Groundwater Hydrology and Management
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Week - 1
Lecture 5
Introduction to Groundwater 5

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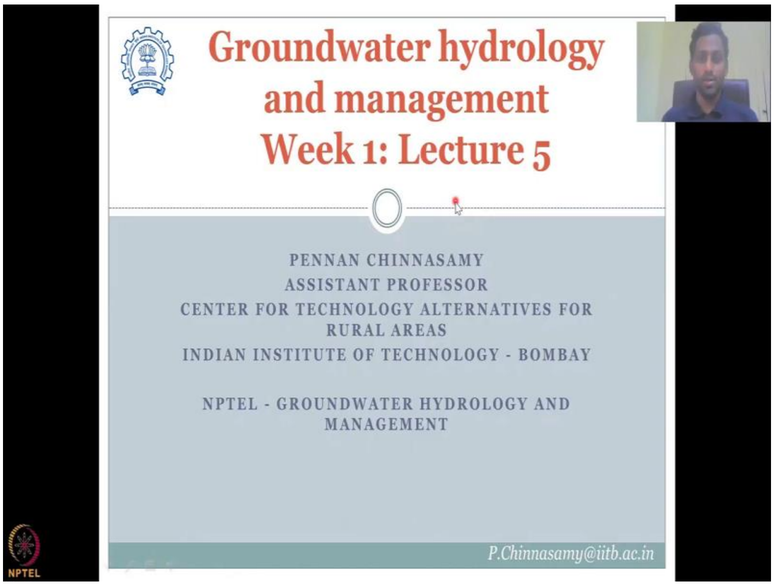

Hello everyone, welcome to the NPTEL course on Groundwater hydrology and management. This is week 1, lecture 5. In today's lecture, we will be completing the first week, wherein we looked at the introduction of groundwater hydrology, some concepts of groundwater and why this course is important, how of course is structure and what you need to take away from this learn.

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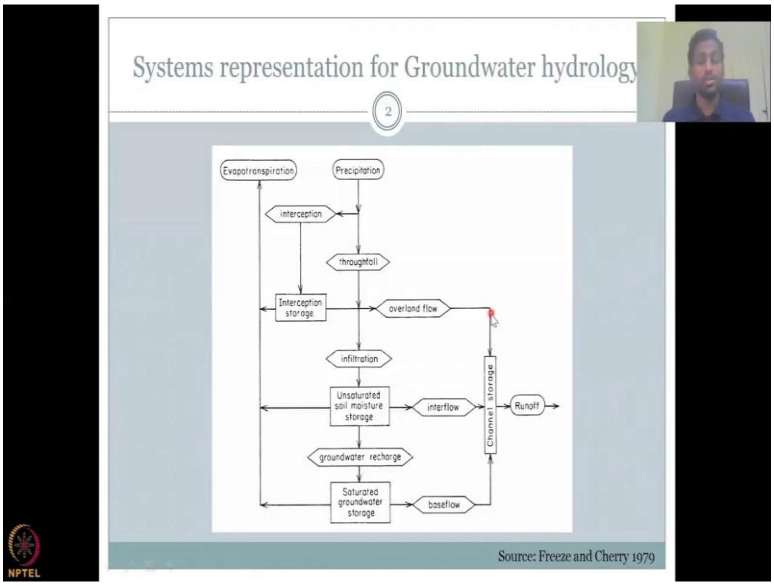

Let us continue from where we discussed in the last lecture, we stopped at the systems representation of groundwater hydrology as a flowchart. So, we said precipitation can come in after leaving some losses for interception and interception storage, part of the precipitation goes through throughfall and hits the land surface.

Once it hits the land surface, the water is available for infiltration. Infiltration is also driven by the gravity because gravity wants to pull things down, same from the atmosphere rainfall comes down because of gravity and then it hits the land of course more gravity to follow move the water down.

So, infiltration happens, part of the water goes as overland flow which means the water goes on the surface and goes into the oceans, rivers whatever is nearby and then the infiltrated water goes into the soil converts the soil from unsaturated to saturated, what is unsaturated? The soil and rock media has porous space in it and when water moves down, water will push the air and fill it with water, not all air can be driven out but it can be pushed and then water takes up the space.

Soil also attracts water, so that plants can take up the water for evapotranspiration and trees also and other living organisms like worms under the ground. So, once this soil profile converts from unsaturated to saturated, you slowly hit the groundwater table and the groundwater recharge. So, below the groundwater table, all the space is full of water. So, groundwater recharge further into this aquifer or the groundwater table will raise the groundwater table.

So, now you see a raise in groundwater table. So, this precipitation has converted through the infiltration into the unsaturated soil and then into the aquifer groundwater storage. What happens to the water? Because of water wants to be in in the most stable potential, it will try to see if it is in a high potential if you go to a low potential until it is balanced, the oceans, lakes etc. are sometimes at the very low potential, especially the sea is at a zero potential.

