Course Name: Watershed Hydrology

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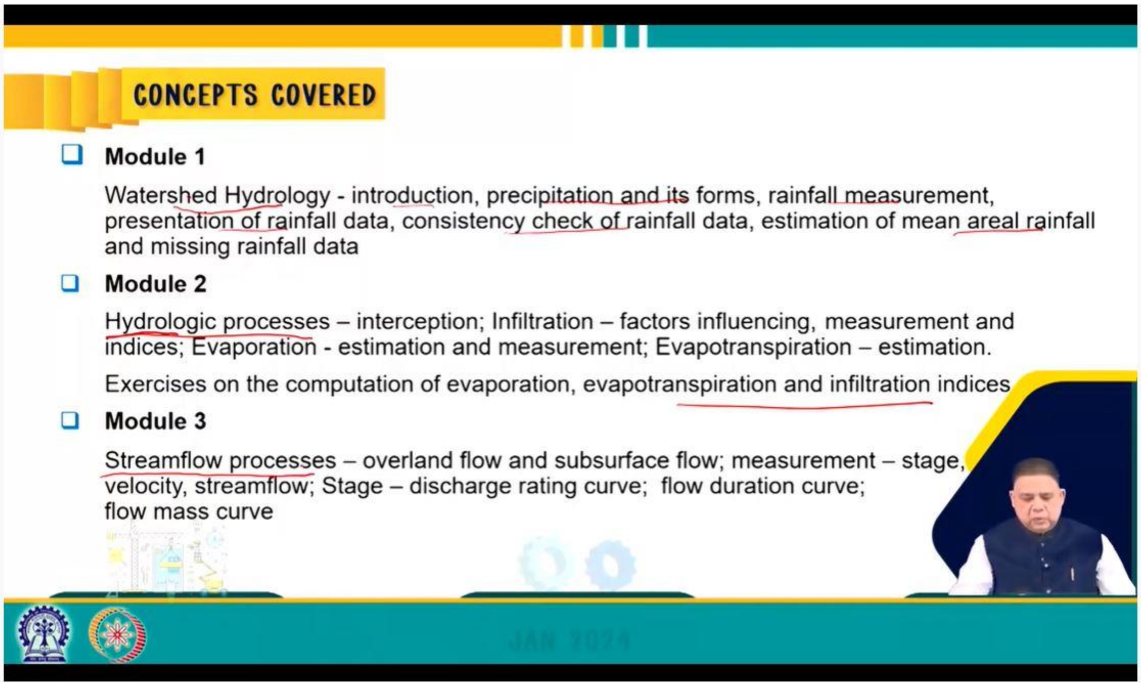
Week: 01

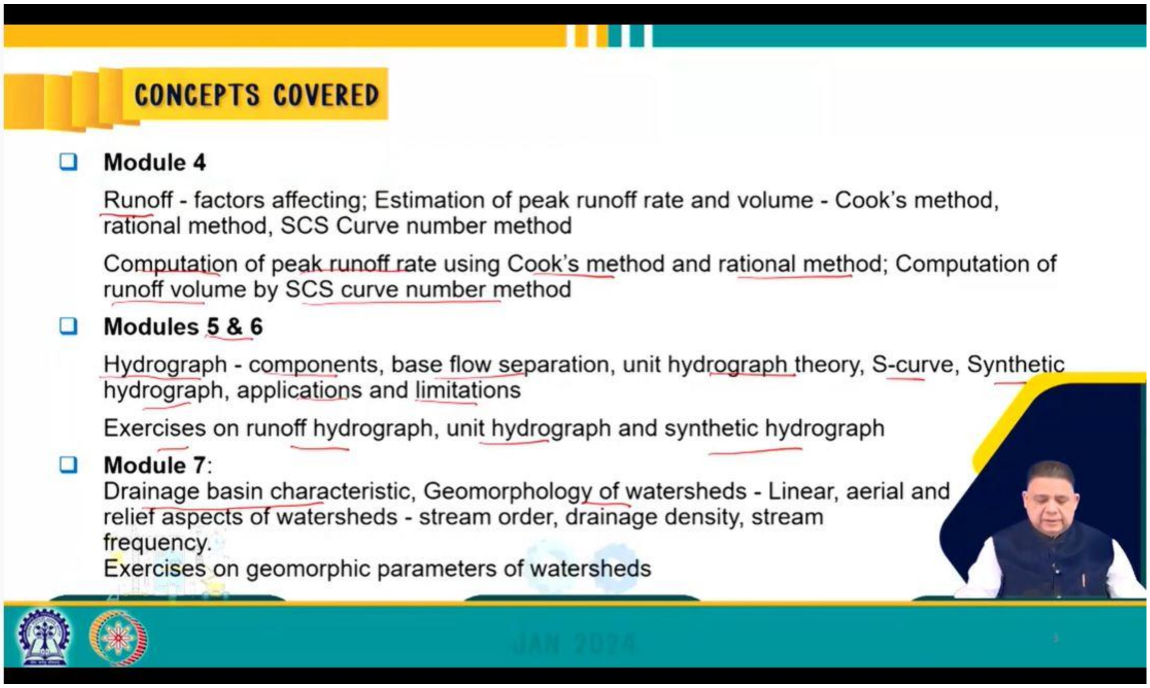
Lecture: 01 - Introduction

Hello friends. Welcome to this online certification course on Watershed Hydrology. I am Rajendra Singh, a professor in the Department of Agriculture and Food Engineering at the Indian Institute of Technology, Kharagpur. We are starting this course today with module 1. We are in lecture one, and this is entitled Introduction. Now, before going into the actual lecture, I would like to give you an idea about the concepts that we are going to cover during this course.

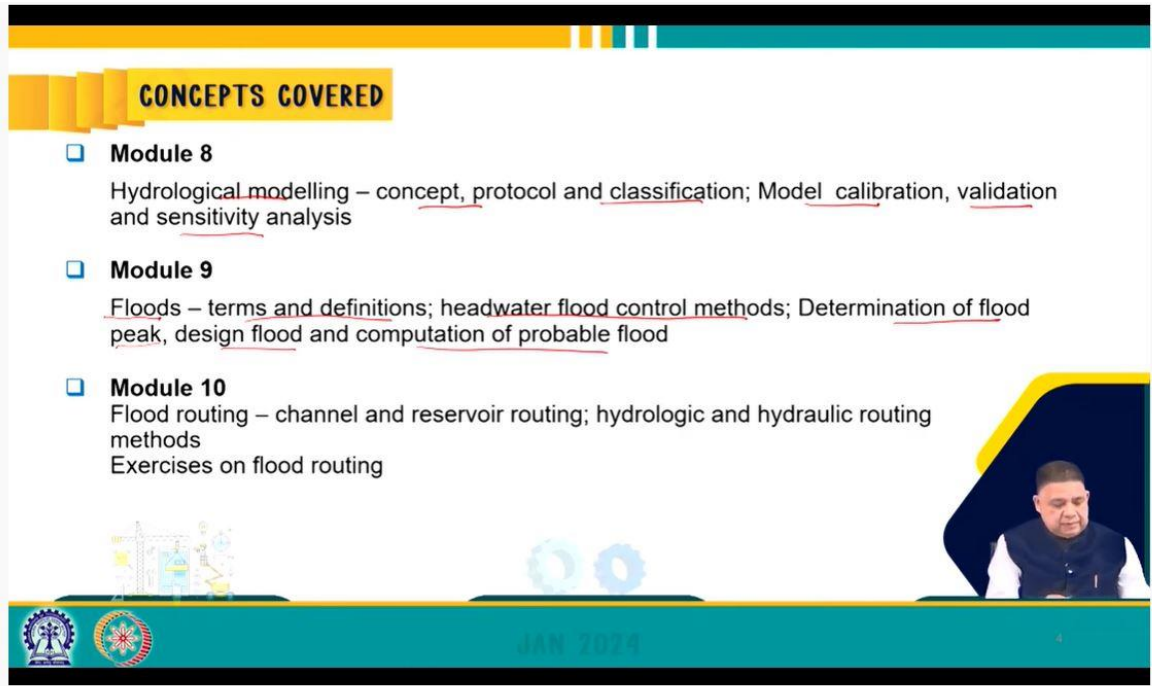


This course is divided into 12 modules. Module 1 will deal with watershed hydrology, and we will talk about the introduction; then, we will go to precipitation and its forms. We will also talk about rainfall measurement and presentation of rainfall data; then, we will talk about consistency checks of rainfall data and estimation of mean aerial rainfall and missing rainfall data. Then, module 2 will primarily deal with hydrological processes. That is, we will talk about interception, infiltration, factor influencing, infiltration, measurement and indices, evaporation, its measurement and estimation and estimation of evapotranspiration.

