Rural Water Resources Management
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Week 05-Lecture 01
Groundwater Hydrology Components

Hello, everyone welcome to NPTEL Rural Water Resource Management course. We are today on week 5, lecture 1. In the previous lectures the past 2 weeks, we looked at groundwater hydrology. And this will be the last lecture series on groundwater, the most specifics about the parameters and how they are helping to understand the groundwater hydrology.

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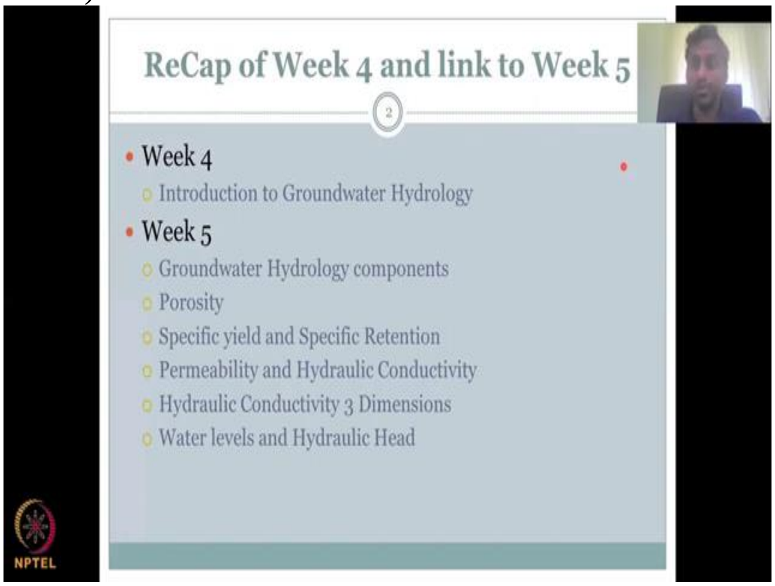

Let us look at the recap of week 4. And then how it is linked to week 5, which is the current week. In the week 4, we introduced the ground water hydrology components. And then we looked at which bodies are monitoring and measuring the groundwater, what are the issues and concerns we looked at. We looked at the data and what are the different methods to collect data.

In week 5, we would look into the specific groundwater hydrology components like porosity, specific yield and specific retention, permeability and hydraulic conductivity. And we will also look at the three dimensions of hydraulic conductivity. Then, what is the hydraulic head, potential metric surface etc.

If you remember in the groundwater hydrology class, we looked at a cross section, a groundwater hydrology cross section. And we showed how different wells are connected to each other by a potential metric surface. So, how that is determined, all those things will be taught in this week.

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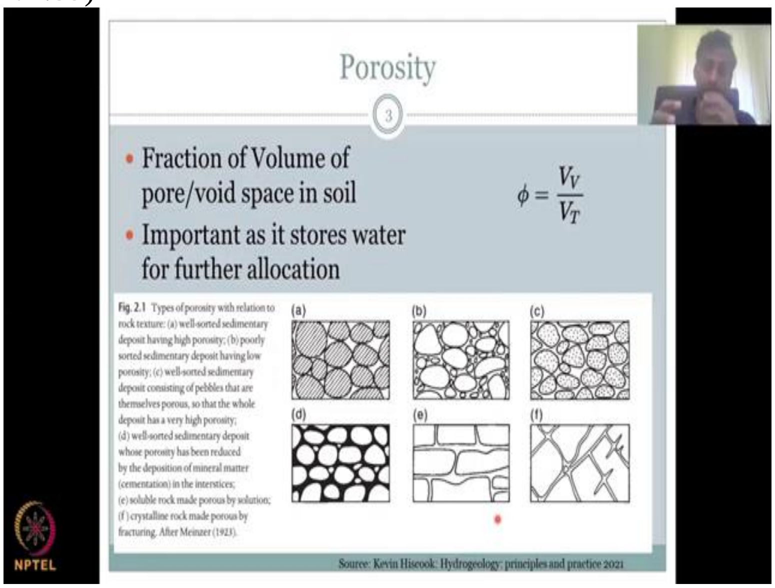

So, let us move on, the first topic for today would be porosity. So, what is porosity? It is the fraction of volume of core void space in soil. So, if you have a soil and you have solid materials in the soil, it is not fully with solid materials. So, for example, you are taking a sample using a cup or a container and if you take it out, if you put soil and take it out or dig and take a soil sample out, it is not fully soil.