So, water would start to move and that contributes to base flow, there some soil moisture would contribute to interflow and then you have your overland flow all combined together in the channel storage like rivers, streams and goes out as runoff, you have some of the water taken up by plants which was evapotranspiration.

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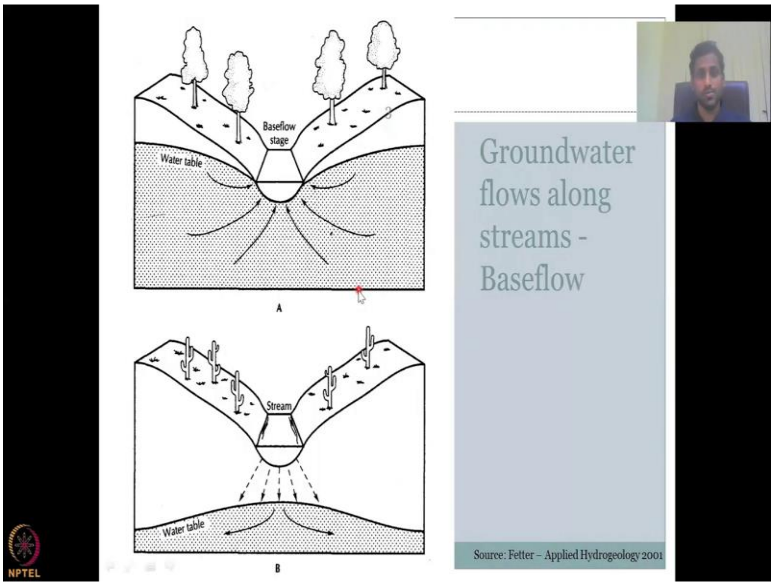

Let us look at the base flow concept this is what I wanted to continue from last lecture. So, you will have water table which is your height of your groundwater level in porous media, you see it in dots and it is not a river. So, a river is like this where there is no dots, stream is like this there is no dots. So, this is surface water, this is groundwater. In groundwater, you still have this solid face, a solid particles, water flows through it, it can only flow when the water table is achieved.

So, you can see the water table is achieved and water moves, where does it move? It moves to the stream, the arrow marks show it because your stream is at a low potential compared to the high potential in the water table. So, water flows from high to low potential. Same here, but in this case, this finishes case you have a trees and agricultural area. So, you have better infiltration and plants taking up the water.

But more important because you have infiltration high in an agricultural area or a forested area, water can reach as fast. When you come to a desert system. You still have a stream, your stream is there. But your recharge is less, maybe because of high temperature, low rainfall and or the infiltration is not happening as good as in your forested area, because you can see cactus, cactus is seen in deserts. So, that is an indication of low rainfall.

So, what is happening is already the water table is much-much lower than the stream level. So, now the stream water potential is high and groundwater is low. So, the opposite happens, which means from the stream, the water comes down. So, when base flow occurs, it is only from groundwater into the stream. But that does not happen always, the stream can also contribute water down, which is called recharge, we will just look at base flow for now.

So, understand the concept of base flow wherein we have water table, and the water table is at a higher potential. So, it has to given to the streams.

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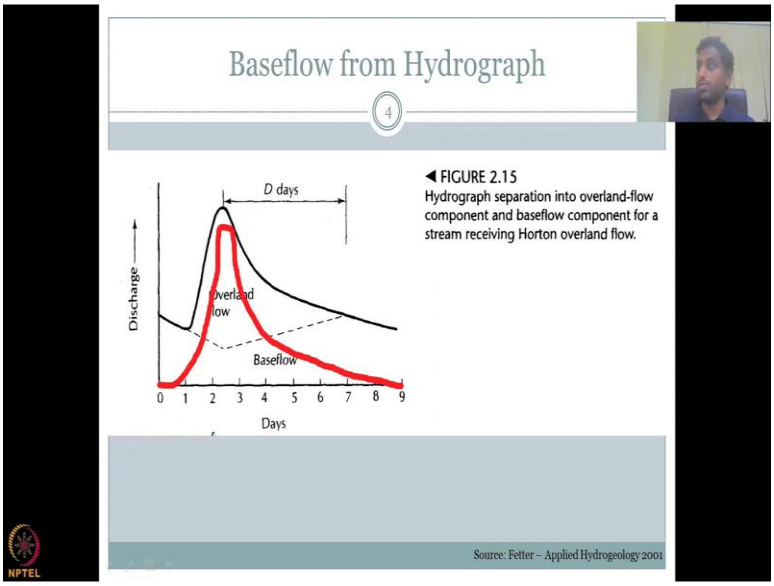

