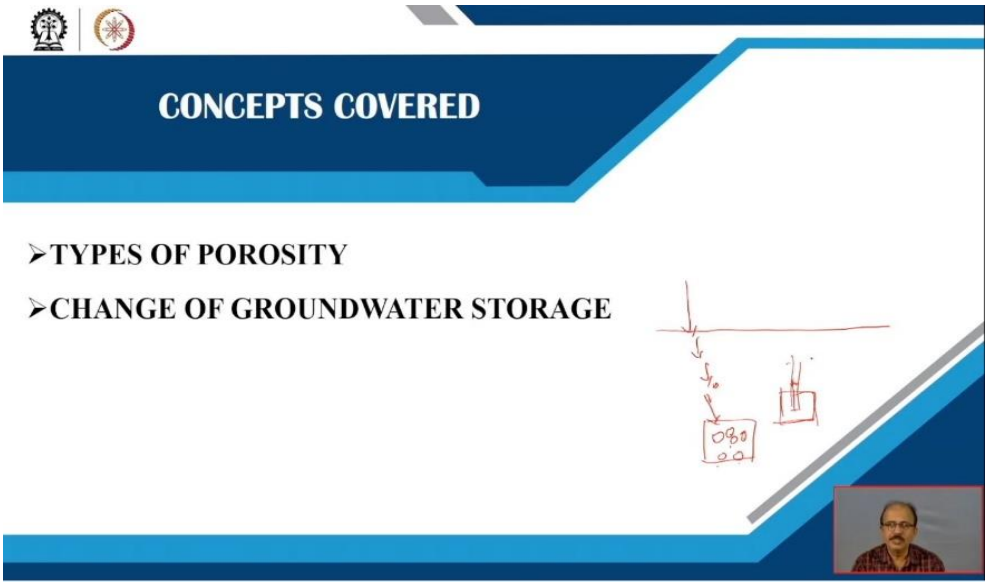
Availability and Management of Groundwater Resources
Prof. Prasoon Kumar Singh
Department of Civil Engineering
Indian Institute of Technology (ISM), Dhanbad

Lecture - 21
Porosity, Permeability, Transmissivity and Storage Coefficient (Continued)

Welcome you all in the part 2 of the module 5 porosity, permeability, transmissivity and storage consequent. So, in the previous lecture we have seen about the different concepts related with the porosity and the permeability of any rocky formations. Now, in this second part just we will know about the more details about some of the other concept specially the about the different types of porosity and the groundwater storage.

(Refer Slide Time: 00:57)



So, change of groundwater storage is also very important for finding the available groundwater resources in any formation with the fluctuation of the groundwater table in the area. So, what we have seen just till, now what we have seen that that then an aquifer remains just inside the earth's surface and this aquifer is having some characteristics which will help in storing the water within it. How the water is coming from? Where the water is coming?

