Engineering Hydrology
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Module: 1
Lecture: 02
Preliminary Concepts

Hello all, welcome all participants to the first lecture of first module of Engineering Hydrology. In the previous lecture, we have seen the detailed course structure and in that we have observed that the entire course has been divided into seven modules. Today, we will start with the first module that is the introductory module. So, let us have the preliminary concepts in this lecture.

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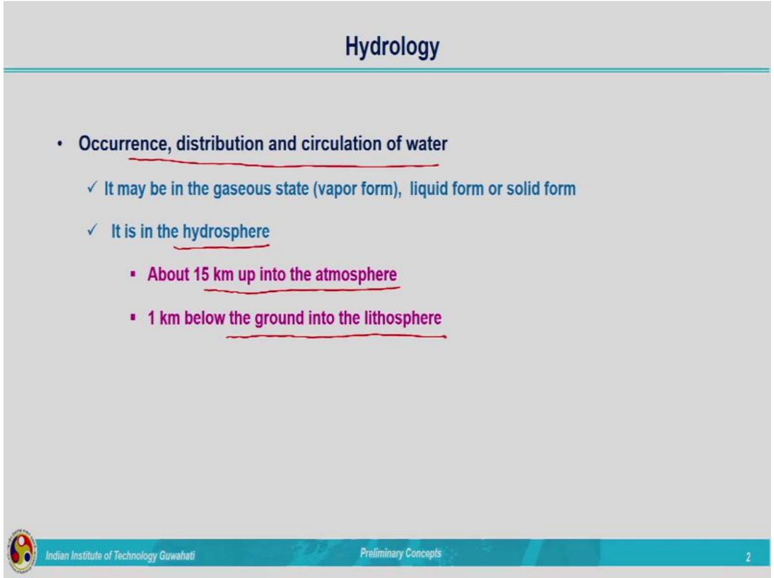

What is meant by hydrology? As we all know hydrology is the science that deals with the occurrence, distribution and circulation of water. Water is present in the earth, on the surface of the earth, beneath the earth and also above the surface of the earth that is in the atmosphere in different forms, such as vapor, liquid and solid.

So, the occurrence, distribution and circulation of water and the study related to that is termed as hydrology. The space where water is present is termed as hydrosphere. So, what is hydrosphere? Hydrosphere is extending about 15 kilometers up into the atmosphere and 1 kilometer below the ground surface that is into the lithosphere.

So, total 16 kilometer is termed as hydrosphere, 15 kilometers up into the atmosphere and 1 kilometer into the lithosphere. So, within this sphere water is present in different states that is in the vapor state, liquid state and also in solid state.

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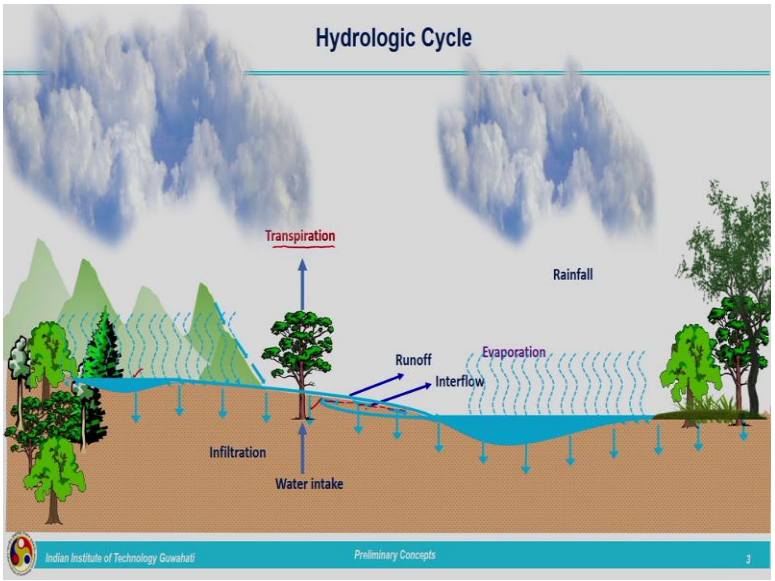

Now, let us start with the very basic concept of water cycle or hydrologic cycle. So, we can understand different processes, which are coming under hydrologic cycle. Plants will be taking, absorbing water from the soil and it will be transported through the stems and it will be escaping out of the tiny pores present in the leaves into the atmosphere. This process is termed as transpiration. So, we know very well what is meant by transpiration. So, transpiration is the process by which water is lost to the atmosphere through the plant leaves.