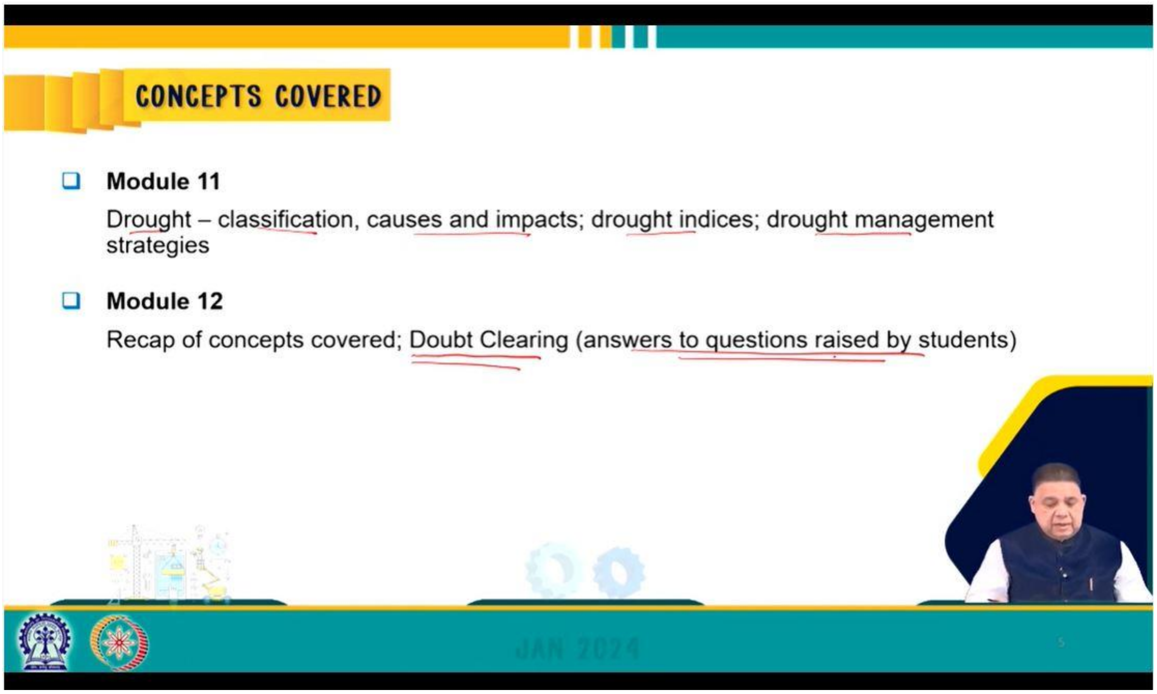
We will also carry out exercises on the computation of evaporation, evapotranspiration and infiltration indices. Module 3 will discuss about stream flow processes, that is, overland flow and subsurface flow. We will talk about stream flow measurement, which is basically a measurement of stage, velocity, and stream flow itself. Then, we will talk about the stage-discharge rating curve. We will discuss the flow duration curve and flow mass curve.



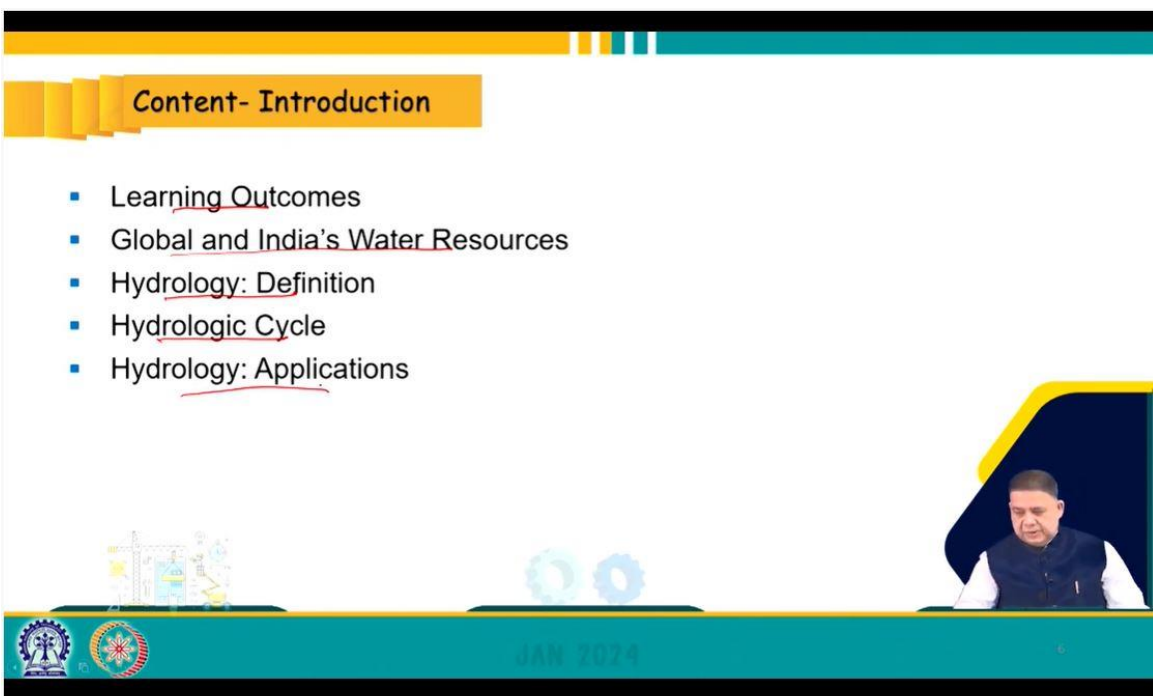
Module 4 will deal with runoff, that is, the factors affecting runoff, estimation of peak runoff rate and volume, Cook's method, rational method and SCS curve number methods of estimating peak runoff rate and volume. We will also include several computational problems in estimating peak runoff rate using Cook's method and rational method and computing runoff volume using the SCS curve number method. Modules 6 and 5 6 are actually two combined modules where we will talk about hydrograph that is the components of hydrograph, base flow separation, unit hydrograph theory, SCS curve that is summation curve, synthetic hydrograph and applications and applications of hydrograph theory as well as the limitations of the hydrograph theory and we will carry out exercises on runoff hydrograph, unit hydrograph and synthetic unit hydrograph. Module 7, we will talk about drainage basin characteristics, that is, the geomorphology of watersheds, linear aerial and relief aspects of watersheds, stream order, drainage density, and stream frequency, and then we will carry out exercises on geomorphological parameters of watersheds.



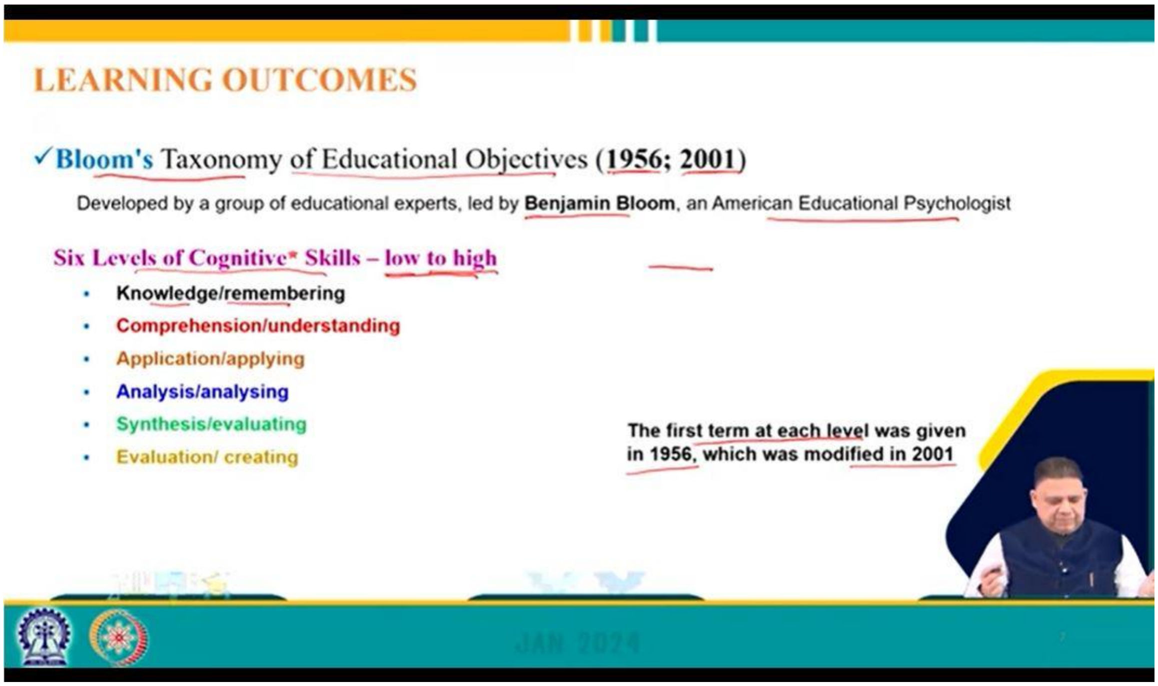
During module 8, we will talk about hydrological modelling, which is the concept, protocol and classification of hydrological models. We will discuss the basic steps of module calibration, model validation and carrying out the sensitive analysis of model parameters. In module 9, we will focus on floods. That is, we will discuss the terms and definitions; we will talk about headwater flood control methods, determination of flood peak design flood and computation of probable flood. In module 10, we will deal with flood routing, which is channelled reservoir routing. We will discuss hydraulic and hydrologic routing methods, and we will carry out exercises on flood routing.



