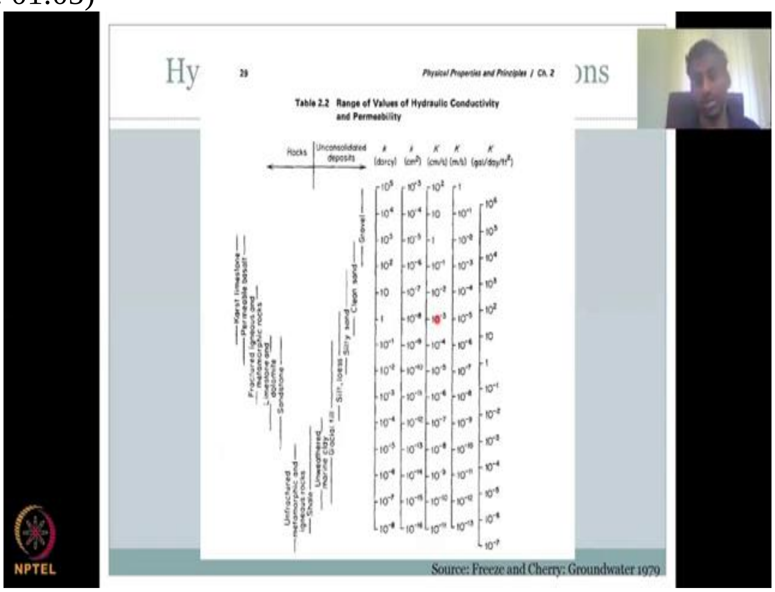
Rural Water Resources Management
Professor Pennan Chinnasamy
Centre for Technology Alternative for Rural Areas
Indian Institute of Technologies, Bombay
Week 05 - Lecture 05
Recap of Groundwater Hydrology Components

Hello, welcome to Rural Water Resource Management NPTEL course, week 5 lecture 5. So, in the past lectures we have been looking at the groundwater hydrology components. And we have looked at specific, most important parameters of porosity, permeability, hydraulic conductivity, specific yields, specific retention etc.

We will be wrapping up the groundwater hydrology component part in this week. And I do hope to recap so that we can link all the different lectures together. So, in this lecture, let us do the recap. And also tie all these parameters together. But before that, as I promised, we will look at hydraulic conductivity and variations. We would also pro the reasons for such variations.

(Refer Slide Time: 01:05)



Let us take the first example. As I mentioned in the previous lecture, there is a big range for hydraulic conductivity properties. And I am just talking about one dimensional. So, let us take one dimension, let us say vertical along the z axis, due to gravity along the gravity. We do have a range for each hydraulic conductivity associated soil material. So, for example, if you have, it could be soil unconsolidated deposits, which means it has been deposited, or it has been weathered those kinds of things, whereas rocks are still the parent material. And from which weathering can happen. So, you can divide it into two, but we will focus here because this is where farming happens and rural water management happens.

This would be mostly on the deep wells and those kinds of things that we need to understand the hydraulic conductivity in those regions. Since we are not dealing with massive irrigation projects for rural, we will be looking at this part. So, let us take one example of silty sands of loads. These are kind of the combination of different materials in soil, different textures, and different sizes, which is mostly common in nature, you will not have one specific type.

