures etcetera in which the water remains. In terms of permeability, we can compare it the four different formations. In terms of permeability aquifer is a permeable in nature, aquitard is a partly permeable in nature not fully permeable partly permeable in nature, aquiclude and aquifuge these are the impermeable in nature.

So, in terms of storage and permeability we have seen the differences among these four different types of geological formations. In terms of yield, because yield is very important a place which is having good amount of groundwater does not mean that it is a very good aquifer. If the aquifer is having the availability to give proper yield from those various formations, then those aquifer are generally the good aquifer.

So, aquifer in general is having good yield so it is best considered geological formations containing groundwater. Aquitard is also having yield but very slow yielding is there but in the case of aquiclude and aquifuge yield is very, very poor say do not yield. An example if you will see the example of the aquifer sand and gravel. Sand and gravel is the example of the aquifer then aquitard the sandy clay is the good example.

For aquiclude the clay and shale these are very good example of aquiclude. And for aquifuge the compact rocks such as granite, basalt these are the compact rock, hard rock this is the example of the aquifuge. Since these are the hard rocks forming by the consolidation of the molten magma. So, these rocks are not having pore spaces that is why water storage is no here mentioned no here. Permeability since it is not having any pores so may not forming any conduit for movement of the water so it is impermeable.

Since it is not having water and impermeable nature so it is also very bad here, no yield. So, these are the four important formations. Now you have to keep in your memory from now onwards that four important formations inside the earth surface formation means the rocky formations inside the earth's surface is generally holding the ground water. Now we will discuss the different types of aquifer in the next class next lecture.

But here we should build our concept that these are the four different formations and the four different formations are generally containing the groundwater inside the earth's surface.

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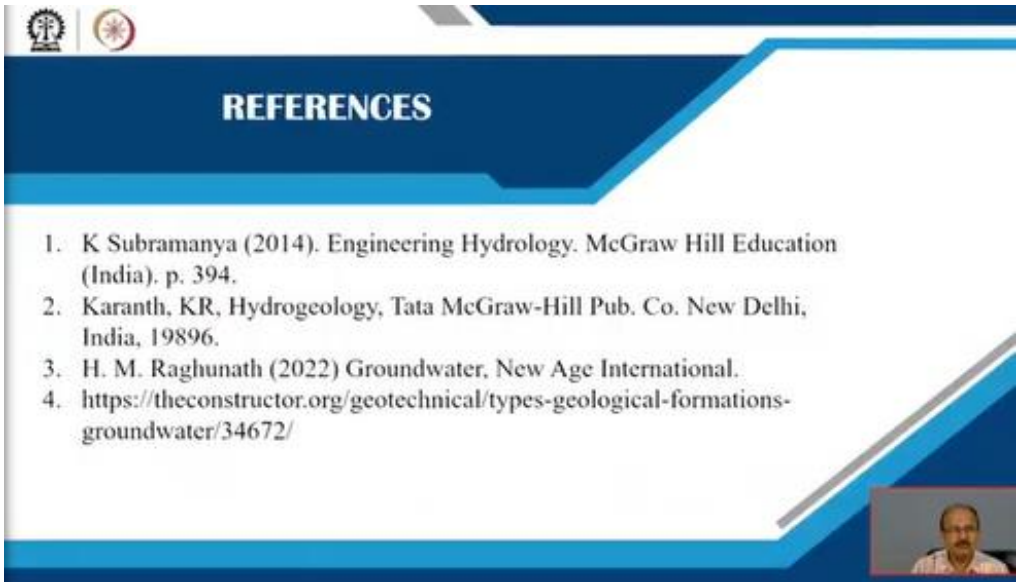

Now these are some of the references related to the lecture.

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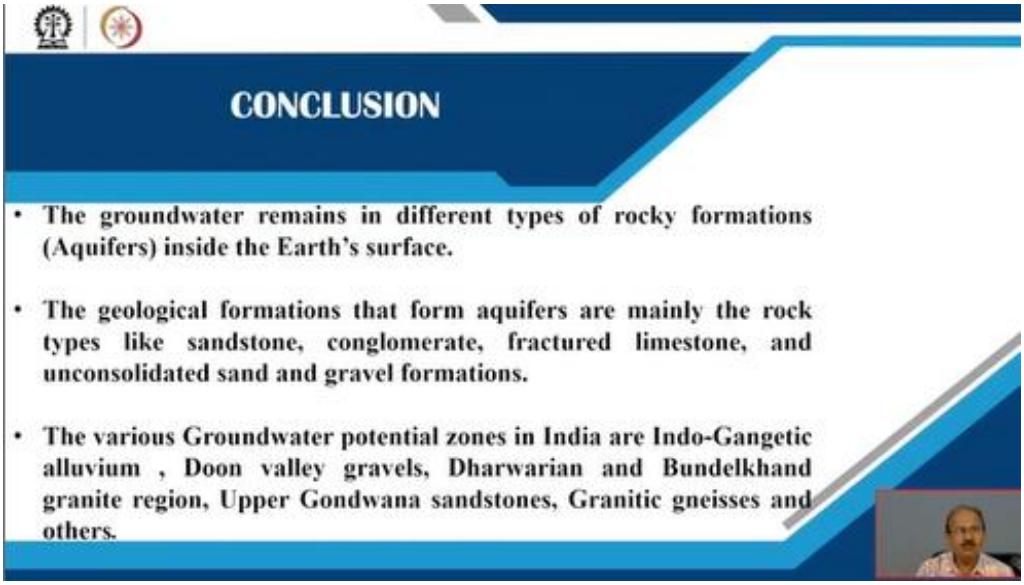

