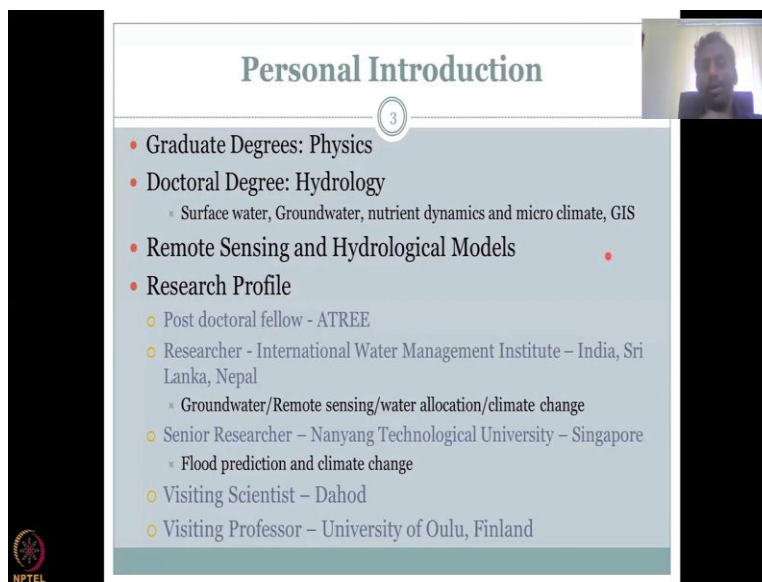**Groundwater Hydrology and Management**
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Week-1 Lecture 1
Introduction to Groundwater 1

Hello everyone, welcome to NPTEL course on groundwater hydrology and management. This is a very unique course looking at specific ground water hydrology and how you manage it across. We will be looking at both rural and urban regions in this part. And we will also discuss why groundwater hydrology is very important, and knowing groundwater hydrology, how you could manage it well with this lecture.

Let us go to the first lecture of the first week, which is starting from today. I am an assistant professor with a Center for Technology Alternatives for Rural Areas, which is a unique department and a special department of across IIT systems because Center for Technology alternatives for rural areas, works on the ground with rural communities problems and tries to seek solutions through technology and development.

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Before we get into the actual course, I would like to introduce myself and discuss how I got into groundwater hydrology, which is very near and close to me. I have graduate degrees in physics, I have one Master's in physics from Bharathidasan University on theoretical physics, then I have a Master's in physics on experimental physics. And then I did my PhD in hydrology.

So, I jumped from physics to hydrology. But however, most of the transfer was easy, because all the hydrological problems as an experimental guy, I found it coming from physics. So, physics is still has the fundamental equations for understanding the process behind hydrology. So, in hydrology, I was trained in surface water hydrology, groundwater hydrology, and also on the nutrient dynamics occurring due to the hydrology and also on microclimate and climate change, because of the changing climate and weather patterns.

I also developed some expertise in GIS and remote sensing because when I came back to India, after my PhD in University of Missouri in US, I found that data was limited and to augment to add more data, we needed to have different data sources. And remote sensing is one such a source, where we have multiple, proxy data for using hydrological models. So, I learned remote sensing in hydrological models.

Then my research profile started as a fellow with a ATREE in NGO in Bangalore. And I was a researcher focusing on hydrology at remote sensing at International Water Management Institute. Then I was placed in offices in India, Sri Lanka, and Nepal, where I did mostly groundwater hydrology research that did some studies using remote sensing in GIS. And also I looked at water budgeting and climate change.