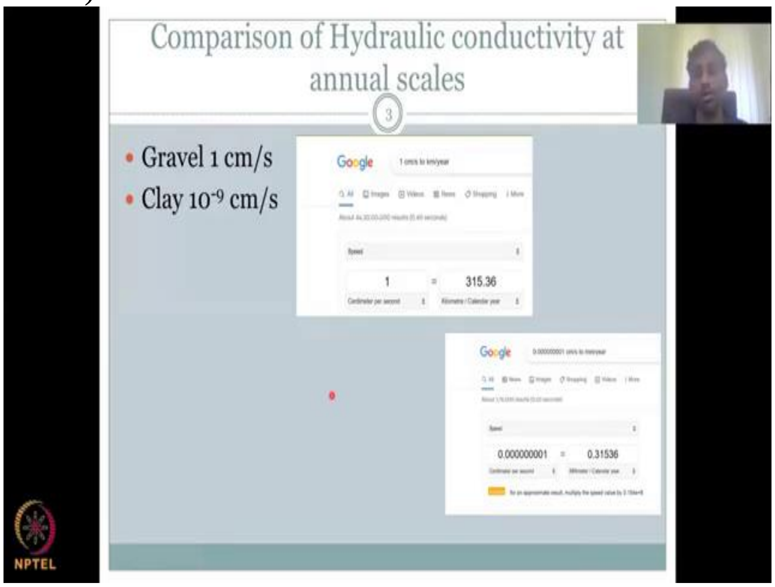
You could have that only in, for example, desert is purely sand, clean sand. And then gravel is along the river beds or along the Himalayan regions where erosion happens. So, all these rocks are part of the mountain and then erosion happens and then they start to move down. When they start to move down, they become round. Because the edges are broken, while they are transported and that is why you see a pebble of gravel everything is shaped wrong, it is not sharp.

But if you break a rock, it is sharp. So, water takes it along and on the way it actually shapes it into a round object or a spherical object, very smooth object. So, coming back, let us go to silty sand or silty loads. And you could see that the range, let us take from here it ranges from your hydraulic conductivity centimeters per second 10 power minus 7 to 10 power minus 3. And this is because hydraulic conductivity is a function of the soil medium and also the fluid.

So, the fluid, we might assume it is just water. So, let us say we are just looking at water. So, we know the density of water etc. But your hydraulic conductivity is an intrinsic property of the soil material also. And here the soil materials via porosity influences the connectivity of the pores increase the influences, the permittivity the permeability of the soil to allow water to flow is different.

So, keeping in mind all these which are mostly on the management side, only some properties are for hydraulic conductivity are natural properties like texture of the soil. But the other things like porosity, and you have the connectivity of course, all those are kind of managerial. Whereas your permittivity, resistivity all those things would be more of the texture class.

(Refer Slide Time: 05:00)



So, let us move on and as I promised, I would do a comparison of hydraulic conductivity at annual scales. We saw these kinds of like velocity, how much easily water flows through? It is not called as a velocity per say, but it is the measure of how much how easily, how easily water flows through and it is a flux rate. So, and it is given as a unit distance per unit time. So, centimeter per second, let us take that unit from the previous lectures and books.

What you find is, you can easily do this on your Google calculator, or you can use your books and calculator etc. for learning purposes, I am showing it in Google calculator. So, one centimeter per second, 2 kilometer per year, that is all I thought, but you can change the number one to nine, etc. But here, the values range from 1 to 10 power minus 2. And then clay is 10 power minus 9 to 10 power minus 6.

I am taking the extreme values in both cases to show how big it is. If you see the first part, the gravel, 1 centimeter per second, is equal into 315 kilometers per year. So, if you drop your water in the Himalayas with all gravel, within a year, it transports itself, it flows across 300 kilometers, along the gravel. And mostly your gravel is on the top, if it gets to the bottom of your gravel bed, and you have a lot of gravel, then also it can flow.

That is why you see under the mountainous regions, you do have rivers that flow. And that those rivers are fed by these groundwater, which comes into gravel structures. Moving on, let us take the clay example. And you will be surprised that 10 power minus 9 eight zeros and a 1 is equal to

0.3 millimeters per year. So, you are not even moving a centimeter in a year. So, if you take clay, and groundwater is into the clay layer, you are recharging it through rainfall or your activities.