Because there is a little bit of space for air and water. And that is initially a void space which is an empty space, when water or air occupies it becomes filled with fluid. So, fraction of the volume of pour to the void space in soil is given as porosity. So, teta here the porosity is given as volume of the voids or the empty spaces by the volume of the total solids, which is a total soil.

So, you take a container that is the total volume and out of this how much is the volume of the voids. So, types of porosity as you could see, the first one is a well sorted sedimentary deposit having high porosity, it is well sorted means it is with size it is of a similar size and a sedimentary deposit it has round shape, which means it has been transported for a long distance. So, it has been weathered properly and so, all the edges are almost, are gone. So, it is all smooth spheres.

So, that is a well sorted and it is not irregularly arranged, it is touching each other which means it is sorted. And there is a high porosity because of the size and the sortment, you have good spaces here for air or water to occupy. Then you have a poorly sorted sedimentary deposit having low porosity. So, what is a poorly sorted? It is the same thing, same almost the same solids, but you have these smaller solids, the size is not the same.

They are almost similar size, but here you have a mixture of big small and very tiny particles. So, what happens is the tiny particles can occupy the void space and that is why the porosity is decreased. So, here the porosity is decreased. Then you come to c, well sorted sedimentary deposit consisting of pebbles that are themselves porous. So, the whole deposit has very high porosity.

So, in this material, you have well sorted same as well sorted into sedimentary but consisting of pebbles. So, a type of the rock. So, sedimentary is the process in which the rock or the material is being deposited, so sediments should be… that is what sedimentary means. And but there is a nature of the solid also so, that nature here in c has holes in it. So, if you take a sample and you can see within the solid you can have void space, you can have pore space.

But on the sample itself, so, here like here you do not have space, but here you have folds. So, like the sponge I gave an example in the previous class. So, here water can go in, air can go in and get stored. This helps in also attracting more water and that is why it has a very high porosity. So, along with the spaces, almost similar spaces in between the sediments, but in the sediments also you have space.

So, all of this together is being used. Then you have well sorted sedimentary deposit whose porosity has been reduced by the deposition of mineral matter, cementation interstices. So, here you do have a similar as a. So, here all we are trying to say is from a to b is of same, similar sedimentary deposition. So, deposition is the same which is through water or something it is getting deposited, but how the pore spaces and the void spaces are filled is different.

So, here you have organic matter or mineral matter, cementation etc happening within the pores. So, it actually drives away the air and water and has very, very less porosity. So, you could see how gradually we are changing in the void space between the solids. E is soluble rock made for porous by solution. So, this is typical rock structure in limestone. So, if you go to caves and stuff, you see water can cut through rock and then flow.

So, that is a soluble rock, limestone is soluble rock where water by going by passing through it can cut a way, a path and then go through. So, that can be a soluble rock interface. And while it is soluble, please understand that the minerals are also transported and this is where the salt content comes in. Salt as not in salty as the food, but the properties of the rock. So, while it is being dissolved, it is soluble. So, it takes the salt from the rock and then goes along.

So, the porous solution is there, which is the water in the pores. And that interacts with the rock, it dissolves it and then takes it along. So, we have a good flow path. So, if you could see it just flows across laterally etc, all are connected well. So, it is having a high porosity, that is why you see a river underneath a cave. So, that is kind of a groundwater which goes in and comes out cutting down cutting through the rocks etc etc.

So, it is called dissolving of the rocks. Then you have crystallin rock made porous by fracturing. So, there are some rocks that have fractures in there. And because of the fractures, the water can come in. The two ways, also the water goes in and creates a fracture. Because water expands in the cold weather or when the water temperature drops down, it expands like if you put water in a cup and put it in the freezer it expands and the size increases.

So, that is why people say do not put a cold drink in the freezer, because the bottle will burst. So, it is that same property that water when it goes into the cracks of the rock, let us say it goes in the morning where the temperature is not as cold but, in the night times the pole temperature can kick in. And in groundwater also we have temperature changes. So, if the water cools down slowly and then it expands.