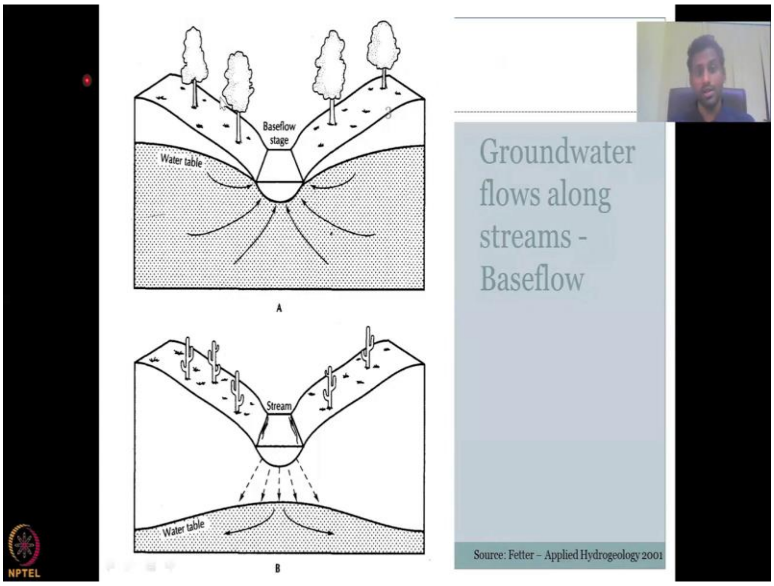

Moving on, we also would discuss in the lecture series, a base flow separation to understand the component of base flow and hydrographs. So, what we do actually is, we look at a time series of discharge industry discharge is the water flow coming industry you would have a peak happening when the rainfall is done and the peak rainfall is done. So, you have a low discharge then climbing limb wherein the discharge climbs and at a peak it stops and then comes down.

So, this is the peak discharge the flood top level in your stream, then it slowly comes down. It does not come down fast as your peak is reached because rainfall is occurring at a high pace it comes. Once after rainfall slows down, the process is slow. So, once you come down what you notice is that your base flow component is already inside your discharge, let us look at how it looks.

So, when there is no rainfall your stream is still flowing, how can a stream flow or a river flow when there is no input to the system. Because your ground water is giving water right. So, the previous diagram also you did not see rainfall on the top. Groundwater is flowing because it is a high potential and low potential, it has not to do with your rainfall. So, that is what is happening. So, this line is your base flow when there is no rainfall, you still have discharge.

But as soon as rainfall picks up the base flow contribution goes down, why would that be? It is because when you raise your level in your stream because of rainfall. So, when rainfall comes, the river level goes up, this level, this level would go up.

So, once it goes up, it is at a higher potential compared to the groundwater. So, initially it was like. Was giving water into the stream, but now your stream level is high, it gives to the water. So, up pushes, up pushes and gives water to the base flow component or it prevents base flow from giving water to the river. So, your amount of baseflow comes down because a peak is happening.

But after your peak is coming down, slowly your stream level is coming down and your groundwater is coming up and your groundwater because groundwater was also recharging because of your rainfall, the same way your stream gets rainfall, your groundwater also gets rainfall in delayed days, number of days you can see. So, rainfall stopped here, but the peak happened to three days later. And after three four days your base load kicks in.

So, now your stream is at a higher potential it was preventing the base flow from coming in and then slowly your base flow comes down. So, now your groundwater comes in. So, this can be explained by this diagram. When the peak happens in your stream, your base flow as at the lowest, the base flow contribution into the stream is low. Then after when the recession length comes when your groundwater is being picked up by base load.

But most importantly after your peak, your stream discharge hits the recession, which mean is climbing down while it climbs down your base flow increases and then comes back to the same line. So, if you imagine drawing a straight line, it will be the base flow component. But inside it has come down and gone up. And then again, your base flow kicks in when there is no rainfall. So, this is called the hydrograph separation method. There are equations for it.

What we need to drive out here is all streams, perennial streams, not seasonal, all perennial streams would have a baseflow component because not everyday rainfall occurs. So, rainfall does not directly flow into your stream, but it flows through the groundwater and comes out as they smoke.

Now, the tricky question, how does this look, how does this discharge look in a situation where you do not have a perennial stream, so, more or less it is a seasonal stream. So, for a seasonal stream, let me draw it your discharge will not start at non zero, it will be zero. So, when the rainfall occurs or before the rainfall, it is zero, and then it will peak and then go down to zero.

So, there is no base flow component before, however, there could be some base flow here coming from the groundwater component. And when the peak is attained, it falls into the session, but again, it goes back to zero, it slowly goes back to zero with your baseflow component, but both the discharge and the baseflow is zero. That is why you do not see a flow when there is no flow in the river.

So, the base flow is zero. That is why you do not see a flow in the river. So, moving on to the, to back my spotlight.

