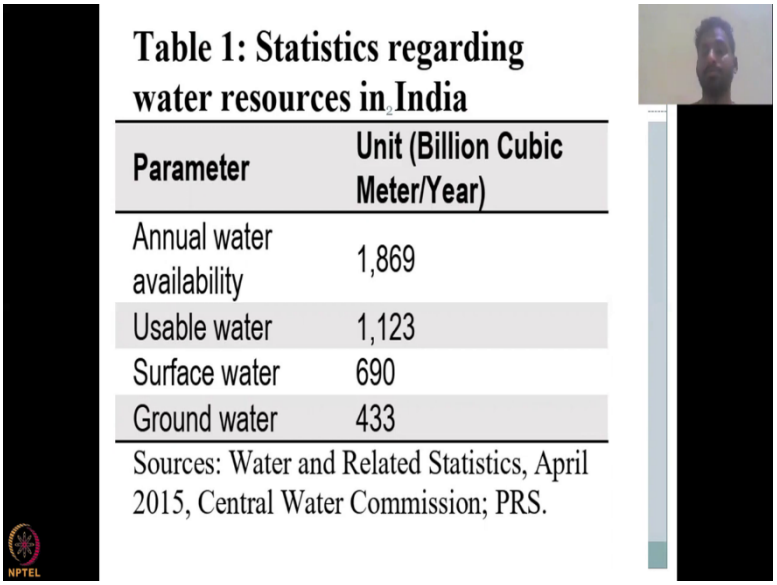
Groundwater Hydrology and Management
Professor Pennan Chinnasamy
Centre for Technology Alternatives for Rural Areas
Indian Institute of Technology, Bombay
Lecture 15
Physics and hydrology of Groundwater Part - 5

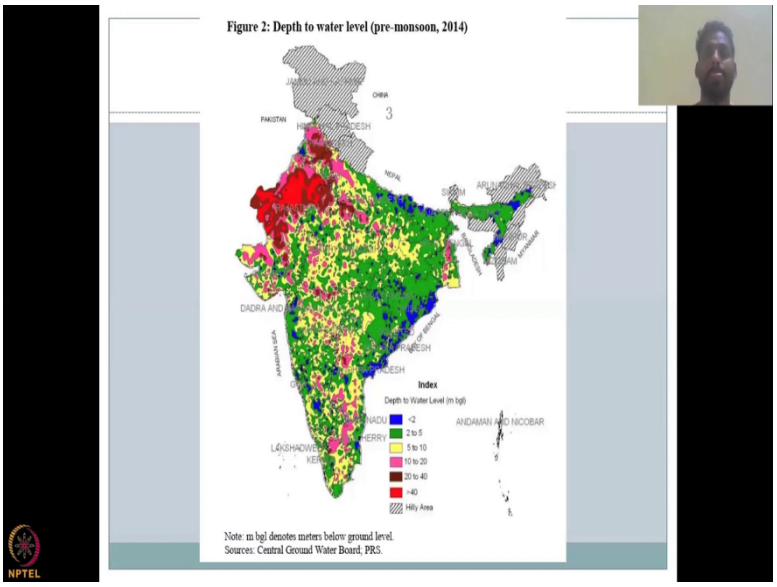
Hello, everyone, welcome to Groundwater Hydrology and Management. Week 3, lecture 4 of the NPTEL series. In this week, we have been looking at the definitions of aquifer, how groundwater gets into the aquifer? And the key aquifers in India. Especially in the last lecture, we looked at the connection between the aquifer formation and how it is related to rainfall, river discharge and also the geology, most importantly the geology of the location.

(Refer Slide Time: 00:54)



We will continue our discussion on the groundwater resources in India to strike the fact that groundwater has become one of the most, if not the most important water resource. Let us look at the statistics as per the Central Water Commission CWC. The annual water availability is around 1,869 million cubic metres per year of which usable water is lesser than that at 1,123 billion cubic metres per year. And the surface water contribution to that total is 690 whereas groundwater is 433 billion cubic metre per year respectively. So, the groundwater is almost very very near to the surface water and it cannot be neglected, that is the driving fact from this set.

(Refer Slide Time: 01:53)



So, how do we manage groundwater? How do we monitor groundwater? So, the depth of groundwater level is monitored before the monsoon and after the monsoon. If you take for example, this image, the pre-monsoon level from the Central Groundwater board Data Archive, what does it tell you? It tells you how deep you have to go to access the groundwater.