So, when it expands it causes a fractures. And that fractures again, will lead to more water being stored and movement of water. So, now we have seen that how porosity could change within a sediment by the nature of how it is sorted and by the nature of how the particle, the sediment particle is available, and also by the process of flowing water. So, water can flow through and cut through the rocks. And water can go in and cause fracturing.

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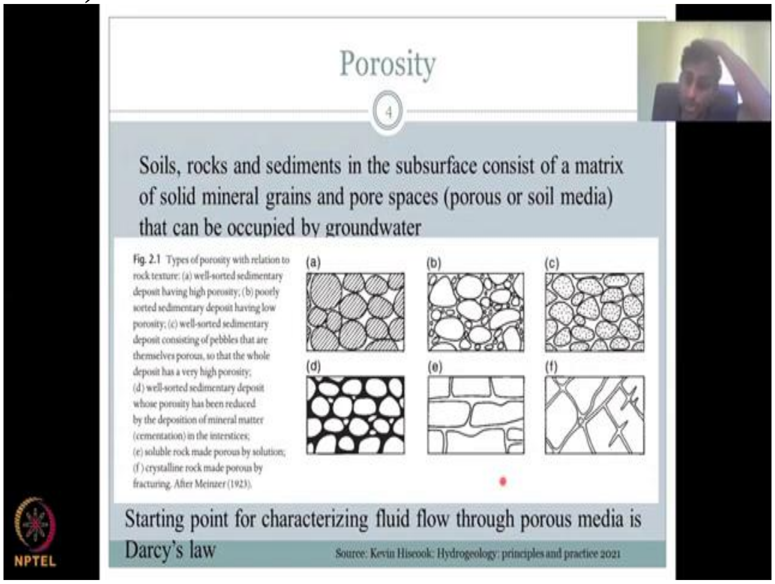

Soils, rocks and sediments in the subsurface consists of matrix of solid mineral grains and pore spaces that can be occupied with groundwater. So, this is the part where you have inside void spaces and in the void spaces are filled with air, slowly water can infiltrate and push the air out. So, that is where you have water being converted into non water, so infiltrated water. So, this is the starting point as we mentioned in the previous classes also. For fluid flow, fluid is a mixture of two phases through porous media as per Darcy's law. And in this week, we will also look at what is the Darcy's law, why is it used effectively.

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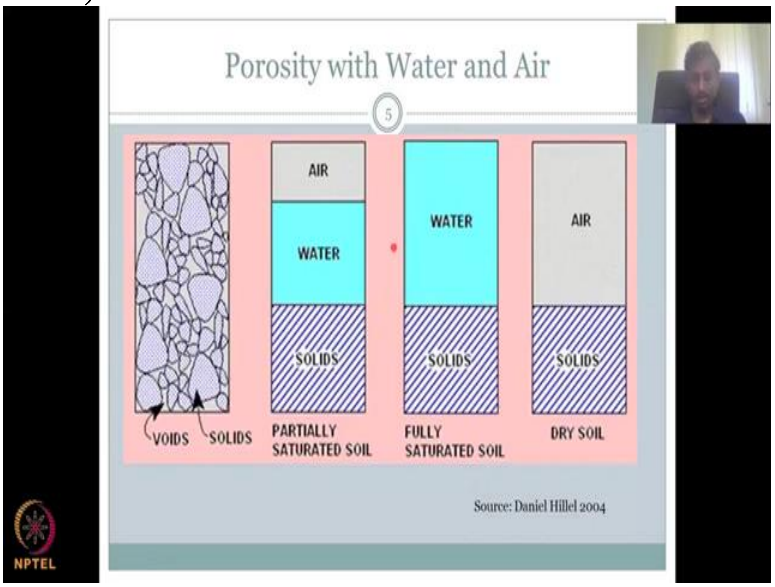

So, the natural porosity of your soil material or your rock material can be looking like this. You have voids, where you have air or water or just empty space is called void. And you have your solids. In a partially saturated soil you could have air, part of the void can be filled with air but most of it water and solids. So, I am just taking a sample, this sample where solids are the same. And this is your void space.

In the void space, the partially saturated will have some air and water. Fully saturated soil will have all the pore spaces with water. And then you have a dry soil where air is full. So, if you asked me, are there not any water in the solids? Yes, there are, so same here, are there not any air small tiny fractions in the soil. Yes, but those are negligible. It is not like it will contribute to, groundwater, this part or even here, the air is enough to push water?