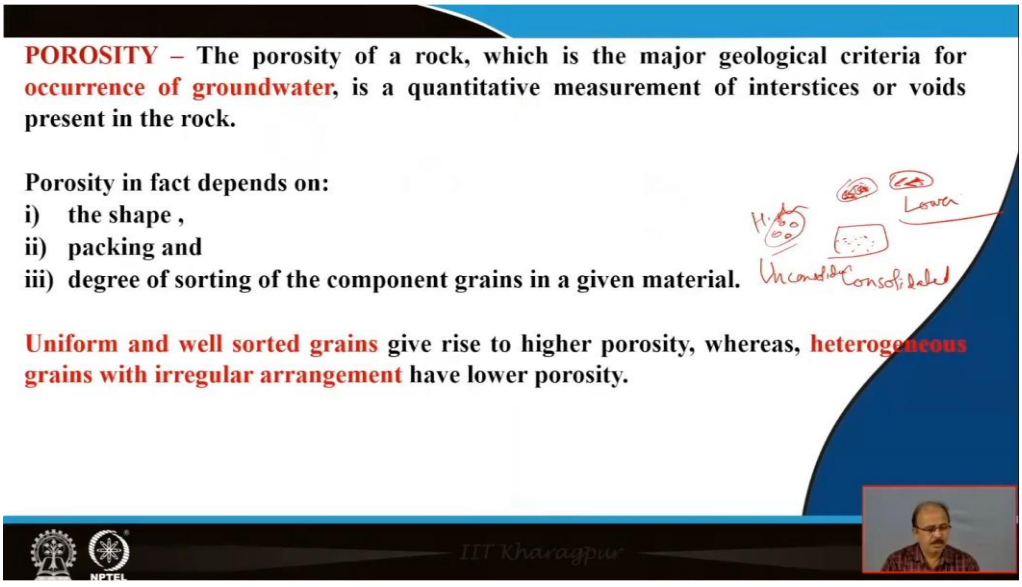
We have already discussed in the previous lectures; we have seen that the precipitation after infiltration after percolations then it in the amount of rain water it enters the rock formations. So, it in the rock formation the different pore spaces are available here. So, these pore spaces the water will remain inside the aquifer. So, this we have discussed we have learned already that the water is storing in the pore spaces available in the rock formations.

In some rock formation we may not have the pore number of pores or the sufficient pores to hold the water to store the water so that that rock will never become a very good aquifer. So, now after knowing the porosity we will discuss how many types of the porosity are there and what is the available groundwater storage capacity of any rocky formation. So, this we will discuss in any rocky formation.

We are knowing that if the rock is this much so it is it is having some area so in this if we will just dig the whale, so the water will get the water level. So, water level we will get this water level will fluctuate sometimes during the dry season the water level will remain at greater depth, in the after monsoon season definitely the water level will be a bit higher than the earlier one earlier on means the pre monsoon season.

So, this usually happens and with this we are knowing about the fluctuation of the groundwater table.

(Refer Slide Time: 03:23)



So, one by one we will discuss the types of porosity, the porosity which we have understood the major geological criteria for what? For the occurrence of the groundwater resources in any formation, it is a quantitative measurement of the voids present in the rock. So, porosity in fact depends on the shape that is very important shape of the formation what is the shape of the formation this this is very important, what is the type of packing inside it?

It is also porosity depends on the type of packing of the grains also. So, some of these suppose this is the unconsolidated rock and this is the consolidated rocks. So, in unconsolidated rocks what we are getting? We are getting the spaces the grains are there but the grains are at a bit greater distance it is not remaining in contact rather, it is just one grain is here one grain here.

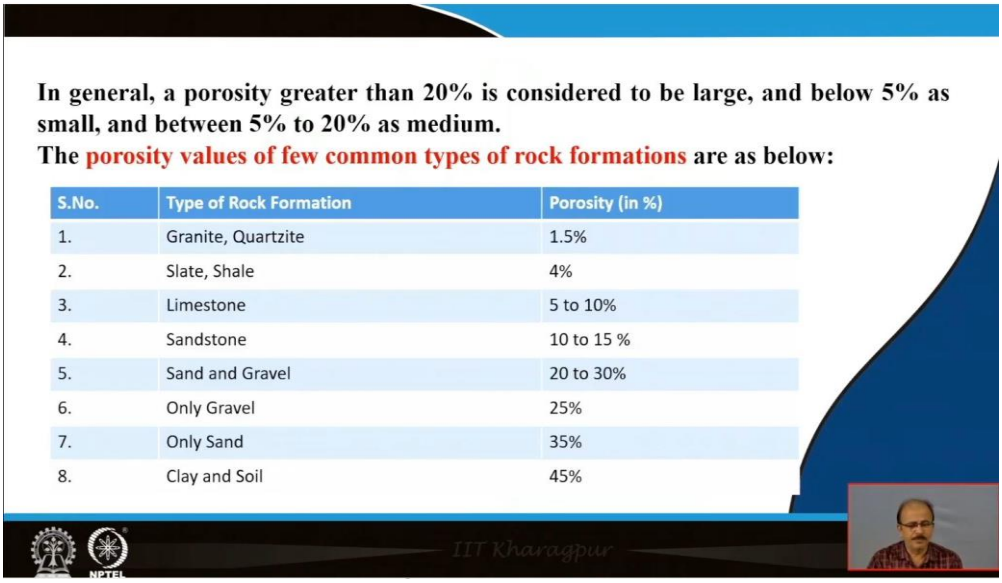
So, a bit more larger spaces are available inside those very unconsolidated rock formations. Whereas in this case packing is not so compact but here the grains are very closely spaced, so packing is very compact in this case. So, this packing also defines the types of pores and the number of pores within the formation. So, that is why the porosity first depends on the shape second the packing and third the degree of sorting of the component grains in any given material.