Look at the units, the unit says depth to water level, metre, BGR, which means Below Ground Level. So, if your ground is this, your well is inside the ground. So, how deep do you have to go under the ground or below the ground to access groundwater. And so, if you have a water level before the monsoon, if you have these data before the monsoon, it clearly tells you how stressed a location is.

Because only before the monsoon you are more dependent on the groundwater. Once whether is monsoon, three months of good rainfall and soil moisture, you will not need your groundwater because you have surface water, dam, rivers etcetera, lakes, ponds all surface waters can be used. But groundwater plays a key role in the pre-monsoon season. So, just before the monsoon, 2, 3 months.

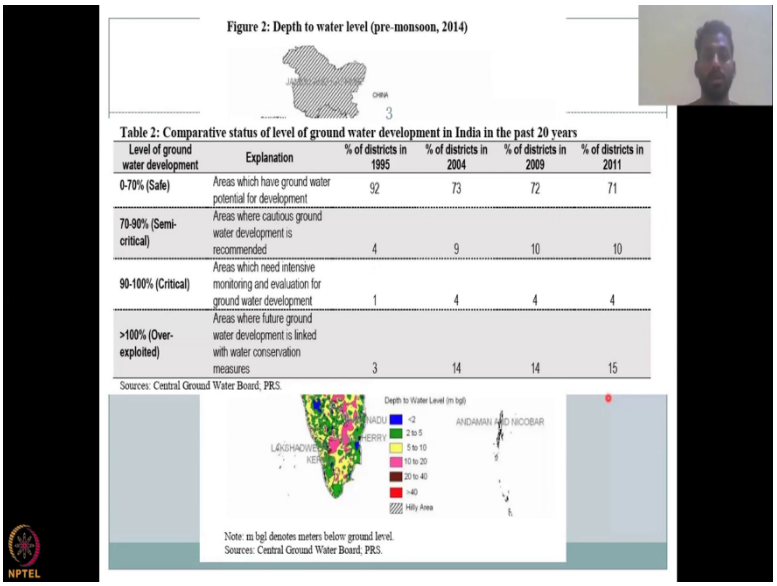
So, if you look at this image 2014, you could see that the groundwater levels are very very concerning or it is deep in Rajasthan and most of the central India where we have hard complex hard rock aquifers and then it is almost more than 40 metres below the ground.

Think about how much energy you have to spend to take the water out and how much water is it going to be.

So, let us take a contrast, this Rajasthan area has each well you have to go at least 40 metres to access groundwater. However, in the Ganges Basin region and along the coastal regions, the blue colour you can get it within 2 metres, within 2 metres the Brahmaputra region etc. So, you can easily take groundwater here less energy less dependency, whereas here where there is a lot of agriculture activity it is very very low.

So, your pre-monsoon water level is a very good indicator of where the groundwater stresses and where you have to put some measurements at once. The next colour you see is 2 to 5 metres below ground water and most of India is covered with it followed by 5 to 10 and 10 to 20. After that the hilly areas are in the Kashmir region and your North-eastern region. Not much data is available also here. So, you can say safely that you know water use is negligible in those areas.

(Refer Slide Time: 05:03)



So, based on this groundwater levels, now, the Central Groundwater Board is taking the water level and they take it in 4 times a year. So, one is your pre-monsoon, your post monsoon and then you have your winter and, in your summer, spring, summer could be correlated. So, these 4 times a year actually gives you a good picture of the spatial and temporal trend of groundwater levels.

So, once you have the levels, you have a pre-monsoon and a post monsoon. So, for example, in 2014, you have the pre-monsoon level, what is the water that has been extracted before the pre-monsoon level? It is a monsoon of 2013 not 2014. So, let us put some time here.

Pre-monsoon of 2014 could be your April, May of 2014. So, what is the monsoon water that comes into the aquifer that this, this pre-monsoon used.

It is the monsoon of the previous year 2013, June, July, August, let us say September, September is the peak monsoon month, for example. So, from September, up to your summer is your peak, monsoon has come your recharge has happened and all the discharges happen, which means you are taking out groundwater. Using this data, you will look at some indexes that is made by the Central Ground Water Board, which is given here.