Then I was promoted as a senior researcher at Nanyang Technological University, which is a key University in Singapore. There I did a lot of PCSWM modeling in flood prediction for the island state of Singapore. A lot of climate change extremes happen and because of that island nations are under tremendous risk. So, some of my work lead into discussing risk analysis. I am also a visiting scientist in Dahod which is with an NGO called San Sadhguru Foundation.
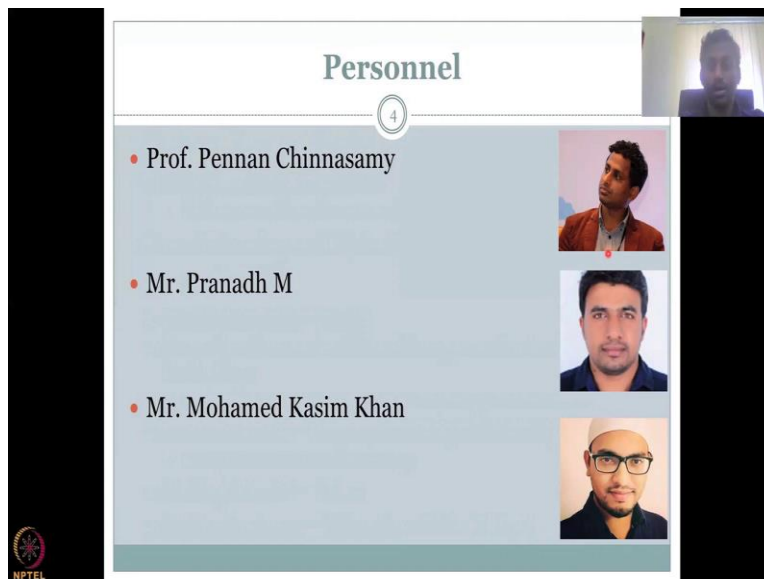
And I am also a visiting professor at university of Oulu, Finland. So currently, I am an assistant professor with a Center for Technology and alternatives for rural areas in IIT Bombay. And I also lead data group called RuDRA which means google data research and analysis labs. It is a data lab focused on rural development. Where multiple data comes in and we use it to find reasons for the issues and how we could better manage them.

So, my background has clearly said that I have been across disciplines but mostly focusing on water in the last 10 to 15 years. I have been working on hydrology and most importantly, groundwater hydrology. I do have experience as a field hydrologist where you go and put in

instruments and measure the parameters. And also I have experience where there is no data I have experience on using GIS and remote sensing.

And using the data that I collect from remote sensing, I used to drive models. So, all these three phases in groundwater hydrology is very important. And in this course, we will be getting an introduction to the complexities of ground water and the theory behind that so that we can better understand it.

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But this I would like to also introduce my team and I am the lead instructor professor Pennan Chinnasamy and Mr. Pranadh M is TA he will be assisting you with all the questions you will have on your home works course curriculum and also another TA is Mr. Mohamed Kasim Khan he will be joining Pranadh on helping you maneuver through this course. Both Pranadh and Mohamed Kasim Khan are PhD students at IIT Bombay.

And they work on hydrological models drought, flood protection, mitigation, and also data structures. Both of them are currently PhD under me.
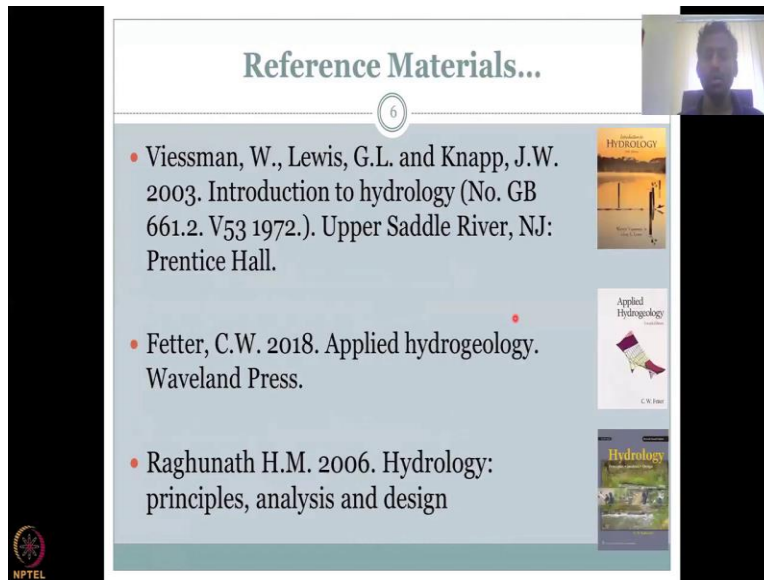
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And then, after the introduction of the personnel, I would like to introduce some books that we will be using for this course. The most important book I would recommend is Freeze and Cherry groundwater book. A lot of government agencies across the world have been using this book and one of the lead authors has been awarded the Stockholm water price which is relevant for today. And also it is as big as an award and it is considered as the Nobel Prize for water in by many people.

So many hydrologists rank this award as very big. So, one of the authors have this award so there is a such a detailed book. And even today, even though it was in 1979, it has been widely used. Then because we are discussing about groundwater, there are some surface water and overall hydrological components we need to be very acknowledgeable about. So for that we have principles of hydrology book by Warren and Robinson.