Why? sorting is also important why it is important? Because, see if grains are uniform and well sorted grains. Well sorted grains we will see the picture also later on then it gives a high if the grains are well sorted see how the grains are well sorted. So, definitely we will give the higher porosity in this case. But when the grains, grains are very poorly sorted means not so species grains are remaining inside it.

Then or we can say the grains are very much irregular in pattern one grain is here, one grain here, one grain is here. So, in this type of distribution of the arrangement or this type of arrangement of the grains it will have the lower porosity it will have the lower porosity, this will have the higher porosity whereas, this will have the lower porosity. So, generally the porosity depends on these three important factors safe packing and pattern degree of sorting.

The arrangement degrees of how the grains are have been arranged within that very formation, so this defines about the porosity.

(Refer Slide Time: 06:19)



Now, in general a porosity greater than 20% is considered to be large. If it is 20% generally it is considered to be large porosity whereas below 5% is small and between 5 to 20% is called as medium porosity porous rock, medium porosity of any rock. Few common rock types or rock formations I have mentioned the porosity in which we can see that the granite and quartzite if you will just recall the previous lectures granite it is an igneous rock quartzite metamorphic rock.

So, both the rocks are the hard rocks, you just recall in the previous lecture both the rocks are hard rocks because granite is forming igneous rock is forming by the consolidation of the molten magma. And your metamorphic rock is forming by the some of the metamorphic activity metamorphism because of the change of temperature pressure and chemically active plates the mineral grains are changing the arrangement of the packing of the rock is changing.

So, metamorphic rocks and your igneous rock both are hard rocks. Since it is hard rocks, so it is these are the compact rocks. So, if the compact behaviour of the rocks, then definitely the arrangement of the grains are very compact so well then we are having the very lesser chances of porosity see 1.5% porosity. So, 1.5% porosity, below 5% is termed as a very small porosity low porosity so it is a very low porosity rock granite and quartzite.

Low porosity rock means in these types of rocks there will be lesser chances of having the good amount of groundwater storage. Second is the slate and shale, so slate is the metamorphic rock shale in the sedimentary rock here also these are consolidated rock

consolidated metamorphic rock consolidated sedimentary rocks. So, 4% porosity is here. Limestone 5 to 10% limestone and sandstone these are also the sedimentary rocks.

Generally, they are also having some sort of compaction, so the porosity is 5 to 10% or 10 to 15%. Sand and gravel we are seeing the 20 to 30% means this is good this is good for any rocky formation, rocky formation holding the ground water resources. So, sand and gravel we are have getting the porosity 20 to 30%. But when only gravel is considered, it is having 25% alone, if the formation or surface in within the surface we are getting information metabolic of the gravel only.