This is a comparative status of the groundwater development in India and if the level of groundwater is 0 percent to 70 percent, which means annually or during a water year, you are taking 70 percent of your groundwater. So, if you take 70 percent of your groundwater not more than that, it is considered safe. Explanation is, areas which have gone out to potential for further development, you are safe, but you can still push the groundwater to take more water for economic benefits and agricultural benefits.

So, if you have a container of your aquifer, aquifers containing groundwater, and only 70 percent is used, you can have some measurements and some interventions to for the use, like for example, expansion of agriculture, different high yield cash crops, those can be introduced there in a safe and sustainable manner.

If you look at the 70 to 90 percent, which means almost 100 percent, almost total of the groundwater has been extracted, those are called semi critical, and you have to be very cautious around it, you have to be very cautious in taking further water because you might easily slip in the 90 to 100 percent. So, you have to be careful. A little bit recommendation is given for further development, but very cautiously.

This is where the 90 to 100 percent, which is called the critical. The critical is kind of concerning because you are totally depleting your aquifer, you are taking all the storage out and keeping it blank. So, if you keep the storage blank the next year, if it is a drought year, we will also face consequences. So, areas which need intensive monitoring and evaluation for further groundwater development.

So, even if you want to push it, there has to be extensive monitoring and evaluation. First to monitor to manage and if the groundwater situation is better, then you can add more interventions for extracting the groundwater, industry etc. But 90 to 100 percent is critical.

So, you better stop extracting more water. What do you do when it becomes more than 100 percent?

You are already eating out all the groundwater that you store, you are already taking out all the groundwater and more, which means you are taking the past groundwater. This is very, very concerning. Areas where for future groundwater development is linked with water conservation measures so you can only access groundwater if you have good conservation measures.

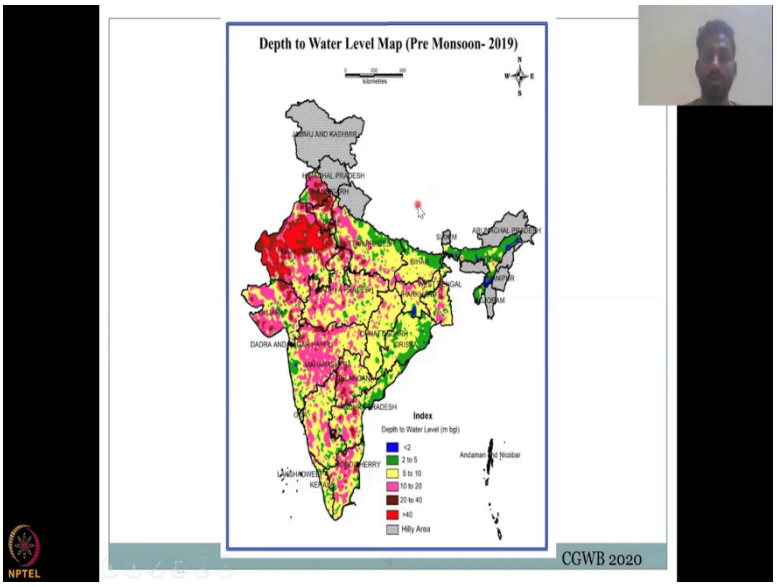
Otherwise, it is better not to use these groundwater resources, which is more critical. Let us see how these different indexes fare how many number of districts or percentage of districts in the from 1995 to 2011. That gives you good temporal trend of how these indicators changed. In 1995, you have 92 percent districts in the safe, 4 percent in semi critical 1 percent in critical and 100 percent over exploit district was 3, more than 100 percent.

So, most of your aquifers were safe in 1995. So, everyone is happy, you can go along and do more groundwater depletion, but then in 2003, 92 became 73. But more concerning is that most of the groundwater that was safe, move down, trickle down into the critical and more probably over exploited condition. Look at the years it is almost 9 to 10 years. So, within that 10-year frame, we have pushed or stressed more groundwater resources that more of them are now in the critical and overexploited.

Plus, for another 5 years, your numbers do not change much, except you lost one more percentage of your safe aquifers and then another 2 years on, you are continuously losing your districts percentage of districts that are safe, and they are. So, if the safe converts to semi critical or critical, at least there is some hope that you could really console the groundwater. The problem is most of them are ending up in your over exploited.

The over exploited is going up. And that is a very big concern, because not only are you depleting the groundwater aquifer as critical and semi critical, but you are over exploiting the groundwater aquifer. So, that needs serious interventions and thoughts to conserve groundwater better.