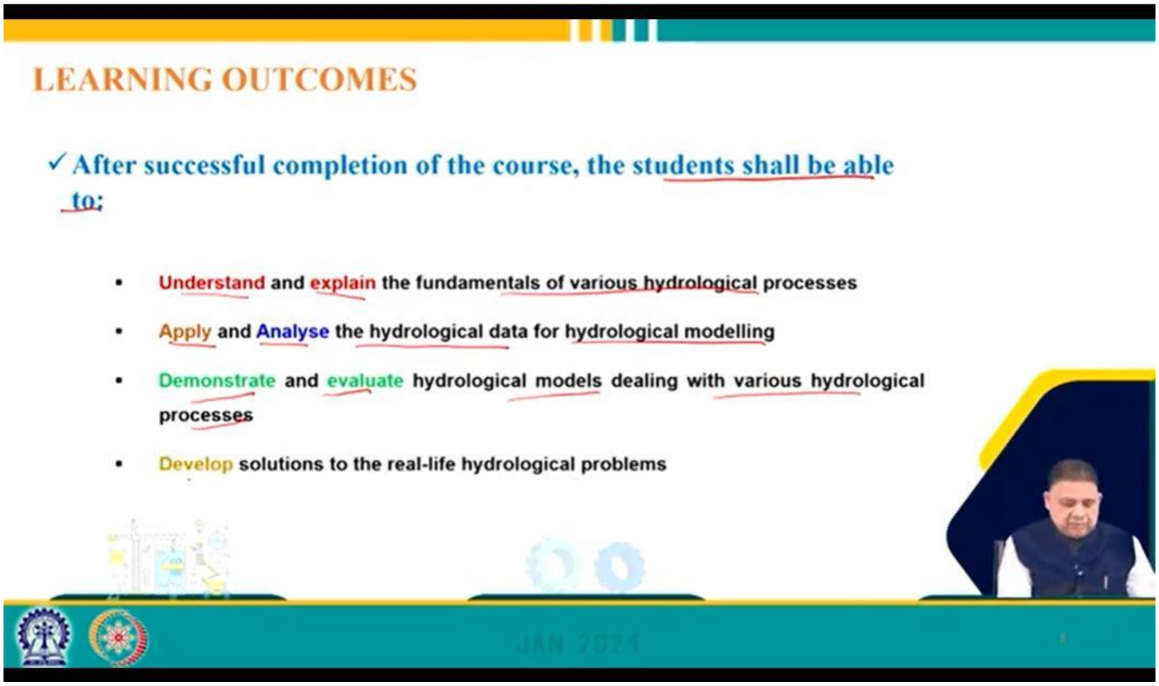
In module 11, we will talk about drought, its classification, causes, and impacts. We will talk about various drought indices that are used, and then we will talk about the strategies for drought management. Module 12, we have kept a recap of concepts that we will be covering in the first 11 modules and also will include doubt clearing, that is, answers to questions raised by students during the entire session, and I will encourage students to ask questions so that we can clarify those doubts in those lectures.



Now, coming to the content of this particular lecture introduction, here we will talk about learning outcomes, we will talk about global and India's water resources, we will define hydrology, we will discuss the hydrological cycle, and we will see hydrology applications.

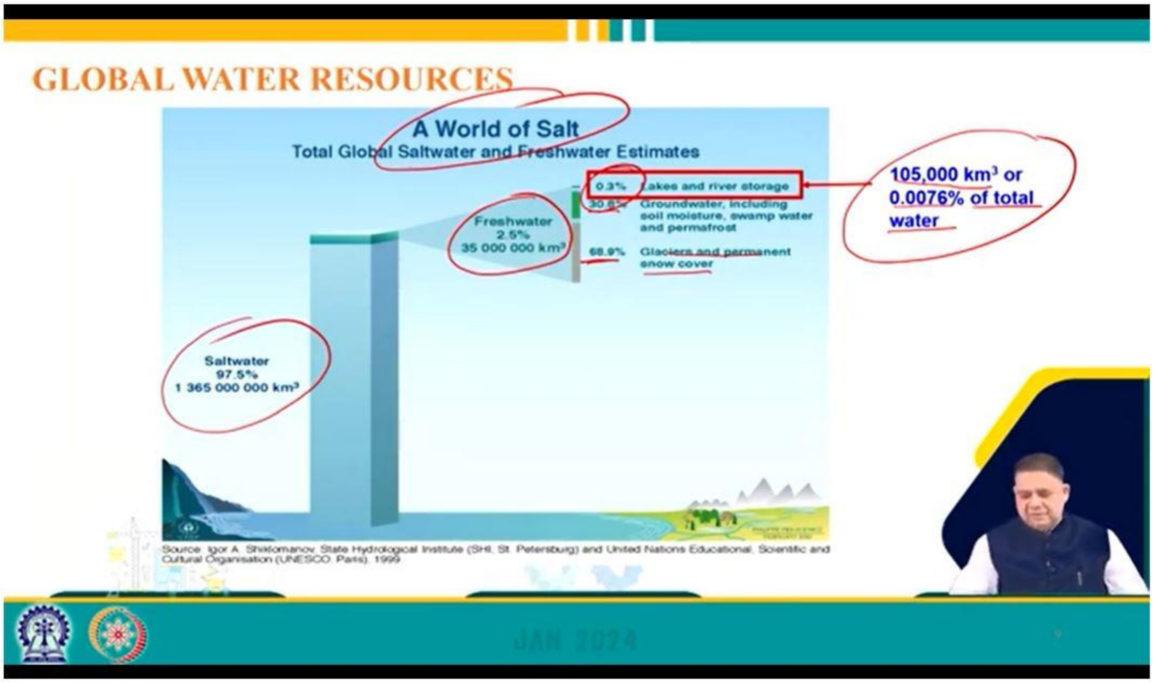


Now, before going into the course content, I would like to talk about learning outcomes and technical education. Basically, to analyse the learning outcomes, we adopted Bloom's taxonomy of educational objectives, which was developed by a group of academic experts led by Benjamin Bloom, an American educational psychologist. This taxonomy was first developed in 1956, and then it was revised in 2001. Now, according to Bloom's taxonomy, there are six levels of cognitive skills, starting from low to high, and before going into these skills, I would like to define cognition. So, cognition is the mental action or process of acquiring knowledge and understanding through thought, experience and senses. That means anything we do in order to learn a thing is cognition, and typically, human beings have six levels of cognitive skills, starting from low to high. These six levels begin with knowledge and remembering. If you look, there are two terms at each stage, and the first term at the level at each level was given in 1956 when Bloom's taxonomy first came into existence. Later on, these terms were modified in 2001.



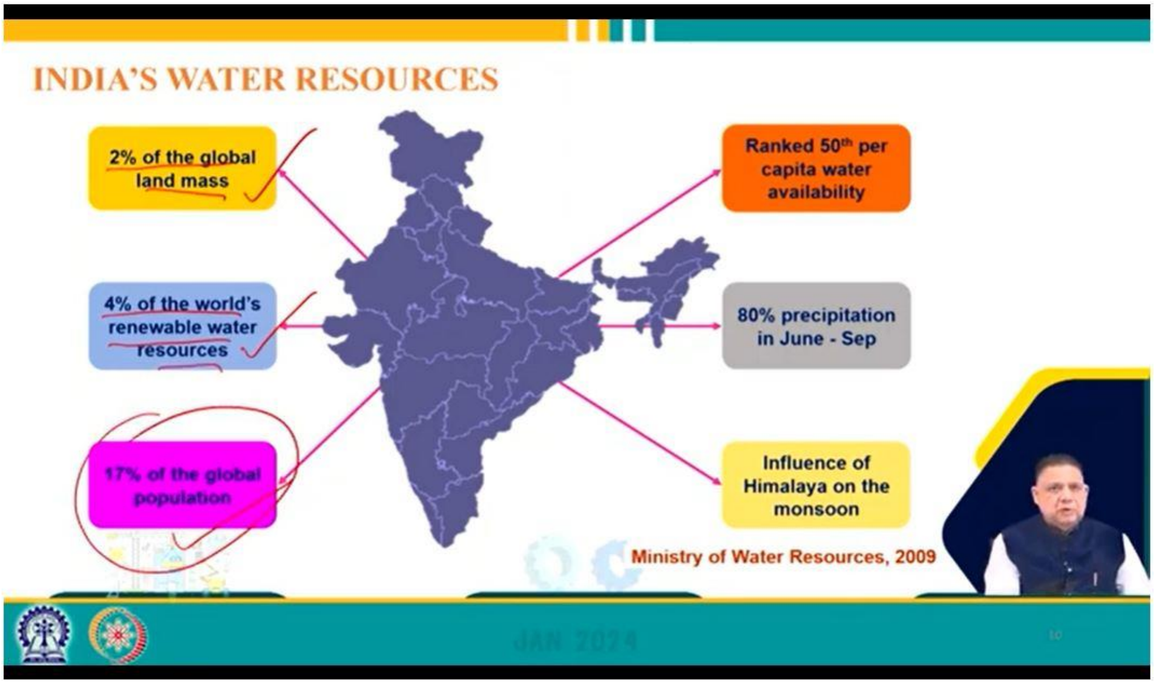
So, it started with knowledge, but now it is called remembering. This is the lowest level, and I think we all recall that when we were toddlers, our parents, especially our mothers while working even in the kitchen, were asking us to repeat A B C D 1 2 3, and that is how we remembered all those letters and numerals that is the first or lowest level of. So, once we remember those letters, then we start understanding, and that is how it comes: A for apple, B for boat, C for cat, and so on and so forth. So, we start linking what we have remembered, we try to understand with other objects, and then once we understand and remember, we start applying our knowledge. Once you apply, you have to analyse and evaluate, and once you have applied and evaluated, then, of course, you reach the highest level, which is creation or creation. Now, as far as this course is concerned, that is how we are going to link it: after successful completion of the course, students shall be able to fulfil these objectives. If you look at it here, I have used the colour code black, which is at the lowest level; I am not using that in our subject because it goes without saying that you definitely need to remember certain things in order to do whatever.