Now, comes the water loss from the water body. Heat energy will be absorbed by the water present in the water body and it will be converted into vapor form and it will be moving in the upward direction into the atmosphere and clouds will be formed. More and more evaporation will be taking place depending upon the day to day conditions and more and more water vapor will be added into the atmosphere.

After that what will happen the condensation of the clouds will be taking place that is, the saturation of the air mass with the water vapor will be taking place or sometimes what will happen, the temperature will be coming down below the dew point temperature and then the condensation of this air masses or the clouds formed will be taking place and as a result of that we will be getting the precipitation on the earth’s surface.

Precipitation can be of different forms. Here I have represented rainfall. Once we are experiencing rainfall, the water level in the water bodies will be increasing and also you can see the surface storage components will be satisfied. After that what will happen along with this process water will be moving into the ground as infiltration. Rainfall is happening or precipitation is taking place, initially the surface storage components will be satisfied. Some amount of rainfall will be infiltrating into the ground depending upon the soil-water dynamics, and after that what will happen we will be having the overland flow. So, the flow will be from the hilly region we will be getting the water flow like this, surface flow like this and on the surface also we will be having the water flow coming towards the water body, that is what is termed as runoff. This is a common phenomenon which we usually experience and when the runoff starts, you can understand that the level, surface soil here you can see, surface soil will be almost saturated.

Because of that saturation water flow will be taking place at the subsurface which is known as interflow. This flow takes place laterally and that will be joining the water body which is termed as interflow, thus increasing the water level in the water body.

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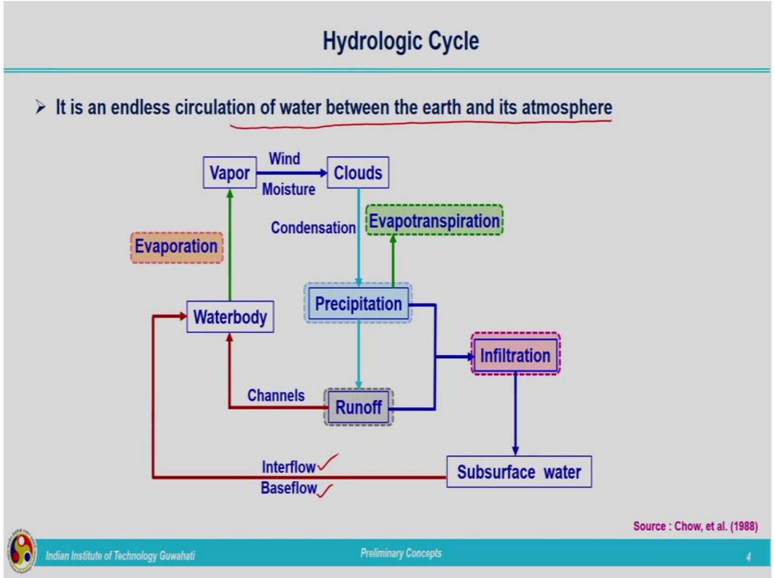

Hydrologic cycle is an endless circulation of water between earth and its atmosphere, that is as the heat energy is absorbed by the water in the water body, it will be converted to vapor form and it will be moving upward direction into the atmosphere and when more and more water vapor is added into it or the temperature is reduced below the dew point temperature then the condensation process will be taking place and we will be experiencing rainfall.

We can see this processes which are explained in the previous slide with the help of a flowchart. We will start with a water body. Water from the water body will be getting evaporated due to the heat energy from sunlight and this evaporated water, that is, the after evaporation water vapor will be contained by the air above the water body.

So, this vapor along with the air will be carried away or transported by wind action. It will be moving up because this moist air mass will be moving up and more and more, water vapor is added into it forming the clouds. When there is a change in temperature, when the temperature reduces to dew point temperature or the clouds become saturated with water vapor, condensation process will be taking place and we will be experiencing precipitation.

From this precipitation we will be having so many losses. As the water reaches the ground surface some amount is getting infiltrated, some amount will be going back to the atmosphere due to the process termed as evaporation, some water will be lost to the atmosphere through the plants, plant leaves by the process transpiration. So, altogether we can tell evaporation and transpiration together some amount is lost back to the atmosphere by evapotranspiration. Then remaining water will be flowing on the surface as runoff and this runoff water will be collected in the channel and it will be moving towards the water body, joining the water body and the evaporation process will be continuing.