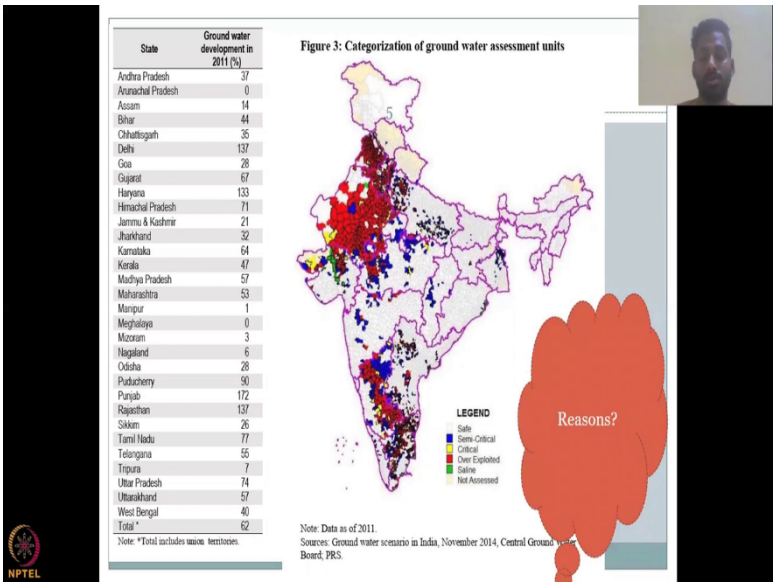
(Refer Slide Time: 11:56)



So, we saw the depth to water level in 2014. And this is the latest version that we have. It is the 2020 groundwater scenario, what do we see here is most of the regions in 2014 that were red are still red, which means it takes more than 40 metres below ground water level ground level to access the groundwater to touch the groundwater surface.

However, the those regions the central region that were green in 2014 have turned now yellow and pink, which is really concerning the green has 2 to 5, whereas the yellow is 5 to 10 and 10 to 20 for pink. So, most of the regions are converting into the pink colour, thereby explaining that there is more critical and semi critical use of groundwater and in most regions overexploited. Because the Rajasthan is not as bad as it was earlier in terms of groundwater depletion, still there is a lot of red colour, a lot of groundwater depth has to be covered to access the water levels.

(Refer Slide Time: 13:20)



Moving on, let us see in 2011, how the percentage was at state level. So, different states access groundwater differently. The chief crops that they grow is different the industrial demand is different, and the domestic demand is different. So, based on this different demand status, the groundwater development is also different.

So, if you look at it here, the most concerning is if it goes above 100 percent, always remember above 100 percent is overexploited 90 to 100 is semi critical, and then you have critical at 50 to 70 those kind of things. So, be very careful when it touches 90 anywhere above 100. So, if we look at the numbers, Delhi has groundwater exploitation much, much higher than the annual recharge, 140 percent.

Which means it is more than the groundwater that is recharge. And some measurements have to be taken urgently. Which is the most worst-case scenario is your highest groundwater development is in Punjab, 172 and Rajasthan. So, the red region that you saw, is still a showcasing that it is the percentage of development is the highest and groundwater level also is declining, along with it the recharge or how much you use annually is also increasing.

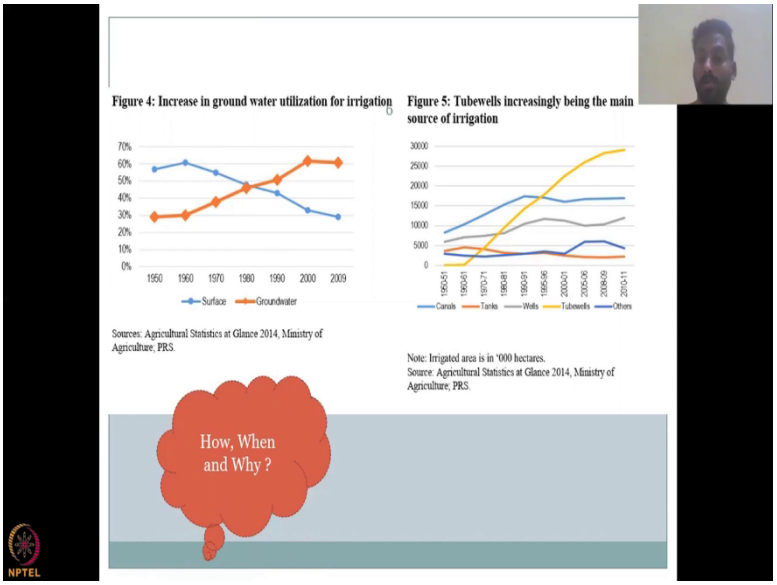
The other agricultural states which are of concern is Gujarat, Karnataka, and Puducherry at 90 percent, Tamil Nadu at 77 percent, Uttar Pradesh, all these are about 70, have to be very cautious. 0 to 70 is safe. But once you get into the 70s, and you become semi critical and and critical, and then overexploited. So, it is very important to stop the current scenario of use, groundwater use and focus more on conservation and other activities.