So, that is what, but the red colour is understanding. So, that starts with the students being able to understand and explain the fundamentals of various hydrological processes. They should be able to apply an analysis of level 3 and level 4 of the hydrological data for hydrological modelling. They should be able to demonstrate and evaluate hydrological models dealing with various hydrological processes, and once they are able to understand, explain, apply, analyse, demonstrate, and evaluate, then they will be capable of developing solutions to real-life hydrological problems. So, these are the learning outcomes, and I expect that after successful completion of the course, the students shall be able to perform all these basically.

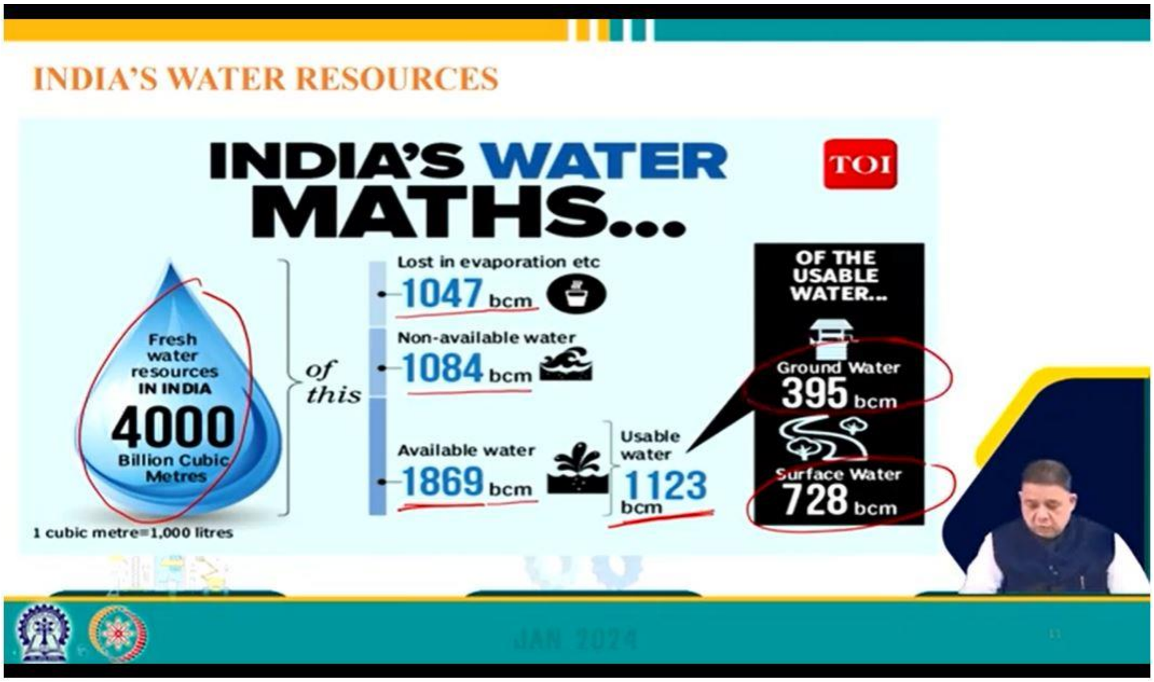


Now, coming to global water resources, as we all know, we basically live in a world of salt that is simply because around 97.5 % of the water we have on the earth is in the form of salt water and only 2.5 % of water, as in fresh water and out of this 2.5 % fresh water around 69 % lies in glaciers and permanent snow cover.

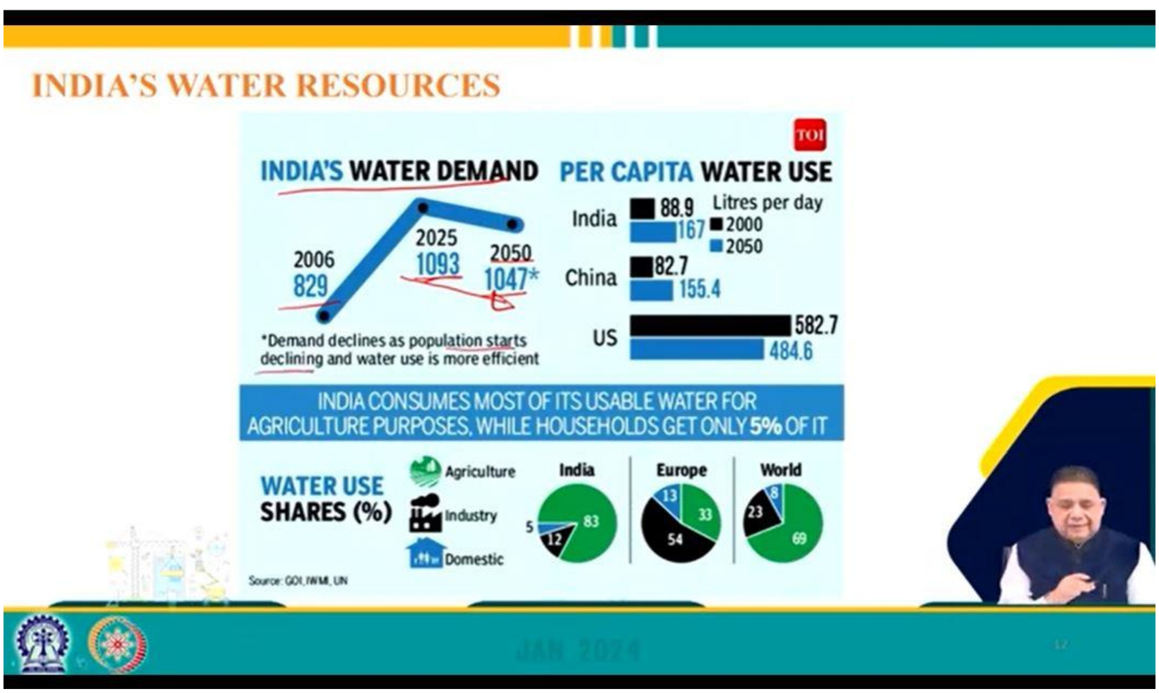
So, 38.8 % is groundwater, including soil moisture, swamp and permafrost and only 0.3 % of water lives in what we can really see with our naked eyes, that is, in lakes and reservoirs or river storage. And if you just count it, then this 0.3 % actually amounts to 1,05,000 km3 of total water or just 0.0076 % of the total water resources. That is what we really use, and we need to be careful about it.



Now, with India's water resources, we have 2 % of the global land mass. India has 2 % of the global land mass and 4 % of the world's renewable water resources, and we support around 17 % of the global population. So, that is itself a big challenge that with 2 % of global land mass and 4 % of the world's renewable water resources, we need to support 17 % of the global population, and that is why it is no surprise that when it comes to per capita water availability we rank 50th in the world. So, we are 50th in the world when it comes to per capita water availability. So, that is water, which is very precious for us from that perspective. Now, 80 % of our precipitation occurs during monsoon season, that is, from June to September. So, that is also a challenge for us, and the influence of the Himalayas on the monsoons creates further challenges as far as India's water resources are concerned.



Now, coming to India's water resources, India's water mass we have a total of 4000 billion m3 of water, out of which available water is 1869 billion m3 of which is available because 1047 billion cubic meters is lost in evaporation and 1084 billion cubic meters is non-available. As far as available water, 1869 billion m3, only 1123 billion cubic meters is usable water, and if we still break this, it is able to water. Around 728 billion m3 of this water comes from surface water sources, and 395 billion m3 comes from groundwater sources.

