Rural Water Resources Management
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Week 05 – Lecture 02
Specific Yield

Hello everyone, welcome to Rural Water Resource Management NPTEL course, this is week 5, lecture 2. Last week we have been in looking at groundwater hydrology and groundwater components the stress is more on groundwater in this week's because we understand that for rural water resources, groundwater is a key resource and it is very important especially now, to conserve it. So, let us go into the lecture for this theory.

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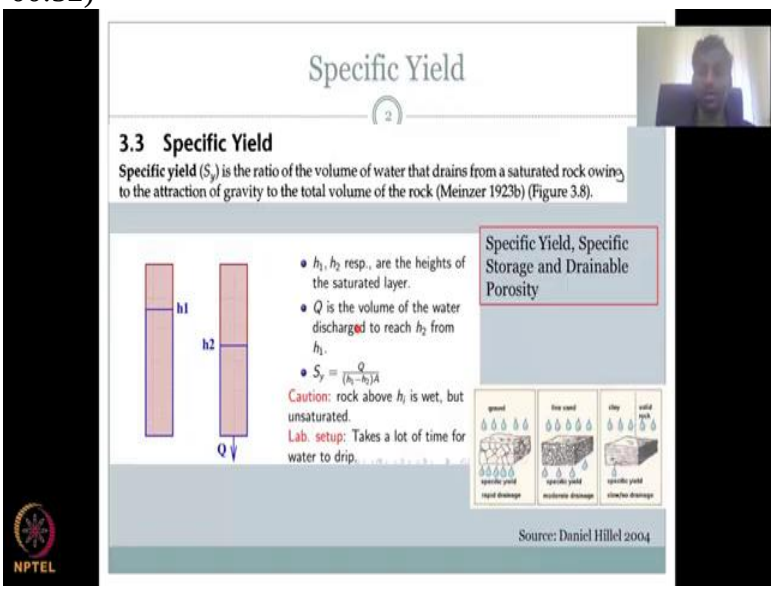

In the first lecture, we looked at porosity, we define the special and polar variations how it can be estimated, in today's lecture, we will look at specific yield. Let us defined as a ratio or the volume that from a saturated rock due gravity total volume of the rock. So, it is visualize to see how we can understand it better. So, we have material or soil material where we want to understand the groundwater hydrology which is in beginning. And h1 is the initial water saturated layer or the water layer and after some time the water table falls down to h2 and that is because of gravity.

So, you have a saturated layer and after gravity so, gravity is working on the layer, so, the water level will drop down. Q is the volume of water which has been discharged because of the gravity to reach to h2 the new level or the new stable level. So, specific yield in this final scheme, the

volume or the water that has been drained due to gravity by the volume of the rock, which is h1 minus h2 by the cross section, you have to understand that all the rock was wet but unsaturated above the water table.

And this takes a long time because gravity acts very slow and it has to overcome the sediment or the attraction of the rock material on water. The different names given specific yield, storage and drainable porosity all are the same and were labeled differently. And it depends on how they would like to term it like specific storage is the remaining water that is in the soil profile and drainable porosity which is drainable because of gravity is given a specific yield is the same and different names given.

Let us look at specific yield in gravel, gravel is big stones with less sediment in it and the porosity spaces also large. So, if you have large volume of water coming the volume of water discharged because of gravity is also fine sand would have a moderate drainage moderate specific yield because some water would be stored in the spaces because of the interactions between the sediment. Whereas clay have very high potential to hold on to water.

And given the same water applied to all, gravel, fine sand and clay or solid rock the specific yield is very very low. Because of the slow or no breakage, in some regions, the clay layer is termed to be an impervious layer which means it stops the water from going through it. So, it is kind of an impervious layer because water gets absorbed in the clay and it actually prevents it from moving further down, which is where gravity acts and pulls down the water. So, specific yield is a very important term to understand the nature of your aquifer to discharge water readily. If it is very slow then the groundwater potential is also very less.