Now coming to the runoff and precipitation, from this also some amount of water will be lost in the form of infiltration. Where this water will be going? This infiltrated water will be joining the subsurface water. Initially it will be penetrating inside the ground surface, near the ground surface we are having the unsaturated zone and if it penetrates again moves in the downward direction it will be meeting the groundwater table.

So, generally we will be telling water will be infiltrated into the subsurface and from the subsurface water also due to the process of interflow or base flow. Interflow is the flow which we have seen with the help of previous figure. Soil surface will become saturated and from the saturated region water flow will be taking place laterally depending on the slope of the area towards the water body.

And at the same time from the groundwater also some amount of water will be moving towards the water body such as rivers et cetera. So, that flow is termed as base flow. So, due to the process termed as interflow and base flow water will be again joining the water body. It will be transported, subsurface water will be transported towards the water body.

And again due to heat energy, absorption of heat energy evaporation process will be continuing. So, we do not know from where it is starting, but this is a cyclic process. Evaporation taking place, wind action will be transporting the moist air mass in the upward direction to the atmosphere and as it becomes saturated or the temperature, reduction in temperature may lead to condensation, which will provide us rainwater or the precipitation and from the precipitation we are getting the runoff, some amount of water loss due to evaporation, transpiration and this process is continuously taking place. So, different processes are evaporation, condensation, evapotranspiration, precipitation, runoff, infiltration.

So, out of these, these processes, that is evaporation, evapotranspiration, precipitation, runoff, and infiltration, we will see in detail under the topic of hydrologic processes. So, this is the circulation that is cyclic process or the endless circulation of water between the earth and the atmosphere. Earth's surface, beneath the earth surface and into the atmosphere. So, you can understand different transformation from one phase to another phase is taking place continuously.

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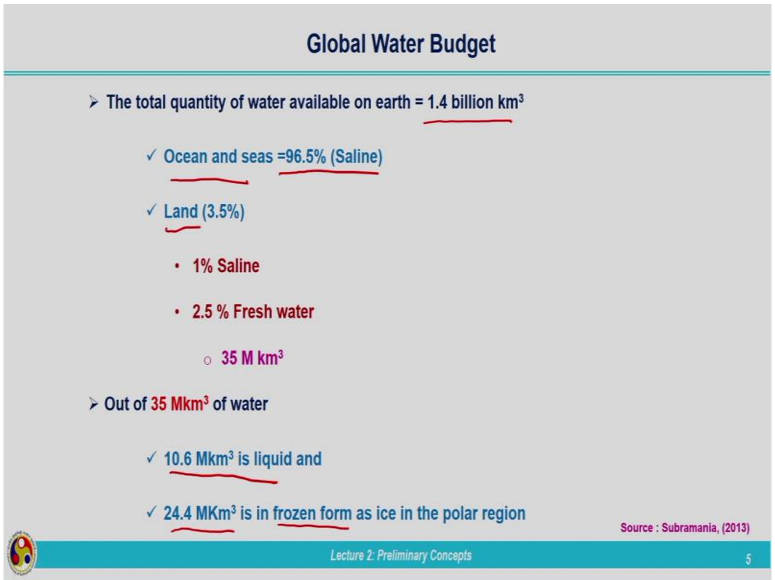

Now, we will move on to Global Water Budget. Total quantity of water available on the earth is around approximately it is 1.4 billion kilometer cube. Out of this 1.4 billion kilometer cube around 96.5 percentage of water is saline which is present in oceans and seas and remaining water that is around 3.5 percentage of water is present on the land surface on the land.

And within this 3.5 percentage itself, 1 percentage is saline that is the water which we are having on the land is only 3.5 percentage and out of that 3.5 percentage of water, 1 percentage is again saline water and remaining 2.5 percentage is freshwater. So, this 2.5 percentage of freshwater is coming out to be 35 million kilometer cube and out of this 35 million kilometer cube of water, 10.6 million kilometer cube is in liquid form and 24.4 million kilometer cube is in frozen form such as ice in the polar region.

So, we are having now I hope you got an idea about the total amount of water which is present on the earth, 96.5 percentage of water is in the ocean which we cannot use and remaining water we are having in the usable form around 10.6 million kilometer cube. So, we need to make use of this water judiciously.