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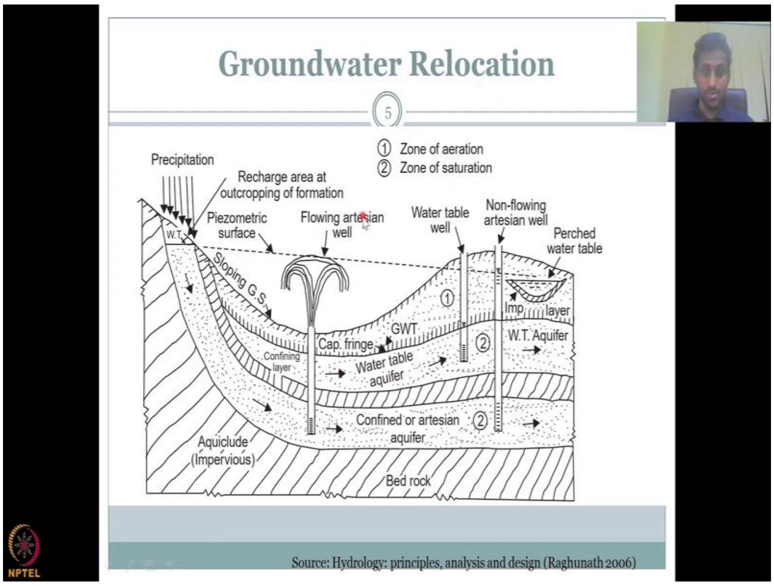

So, moving on. You have the groundwater relocation. So, what is the groundwater relocation? You have seen the base flow component. Now, you could also see that groundwater does not always have one aquifer or one water table, you can imagine to have another saturated zone below the aquifer.

So, I will not get into the detail because this would be a very focused discussion. But what I wanted to get is groundwater is being relocated through its journey. So, from the precipitation, what is called precipitation when it comes from the atmosphere into the top surface? Once it hits the top surface, it becomes infiltrated water, then it takes a name as soil moisture, as you can see here.

After soil moisture, it gets into percolation and goes into the groundwater, this one and this one. Within the groundwater, it does not stay there because of the potential difference it starts to move. And that movement gives way to groundwater flow, groundwater hydrology, and at the end, it can go to base flow and into oceans or rivers or lakes depending on where it is situated. And within the groundwater, different layers can be created depending on the layering of the rocks.

So, suppose you have a layer of rock which is impervious, which means it does not allow water to flow. So, all the infiltration cannot pass on this layer. So, it has to go this way. Same way, your ground water is coming, it cannot go up because this layer is preventing same this layer Aquiclude impervious layer is preventing it from going down, so it moves lateral. So, you have two lateral flows because of the presence of an impervious layer.

So, groundwater relocates, it relocates to the place where it has less resistance and where it can flow.

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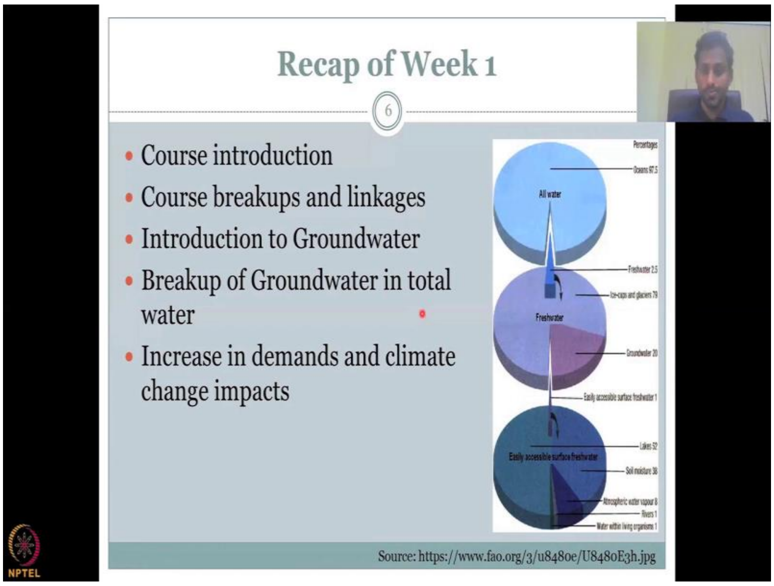

So, with this, I would like to recap the week one. So, you have seen the introduction to the course as why we need to study groundwater as a resource, why we need to study groundwater hydrology. Let us do a short recap. We did the course introduction on why it is necessary and especially for India. We did some examples of case for an India why and how much we extract, we looked at a particular state to look at how much water is available, how much water is the demand, and what is the stage of development.

We also look at, of course, breakups and linkages between the week, so we go strategically from one week to the other week, and we carry on the learnings so that at the end you take the combined learning to manage covered. We gave an introduction to groundwater what constitutes groundwater, and we discussed the porous space and water gets into the pore space, which initially had air, now it has water and that water constitutes the groundwater.

The groundwater hydrology, which means groundwater movement occurs when these pore spaces are connected. Breakup of groundwater and total water budget. We showed this example from FAO where you saw that all water is 97.5 percent is salt. So, if you take 100 percent water, 97.5 percentage is saltwater and oceans only 2.5 percent is freshwater, of the 2.5 percent only 21 percent is usable through groundwater and easily accessible surface water.