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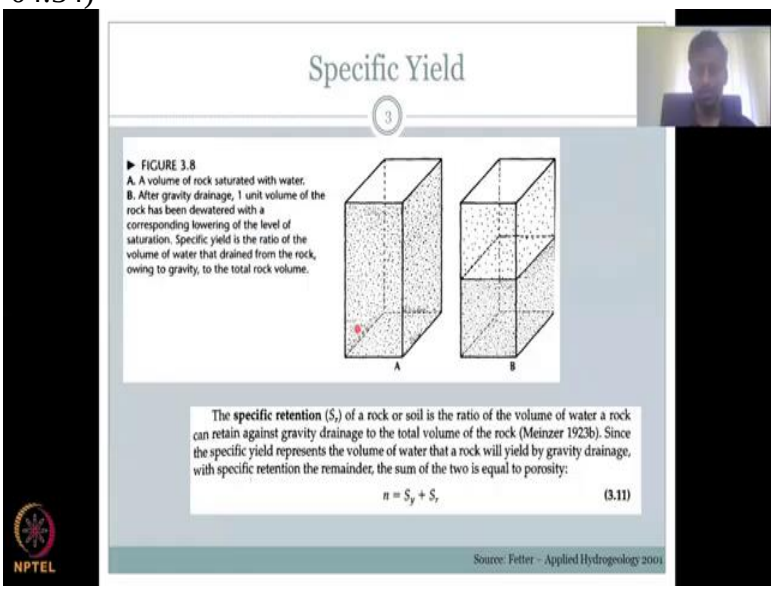

Let us look at another figure, where A is your volume of rock saturated with water so full of water is now gravity is acting on it so you have watered the field you have a saturated layer and now gravity is pulling water up, after gravity drainage 1-unit volume of rock has been dewatered corresponding level of the saturated. So, you have lowered the level of the saturation by taking out 1 unit of water due to gravity specific yield is the ratio of the volume of water that drains from the rock owing to gravity to the total rock body.

So, now a Q is the unit that has come out due to gravity and that divided by the total rock volume gives you the specific yield, another important parameters specific retention or Sr of rock or soil and it is defined as the ratio of volume of water rock and retain against gravity. So, this is kind of opposite to yours specific yield. So, how much water can be retained against gravity specific yield is with gravity, how much volume can come out that is the ratio in take owing total volume.

Whereas here it is the water that is retained in the rock to the total volume of the rock, since the specific yield represents the volume of the water that a rock will yield by gravity drainage with specific retention the remainder the sum of the total is equal to porosity, which is n is equal to Sy plus Sr. So, let us think about it n is your volume of void by the total volume of the solid. So, we have BV by VT whereas Sy is your volume of water that has been dewatered that has been come out of the system by your total volume of the solid and whereas the specific retention is the water remaining in the profile by the total volume of the rock.

So, it is actually the sum. So, if you sum both Sy and Sr 0 porosity because it is a totally saturated system and which means there is no air only all the volume of the voice absolute water and in specific yield some water is released due to gravity and in specific retention the remaining water is held down. So, the total water is now combined together as porosity.

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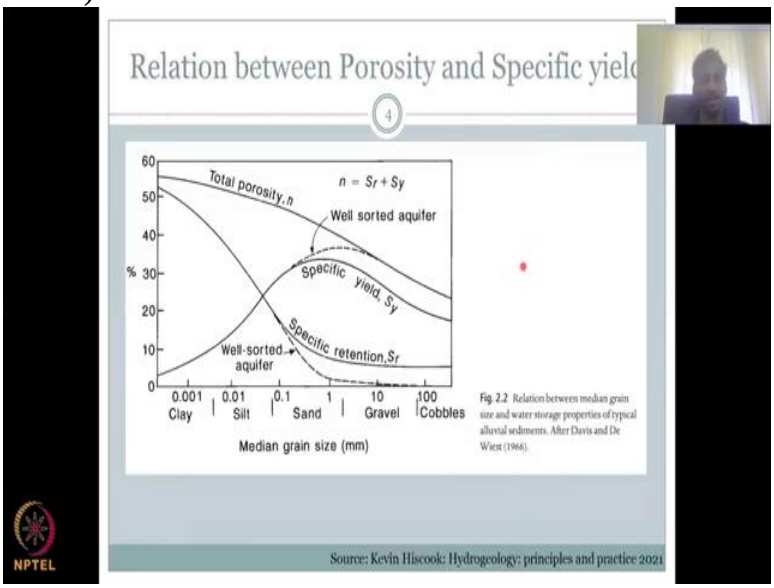

Let us look at a graph to better understand the relation between porosity specific yield and specific retention. So, you have total porosity as n which is the summation of specific yield and specific retention n is equals to Sr plus Sy and we have the grain size of your soil profile rock profile here clay, silt, sand, gravel, cobbles percentage on this order for porosity or specific yield or specific retention.