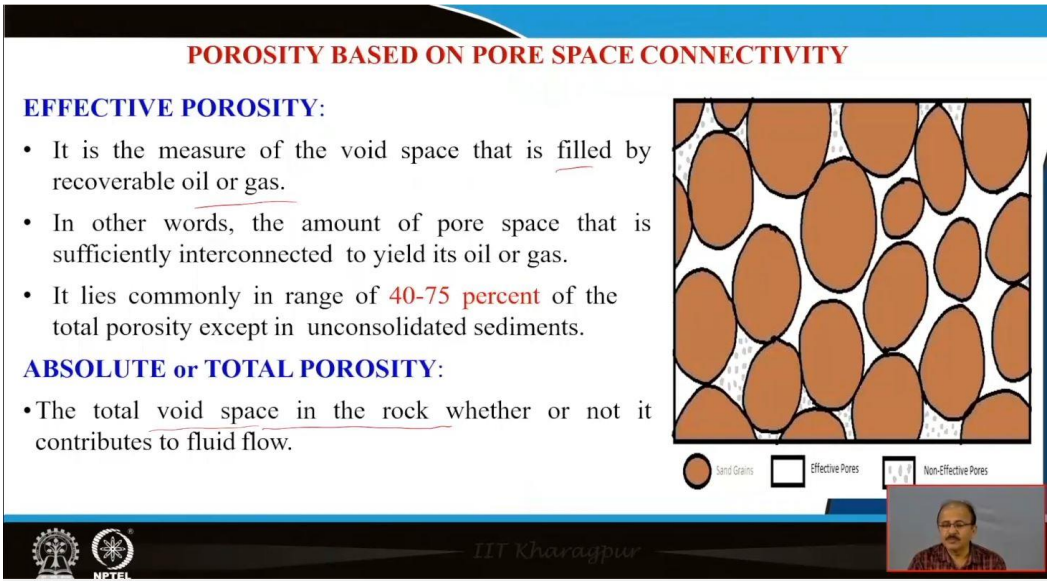
So, it will have the porosity is about to 25%, only sand is one of the best aquifers that is 35% aquifer and if the clay and soil is remaining, so then 45%. So, from sand and gravel to clay and soil we are seeing the porosity of the formations is increasing. So, porosity of the formations is remaining high. So, it means that in these types of formations we are having the chances of getting more amount of groundwater within the earth's surface.

So, that is why when we are just taking boring some of the well in any area, we are seeing the characteristics of the sand of the place. If we are getting clay soil only then we are just avoiding the area just we are replacing the place from that place to some other place. Why? Clay is a very good for the porous as far as porosity is concerned it is very good. But as far as permeability is concerned it is not so good it is bad clay is impermeable in nature.

So, that is why it may hold water for some period say for months say for one year you will get good amount of water from that very well. But after some time, it will become dry and it will become dry, why? Because, the; water will be exhausted why because it is not having the ability to either to receive the water off to transmit the water its permeability is poor. So, that is why that is why the sand and gravel soil is good one, gravelly only is good one.

Sand is gravel good one and clean soil is good one at least when the clay and soil will remain definitely it will hold some amount of water. So, this is the concept of the porosity in the any rocky formation which is holding the water.

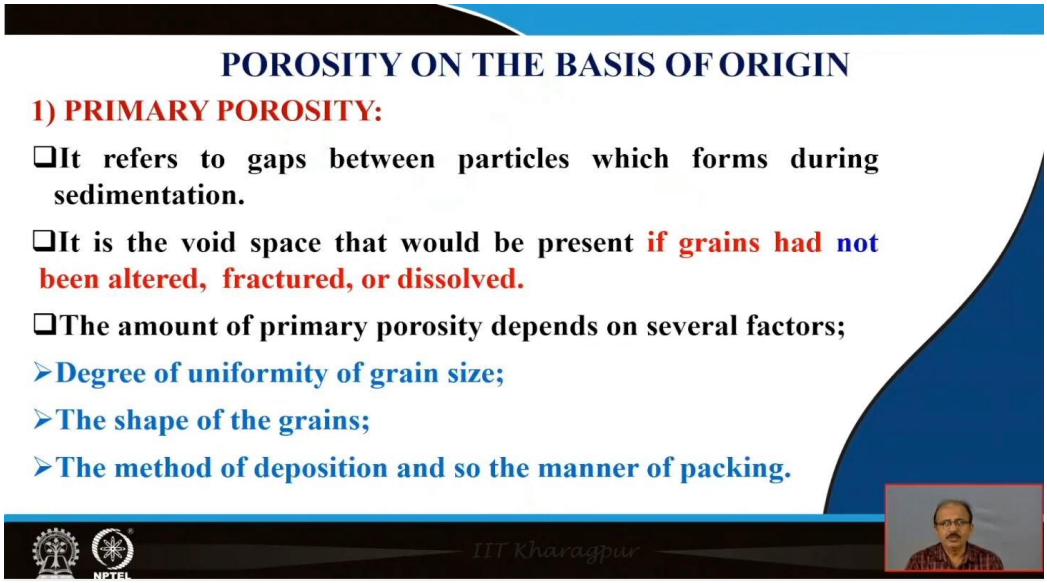
(Refer Slide Time: 11:29)