No, it is a very small part which as I said earlier, it cannot be taken out. So, there are some amount of water or air in the soil, which can never be taken out. So, even by plants, it just remains there because of the property of the soil. So, that is why if you want to get accurate estimates, you have to take the sample, crush it and then put it in an oven overnight or even for a day at 100 degrees. Think about cooking or baking the soil for 100 degrees for at least one day.

So, that is how much energy and time you need to spend to drive out the air into vapor. So, then only at that point the soil will give off the air and water. So, it is very important to understand that that is the extreme cases and it does not contribute to onward much, only these two phases contribute which is you have a void space. And part of it has air, part of it has water which is saturated partially, if it is a fully saturated soil all the spaces with water.

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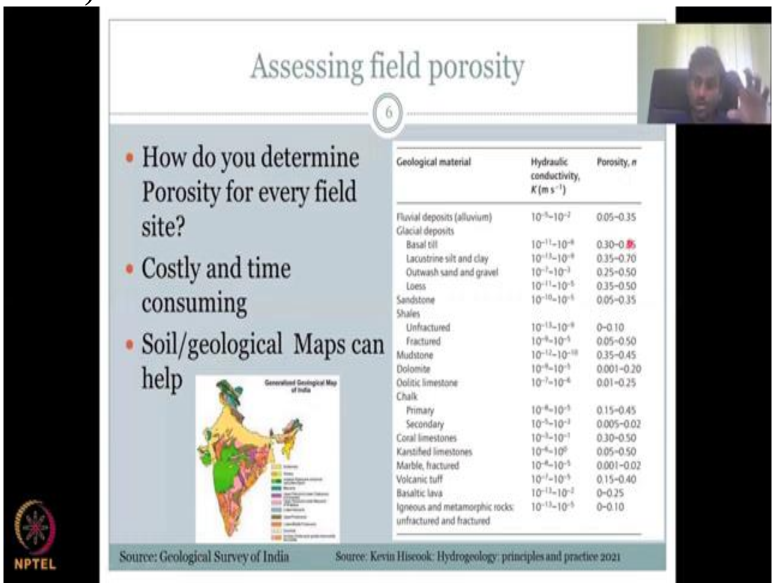

Assessing field porosity, how do you determine porosity for every field site? Is it possible to determine at every field? For example, you have a village and 30 feet or 40 acres that you may need to go in conduct a water source assessment for which porosity is important to understand the groundwater, is it possible to go to every location and take a sample? No, it is costly and time consuming.

So, but you know that by the process of understanding the solid material etc, you can back calculate the porosity. It is not an assumption, someone else has done it for you through a lot of time in the lab and literature based, so we can use that. So, soil geological maps start with understanding geology of a location. Let us take the village ideal for example, 20, 30 acres.

If I know the geology, the first base the background is the geology then the soil. So, if I know the geological map, I can estimate what type of soil would have been formed. Because your soil formation is nothing but your geology which has been weather. So, you have the weather, unweathered geology on top of it you have a soil. And this geology maps are available, same way based on this there are soil maps in India.

Then, using the literature, which I am giving now, you would estimate what is the range of porosity. Let us have a look. So, the fluvial deposits or alluvium, where we saw earlier along the Ganges belt, along Kaveri, Brahmaputra, Krishna basins, you do have a high porosity 0.05, 2.35. Please look at the range. It could be anywhere from 0.05, 2.35. So, 0.05 is because some of the intermediate voids can have fine fine sediments that can go in which we saw earlier in the class like the last slide.

You can have a sediment deposited, but if it is also having a non-well sorted sediment, you can have small particles inside. And that happens in the Ganges etc because it, sedimentation is occurring almost every day. Every day you have sediments flowing depositing, flowing depositing. So, by that process what happens is the fine particles can go inside and deposit. So, then you have glacial deposits on the Himalayas which have very very high porosity.

Because it is big boulders, big rocks and it is pretty well sorted. So, it is sorted like this and inside you have big void space. And then we have sandstone, shale, mud stone dolomite etc. So, here comes the almost smaller smaller ones which are found mostly in your central India. Then you have example fracture 0.01 to 0.02, the fracture hard rock aquifers we saw last week in class that most of India has hard rock, semi hard rock in console consolidated aquifers.