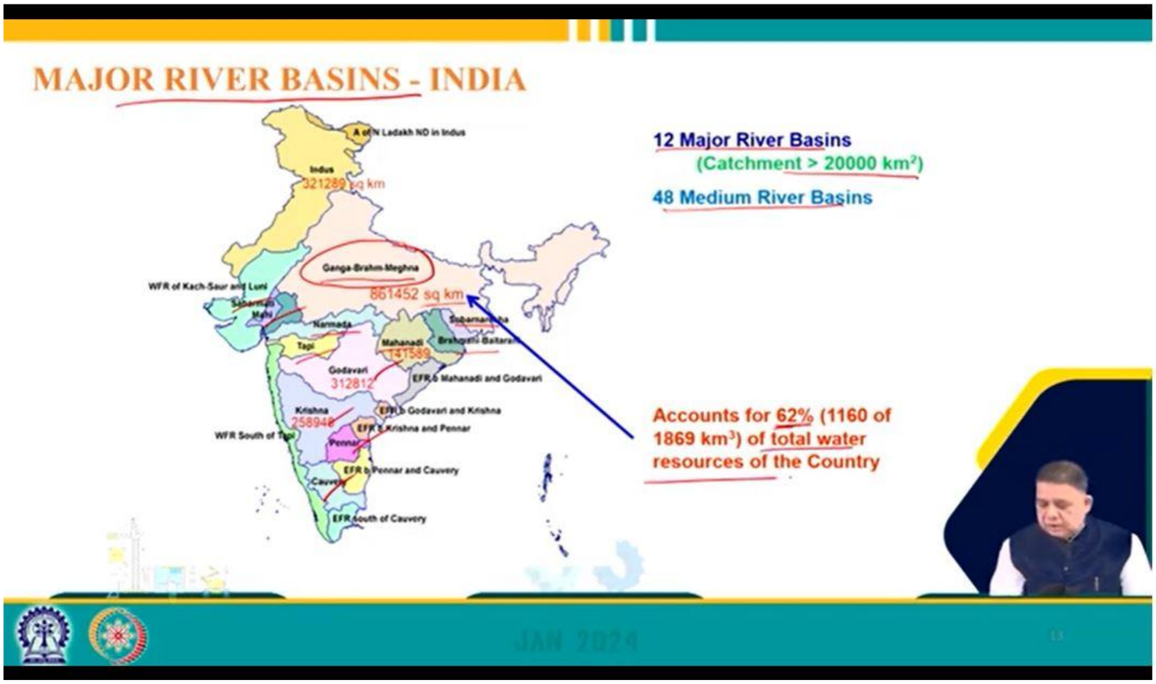


India's water demand, which was around 829 billion cubic meters in 2006 that has gone is projected to go up to 1093 billion cubic meters in 2025, but and it is projected to be 1047 by 2050. So, as you see, between 2025 and 2050, there is a projection of a decline in water demand, and that decline basically is because it is expected that our population will decline and get stable, and also, water use will become more efficient because we are every day we are getting very efficient water-efficient gadgets. For example, in our household kitchens, we now have this water, which uses only about 20 128 of water that was wasted earlier when these washes were not being used. That is why water use efficiency will go up because of modern gadgets. As far as per capita water use is concerned, in 2000, our per capita water use was 88.9 litres per day, which is likely to go projected to go up to 167 litres per day, and that is because of the changes or improvements in our lifestyle.

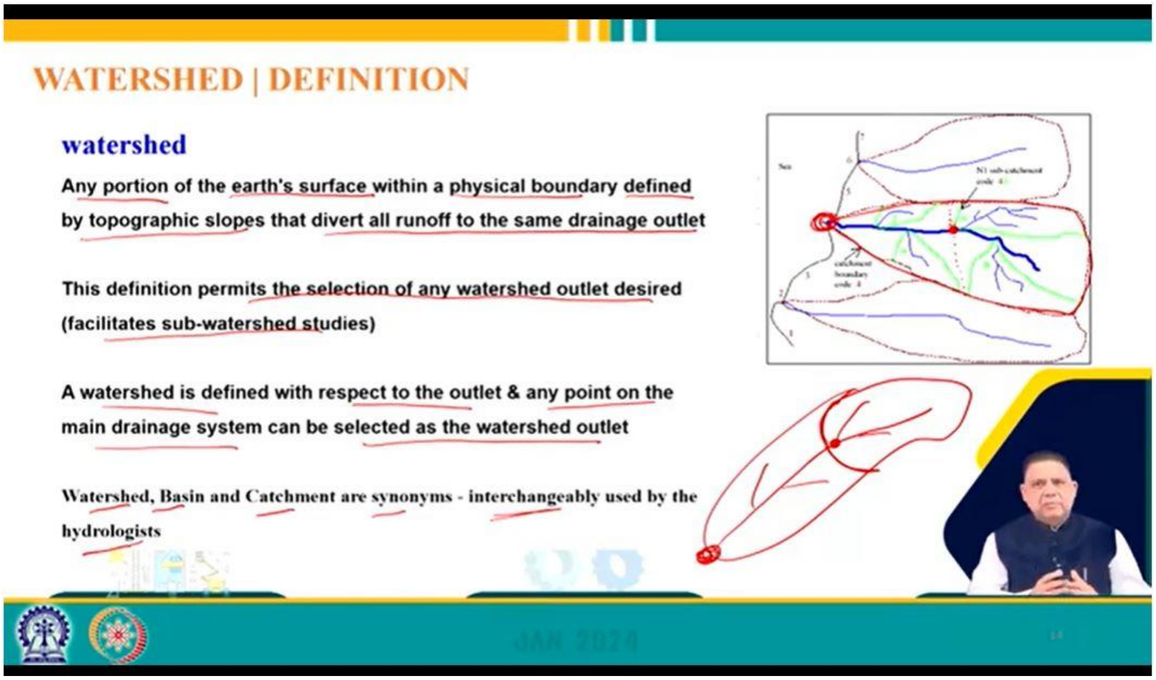
If you look at China, the numbers are more or less similar. In 2012, it was 82.7 litres per day, and in 2050, it is projected to be 155.4 litres per day, but if you look at the US, the numbers are staggering numbers because they are probably one of the largest users of per capita per day water and in 2000 the values were 582.7 litres per day, but they are projected to go down to 486 points 484.6 litres per day in 2050.

So, we are pretty stable in a sense, but not in comparison to advanced countries like the US. Now, coming to water use share % in various sectors especially, we will talk about the agriculture industry and domestic. If you look at India, most of our water use is in the agriculture sector. We use around 83 % of our water resources in the agriculture sector, 12 % in industry, and only 5 % for domestic uses. If you look at Europe's corresponding numbers, 33 % are only in agriculture, a staggering 54 % compared to 12 % in India, which goes to industry and 13 % in households so, as you can see the industrial water use shows that they are more industrialised countries and they are more advanced country.

And if you look at the world numbers, the world average in agriculture is around 69 %, industry is 23 %, and household is 8 %. So, it is probably a water challenge that we need to reduce water consumption in the agriculture sector and increase the industry and domestic sectors.



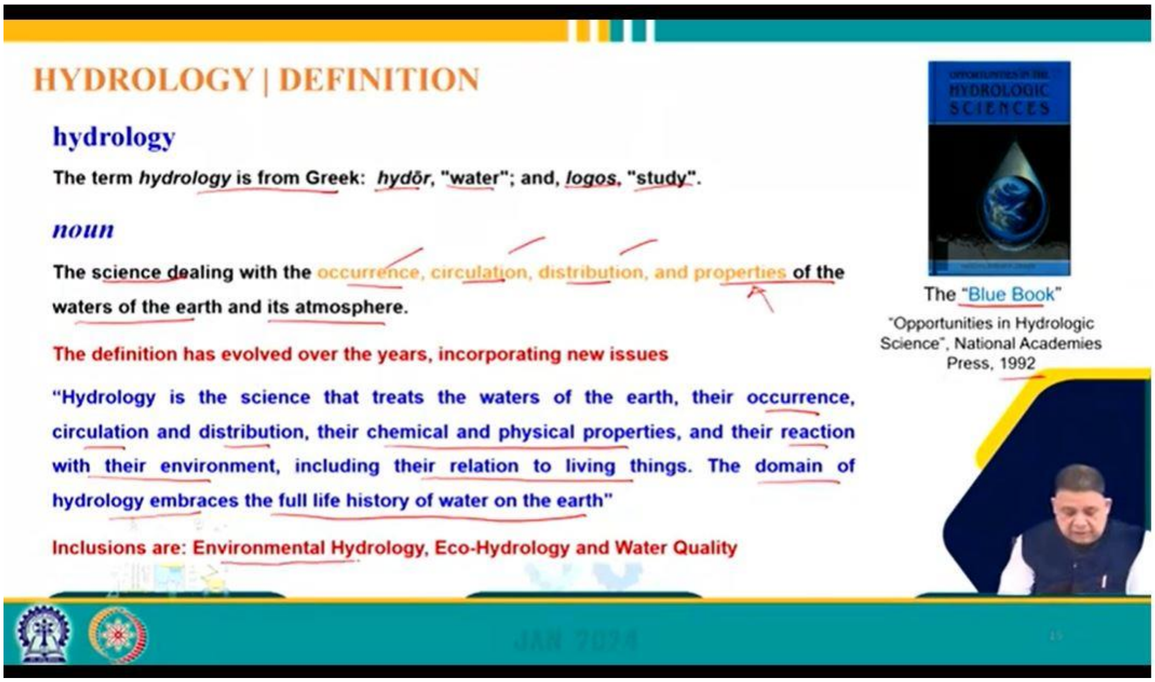
Now, coming to major river basins in India, we have around 12 major river basins, which have catchments greater than 20000 square kilometres, and we have 48 medium river basins. If you look at the map, then you can see that these major basins are Ganga, Brahmaputra, Meghna, Subarnarekha, Brahmani Baitarni, Mahanadi, Narmada, Tapi, Sabarmati, Mahi, Krishna, Godavari, Penar, Cauvery here and there are some east flowing and west flowing rivers other than these significant rivers. But if you look in a nutshell, the Ganga Brahmaputra, Meghna, which accounts for 8,61,452 square kilometres of the catchment area that accounts for around 62 % of the total water resources of the country or out of 1869 cubic kilometres of water accounts for 1160 cubic kilometres of water.
So, that is very significant from India's water resources point of view.