Next is the just the types of porosity we will see with this background effective porosity. Effective porosity is the porosity which is the measure of the void space that is filled by recover oil and gas. So, we can say the effective porosity is the void spaces which is filled up with the fluid. So, here the amount of pore space is sufficiently interconnected to yield its oil or gas. So, it lies commonly in the range of 40 to 75% of total porosity except in unconsolidated sediments.

So, this is called as effective porosity. Absolute or total porosity is the total void space in the rock whether or not it contributes to fluid flow that does not matter. But the total number total void space present in the rock is generally termed as the absolute or total porosity. But here, only those very void spaces which are filled by recoverable oil and gas is called as the effective porosity. So, this is one type of just the classification of the porosity based on the pore space connectivity.

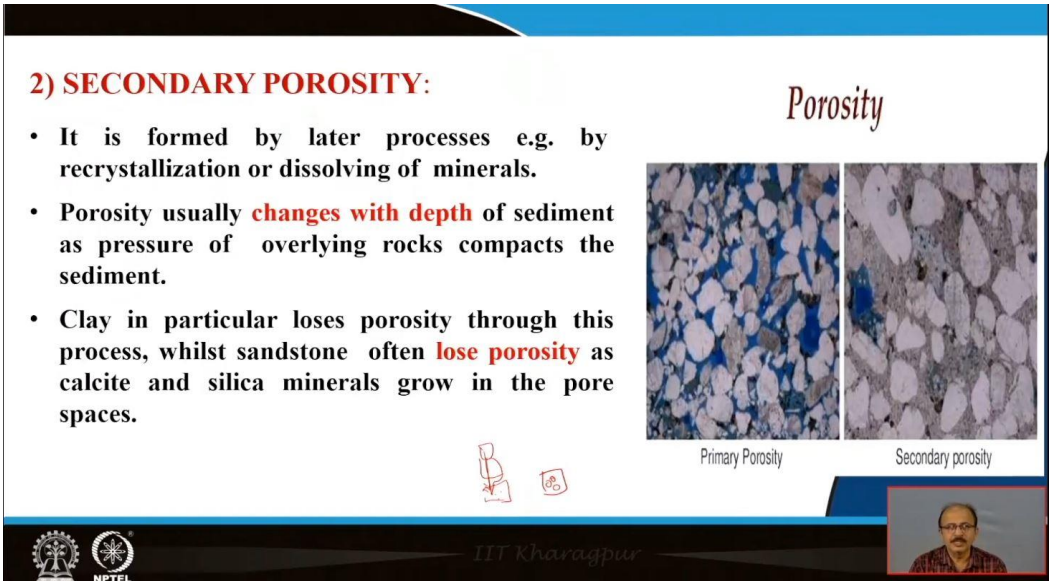
(Refer Slide Time: 12:41)



Now, primary porosity refers to the gaps between particles which forms during sedimentation, whatever the particles have developed this is called as the primary porosity. During the formation of the rocks the available gaps available space which remain present is termed as the primary porosity and it is the void space that would be present if grains had not been altered, all the grains are remaining as usual fractured or dissolved.