All these would have a very very low porosity, volcanic tuff, basaltic lava all these. So, most of the rock materials are metamorphic, unfractured and fractured. Unfractured means it is not weathered that properly, fractured means water has gone in and broken. So, all those things can happen. So, this is very common in India. Secondary chalk is common, shales are very common and then your fluvial deposits and glacial deposits.

So, I know now from the geology, I can estimate the porosity. And then if it is a well weathered soil, then we can look at the soil map. So, as I said the geology maps are available, you can go to Geological Survey of India, you can download these maps. And then based on this given geology type, you can come back to this slide or the book and then take the values for your thing. But it is a range. So, how do you understand where it ranges?

It is depending on your field research, you can take some samples and then say okay, the porosity is this much. But ballpark you can get. Normally what people do is if you have two extremes, they take the average, or a midpoint in it. So, the range is big, but you can take a midpoint. And if you know as I said, if it is a young fluvial deposit, then you can take 0.05. If it is a well structured, well sorted fluvial deposits, you can take 0.35. So, use the previous slide where we looked at the sorting of the rock material, the sediments and then come back here to see where the range can fit in.

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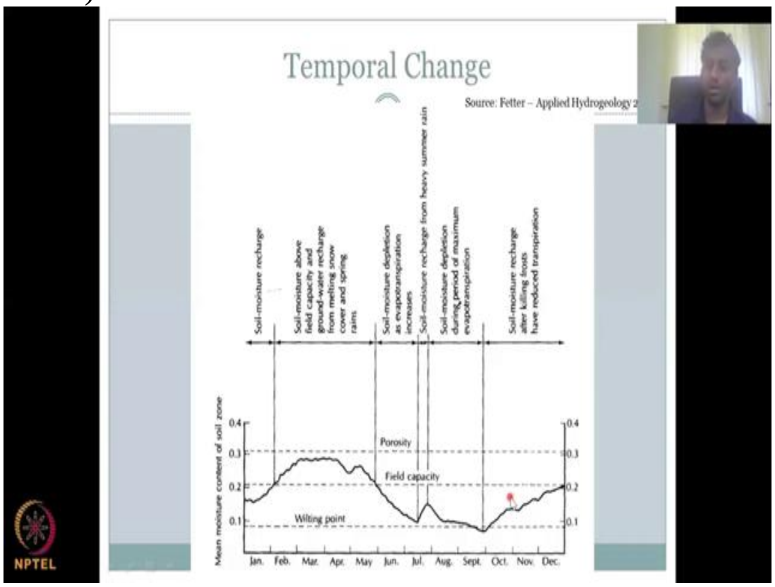

So, here is your time on the X axis and mean moisture content of soil on the Y axis. So, it is a temporal change in mean moisture content of soil. So, your soil content is not going to be constant throughout the year. It is because your porosity is constant. So, you have good porosity. But water can go in or go out depending on the use. So, if precipitation water can go in if you pump water can come out or freeze evapotranspiration can actually dry the water out.

So, soil moisture recharge, let us start with rainfall season. So, you have your soil moisture recharge, so, the soil moisture is filling up, let us first take a step back and look at the three capacities there in the soil moisture. If it is below a particular point I told earlier the plant cannot take the water out, it is too hard for the plant to take the water out it will die. So, that is a wilting point. So, that is very very less soil moisture.

Then you have field capacity, which is the best condition for the plant to take water because it is well saturated and it is easy for the plant to take. It is not full, full and dripping because it cannot suffocate the roots. So, that is field capacity. On top of that is the maximum porosity. So, this is a maximum water that can be stored because that is the maximum porosity. In between that we have the field capacity.

Field capacity is after the saturated water has come down after gravity has taken up the water stays in the soil because of the soil's properties and that is the easiest water for the plant to take out. So, what happens is when the soil recharge from down the soil gets recharged, so your moisture is coming up. It is in the best capacity of the field capacity, so the plants can grow well during this part, this part of the months.

And then you have soil moisture about field capacity and groundwater recharge from melting snow cover and spring, rains etc. This is spring season when your, after your monsoon after the winter, snowman is already there it starts to melt. And then you have a peak summer in this part. So, what happens is your water comes down from the pore space because plants have already taken it up.