This is also visually represented. So, if you put it visually it makes more sense. That is why always you should think of doing it as a map rather than as a table. Here you have the overexploited red regions mostly in Rajasthan, Punjab, Delhi, and Haryana. So, those clusters are very close to each other neighbouring states. And what you see here is localised groundwater depletion scenario, which has been spreading across this Rajasthan, Haryana, Punjab region.

Delhi could be explained because of the population that they have, and the lifestyle to support the population. But Rajasthan, Gujarat and all the other regions, which are predominantly agriculture oriented, should wake up, they should wake up and those something to slowly stop the current groundwater use, reduce the current groundwater use, and then have better management plants.

If you look at the central region, most of it is the safe whereas this is the 2011. So, it is not the recent one, but I am just comparing the two because of the data we have for percentage development. And then if you look at the southern regions of Tamil Nadu, Andhra, Karnataka, Telangana, Kerala, us have a lot of overexploited scenarios, most of them would concentrate on the urban cities as Bangalore, and agricultural areas in Andhra and Karnataka. But the given take from here is there is multiple uses for groundwater and if we do not agree to reduce it below the overexploited condition, which is below 100 percent of recharge, then we cannot sustain the groundwater use for a long time. So, it is imperative to do this.

(Refer Slide Time: 18:07)



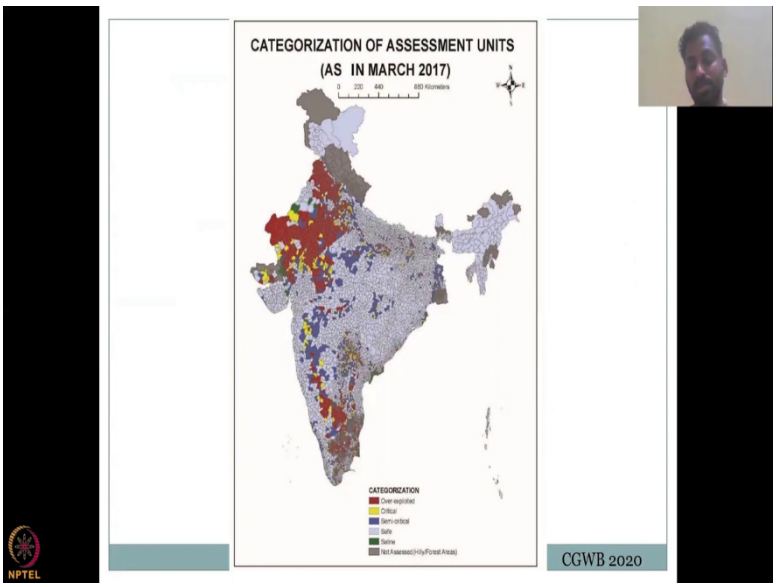
So, what are the key reasons? The reasons is as I said, in my introduction slides, groundwater is mostly used for agriculture and agricultural productivity demands a lot of groundwater. Any water, but specifically groundwater during the Rabi season, where there is no monsoon. So, if you look at this figure, the first figure by Professor Shah, you could see that the surface water use has been decreasing and the groundwater use has been increasing.

They fluctuate, they change the directions, almost in 1980s. You see that the surface water storage, use has become down whereas your groundwater use has become up. The surface water structures are also not less, excuse me, not maintained well, and that leads to more groundwater access, and because people have better engineering concepts to access the groundwater.

The other figure which is very interesting from the agriculture statistics, in 2014, is the number of tube wells or wells that use or create access to groundwater, all of them have skyrocketed after the 1960s. So, around 1960s you have more number of tube wells coming up. You will access both the shallow and the deep aquifers. They access both the confined and the unconfined aquifer so all the groundwater is being quickly taken out of the system for agricultural use.