Where you get the understanding of the basic hydrology. Then we also have physical hydrology book by Dingman. And these books even though they are old, outdated, people might think it is not the case. Because the principles and fundamentals of hydrology and ground water is the same. The physics and the science is the same, maybe the management etc. would change.
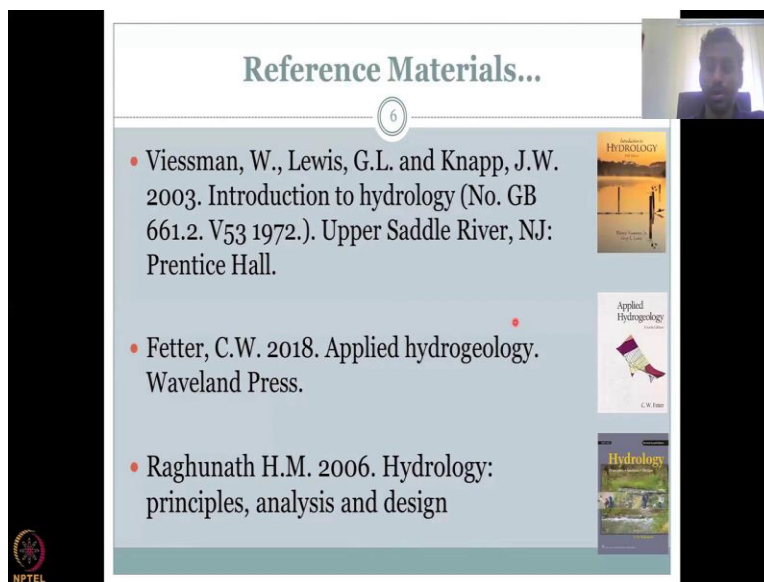
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I also have some more other books, Introduction to hydrology by Viessman at a 2003. It is a good book, I have taken some notes out of it and more important if it is applied hydrogeology Fetter 2018. So for India based India focused work extensively the hydrology principle analysis and design book by professor Raghunath 2006. On top of this, there has been a lot of discussions using my field experience for the past 15 years.

We will be discussing literature, which is very new and relevant. That literature published in international scientific journals and academy thesis. We would also be looking at government reports and NGO reports. They might not be as cited as papers because they are not in the

scientific scholar domain. However, those reports are very, very important because it is a government's report and NGOs work on the ground.

Their mandatory is not to publish as a academic journal or an academic work. Because for them, they would like to share their results and reports widely. And for that nonscientific journal publications is what they choose. So, we will be looking at a lot of those reports and books for this class.

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So, course introduction and topics will be covered today. So, this first lecture is to sensitize everyone on the course, course need and this is the hydrogeology map of India around the central ground water board. In short, it is called the CGWB it is a government of India entity who is the key for monitoring groundwater across India. One of the course does and topics that will be covered most importantly groundwater hydrology.

We will be looking at the overall groundwater hydrology importance in India. Why do we need to have such a course for India? So, that will be covered and also introduction, data and modeling. In this course, we would look into how to collect data how to use collected data from government records and NGOs resources. We would also see how you could understand the need for modeling.

Because modeling itself is an advanced course you would need a longer lecturer for that or full lecturer series for groundwater modeling. What we would be looking at here is an introduction to

models, how they work, what do you need to run the models in terms of data, computing power, and also understanding. Then we will look at a lot of case studies. Case studies are very important to understand the application of groundwater.

So, if you look at the way the course has been constructed we given introduction to groundwater and its components, we discuss about the importance. Why you should be have such a course for India?. And then we get into knowing the concerns and issues in India, we get into collection of data, monitoring data, and then modeling. And then we look at case studies, case studies, from government reports and journals et cetera.

And my personal fieldwork on how these data and other aspects can clarify us on the problem of groundwater in India. And then we would slowly get into understanding the methods to solve this big problem for India.

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Before I jump into week 1's structure, I would like to also look into the course introduction, which I break up the different week structure. For today's lecture would be trying to sensitize on how the course would be staggered, and what would be taught in every week so that a students who want to attend the long term can have a vision. Otherwise, I do not want to keep you and have later a concept which you may not be interested.

And I also dont want to give surprises on your week contents. So, I will discuss in the first lecture, which is today, the overall week structure and what will be covered in these lectures. So,

in the first week, it will be mostly introduction, I would go week by week topics what to expect and what not, so that you can also prepare for example I do have some topics on GIS. So, you could go and see what is GIS? What is remote sensing? What do you mean by satellite data?