So, what do you see here is in a well sorted aquifer. Which means it is sorted almost same size, there is high porosity in clay, silt, but when it comes to sand which is very small it comes down. So, you have lesser and lesser porosity or percentage when it comes down specific tension. The total porosity is almost 60 percent to 30 percent so, it is also coming down, but your specific retention comes down very fast in gravels and cobbles because the gravels and cobbles cannot retain that much water it may have high porosity, but all the water would fall down due to gravity.

And that we saw in the earlier slide we discussed about specific yield. So, in clay the specific yield is very less not a lot of water comes out in silt as the size of the grain increases you have more water easily available for gravity and it is well sorted aquifer you have a very high amount

of specific yield but normally well sorted aquifers are not available. So, you have a specific yield tapering off in sand, gravel and cobbles.

So, the worst is the clay the specific yield gravity cannot pull down water whereas gravels and cobbles it is easier to pull down whereas sand it is much more easier. So, when you play in the beach, you see bigger sand castle or you can see water coming on the shore over sand and after the wave goes back, you could see that the water just flushes down so it quickly comes down because of gravity.

And that is why because the specific yield is very high in sands. So, how much water was retained? It is the opposite. So, specific retention if we look at in clay it is very high, whatever water the clay has, it will not let it go it will hold on to it tight and long. And it is the same procedure for plant available water also. So, does not mean that clay soils are good for plants no, because if gravity cannot pull, the same pull might be exerted by the plants only some plants with higher cooling capacity can grow in clay soils.

The good part is clay can fight gravity for you and keep the water up. But the force to take the water should also be high for plants. So, only some plants can grow like for example, cotton goes well in clay soils. So, the specific retention is very high, and then it slowly comes down, slowly comes down as your size increases. So, clay cells will have a higher retention. But when it comes to sand, the water just flushes through gravel, it does not stay cobbles, it does not stay.

The specific yield is very high in these higher grain size materials. And that is why your specific retention is also very small it is the opposite. So, in a well sorted aquifer, when it is fully sorted, it just goes to 0, the specific retention goes to 0 which means all the water is drained. So, this graph clearly explains the relationship between your specific yield, your specific retention and the total porosity. We have also discussed the specifics of when these specific yields can be high and specific retention can be high.

Think about a cricket pitch or golf course, you do not want water to stay there when there is a rain, you do not want water to stay there. So, what materials will they use, they would use a material with high specific yield, for example, you have sand, gravel and cobbles under the course under the golf course or under the pitch so that when water falls quickly it goes down and then throw the gravity you can extract the water out.

So, only on the grass surface there are some water which they use some techniques to remove it. But in a rural setting, it is the opposite. You do not want water to flush down totally due to gravity you want water to stay as long as possible, so that your plants can survive. So, in that perspective, your retention is high in silt, which is your combination of sand silt and clay and good soil is good for plant growth.

This is the fine size sand, but clay is much much finer, so much much attraction on the water particles and sand again as you move up in grain size you will lose more water to gravity. So, specific yield the Sy the retention is very, very low. So, somewhere you need to balance it up. If you want good groundwater potential, you would go to gravels and cobbles think about where you would use it in a rainwater harvesting structure for example.

Most of us have rain water harvesting structures what would they do they would have gravels cobbles sand so that water can flush fast into the ground and sand and silt can act as a filtering material and then it goes to the groundwater aquifers. So, it is very important to have such a strata to capture the water and also quick specific yield so that water drains so that more water can be put in.

If you have a clay soil, then you cannot have a rainwater harvesting you will have to put in gravels and cobbles to put push water faster into the groundwater aquifer. So, these are how you can visualize the porosity concept in your rural water management, urban water management and especially for groundwater management.

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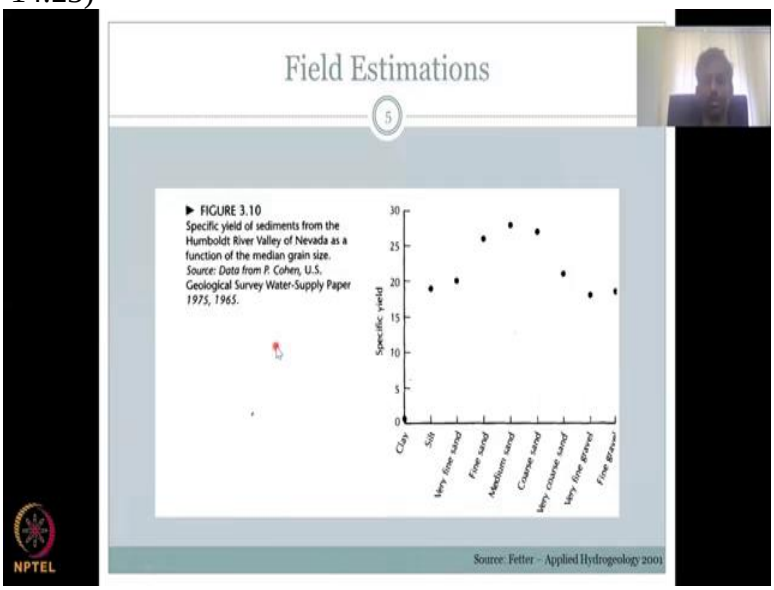