Now, in this course, watershed hydrology will begin by defining watershed. A watershed could be defined as any portion of the earth's surface within a physical boundary defined by topographic slopes that divert all runoff to the same drainage outlet. So, if you have any drainage area that drains water to a single outlet, then we can call that a watershed and this is also shown in this picture here. Now, the advantage of this definition is that it permits the selection of any desired watershed outlet or facilitates sub-watershed study. As you can see here, this one is a large one. is there, this one if you talk about this one, this is a watershed as per our definition because the topography is such that the entire water will be draining to outlet number 4 here.

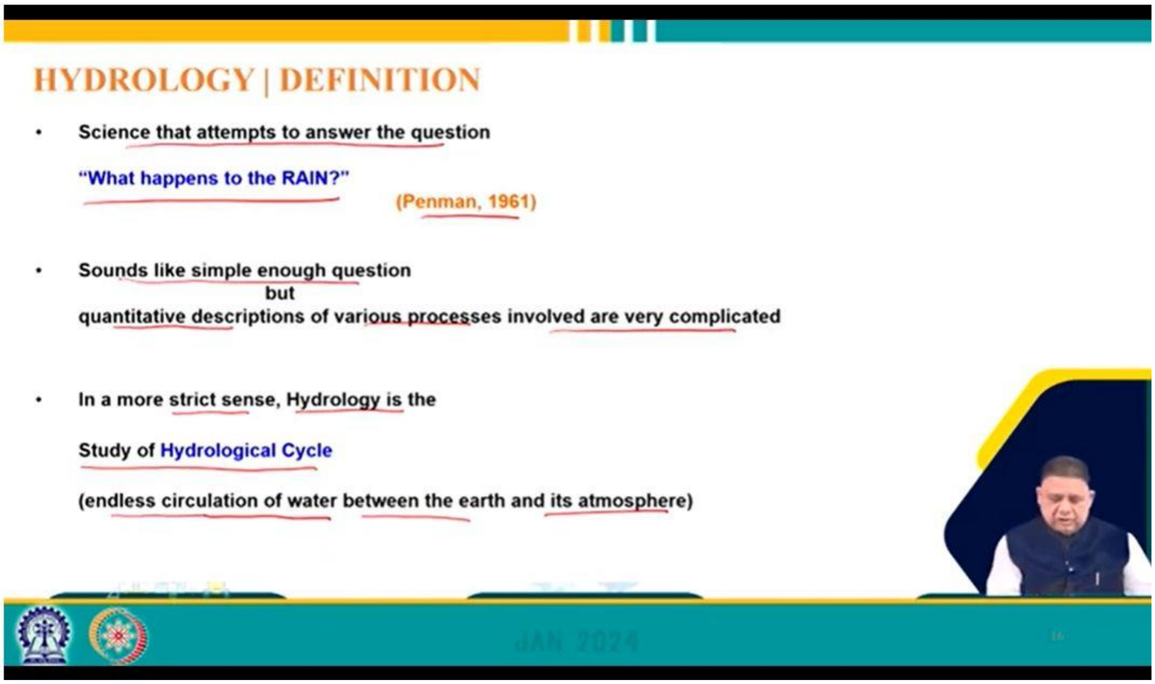
Now, the advantage is I said that this condition allows us to select watersheds anywhere. Now, suppose I want to select watershed here. I want this to be the point of my interest, and then, knowing the topography, I would be required to delineate this area. I can delineate this area. So, that becomes the catchment and the entire water from this area. If the topography is ok, then that will be draining too. So, we require a topographical map to decide on the drainage divide. So, a watershed is defined with respect to the outlet, and any point on the main drainage system can be selected at the watershed outlet.

So, that is why if I have a water project here at this point in the this river then this point this becomes my watershed and this becomes my portion of interest rather than this. So, depending upon which outlet is of concern I can delineate the watershed or the larger watershed and then I can work on that. At this point I would just like to mention that watershed basin it catchment the three terms are synonymous and they are used interchangeably by hydrology. So, many time in our discussion I will also use basin or catchment, but they all mean the same. So, watershed basin and catchment will be interchangeably used in our discussion also.

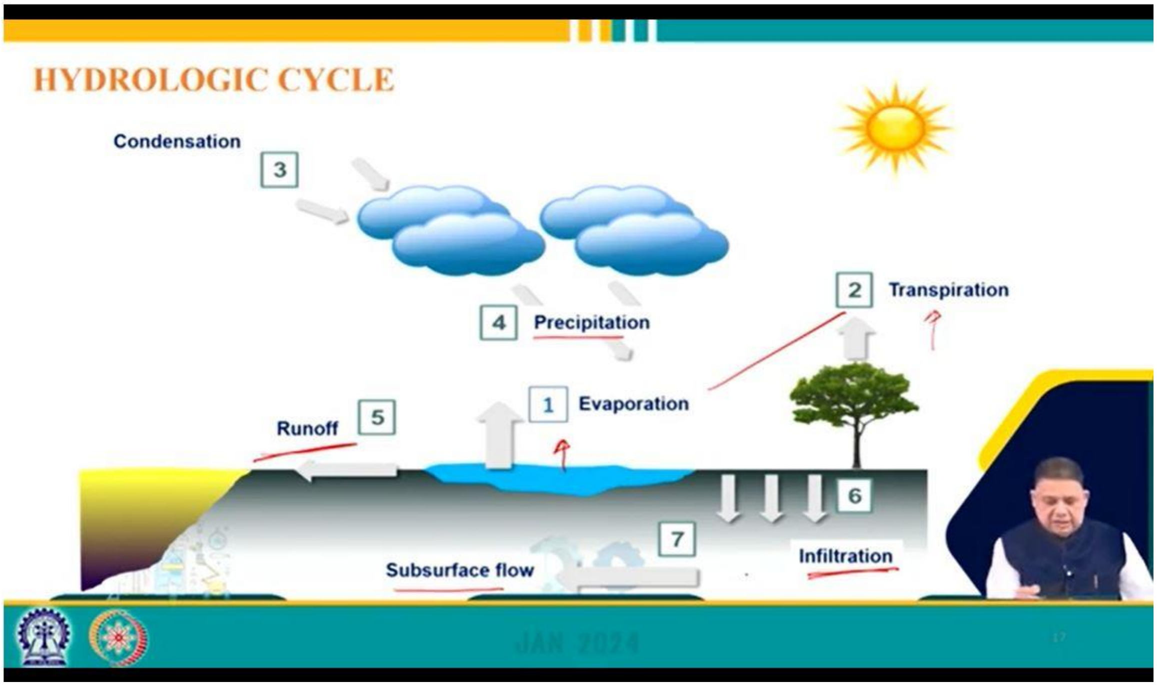


Coming to defining hydrology the term hydrology is from Greek hydor which means water and logos that means study. So, basically hydrology is study of water is a noun it does it define it is defined is the science dealing with the occurrence circulation distribution and properties of the waters of the earth and it is atmosphere. But over the time this definition has gone has evolved then lot of changes had been incorporated new issues had been incorporated in the definition. And the latest definition or the most comprehensive definition is given in the blue book which is opportunities in hydrological science published by national academic press in 1992. And as per the definition of hydrology is that the hydrology is the science that treats the waters of the earth occurrence circulation and distribution their chemical and physical properties and their reaction to their environment including their relation to living things.

The domain of hydrology embraces the full life history of water on the earth. So, as you can see that when we were defining hydrology earlier we are only talking about occurrence circulation distribution and may be properties, but not defining what properties, but in this definition clearly there are three distinct inclusions. One is the environmental hydrology that is because this definition includes the reaction of water with the environment, then eco hydrology because includes relation of water to living things and water quality because it talks about the chemical properties of water also so water quality. So, these three are new inclusions and these are the new three areas which become whichhave become a part of hydrological study over the period of time. But one of the simplest definition of hydrology was given by Penman in 1961 and Penman defined hydrology as the science that attempts to answer the question what happens to the rain.