So, those things you can have self-learning a little bit, but most importantly, it will not be in detail, it will be an introduction, so it will be better to understand this through some homeworks. Introduction to groundwater and why it has to be studied. We will be going through that aspect today. And let me start with that aspect. So this is the central groundwater boards latest report at 2020 giving an image of the monsoon level in 2019-2020.

So, this image shows the groundwater depth or depth to groundwater for the year 2019-2020. And you can see that some of the regions are dark red, which means it is very, very scarce the water. just for now let us look at dark red and pink as the concern areas. We will get into why is concerned etc. So, let us come back to why should we have such a course for Indian context ground water course.

It is very important because India is first an agrarian nation, which means, most of the livelihood for Indian population is still through agriculture or agriculture allied industries like food, cooking, or the allied industries transportation shops, selling groceries, fruits etc. But farming is the biggest livelihood option in India by population. And the second part is not all groundwater or surface water is used equally in India for irrigation.

So, if you take traditionally the olden times, most of the irrigation was through surface water or rainfall. So, not all land is only used for rainfall irrigation in India, there is a lot of use for groundwater. Groundwater access has become very easy in the recent years, because there has been a lot of technology and development on pumping and installation of pumps to collect water. So, initially the wells were done by hand you know, people used to dig well or tank and et cetera for water.

But nowadays, you can just have a rig or a big machine which is mounted on a truck, it can come through your area anywhere any area village, put down the borehole and then go for one lakh or two lakh rupees. So, the Ease in groundwater access has come and also the pumping cost has come down the power needed to come the water has come down through diesel power and also electricity motors.

The other thing is agricultural expansion. Indians have also looked at the population at a very, very different angle right. India is set to overtake China some years which means the population is ever increasing and the weight of supporting the food distribution or feeding this growing population is on farmers not on technologies not on any different group of science and technology it falls on the farmers, the farmers have to feed correct.

So, what do they do? They are forced to increase the productivity to increase the yield by going multiple times. So you can have one feed you can grow once and feed people but if the food is not enough, what do you do? You grow again, you grow again okay for which water is one of the most important resource for agriculture. So on one side population is increasing because of which food demand is increasing.

And because of the food demand, your water demand has been increasing. Because agriculture is driven by water. And all water, which is used, is not only from rainfall or dams and canals. So that is why groundwater has been used. So that is point number 1. In point number 2 climate change extremes have kicked in. And in the recent years, you have seen a lot of droughts and floods in India, which means the availability of rainfall is questionable.

It is not happening in distributed time so that you can use it widely for 3 months for example, a crop, if you have monsoon for 3 months, you are fine. But what happens if the rain is concentrated in one month or two months? We will get a big flood and that flood can wash away your crops. More importantly, there is no water for growing the crops or sustaining the crops and at those circumstances groundwater is used.

So groundwater has become the buffer or saving tool during climate change extremes both floods and droughts. So there is no rainfall for one year or two years because of a big drought. Then groundwater was being used to augment and grow the crops. So groundwater is a tremendous pressure, especially in India, because of these two factors population, food, and then climate change extremes et cetera.
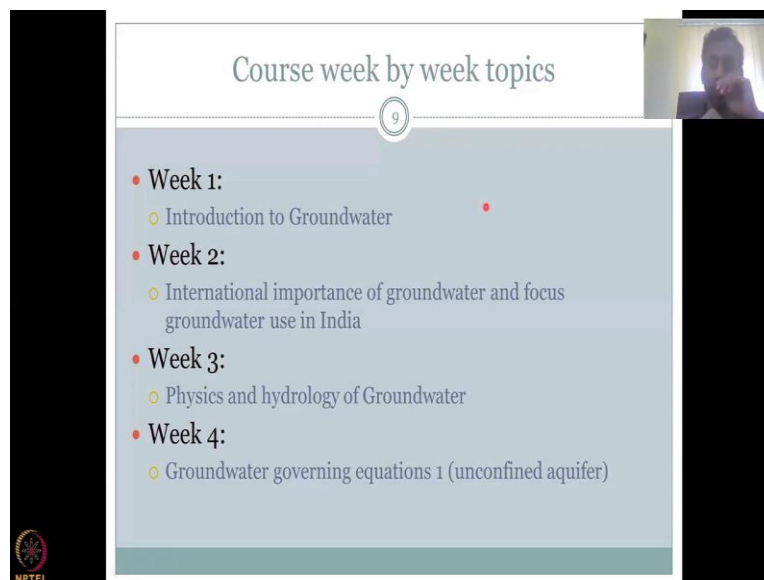
And because of that, India is the world's leader in extraction of groundwater, CGWB approximately estimate said to be 245 kilometer cube or billion cubic meter. Which is almost almost higher than the total ground water extracted by US and China. So, I say almost because

China's numbers estimates is not very clear for everyone but US is. and if you know the crops, irrigation patterns, et cetera, we can estimate.