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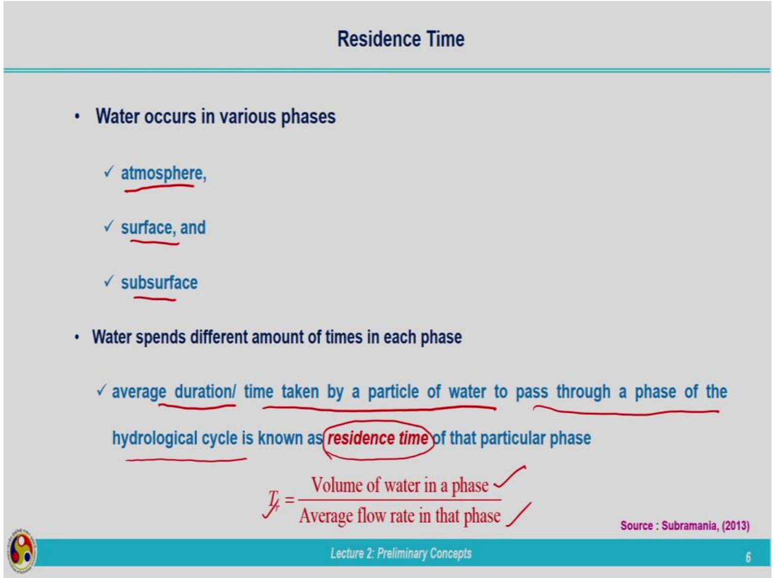

Let us see, what is meant by residence time. As you know water occurs in various phases in the atmosphere, surface and subsurface. In the atmosphere, it is in the vapor form, on the surface and subsurface it is in the liquid form. So, we need to understand how long water will be existing in all these phases.

So, there is a time which we are defining for that, that is what is termed as residence time. Water spends different amount of times in each phase. So, the time which water is spending in the atmosphere is different as compared to the time it is spending in the subsurface or surface. So, residence time is defined as the average duration of time taken by a particle of water to pass through a phase of the hydrological cycle, that is what is termed as residence time.

So, for a particular phase, how much time water is existing in that particular phase. For example, in the atmosphere, in the vapor phase, how long it is existing, after that after certain time, because of condensation this vapor will be converted to water and we will be getting the rainfall. So, the vapor form is converted to liquid form. So, we are interested in how long this water is present in vapor form in the atmosphere. That is what is known as the residence time of atmospheric water.

So, in the similar way, we will look into the residence time for surface water and also ground water. It is denoted by T_r and it is given by the expression

$$T_r = \frac{\text{Volume of water in a phase}}{\text{Average flow rate in that phase}}$$

So, residence time T_r can be calculated if we know volume of water in a phase and also average flow rate in that particular phase. Let us see how it can be calculated for rivers.

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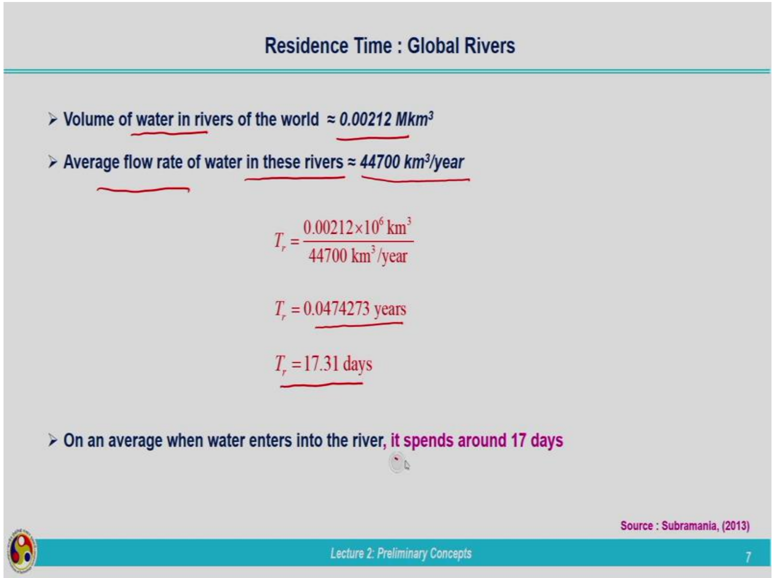

In the case of rivers, we are having volume of water, this is a global estimate, volume of water in rivers is coming to be around 0.00212 million kilometer cube and now we need the value corresponding to rate, that is average flow rate of water in these rivers is approximately calculated to be 44,700 kilometer cube per year. It is a huge value since we are considering all the global rivers. So, T_r can be calculated by taking the ratio of volume of water in the rivers to the average flow rate.

$$T_r = \frac{0.00212 \times 10^6 \, km^3}{44700 \; km^3 / year}$$

So, this is calculated to be 0.0474273 years, if you are converting this into days, it will be coming out to be 17.31 days. So, residence time in the case of global rivers or surface water is coming to be calculated to be around 17.31 days. On an average when water enters into the river it spends around 17 days.