So, surface water is only 1 percent which is your lakes soil moisture, soil moisture you can also combined into the top surface. So, the easily accessible water could be 1 percent, whereas the 20 percent is groundwater, of the 20 percent groundwater, only half of it can be easily accessible. So, if you run the numbers anywhere from point 5 percent to 2.7 percent of the total water available in the planet is groundwater that can be easily accessed.

So, of the freshwater, groundwater still is the biggest contributor. And so that is why there is tremendous stress on groundwater for agriculture, domestic use industrial use, you name it, groundwater been exploited. So, if we do not understand the relevance of groundwater in the overall budget, we are losing the groundwater. Think about if you pull the water out and water the plants or you use it for industry. It goes back as precipitation through evapotranspiration.

So, when you apply through the plants, it evapotranspires mostly to clouds and then forms precipitation. Where does the precipitation go? Is it going back to the groundwater? Not, it goes back to rivers and lakes. So, you have depleted the groundwater, you are not putting back to water, but you are relocating the water as surface water at a much faster pace, which took a long-long time for groundwater recharge.

So, increasing demands are occurring, there is tremendous increase for groundwater because climate change is impacting the world. There are many- many floods often floods and droughts. So, let us take an example. If you have floods, the whole city is flooded, which has bad water on it, which water are you going to drink? You are not going to take that water and purify it and drink it. People go to wells because the flood water takes time for it to pollute the groundwater.

So, if I want to drink during a flood, I would rather go to the groundwater. Take it, purify it, and drink it. If you are taking your floodwaters it can be contaminated. Then come to the drought. As the name suggests, there is no rainfall, there is no water in the surface. So, how do you irrigate? How do you drink water, you have to go to the groundwater. So, in both extremes, groundwater is kind of an mitigation and adaptation to, it creates a buffer for you.

Animals do not have that luxury. If they do not find water, they have to migrate. So, you see elephants migrating along the western Ghats. You see animals dying, walking kilometers without water, if they cannot take and then get water they find for a waterfall or waterfall is somewhere where the warm water comes in and discharges. So, it is very-very important groundwater in the terms of climate change.

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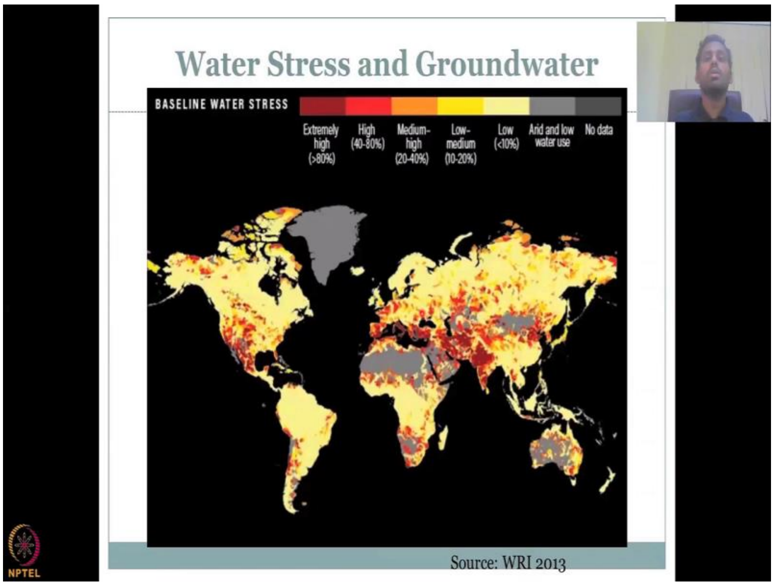

The water stress has increased tremendously across and the baseline water stress shows that most of the countries that are under agricultural livelihood options are staring at water stress either high or extremely high. And when there is water stress, people go eventually to their own water, assuming that it is an unlimited supply of water.

So, what initially was stopping them from taking groundwater, the technology was not good enough. You had pumps that can only pull water to a couple of meters. The process was expensive, you have to put the bore well, you had to put a pump, energy to pump the water was all expensive. Right now it is the opposite. A borehole can be drilled at any location just by rig which is put on a back of a truck.

Initially it was a big lorry which would come bigger hole or dig and then put the borehole but now I have seen a very small size trucks with high power machine that can drill anywhere, the immensity put your well and then go ahead. Same way the pumps have become more efficient, more powerful and less expensive. So, both sides it is hitting the groundwater. At easy access and cheap pumps that can literally pull all the water out.

So, you have pumps on one side and then you have access to groundwater on the other side. One more aspect I will throw in here, there are low cost energy options for pumps, diesel power pumps, solar power pumps, you name it, there are multiple different power sources for groundwater now. So, all would eventually get in and take all the water out and do not want to put it back in through efficient means that actually means and that is one aspect we will be covering the lectures.