So the estimates now tell us that, even if you take groundwater used by US and ground water use by China which is that second and third ranking highest extractors of groundwater, India's groundwater use is much, much higher. We do not have as big of an area like US or China, we do not get as much rainfall as US and China. But we are putting so much pressure on groundwater.

So by these factors, I hope you understand that understanding groundwater is very, very important for India. Preserving groundwater is very important for India. And managing groundwater in a scientific way, is important for India. And for this, this course has been designed to introduce the concepts to sensitize you on groundwater hydrology, and the methods of management practices.

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Let us look at the course week by week topics. In the first week, we would be looking at the introduction to groundwater, and also why groundwater is important. In week two, we would discuss some international use of groundwater like in different countries, how it has been used. And we would focus more on groundwater use in India. So, we will have understandings from other regions, what do they use it for? How do they grow the crops etc.

And then we will focus on groundwater use in India. Week three, we will discuss the physics and hydrology of groundwater. As I said, physics drives these systems. And it is very, very important to understand why water would get into the ground, why water moves across the ground as groundwater, and also where does the water go in by what processes what is the pressure, how does the flow from one point to another point all these different aspects we will be discussing.

In week four, we will be looking at groundwater governing equations as I said, once the physics is established, you will have a setup model or understand the groundwater. So, there are water governing equations, we should be discussed in week four. And there are two major types of aquifers unconfined and confined. In the week four we would look into the unconfined aquifer. This type of aquifers will be discussed earlier for your benefit in week three.

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Moving on in week 5, as I said we would be looking at groundwater governing equations for the confined aquifer which is the part 2. So, both are very important to give you a small peek. So, groundwater 1 equations would be on unconfined which is your shallow wells, where farmers can dig a well and the excavate land a little bit to have a big well and then they take water out. Whereas your weak five would be on the deeper tube wells which more urban houses uses.

And then you have farmers pumping water from deep, deep bore wells. So, those equations are different, both are separate and they will be different and we will be looking at what are the equations that govern and how they govern the system. Week six is important once we

understand the differences between the two, then we would also understand the need for recharging and discharging these two units differently.

So, in combination we would be looking at ground water recharge and discharge. Once we understand the concept of groundwater recharge and discharge we will get into types of groundwater wells and pumping sources. So the types are very important to understand the groundwater reuse. So, just using it abuses overusing it and groundwater conservation. So for that, it is very important to understand the structure of groundwater wells, because only through wells, you are accessing the groundwater and also understand the pumping sources.

So, we will just distribute our focus on not only wells, but also understanding the types of pumping sources, water being used differently through the groundwater wells, all those things we will be discussing in week seven. In week eight, with all these understandings from the previous weeks, we would construct a conceptual model for groundwater. A conceptual model is something that and explain the processes visually.

So, if you have the equations and if you have the types et cetera on paper, or on a report, it is not as clearly driving the message. But an image which is captures all these aspects can be used as a conceptual model. And, and those models are the base for groundwater models where you need to first create the conceptual model and groundwater model is being run. It is similar to solving any physics problem was what do you, what is your your professor or teacher asked you to do?

First draw the problem, right? If you have a physics equation about motion, or velocity finding the acceleration, they will ask you to draw, and then put the values and then give. So, similarly a concept can be put in as a conceptual model for groundwater.

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Moving on, in week nine, we will be looking at groundwater data in India, what are the different data resources that we can use? In week ten, we will be looking at management around water quantity and quality in India. So this week is very specific about how can you manage the ground water, both quantity wise and better quality wise for India. In week 11, we will be introducing some groundwater modeling and groundwater software packages in this lecture.

It will not be a full-fledged in depth exercise, because both of these topics will itself take a course. So, in the week 11 will be only introducing you to what is the groundwater modeling

concept, how do they model it with a computer simulation? And what are the different ground water software packages both open source and pay per use models?

And then we wrap everything up at week 12 by discussing some cases studies in India very important case studies which have been considerably used and widely discussed in India. So, that you get an understanding of why we need to study groundwater and how can we use groundwater in solving these problems but this I will see you in the next lecture. Thank you.