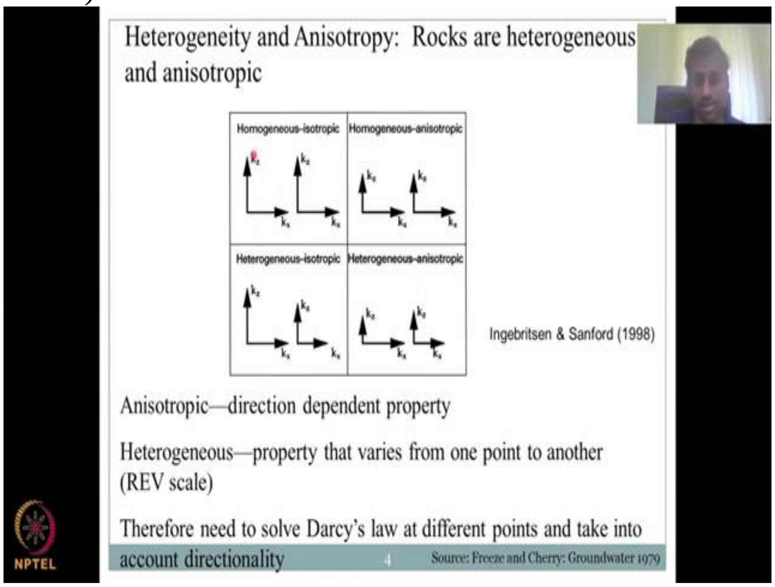
Water does not move that fast. It does take a long, long time. So, if your recharge area is 1 kilometer, and your 1 meter at least let us start with a meter. So, your recharge area is one meter, you have a recharge dam or something. And then water fill fills in. And then it comes to the clay layer. For it to come to your point, which is 1 meter difference, how many years does it take? Given that it moves only 0.3, 0.3 millimeters per year?

So, do the calculations, how many millimeters are there in a meter? Do that 10 power minus… So, do those calculations and then get at how far this water is being transported. So, it is approximately 10 power minus 3, am I right? Right, so you are not even getting at your meter within 10 years. So, those estimates that I showed clearly in the previous lectures on how water moves, sometimes it can be so like here, for example, it can come in within a day, the water.

That is why it can transfers 300 kilometers in a year. So, let us divide it by 365, approximately, so 1 kilometer per day, the water can move in a gravel bed, 1 kilometer. But if you come to your centimeter analysis, millimeters for your clay, it does not even move within 10 years. So, this is the analogy you need to understand when you are doing your groundwater related recharge mechanisms, groundwater use also.

So, if someone is using too much groundwater in those regions, you need to tell them that this is not sustainable, because you can pump it within a day, you can pump 10 liters, 20 liters within a minute. But how long does the water take to come to that point is the question. So, you are actually depleting an aquifer or a storage, which has been sitting there for a long, long time. So, you need to be very, very calculative about it.

(Refer Slide Time: 09:47)



Moving on, under the variations of hydraulic conductivity, multiple factors that contribute to higher, to the complexity of hydraulic conductivity, let us look at some. Heterogeneity and anisotropy, rocks are heterogeneous, which means inside your soil material, inside the rocks, you do not see the same size, same types of soil, there is always a mixture. As I clearly said earlier, you do not find a pure one type of soil or rock in, in a location.

It is heterogeneous, let us define heterogeneity and anisotropy. So, let us take one example, this is your soil bed, I am leaving the y plane. So, you have your z plane and then your x plane. So, there is another y plane. I am not looking at it because this is a 2D image. You are seeing only z and x direction. So, there could be one y direction this side, but we are not going to look at it.

First sample, so I am taking four samples, and I am going to explain what is homogeneous, heterogeneous isotropy and anisotropy in terms of hydraulic conductivity. So, hydraulic conductivity is given as K, sometimes they will write a small k also, so do not get confused with permeability. Mostly only hydraulic conductivity is used for your modeling because permeability is a function within new hydraulic conductivity.

So, coming back we do have a location so this is a location in the soil sample I take and I look at your sample, sample and analyze the hydraulic conductivity, I am analyzing here. So, two points in a soil I am taking a sample and what I see is, it is the same. K x is the same as K x the value. Let us say it is 5 meters per second, it is also 5 meters per second here. So, it is homogeneous, which means it is same and isotropic, along the distance, along the planes along the directions also it is the same.