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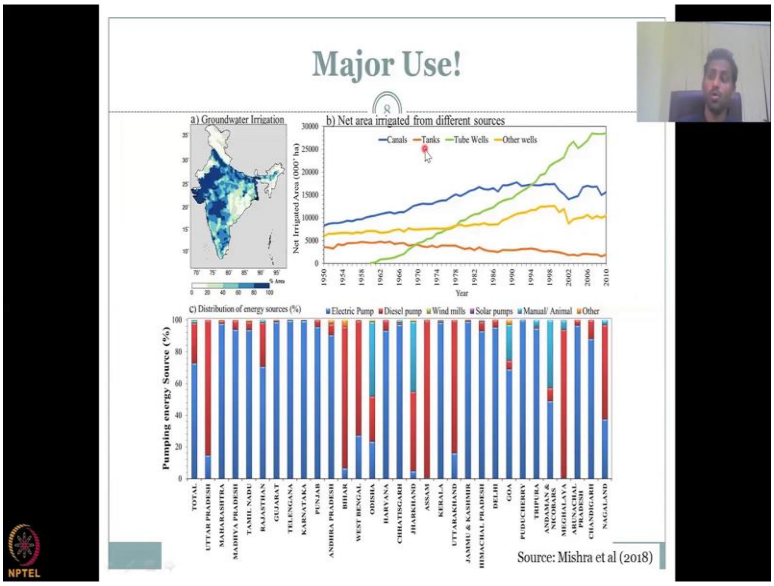

Let us take this debate with data. So, in this paper, what you see is groundwater irrigation map and you see the percentage of area. Almost 100 percent in Gujarat, Rajasthan, Punjab, Haryana and your Maharashtra the Vidarbha regions, the dry regions, some parts of West Bengal even along the Ganges, you see a very heavy percentage of area is irrigated by groundwater, it could be the double crop, triple crop.

So, but still irrigation is happening. And even if it is one time you can put it as 100 percent of that area is covered by groundwater irrigation. Is this reflected in other means? Yes, let us take the net area irrigated from different sources, you could see from 1950 to 2010. And the net area irrigated initially was with canals.

A canal is a distribution system through a dam. So, you would construct a big dam, a large irrigation dam along the river, and then water would be stored. Once water is stored up to a particular level before the Rabi season, which is before non-monsoon season, they will slowly release water in channels, in channels to areas where farmers have procured land around the channels for agriculture.

It does not go to every farm, wherever the channel goes, it will give the water. You can put a lift irrigation, or you put a pump and then take the water that is obtained, but the channel does not go to every farm. So, what has happened is that canals area has increased from 1950s. That was the good revolution, which was happening, but then it stopped. It did not increase much.

Same way, your tanks, the tanks, which would store water and then distributed or store water than you pump it, also did not increase in fact it decreased. What has increased in the other works. The other works are your shallow wells, which is your top part of your groundwater. The shallow wells are not taking much water, but it did increase from 1950s to 2010, little bit and stagnated. What has happened and is still continuing to happen is the access to tube wells.

Tube well irrigation has boomed like suddenly and it just exponentially increased. And it is growing at a very-very alarming and unsustainable rate. So, this is the distribution of energy sources, which state uses what percentage of energy is used by different sources. I started talking about solar, so you have solar pumps, windmills, diesel, electric pumps, manual is when you step on it, or cycling and take water, or you can also have animals going around and then pumping.

So, what is more important is to understand the area irrigated by tube wells has tremendously increased. And these two are groundwater resources, whereas these two are surface water.

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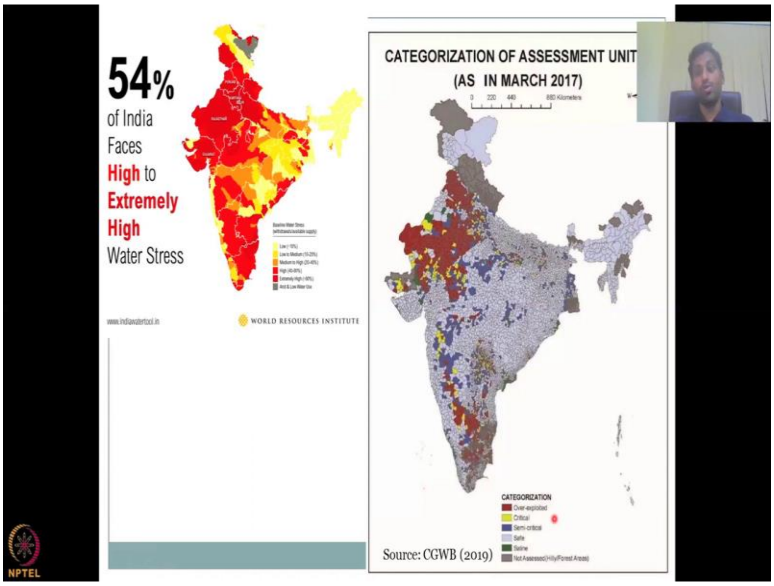

So, on the overall groundwater use has increased tremendously. This does not look good for the water stress image. So, 44 percent of India is looking at high to extremely high-water stress as per the WRI, and that areas where they demarcated, coincide exactly with your groundwater map. So, this is a different data source. This is a different data source. But what matches with them is that the water maybe the surface water has already dried out.