And your water is being depleted by evaporation. So, soil moisture depletion as evapotranspiration increases. The plants have taken up and the evaporation has driven the water out. So, it comes down what happens is it comes down below the feet capacity. Now, the plant is suffering, it needs water, you need to irrigate it. So, soil moisture recharged from heavy summer rain. So, suddenly the small peak, small peak because you do have summer rains.

In summer one or two days, you get good rain and so suddenly there is a good peak and then comes back down. Then your soil moisture depletion during a period of maximum evapotranspiration. So, this is again another big summer driven event. So, a big drought or a big hot weather can take more water out and it goes down your wilting point. Once it hits wilting point, you need to give water.

If you do not give water, the plant fades. So, that is what irrigation is. So, here is the peak irrigation time, here is your rainfall and snow melt occurs, you are in a happy situation for plant life water management in the village. But then when field capacity is there and goes below you need to be cautious and then some intermittent rainfall can happen. But then after this summer you have your monsoon.

So, your monsoon picks up September October November. So, soil moisture recharge after killing frost have reduced transpiration. So, this is a example from the US, but it can be applied to anywhere it is the same thing. If you do not have a frost, you have a rainfall season. So, you have a good rainfall then recharge then a good summer which actually drives all the water out then comes out.

So, this would be your period of irrigation, this is what you need to plan if you want to draw, drive crops up. So, if it is a good farmer who says no I am okay only with this crop which is the current crop and little bit of subsistence farming, like farming for vegetables, fruits for the house, that is fine. You do not have to have good water resources for irrigation. But if you are going to put rice and paddy here and then another big hungry crop, cotton and sugarcane then you need to actually put in a irrigation structure.

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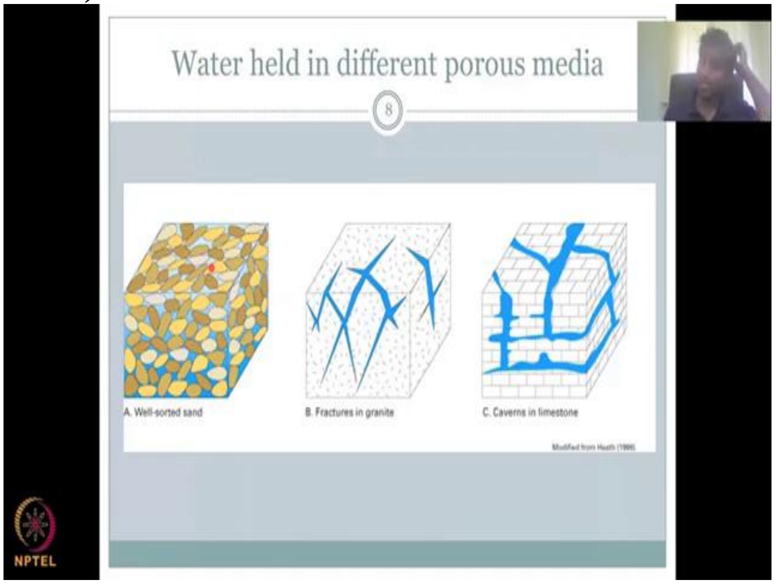

Some more let us move on to look at the 3D visual. Well sorted sand as I said, a well sorted means all the small particles are taken away almost similar size, you have good water storage, very good water storage across the domain you have it and this is your alluvial aquifer experience. So, this example can be taken for those solids, soils and rock material which are well sorted.

And then the fractures in granite which is mostly your hard rock aquifers central India, this is your alluvial Ganges. This could be looked at as your central India, South India those kinds of hard rock aquifers, where you have fractures in granite. And in the fractures you have water. So, if you put a pump here you take this water. If you take on the sides, you do not have water. So, what is driving it? It is the presence of the fractures which is driving.

And then you have caverns in limestone. So, this is the limestone in your mountains or underground where you have a rock that can be dissolved by water. So, water flows and it can cut and dissect and then go through. So, these are limestone materials and the water can be stored along the cracks and crevices where it flows.