Now, let us take homogeneous and isotropic. So, for example, what I mean isotopic is Kx is equal to Kz, so, sorry here it will be 5 meters per second 5 meters per second, that is isotropic. It is the same value in both the directions, whereas homogeneous anisotropic is you have it different in different directions. So, Kz is shorter than Kx, Kz is shorter than Kx. But, it is homogeneous if you take two points in the same sample, it is the same value for Kx and Kz.

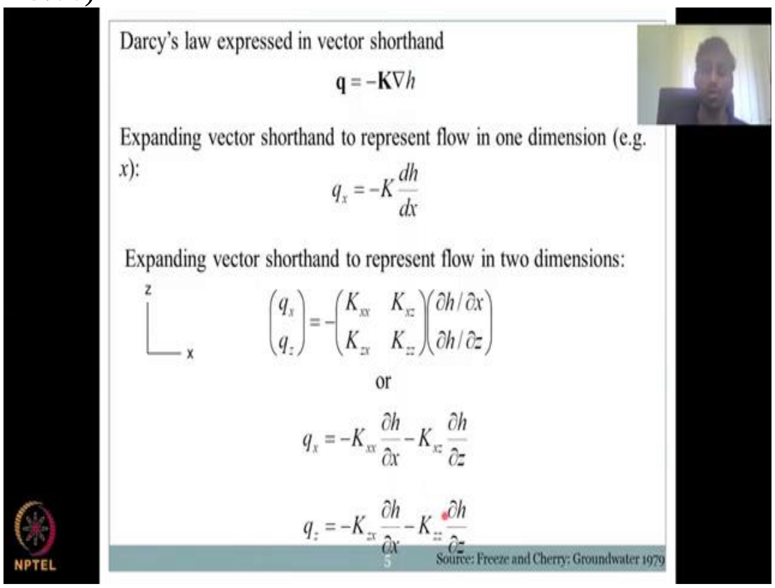
So, your values are the same along the sample. So, it is homogeneous however, the X Y Z planes may differ. So, heterogeneous means, if you take two samples in different points your Kx Kz are different. So, Kz in point one is not equal to Kz in point two. Kx in point one is not equal to Kx and point two. However, it is isotropic, isotropic means Kx is equal to Kz. So, you can see Kx equal to Kz. So, both are equal.

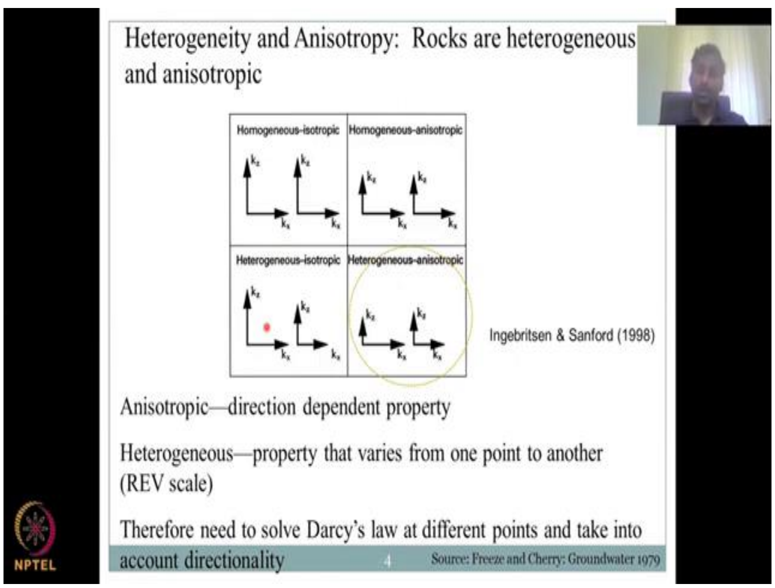
Same here, heterogeneous and anisotropic. So, two samples are two different locations and both Kz and Kx are not the same. Also, if you go from one point to the other point the Kx 1 is not equal to Kx 2. Same Kz1 is not equal to Kz 2. So, you do have totally different values when you take in a two different locations. Ideally this one is the best or you can also go along with this one along if you have Kx and Kz estimated.