Moving on, let us look at a particular field sites sample specific yield of sediments taken from the Humboldt River Valley of Nevada from the book as a function of the median grain size. So, what we could see here is the specific yield is very very low for Clay. And it starts to increase as the size of the grain increases. So, it starts with silt verifying sand and then medium sand coarse sand almost the same and then it comes down very coarse sand very fine gravel, gravel plus specific yield comes down.

So, the best to drain the water would be sandy material sandy soils. But then if you have gravel in between, then you can arrest the water, but the worst is clay. So, clay is almost at 0. So, please understand that specific yield is differs at a different region. And that is why they there is always a range. And most importantly, specific yield is acted upon gravity. The other thing that can also induced specific yield is when you have a cone of depression.

So, we have talked about cone of depression in our groundwater class, when you pump too much then you artificially induce water to go through your pump. And that can also push water because specific yield, they can also push water to bring down the level of the water table. So that is how we estimate specific yield we have a water table and the water table comes down and how much water is dewater to take it out and put a ratio to the volume of the rock or the material.

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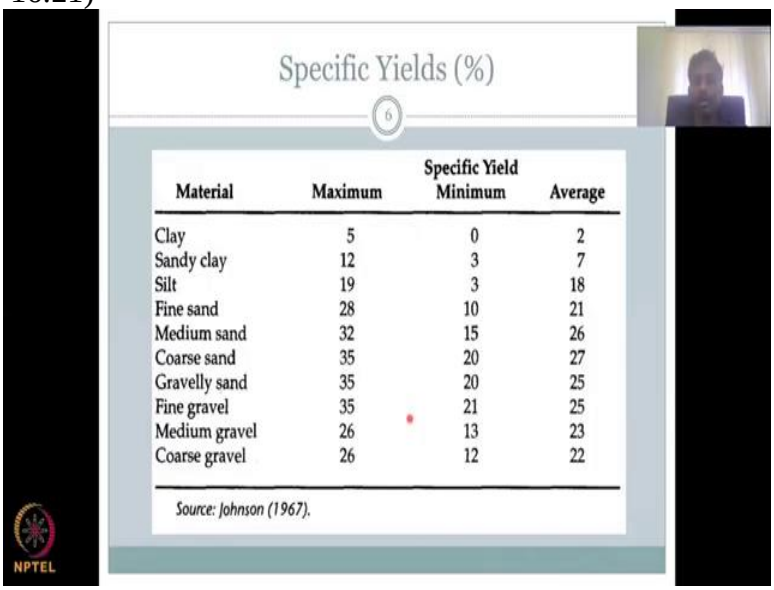

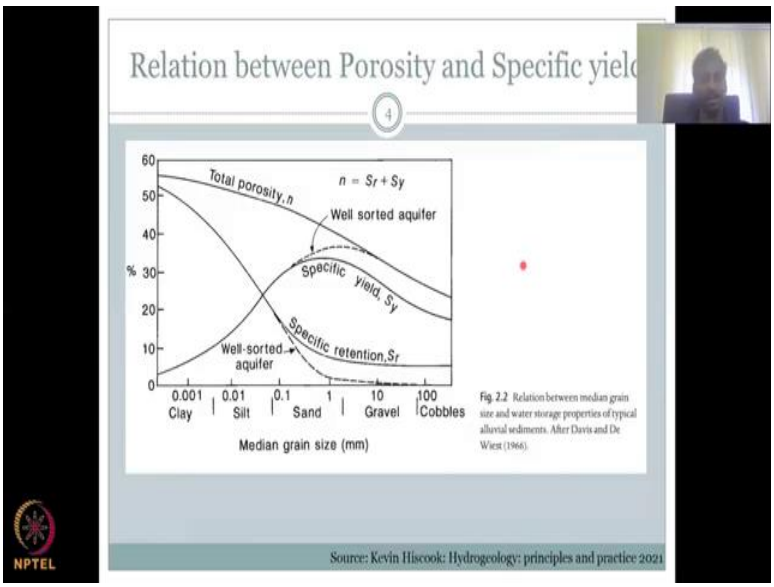

Moving on let us look at some regions it is always a range it is not one value. So, I am using multiple sources you could see I will use freeze and cherry book which is mostly trusted for these values. I have also used some case studies and other books from India also to look at the variations and the values. So, specific yield clay could have a maximum of 5, minimum 0 and an average of 2.