It means without any disturbance in any formation whatever the pores spaces. Why these spaces are there? Those porosity are termed as the primary porosity; the amount of primary porosity depends on few factors say degree of uniformity of grain size grain size will remain uniform. The shape of the grains and the method of deposition and the manner of packing in the earlier slides I have discussed this thing that fact that the porosity depends on the shape size and your manner of packing arrangement. So, this is about the primary porosity.

(Refer Slide Time: 13:52)



Now, the concept of the secondary porosity is that it is formed by latter process that is by recrystallization or dissolving of minerals some of the minerals. Say here this is the primary porosity without any disturbance the primary water porosity we are getting in these spaces. So, these are the primary porosity but in the case of secondary porosity generally it comes; changes with depth of sediment at pressure of overlying rocks compacts the sediments.

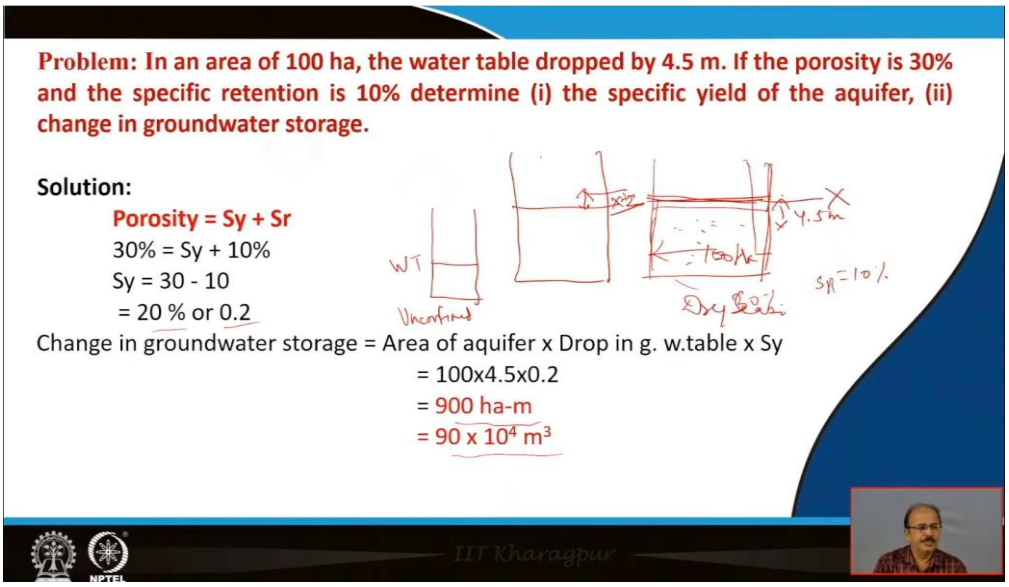
So, the overlying rocks say if one rock is here and one rock is here, so this rock will just put pressure to this rock and the porosity the original porosity which where earlier during its formation will alter, why? Because of the pressure of the overlying rocks, it will alter. Then the available after this pressure then the available pore spaces within the rock will termed as the secondary porosity.

This is termed as the secondary porosity or by dissolving say some minerals are remaining in this rock. In this rock some minerals are there which has dissolved. So, it has created some space and this that is why we are getting some void space within it, so these are the cases of the secondary porosity. Clay in particular loses porosity through it this process while sandstone often lose porosity as calcite and silica minerals grow in the pore spaces.

So, because of the growing of the calcite and silica minerals sandstone also loses porosity. So, that is why because of some processes if the original porosity is altered, just it is altering. So, definitely the porosity is the secondary porosity. So, primary porosity is the porosity which will remain as usual as when it was during the formation of your rock or we can say during the sedimentation of any rock the available space is termed as the primary porosity.

And because of some changes requisition or dissolving of minerals or some pressure, the primary porosity disturbed and then the available porosity is termed at the secondary porosity. So, this is about the secondary porosity. Now based on this concept of the primary and secondary porosity we will solve some numerical and then we will learn a bit more about the processes.