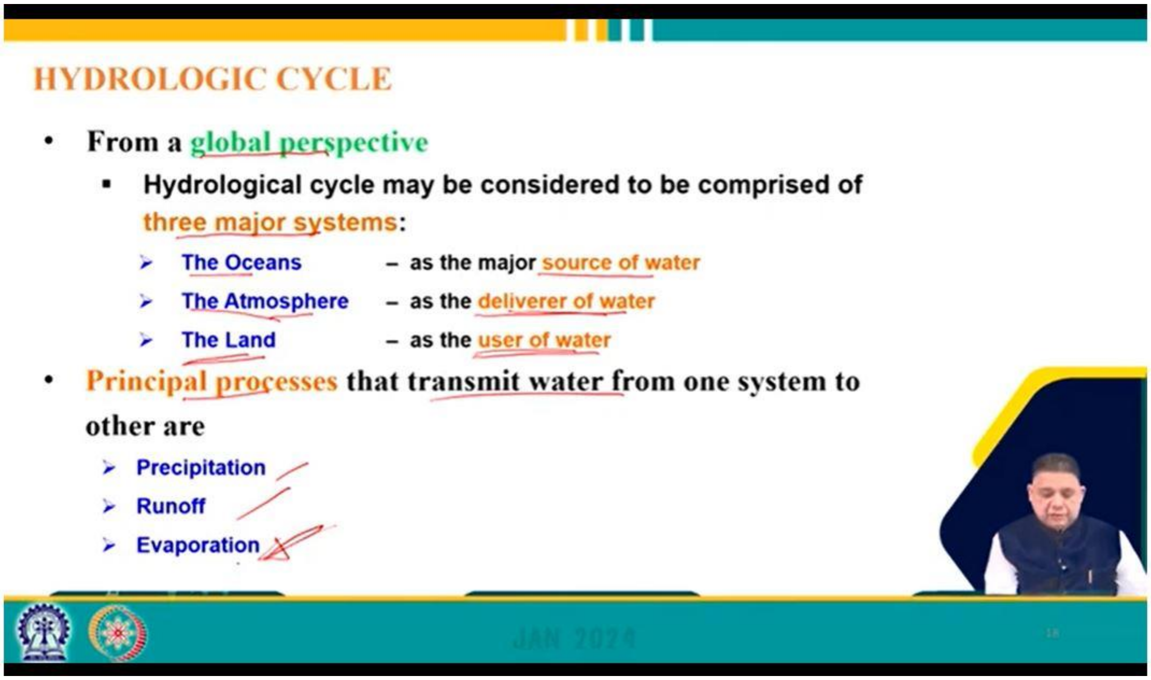
Now, we all know what happens to rain because we have observed rain rainfall occurs it is intercepted by plants and buildings it reaches reaches this ground surface flow starts taking place and several other processes occur. So, basically we all know what happens to rain and that is why it sounds like very simple question that what happens to rain I know, but the challenge is in quantitative description of various processes that are involved in the in this process within this entire phenomenon and these are very complicated basically. Hydrology could also be defined or in more specific sense it could be also treated study of hydrological cycle which of course, is endless circulation of water between the earth and its atmosphere. So, hydrological cycle is endless circulation of water between earth and its atmosphere and if we study hydro cycle then it amounts to studying hydrological hydrology.



Now, this this this is the picture of the hydrological cycle this is important and I am sure that you have also seen in your junior classes science textbooks and so, this is typically we we have an environment where clouds are there water is there, land surface there, plants are there, sun is there.

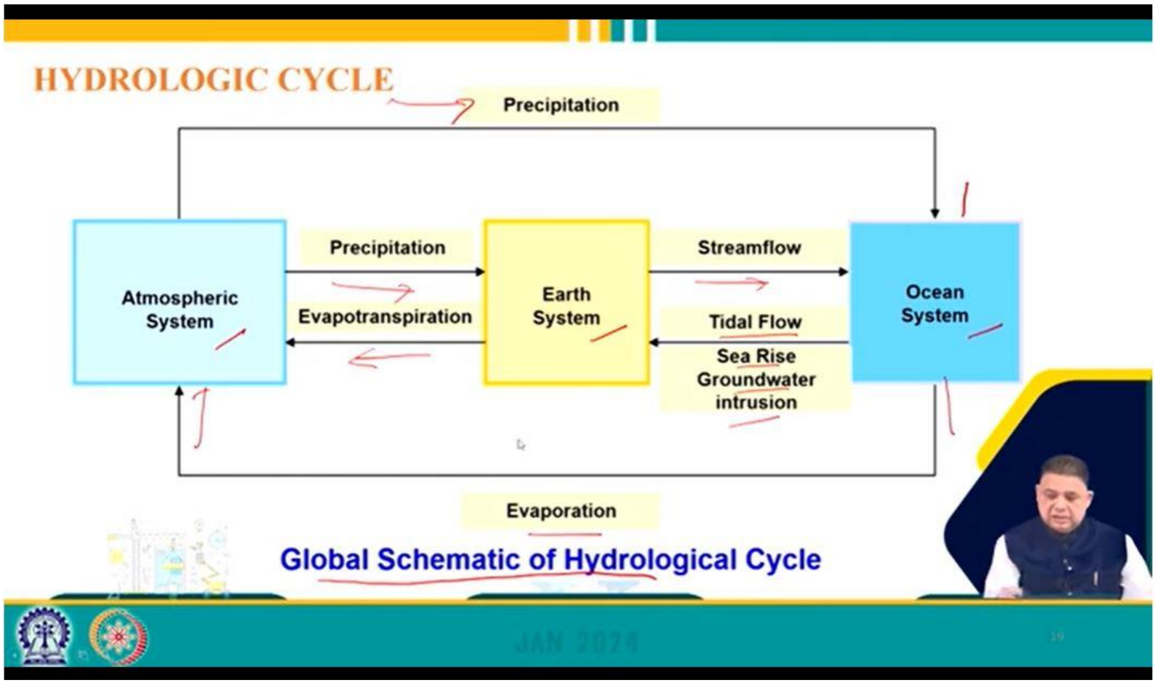
So, it all starts it all starts with sun providing the energy and because of the heat and the water from open water surfaces or large water bodies sea oceans rivers etcetera it starts evaporating. So, that process evaporation. Similarly plants we all know that they transpire water from their surfaces in order to meet their water requirement. So, combined together this evaporation and transpiration they carry water from land surface or plant surface to atmosphere where cloud formation takes place then obviously, when situation arises condition occurs and once condition occurs then precipitation takes place. When precipitation occurs water reaches the earth surface a part of it gets infiltrated and then remainder start flowing on the surface and also when the water infiltrates it goes further down it percolates and surf surface flow starts taking place.

So, this is what hydrological cycle is these are various processes involved and we will be talking about all these processes they are already given you the concept that will be covered you see you if you recall almost all these terms we have discussed and we will be discussing about all these in our discussion.



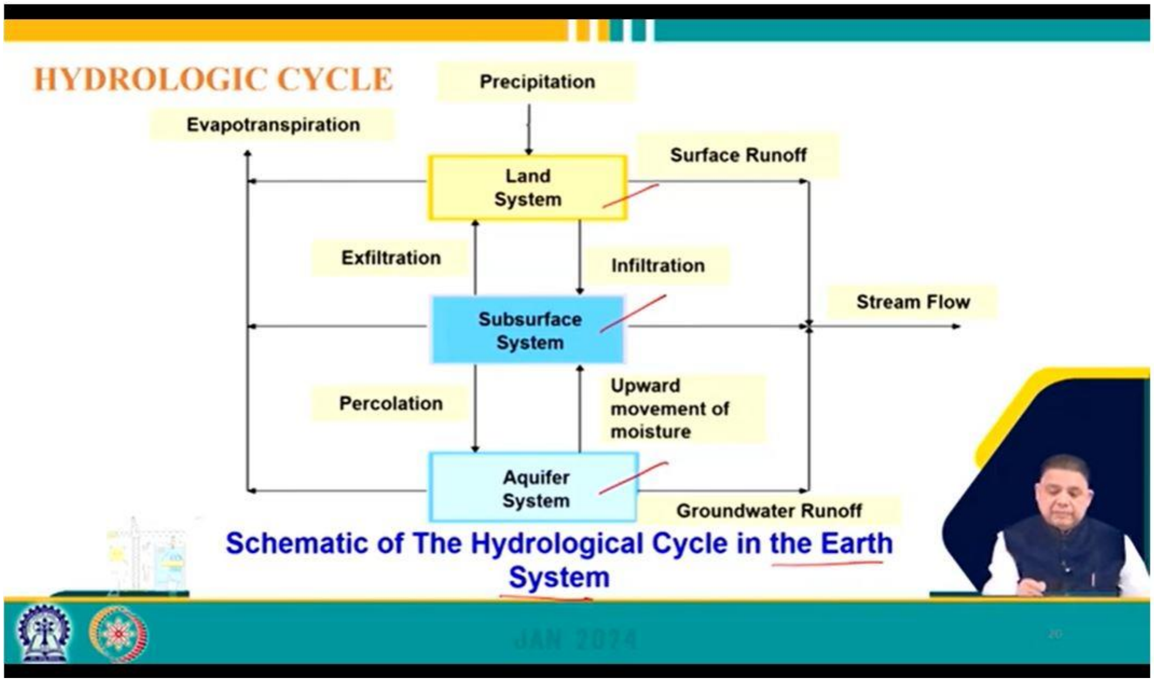
Now from a global perspective hydrological cycle may be considered to be comprised of 3 major systems the oceans the atmosphere and the land. The oceans are the major source of water atmosphere is the deliverable of water and land is the user of water. So, we have already seen that the entire hydrological cycle starts with evaporation from water body that is from oceans. So, that x is the source of water and once water gets into atmosphere cloud formation occurs condensation occurs precipitation takes place.