For example, if you are working in a field and you find it as homogeneous and isotropic, you only have to find K value in one direction and then you can apply it throughout the field. So, that is the best case scenario, but it is not possible in a natural system. This is what was assumed in your Darcy's equation at all right. So, coming back to homogeneous anisotropy, this is also can be okay, because it is at least one point I can take in the sample and assume everywhere, it is the same. But the reality is this, it is very heterogeneous and anisotropic.

So, anisotropic direction is very very dependent on where you take the sample, how you take the sample etc. So, it is a direction property, anisotropy whereas heterogenous is a spatial property. So, property that varies from one point to another. Therefore, there is a need, now you as I said Darcy was solving in one dimension. So, now they know that it is not the same in all planes and may not be the same in all locations within your sample. So, there is a lot of variations of hydraulic conductivity. Therefore, there is a need to solve Darcy's equation at different points and take into account directionality.

(Refer Slide Time: 15:06)





Because you, so water flows is a directional if you do not have direction, where will the water flow? It can flow anywhere it likes and then create storages pools etc. So, it is always important to visualize the groundwater as a 3D component, along three planes. Most probably your X and Y plane are almost same. So, which means isotropy could be there in a Kx Ky, but Kx and Kz are not isotropic. Why?

Because you have your, also there is another pull of gravity acting on it. Please understand that this is the real case scenario. And most cases are like this however, you can get away with Kx Ky plane, but Kx and Kz are not the same and between locations also it is not the same. So, this given like this someone can ask me how many samples should I take sir? How many is it possible?

It is not possible to take a lot, but at least you could average it out, average the differences out by taking some samples and having a clear understanding of how the hydrology behaves. So, basically if you dissect your aquifer or your ground profile, under the ground the profile of the soil into different specific unique structures like layers, layers or structures, then you can assign of homogeneity and isotropy in that location.

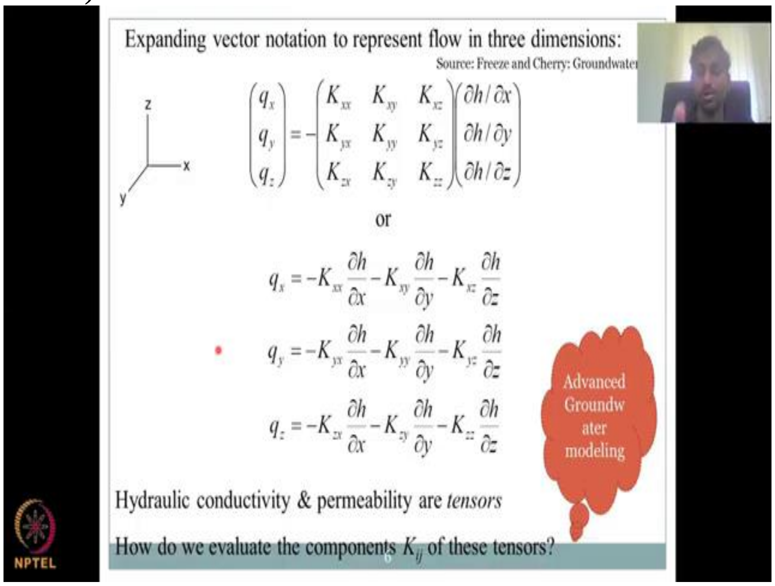
For example, I have four layers in my cake or my soil layer, the first layer can be this. The second layer can be this, third, fourth like that. And you can put one value for each. So, now you have created a heterogeneity in the soil profile. And also, you have introduced anisotropy by giving two different values for Kx and Kz. Do not give the same values, those can be estimated by your groundwater model.

Darcy's law expressed in vector shorthand can be q is equals to minus K hydraulic conductivity, which is q is your water velocity minus K del h. So, gradient of h hydraulic gradient as I explained in the previous class, which is a function of your difference in the head by difference on between the two wells. Expanding vector shorthand to some flow in one dimension, we have qx.