(Refer Slide Time: 16:30)



So, this is one of the problems

In an area of 100 ha, the water table dropped by 4.5 m. If the porosity is 30% and the specific retention is 10% determine (i) the specific yield of the aquifer, (ii) change in groundwater storage.

Porosity = Specific yield (Sy) + Specific Retention (Sr)

30% = Sy + 10%

Sy = 30 %- 10 %

Sy = 20 % or 0.2

So, Specific yield of the aquifer = 0.2

Change in groundwater storage = Area of aquifer x Drop in ground Water table x Sy

= 100 x 4.5 x 0.2

= 900 ha-m

= 90 x 10^4 m^3

So, this much volume of water is remaining is the change in the ground plus storage in that this very formation.

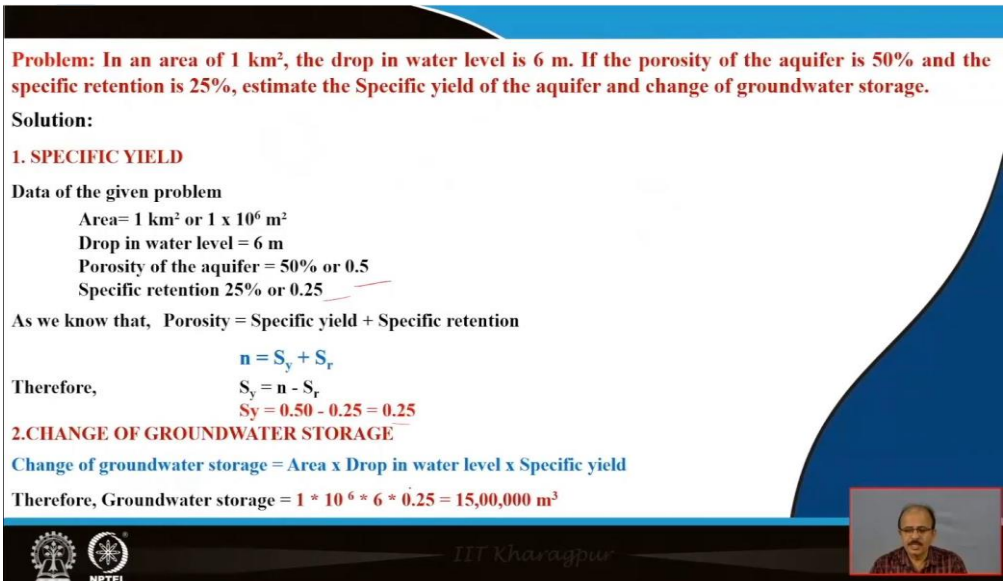
When the water table will drop by 4.5 meter it is a very important calculation very interesting also. How to find out the groundwater storage of any area? When we; are having the value of specific retention or specific yield or porosity and the change in the water table. Changing the water table fluctuation means dropping the groundwater table or changing the ground water total fluctuation means.

That during the summer season this may be the case of dry season but in dry season say summer season but in after monsoon definitely there will be the charge in the formation. So, what will happen this is say it is up to 4.5 or say it is at X, so this will just this X we are getting the fluctuation at this point say x + 2. So, this much has increased because of the recharging of the area after the monsoonal period and this gives us the change in the fluctuation in the water table in of any formation.

This is very important concept and through this we can get the idea about the water availability of any area if we are able to know we are just finding the water table of the area by monitoring with some instrument the depth of the water table in any in the surrounding wells then during the pre-monsoon season means summer season. And then after monsoon again we are monitoring the same well the depth of the water table.

And if you will just see the difference, you can able to find out the change in the groundwater table or you can able to find out the water table fluctuation of those well which you have monitored for in the area. So, this is a very important and interesting calculation related with the availability of groundwater resources.