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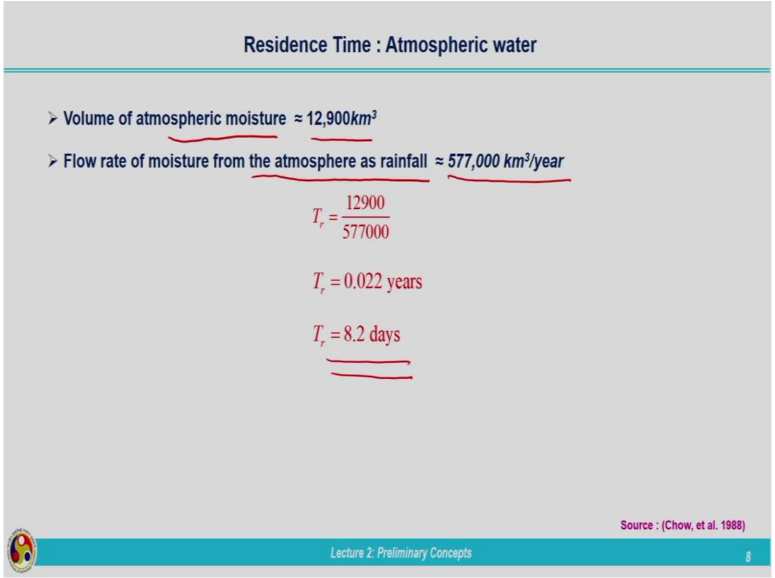

Now, what will be the corresponding value when we talk about atmospheric water. Volume of atmospheric moisture is 12,900 kilometer cube, it is not the exact value, this is an estimate. So, this is approximately 12,900 kilometer cube. Now, we need to see the rate, flow rate how much it is. So, flow rate of moisture from the atmosphere in the form of rainfall is 577,000 kilometer cube per year. So, if we calculate this residence time,

$$T_r = \frac{12900}{577000} = 0.022 years$$

it will be around 0.022 years. In days, if we convert it into days it will be 8.2 days. So, you can see in the atmosphere, water will be present in the form of water vapor only for 8.2 days. It is a very small duration. So, that is the reason why we cannot forecast the rainfall for long time.

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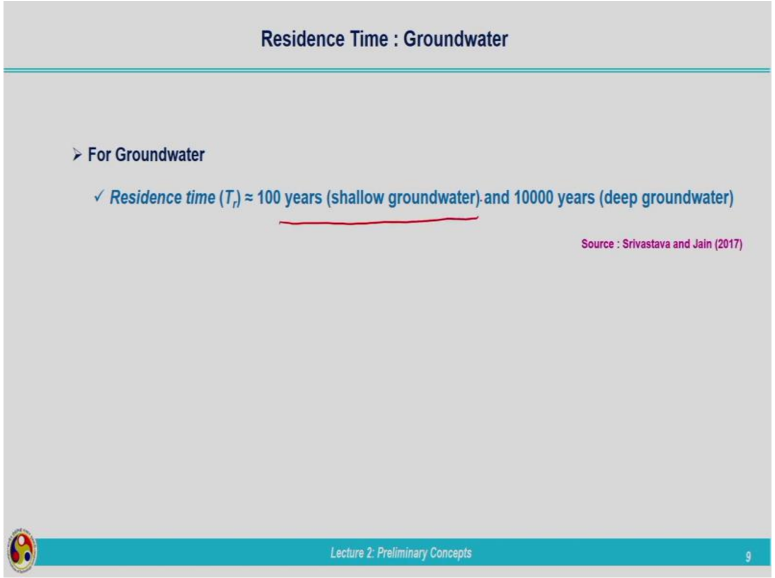

Now, coming to groundwater, it is calculated to be approximately it is around 100 years in the case of shallow groundwater and 10,000 years in the case of deep groundwater. So, for a long period water is residence time for groundwater is a very high that is approximately from 100 to 10,000 years. So, for a long period water will be tapped as groundwater.