So, water delivers water is delivered back to land and so the atmosphere is the deliverable of water and of course, the land when it reaches it gets utilized for various purposes. So, land is the user of water and the 3 principle processes that transmit water from the atmosphere from one system to other are precipitation runoff and evaporation and we have also again seen in our hydrological cycle discussion that it all starts with evaporation. So, evaporation is a process through which water goes from oceans to atmosphere then precipitation which delivers water and runoff which flows through which the water flows on the surface and get gets used for different purposes.



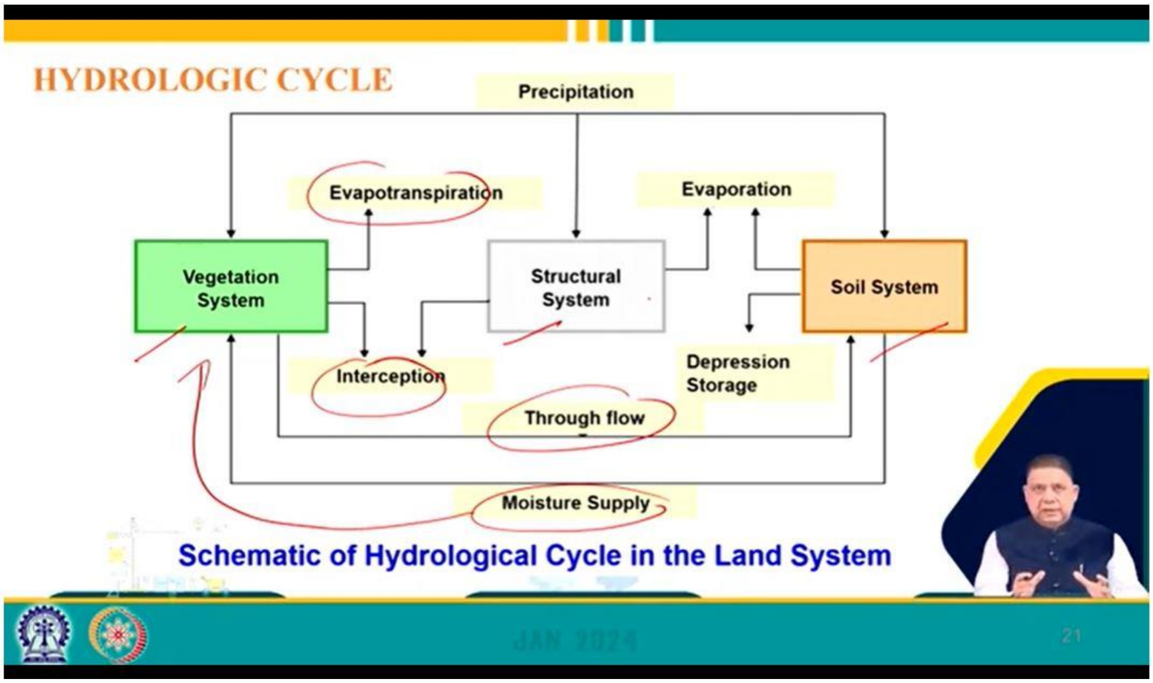
Now, hydrological cycle can be studied at different scales. So, this we can talk about the global schematic of hydrological cycle which has 3 different systems atmospheric system, earth system and ocean system and of course, we know that when evaporation occurs water from ocean system reaches to atmosphere where precipitation takes place and water reaches the ocean system a part of that a part of that reaches the earth system and from earth system evaporation or evapotranspiration takes place and water reaches back from earth system to atmospheric system earth system stream flow occurs and water reaches the ocean system and ocean system to earth system it might go through tidal flow or sea sea water rise or groundwater intrusion.

So, that is why all these 3 systems are interlinked.



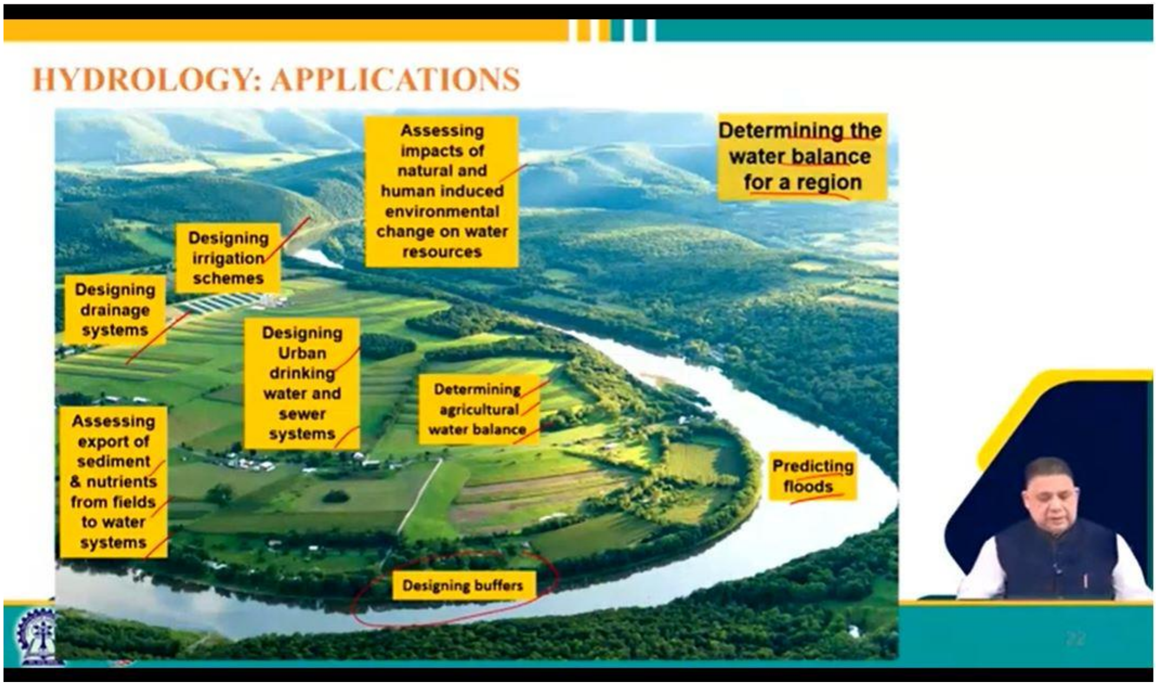
Now, if we zoom into this earth system we can also talk about schematic of hydrological cycle in the earth system and then we will have 3 new systems land system, subsurface system and aquifer system. So, obviously, precipitation take place on the land system and from where runoff surface runoff is generated and reaches the it is a form of a stream flow reaches the oceans. Then water gets infiltrated reaches the subsurface system from where again surface flow takes place and water reaches the stream flow. Then water gets percolated here reaches the aquifer system from water groundwater flow or groundwater runoff take place and that contributes to surface flow.

On the other side if you talk about evaporation or evapotranspiration that keeps on occurring from all these land system subsurface system as well as aquifer system. Then from some other processes are like there is an upward movement of moisture from aquifer system to subsurface. Similarly, filtration is just a reverse of infiltration from the subsurface system to the land system.



Now, further, we can further zoom down into the land system and can get three different systems that are vegetation system, structural system and soil system. So, here again, precipitation occurs and falls on all three systems, vegetation structure and soil system, and then from vegetation, evapotranspiration takes place, and some interception occurs.

The structural system also intercepts water from where vegetation system evapotranspiration takes place, and through fall from the vegetation system goes to the soil system. From the soil system, moisture supply is available to the vegetation system, and evaporation occurs from the structural system as well as the soil system. Also, the vegetation system, through fall, supplies water to the soil system. So, this is how we can look at hydrology from different angles at different scales.



There are numerous applications of hydrology. If you look at the watershed or the area, there are plenty of applications of hydrology that can be used to determine the water balance for a region. Say, watershed, we want to find out what happens and what quantities of different processes can be studied. We can predict floods by studying hydrology; we can determine agricultural water balance, which means we talk about agricultural land and the agricultural area, then we can talk about what happens, how much water is being used by plants or crops and so forth.

Then, we can design drainage systems and irrigation systems, assess the export of sediment and nutrients from the field to the water system; we can design an urban drinking water and sewer system, and assess the impact of natural and human-induced environmental changes in water resources. We can also design buffers that are the plantation that is required to check the pollution which is coming from agricultural land to the water. So, there are several applications, some of which we will see through our discussion. With this, I close this lecture.

Thank you very much, and I encourage you to give feedback so that we can improve in future lectures.

Also, please raise your doubts and questions through various forums that can be answered. Thank you very much.