(Refer Slide Time: 22:41)



Next it is also, In an area of 1 km², the drop in water level is 6 m. If the porosity of the aquifer is 50% and the specific retention is 25%, estimate the Specific yield of the aquifer and change of groundwater storage.

Data of the given problem

Area= 1 km² or 1 x 10^6 m²

Drop in water level = 6 m

Porosity of the aquifer = 50% or 0.5

Specific retention 25% or 0.25

As we know that, Porosity = Specific yield + Specific retention

n = Sy + Sr

Therefore, Sy = n - Sr

Sy = 0.50 - 0.25 = 0.25

2.CHANGE OF GROUNDWATER STORAGE

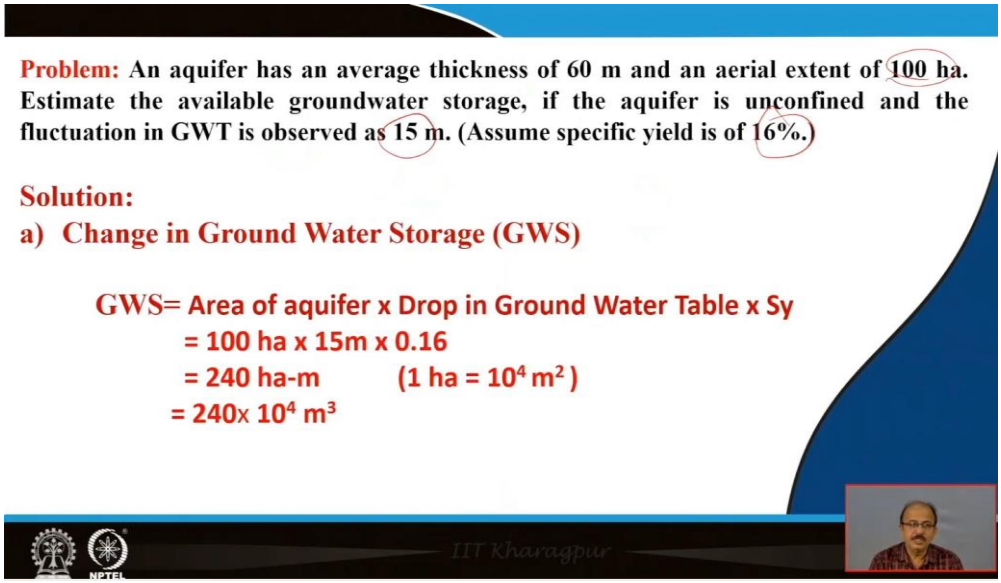
Change of groundwater storage = Area x Drop in water level x Specific yield

Therefore,

Groundwater storage = 1 * 10^6 * 6 * 0.25 = 15,00,000 m^3

So, this much we are getting as ground water storage. So, usually what is happening in the storage area it will change of the groundwater storage will fluctuate or will vary with the drop in water level and the specific yield of the formation. So, whenever we are computing such type of problem, we should remain alert to know about the actual stage of the fluctuation of the water table in those very formations.

(Refer Slide Time: 25:35)



Now, next problem is that An aquifer has an average thickness of 60 m and an aerial extent of 100 ha. Estimate the available groundwater storage, if the aquifer is unconfined and the fluctuation in GWT is observed as 15 m. (Assume specific yield is of 16%.)

So, huge fluctuation is here 15 meter fluctuation is too much, so assume is specifically of 16 percent. So, now groundwater storage we know is the area of aquifer into dropping ground table into Sy, so 100 hectare area is there;

Change in groundwater storage = Area of aquifer x Drop in ground water table x Sy

= 100 ha x 15m x 0.16

= 240 ha-m

So, here 60 meter thickness is given but we have not to take this much because we have only the area we have to take, this area we have to take then the fluctuation we have to take this much fluctuation and the yield.

With this we can compute this GWS of any groundwater any water storage formation inside the earth's surface. So, these two concepts are very, very important for finding the details about the specific yield and the ground change in the ground storage of any formations which are holding the groundwater inside the earth's surface. Thank you very much.