Now, we have seen starting from different hydrologic processes and we have got an approximate estimate of global water. We have seen in the global water budgeting and how long water will be present in a particular phase that also we have seen. Now, for the analysis or assessment perspective, if we talk about all these processes, hydrologic processes, if we want to have the quantitative assessment of these processes, we need to have an area on which these water have been applied. So, will look into that particular terminology that is what is termed as catchment.

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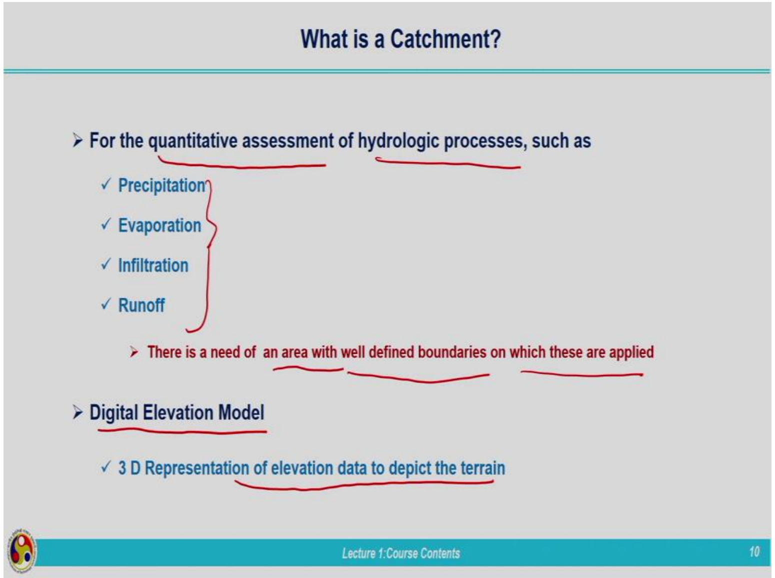

What is a Catchment? So, as I told you for the quantitative assessment of different hydrological processes such as rainfall, evaporation, infiltration, runoff. Precipitation I am talking about as rainfall. So, all these processes, we have seen under the hydrologic cycle and for getting a meaningful understanding of this, this should be acted on an area.

So, what will be that area that is what we are going to look into. That is the area with a well defined boundaries on which these are applied. Otherwise, how can we quantify this that is, consider an area, plain area or maybe undulating area, whatever it is, rainfall is falling on that particular surface, how can we quantify this much of flow has been occurred.

So, the flow which will be taking place on the surface will be depending on the slope of the area right, from higher elevation to lower elevation water flow will be taking place. So, within the entire area, how much water will be there, how can we do this analysis. So, there should be an area contributing all this water which is falling on that particular area.

So, we need to have detail about that area with a specific boundary. That is what we are going to see under catchment. So, the elevation of a particular area can be obtained from the digital elevation model. In the course surveying you might have studied the contour maps, you might have done the labs related to surveying and leveling related studies you might have done, from that you might have derived the elevations of the different points on the land surface and based on that you might have plotted contour lines.

So, digital elevation model is a 3-D representation of the elevation data to depict that particular terrain. So, with the help of this digital elevation model, we will understand that particular drainage area with a possible well-defined boundary.

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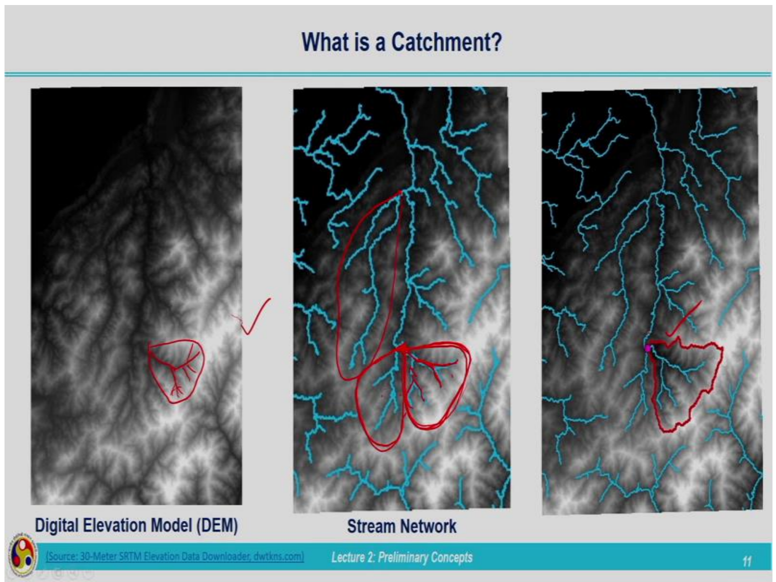