And that is why they have been using their bit of excessively using groundwater. And you could see the same regions having more groundwater use, or abuse, I would say, because it is at over exploited stage. What do you call over exploited is if you have 100 rupees put in your bank, you are taking 120 rupees out, so you are taking more than the water that came in. And at a quicker rate.

So, your 100 rupees would have come after you work hard for one month you put it in, and then you take it and buy something within a minute. It is not going to be used for the whole month. That is what I am trying to say and also accessing 120%. So, you are actually eating in your deposit or you are eating as a credit which you have to eventually fill the next month. Groundwater works in a similar way, except that your account is leaky, which means your 100 rupees does not stay there it there are some leaks which leak out like an interest like a credit card interest.

So, it is very-very important to understand that if you have a water stress, you should not over stress your groundwater. And if you are using your groundwater over then the recharge rate, there has to be some mechanism to put back water into it or reduce your consumption.

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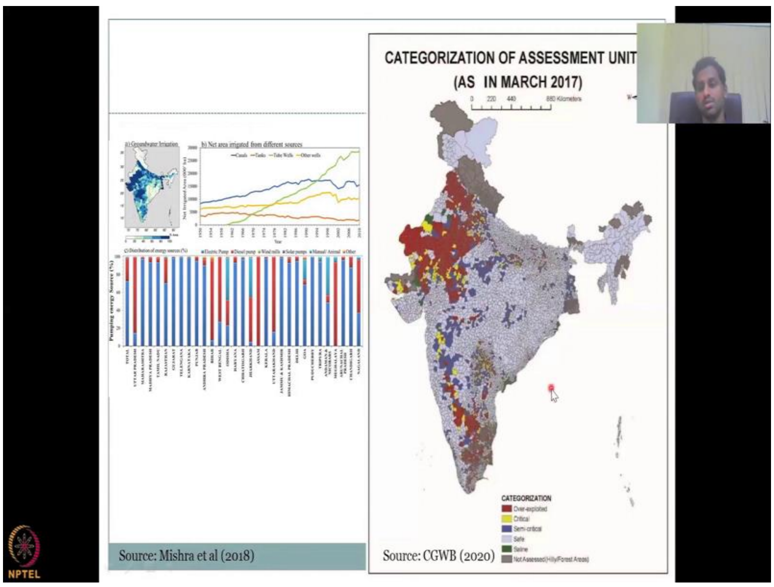

That would be my aim to drive across this lecture when we finish. Let us do the other comparison if you look at this area and this area it matches. So, wherever the groundwater irrigation is happening 100 percent, it is over exploited, which means it is going beyond the natural recharge rate. This is highly unsustainable. So, this is a central ground water board reports and it is another study's report.

If you look at that, and you look at where areas are, this could be your agricultural data. We go to census data, irrigation department data, what do you could see is wherever the blocks wherever the spaces, which is 100 percent matches almost exactly with your over exploited blocks in India as per 2017, which is the latest CGWB yearbook.

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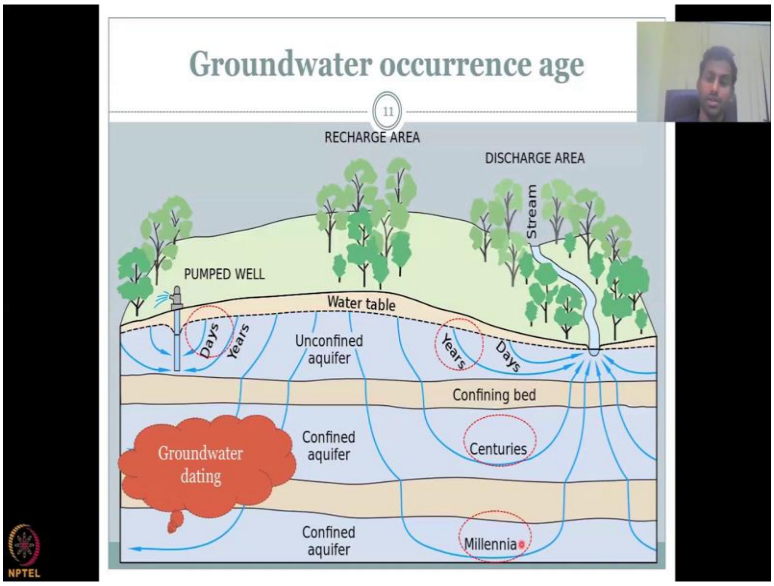

The other point I wanted to take away here before we conclude is that groundwater takes its time for recharge, it does not reach as fast. You can put a pump and take the water within a month or your season in three months, but the water that comes into your pump will take one year. So, whatever water you used from the previous year, you cannot use successfully within a couple of years.