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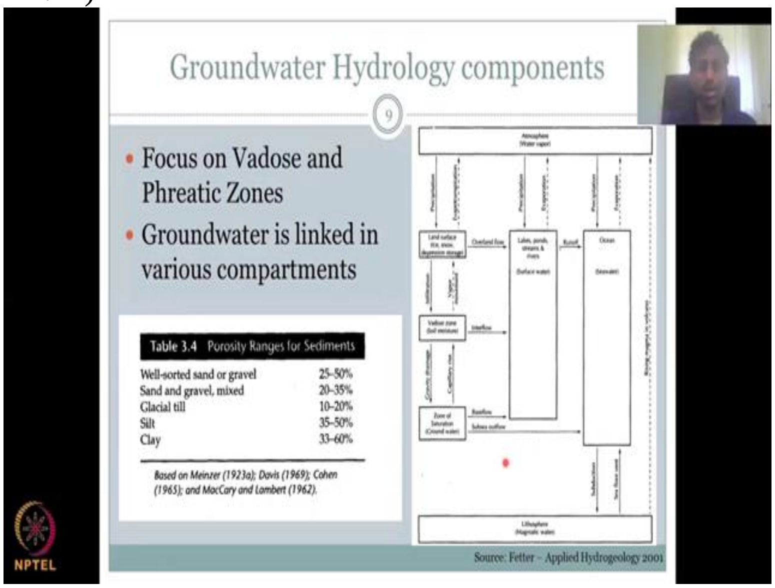

Moving on, so focus on vadose and phreatic zone is going to be the important parts in the next more classes. Because what we have here is we have a focus on vadose zone and phreatic zone. Vadose would be your undersaturated a zone and your phreatic would be your saturated. So, what happens here is you have atmospheric water vapor precipitation occurs, land surface depletion etc.

Infiltration of the water occurs into the Vadose zone, the first zone which is your unsaturated zone. Then you have your phreatic zone or zone of saturation. So, through gravity water moves down, part of it goes as baseflow, part of it goes as interflow. And at the land surface you have surface runoff, we will discuss these all well enough in the hydrology class. So, then you have precipitation and evapotranspiration is the losses from lakes, water bodies, ponds.

And then it can also go to sea water, the same thing can happen in sea water. And this is the magmatic water the under, under very very deep conditions, you do have the magma water driven by lava etc. And it can also come to the oceans. So, groundwater can exist from here the vadose zone until the magmatic water. The vadose zone is still having less water because it is not fully saturated.

And same here the magmatic water is very very less in, in volume, but this is the biggest water resource for groundwater. And here is where you go and see that after some time, it does go to the seawater. So, freshwater is pushed into the saline water and also into lakes, ponds and rivers. So, groundwater is linked in to various components. If it is an urban city, where you have all this land as cement and roads, then water-falls and then goes here.

So, these two paths are not available. So, you can see visually like, where the water is starting, how it goes into groundwater, and then how it is managed. Please also understand that porosity ranges are different as per different literature. So, always use when you want to do a field work and you are trying to get literature for a, use literature which is based out of Indian studies or some Indian studies have used it.

So, all the books I am referring to you would find Indian studies using those literature values. So, well sorted sand or gravel around 25 to 50 percent. If you put the percentage it is that 0.25 to 2.50, sand and gravel mixed would be 0.2 to 0.35. Glacial Till which is of the Himalayas etc, 0.1 to 0.2. And then your silt 15.35, 5.5 and clay would be 0.13 to 0.6 percent. So, all these are taken from very, very old studies, you can see the dates.

But again, the porosity does not change for a particular rock or material because it is the nature of the rock. So, you do not, there is not much changed by new studies. If only if maybe new technology to find better results it is fine, but again as I said it has been crushed, put in the oven heated, evaporated. So, all those values are pretty accurate. So, through these lectures, we have seen how groundwater enters into the phreatic and vadose zone through the porosity.

We looked at porosity in detail. We have defined it and seen how it changes spatially through the layers and also sediments and etcetera. And also, we looked at the temporal change in soil moisture. So, this soil moisture is very, very important to understand the plant water requirement for agriculture. So, all the water which is the soil can only be going into the groundwater recharge.

It cannot have 0 soil moisture and groundwater, maybe through aquifer, yes, it can come from far away. But in your location, you have to have a good soil moisture to have a good shallow groundwater aquifer. And that is where we would stop and go to the next component of the groundwater hydrology in this class. Thank you.