So, we are putting the x notations in the equation in just one plane, x axis. You have minus K dh by dx. Now, expanding the vector in two dimensions, slowly you see how the complexity comes creeps into the equation you have qx qz, which is equal to minus K xs Kxz Kzx Kzz del h by del x del h by del z. So, or you can expand it as this.

So, slowly, you could see I am just going to go through the first one qx is equals minus Kxx. Del h by del x minus K xz d h by dz. So, you have your passion differentiations also. So, slowly you have made the equation complex, but please remember, we are not stopping at two dimensions, we have three dimensions.

(Refer Slide Time: 18:41)



So, it gets more crazy, the equation. So, you need to solve all this to find a q in each direction. And as I said, you can probably get away by saying q x is equal to q y. So, you do not have to do this, but still the z component in the different directions has to be accounted for. So, eventually you will be solving this and since it is not solvable that easily through hand, it takes a long time. And we have to take a lot of assumptions, sometimes the models help.

So, when we go through the final stages of this course, I would go through an introduction of the modeling software's. And just so that one should not ask why are we learning models when we can do this two hand or manual calculations. It is important to understand, it does take a long time and error prone. So, if you do it by manually, sometimes you will be missing the connection between the dots.

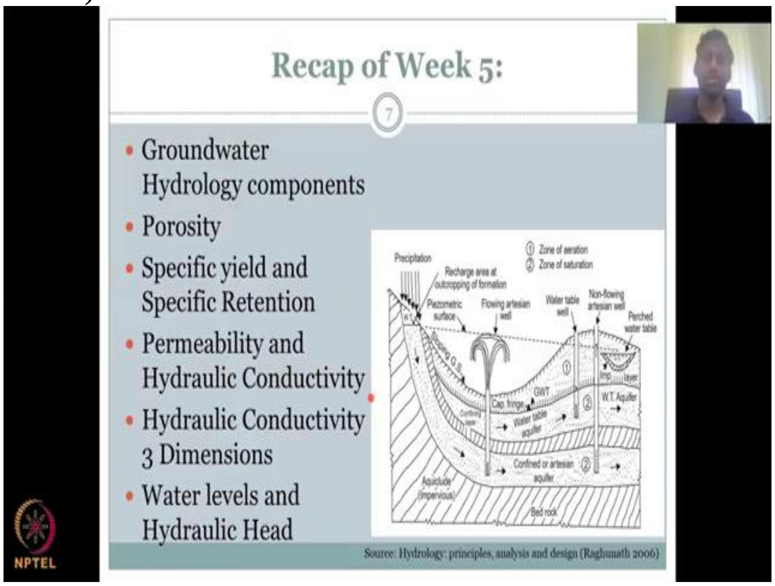
So, there is always two for example, you have to take one well or another well find the cube, then go to another well another well. So, think about how many wells you need to put in your visual imagery, and then estimate qx along the way. So, it does take a long time. So, please understand that part. So, hydraulic conductivity and permeability are tensors. How do we evaluate the component Kij of these tensors by solving them.

So, as I said, you need to solve them in a very unique and very careful way to account for the variabilities in hydraulic conductivity across the plains Kx Ky Kz. And for that each K value has to be important. So, you need K x axis is here, Kx y is maybe somewhere here. So, you need to understand that the variabilities of the hydraulic conductivity plays a role in this and it is a three dimensional property.

So, all this solving and modeling is part of the advanced groundwater modeling course. But, as I said, I will just give an intro on why you need models, how to self-learn models in the classes to come. Some of these models are free open source, we will be only promoting open source so that everyone can access it.

And the beauty about open source software is a lot of people have access to it and a lot of people contribute to the material which means like if you have a section of this material, and I am working on it for example, I can go in the forum or group, Google group or something and post comments on how to solve it differently. If someone has a problem, they can put it on the group and we can discuss it. So, all this can be done in open source software.