And then the conclusion of this lecture second lecture is what we have discussed in the total four different parts of the lecture that our earth crusts our earth's interior is made up of crust, mantle and core. So, this is the earth surface on which we are generally getting the precipitation. So, this is the surface on which we are getting the precipitation. We are discussing for the groundwater availability.

So, definitely the precipitation is the only and only recharge source which is generally giving the groundwater to our earth's surface. The water which is flowing just from the topography of the earth surface is the surface water, good example is lakes, ponds rivers etcetera. But those amounts of water which is just infiltrating and percolating down and reaching to the any rocky formations which those formations are termed as aquifer.

So, storage area inside the earth groundwater storage area inside the earth is aquifer. So, in this lecture we have discussed about the different types of rocks formations inside the earth's surface. We have seen in the previous lecture if you will recall just see few sandstones few conglomerate few fractured limestones these are remaining at certain depth inside the surface and they are holding the water.

So, in greater detail we have discussed this topic that is the geological formations which is termed as in general aquifer. In greater detail for the different places of our India and also, we have discussed some of the key clues for getting the good amount of groundwater in certain rocky formations this also we have discussed in greater detail. So, the point is very clear that the rain water will convert into the ground water.

But this recharging is not homogeneous at every place, it varies from place to place. Somewhere at one locality somewhere you may get good amount of groundwater but at the same place you will not get good amount of groundwater. So, the there are several factors related to this problem. Because here while discussing I have told you that lithology, I have discussed earlier then stratigraphy and then structure of rocks inside the earth's surface.

These are very, very important your points which are generally responsible for the availability of groundwater inside the surface, very important point. Because the types of the rocks are also important say clay is having the availability to store the water but clay is not having the availability to transmit the water. The point is clay is also there, sand is also there but sand is having the availability to store the water as well as to transmit the water.

So, different types of rock types are just behaving differently for the accumulation of groundwater inside the surface. Stratigraphy is also very important say something sometimes suppose this is a very good rocky formations very good aquifer. But here just some different rocky formations have come here. So, this is very bad means it is compact rock, hard rock. So, it will not store the water not allowed to move the water.

But this is a very soft rock, sandstone sand is there so it is having the availability to store the water as well as to transmit the water. So, besides this one more thing I have discussed in fold and fault, in this lecture I have discussed fold and fault. If some rock is just crumbling because of the horizontal movement inside the surface. So, then what is happening the place of availability of the groundwater aquifer is changing that is changing even the fault we have discussed the fault also.

Fold and fault which are the structural deformation inside the surface which are very responsible for making the availability of the aquifer at the same place in different behaviour different nature. You may get water; you may not get water. So, the sum total is that the geological formations which are aquifer are mainly the rock like sandstone sedimentary rock is there, conglomerate sedimentary rock is there, fractured limestone sedimentary rock is there.

So, in this way sedimentary rock is a very important rock which is holding the groundwater inside the surface. The point also I have discussed in this in last two lectures that sedimentary rock is forming one this by the sediment by the consolidation of the sediment. So, sediment is coming from where? From some weathering phenomena. So, it is settling one by one. So, what is happening? Here in the pore spaces, there are chances for accumulating the groundwater.

This is the pore spaces which is just holding the groundwater so that is why sedimentary rock is a very good repository of your groundwater inside the surface. In this second lecture I have also given some of the points related to the groundwater potential zones of India importantly the about the Indo Gangetic alluvium, the Doon valley gravels, the Dharwarian and Bundelkhand granite region, upper Gondwana sandstone, granitic gneisses and others.

So, in this way I have tried to tell you about the details about the rocky formations which are holding the water but we should keep in mind that the four important formations that is the aquifer, aquiclude, aquifuge and aquitard are very important geological formations which are responsible for the development and for the occurrence of the groundwater inside the earth's surface. Thank you very much.