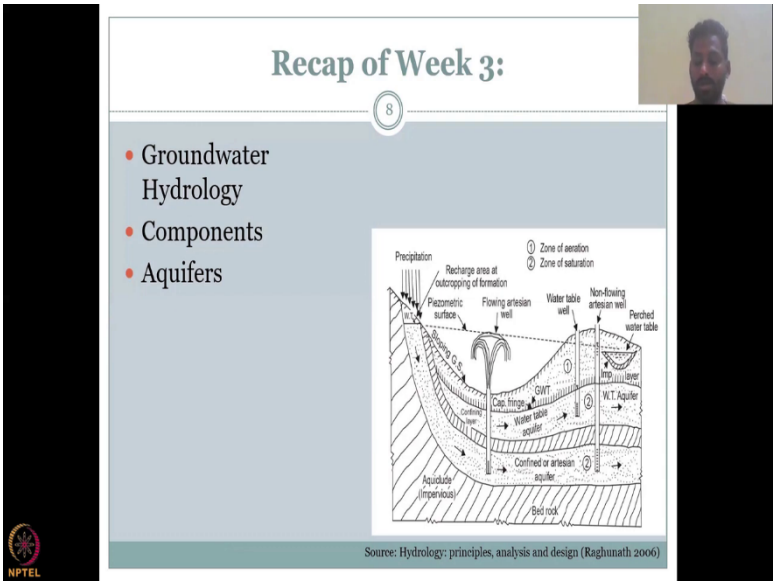
However, the canal's use has stagnated, your tank irrigation has almost come down from the initial use, whereas your wells and tube wells are increasing. Is this a sustainable sign for agriculture? No, it is not. Because like any other natural resource, we will run out of groundwater. If we do not manage it when.

(Refer Slide Time: 20:25)



How, when and why does this happen? This all happens mostly in the pre-monsoon season, because in the Rabi, they use your rainfall for irrigation, but most of it is in the pre-monsoon season and that is why the Central Groundwater Board takes the pre-monsoon and the monsoon data to make these maps. The maps look really informative, but what are the policies that are associated with these kinds of images are still highly.

(Refer Slide Time: 20:58)



We do not see much happening otherwise, the groundwater levels could have come down, or recharge has could have been increased. But we do not see that in general. In general, the groundwater levels are continuing to decline and they are not sustainable. With this, I would

end the week 3 with a recap. So, in week 3, we discussed about the groundwater hydrology, what do you mean by groundwater hydrology?

What are the different components in the groundwater hydrology explanation? We looked at zone of aeration, zone of saturation. How water moves from the surface into the soil profile and the rock metrics? We discussed about the porosity being one of the key factors where water gets into the system and stays there. And with the fact that most regions with less permeability and porosity cannot support groundwater activities.

We looked at different components of groundwater, especially the recharge and discharge and we looked at how it is bound by time. Which means how long does it take for certain aquifers to recharge and discharge water. Along with that, we look at the definition of aquifers. First, we define what an aquifer is and what constitutes an aquifer? An aquifer is made of your solid particles, soil, rock matrix along with that, the groundwater.

So, there are multiple, multiple dependencies of this aquifer. So, how it is it is developed or created? And the most important one is the solid material which comes with geology. So, Geology pay plays a very vital role in the formation of an aquifer and multiple aquifers across the globe. In India, 2 major aquifers we recall one is your hard-rock aquifers and the other is your alluvial aquifers.

The hard-rock aquifers are mostly in the unconsolidated, semi consolidated formations, whereas your alluvial aquifers are all in the unconsolidated. Which means there is a lot of water that recharges comparatively and a lot of water can be taken out for discharge. We also looked at how a well is placed and the potential metric and water table concepts? We looked at differences between the alluvial and metamorphic rocks, aquifers, etcetera.

We also plotted the river networks along with the aquifer storage units to showcase that we can explain the formation of these aquifers from water. So, the water can give back to the groundwater. But in our case, since there is no active life groundwater component discussed, we did show that the aquifers can lead to better groundwater management by giving water to the hydrological springs, waterfalls and rivers and vice versa can also happen depending on where the water table is.

We defined the high potential to low potential concept for groundwater and with this, I think we covered most of the components for groundwater and in the next class we will slowly

introduce, how do you document the flow between two points, both in the unconfined and the confined aquifer. With this, I would like to take leave from you. We have finished week 3 successfully and we will so start week 4.