(Refer Slide Time: 21:45)



Moving on, let me recap this wonderful week of groundwater hydrology discussion and then we will wrap today's lecture. So, groundwater hydrology components we looked in into the past week. All the 4 or 5 lectures, we looked into specific groundwater hydrology components namely specific yield which is your trainable porosity, specific retention, which is how much water the soil can retain after gravity can act and pull the water out, which is more important for your plant life.

We looked at porosity which is a combination of specific yield and specific retention. And your porosity is nothing but the volume of voids to the volume of total solid. The volume of voids is very important parameter in your soil profile for groundwater, because that is where groundwater can be stored. And once the porosity is being connected between each other, then water flow can occur.

If you have a groundwater soil component, where water can enter, but it does not get connected between the pores then what happens it just gets stagnated like a perched aquifer. So, that also we would be not looking at here, we have the perch aquifer. So, we will be not looking at it in detail, we did not look at it in detail because the presence of such aquifers is very limited. So, most of it is connected, there is some connections so that groundwater flow can happen.

So, the components are different, you have groundwater recharge, groundwater discharge groundwater flow. And for the flow, you need to have the connections. So, that is one thing. Then we looked at groundwater recharge and discharge. We looked at spatial temporal variations in turn water recharge, spatial as layers between.

So, for example, the top layer or the confined layer can recharge from some days to some years, this part, some days to some years, depending on the type of soil material, because the soil hydraulic conductivity is varying factor. Then we looked at confined aquifers and the recharge time goes anywhere from years to millennium. So, it is very important to understand that just putting, you can easily put a well and take the water out, but you need to understand how long the water takes to recharge.

Then we moved on, we looked at these factors and how they are connected. We also looked at permeability and hydraulic conductivity. Permeability is the factor of the soil that allows permits the water to come and it is a function of the connection between the pores. We also looked at pore velocity, effective porosity, those kinds of concepts. We also then looked into the variations of them, the units of Darcy's etc.

Why were they varying? It is because of the nature of the soil profile and the nature of the fluid. Then we move to hydraulic conductivity, which is one of the most important parameters and we saw that it was a function of your pore properties and also your fluid properties. You can interchange permeability and hydraulic conductivity through these constants. We also saw that hydraulic conductivity is not granted to be the same across areas.

There is a spatial difference because it is heterogeneous and anisotropic which means, it is not the same in multiple places that you take, the hydraulic conductivity can differ. And within the same location, it is not the same in all the planes x y and z. So, understanding this is very important, because your groundwater pump is z direction, it just pulls it out. But water does not go that way.

So, when you do engineering, and bypass these processes, it takes a long time for the water to reach us because it follows the laws of physics. It has to go through gravity, it has to go through the z profile then spread out when there is an impervious layer these kinds of things. Then, we moved on to hydraulic conductivity, three dimensions and the complexity of it. Because we know the variations.

So, then we looked at the three-dimensional aspect and how complex it is to solve these equations, which guarantees that it will, it will take long time for you to manually and some errors can creep in. So, it is always good to use a model. Then we also looked at water levels and hydraulic head. How is a water level defined, how is a hydraulic head defined and potential defined, all these we looked at given an example of a ground surface or well.

And from the data, we defined a datum at zero and from the zero level how far is your profile? We looked at these different concepts to understand one value is if you know these components for hydraulic conductivity, porosity, specific yield for groundwater, you know how it flows. So, once it flows into your wells, now, you all you have is your water level. And from your water level, how do you understand groundwater flow, which is your Darcy's equation.

So, we also looked at Darcy's equation which was giving flow and the velocity. And it was showing that it was in a negative direction of reducing head, because it flows from high potential to low potential, high head to low head water. So, all these things we covered so that now we are ready to understand taking a soil from the field or a rock profile we understand what would be the porosity.

We visualized it as porosity specific yield etc. And depending on that we know how much water can come in recharge. And once the recharge comes in and stays as a water level, we know how to estimate from one water level to another water level, the flow which is q. Getting into your, your recharge etc etc activities we will not be using models for that. Because the recharge and discharge activities totally depend on land availability, funds availability etc which we will be covering in future lectures. With that I would like to conclude today's lecture. Thank you.