So, most probably as I said we will take the maximum and then take an average to get at where it stands. And most probably it will be on the higher end. But sometimes you will just strike it in between. So, coming back the average is normally used in a lot of literature and clay has a good

range from 0 to 5 sandy clay 12 to 3 the range you could see it expanding silt can have 19 to 3 fine sand 28 to 10 medium sand 32 to 15 and so on I would not be reading all these values.

But for coarse gravel it is 26 to 12. So, what do you understand is there is some difference some range is created, why is there a range let us pause for a second and think why such materials will have a range and not one at a time. Because the climate and the use of the land is not the same across let us visualize you have a clay feet, I might have a tractor so I have tilled the land it is clay but I have tilled the land, I have done a lot of work to stabilize the soil on the sides and also I have put in plants where it can infiltrate deeper into the clay pick specific plants.

So, what happens is through the pathways through these pathways, the porosity has increased and specific yield is a function of porosity. So, you can have clay, but you can do things to increase the porosity you can do management to increase the specific yield. So, water can go and so, if you have more pore spaces water can go and yes clay holds on to the water, but if there is excess porosity or excess pore space water gets stored and flushes out due to gravity.

Remember, since it is very small the size of the grain is very small and going back to this slide the size here you have it very small, which means it has more surface area to attract water. There are many many clay particles the volume is the same if you take 1 kilogram of clays silts and gravel the volume is the same or the area or the mass is the same but the surface area of connection, the water is much much bigger in clay silt and sand.

Because the size is small so you have a circumference and you have a more surface area in connection with the water. So, now how do you overcome it by increasing the porosity? So, by increasing the porosity, what you do is you create more void space for the water or air to come in and right now we are talking about specific yield. So, we have to saturate the soil by putting applying full water and water can be easily drained compared to a non-irrigated land or a non-agricultural managed land.

So, tilling is one thing that can introduce porosity into your soil and materials and you have a mixing of various aspects in clay when you tell. So, that is one thing that we can do now, but the more natural thing is to let the vegetation take care of porosity. So, if you have a good tree cover, if you have good vegetation, native vegetation with deep roots that can go in and break the soil structure, then you have more porosity.

So, porosity is an aspect that can be changed. Suppose I have clay, I put on one side, I put crops so you have root zones developing and more porosity. On the other side, I have clay and I am putting a road on top of it. How do you put a road you put gravels etc. But then you put a tar and then you have a road roller which goes on, which means you are compacting the surface. So, when you compact, we have already clay with very less pore spaces, when you compact, it gets more pushed.

The weight of the soil material or clay material does not change the weight is same, but the volume has changed, you have pushed it down. Same thing you can take an experiment at home, you can take a beaker, you can take a soil, break it down and then shake it and put it in a container you will see the volume is high. Now, take half of the volume of that container and put it in another equal container you have equal volumes in the other one you can push it just by some force, you can push it and you can see that the soil material will come down.

This is the same thing which will happen in our field. If you compact it too much it could be compaction by tractors, it could be compaction by people walking on it or even grazing of animals then you compact the soil which means your porosity is reduced. So, no more water can go in and your drainable porosity, your specific yield all of these components come down. So, land management is related to these key parameters of porosity, specific yield, specific retention as much as your water availability.

So, when we say rural water management issues, it is not just that I am not getting water from rain fall climate change is happening monsoons are shifting, but I am having a flood or drought. It also includes how you manage your land, how well are you managing are you having the correct species of plants and trees to increase the porosity to increase the water retention in your soil. And if you overdo it by non-native species, what happens all the water is taken out and then your clay cracks.

So, clay is a very very tough soil system to work with compared to the other things. So, a low is a combination of sand, silt and clay we will not get into soil structures a lot because this course will be on water, water management with some more specifics of the ground water. So, always there is a range understand there is a range because of hydroclimatic changes because of the size of the clay also clay does not have one size it is a ranged.

So, depending on what clay size you have, you have a specific yield, but most important depending on how the land is used, you have a difference in specific yield. So, this understanding would help us better understand the ranges and also better understand how we can conserve our water. Thank you. We will see in the next class.