So, that is what has happened because of the technology and development in pumps. You have put the pumps you are using the water, yes, but is it an annual water, no. It is a water that has been stored for years. So, you could see that some aquifers or some storage units, the water takes days and years to come. Whereas some units it will take centuries. And some unit will take millennia thousand years for the water to come.

And all these have been proved through groundwater dating studies wherein radioisotopes have been used to date the water like carbon dating, and they have found that the water that particularly very deep locations have taken a 1000 years to the recharge.

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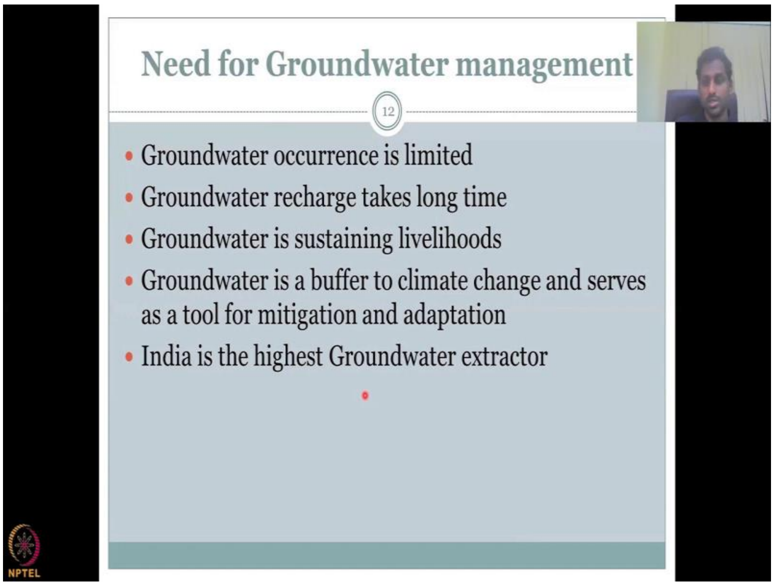

So, with that, we are going to conclude on a driving statement for the need for this course. Groundwater occurs is limited and also your food production is increasing because the population is increasing, tremendous stress on the farmers. So, what can they do? They have to eventually go to groundwater aquifers to take the water, irrigate and then feed in. So, the growing population puts tremendous stress on increasing the food production in the country. So, do not waste food.

And also coming back the farmers have no choice. But to continue if the situation continues. Like you have to eat rice, you have the paddy and other things which are consuming water, sugar for example, too much water, then they have to get a groundwater aquifers and then pumped. Remote recharge takes a long time. So, it is not as quick as you pump the water gets recharge.

Groundwater is sustaining livelihoods because farmers, industries, etc. they take this water for their use, even urban centers when the public supply through pipes is failing. They take groundwater to serve to support their livelihoods and sanitation. Groundwater is the buffer to climate change and serves as a tool for mitigation and adaptation. It is one of the best I would say to which is available.

And India is the highest groundwater extractor in the world. It extracts almost 245 kilometer cube, which is more than the combination of the next two countries which is US and China put together. So, let us think about that and see if this course is very-very important and needed.

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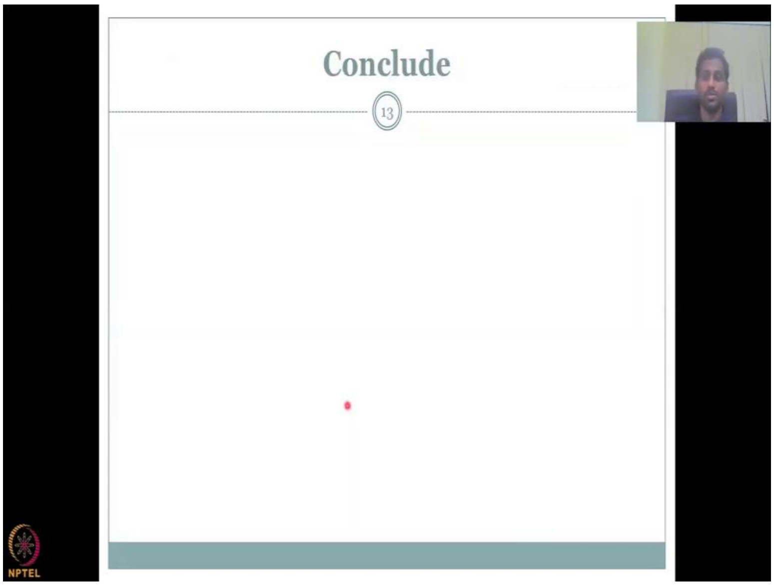

With this, I would like to conclude the course for the first week and the introduction part is over and we will be jumping into the specifics on groundwater hydrology in the weeks to come. Thank you.