So, this is a digital elevation model, which I have taken from the, this particular website, earth explorer website and in this you can see when you see this you can see some nerves type of features on the surface on this digital elevation map. So, these are representing the drainage lines within that and if you check you can clearly draw a well-defined boundary like this while observing the digital elevation model itself you can get an idea of a particular area with certain stream network and also well-defined boundary. So, these things with eye observation I have marked on this particular digital elevation model. And now, by making use of the software, you can delineate or you can represent the stream network which are present in that particular area.

So, as I have marked we are having the well-defined stream network here. So, by observing the digital elevation model itself we can get some idea about this drainage network. So, that has been plotted by making use of the software. So, these are the different drainage network or stream network present within this area.

And after that you can understand depending on the slope of the area, water will be flowing from higher slope to lower slope or higher altitude to lower altitude. So, that way we can identify a point where all this water will be collected. So, that particular point that is from within this area if I am plotting again the water will be draining through this stream network, all the water from this area will be collected within the, collected by these drains and all this water will be collected at this particular point.

So, the entire area coming within this will be contributing water towards this single outlet point and towards this side again if you look at this side you can draw another drainage basin or drainage area, which will be contributing towards this side. In the similar way, if we consider other part of this catchment, you can see you can plot clearly draw a divide line like this.

So, when you look into the digital elevation model or the contour map, you can clearly understand in which direction flow will be taking place. So, from this area, the entire rainfall which is falling over there, will be falling within this area, it will not be falling towards this and within this boundary whatever rainfall is falling it will be collected at the outlet point.

So, this has been separated out and I have drawn this drainage basin here in this map. So, this is a very small area within the entire area with a single outlet, where entire water from this drainage area will be collecting.

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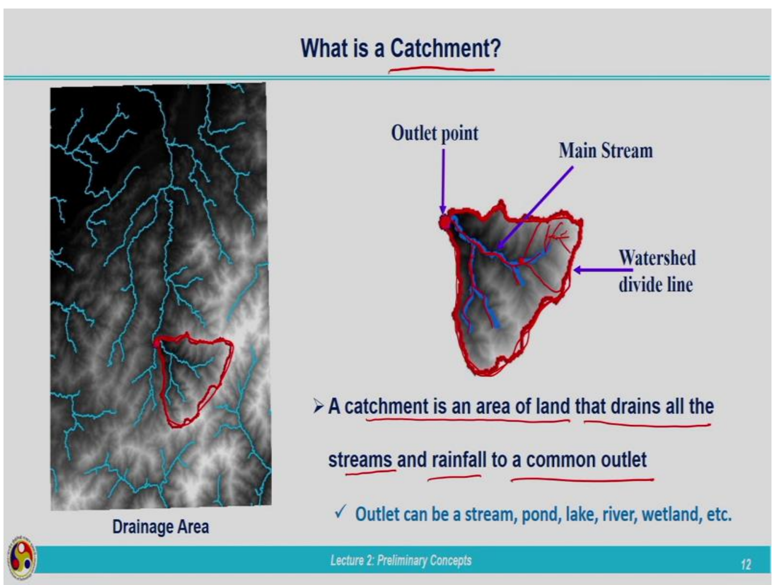

So, this is the drainage area and that I have depicted here again and now, if we are taking separately this particular area is termed as catchment. Watershed, catchment, basins; different terminologies are there. So, this area we have separated out from the entire part of the digital elevation map by identifying the outlet point and stream network. So, one by one we will look into the parts. This stream network will be having main streams and tributaries connecting to it.

So, this is the main stream as far as this catchment is concerned. Within that again we can go for dividing smaller drainage areas depending on the stream network. Here you can see small small networks are there, you can see here and here, it is connecting in this way, all the drainage lines are not marked here.

So, in this way, if we are considering some outlet here, this particular area may be contributing to this outlet point. So, this drainage area can be again divided into smaller smaller areas. So, that way we can have sub areas within a main drainage area. So, this is the main stream and when we look at this boundaries, that is what is known as the watershed divide line and coming to the outlet point we have identified where the water from this entire area will be collected. Entire water will be draining off to a particular point depending on the slope, that point is termed as the outlet point.

So, this area is nothing but our catchment. How can it be defined? A catchment is an area of land that drains all the streams and rainfall to a common outlet point. This area is termed as the catchment. So, again I am repeating catchment is an area of land that is draining entire water within that to an outlet point. This outlet point can be a water body or stream, pond, lake or anything, any of that type of feature can be an outlet point.

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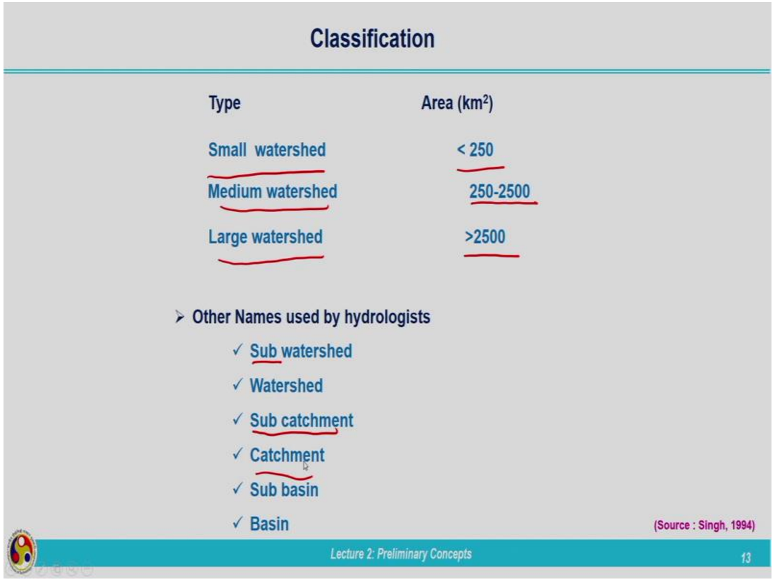

Now, when we talk about catchment. Different classifications are there, you might have heard the terms catchment, watershed, basin; all these are synonyms. So, how can we understand whether this is a catchment or watershed or a basin. Depending on the area of the drainage area, we will be classifying it into different categories. Based on area if the area is less than 250 kilometers square, we will be calling it as a small watershed, and if the area is between 250 to 2500, it is medium watershed and then the area is greater than 2500 kilometer square it is termed as large watershed. So, this is the general classification of watershed; small, medium, large. And again in some of the books or commonly we will be making use of terms such as sub watershed, watershed.

Sub watershed, I have already shown you when a catchment is delineated, within that itself, we could identify small watershed. So, that is the sub watershed. If the area is slightly more, it will be termed as catchment and sub catchment. Then comes the sub basin and basin. So, in the case of rivers and all we will be telling river basin.

So, these are the classification, within different textbooks, different area criteria have been given for this classification of watershed, catchment and basin. But generally we will be using it as synonyms.

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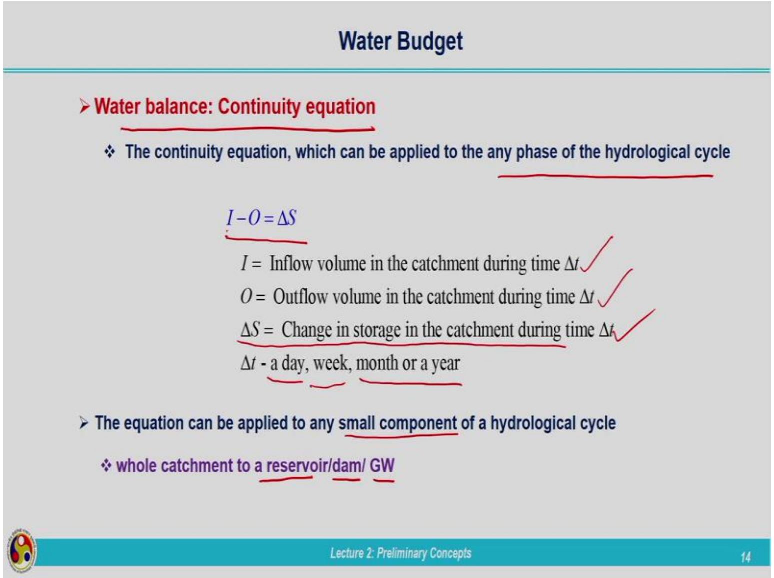

Now, coming to the water budget. We have seen the global water budgeting. Now, if this global water budgeting the principle same thing can be applied to small entity, hydrological entity. So, this can be done by using the water balance equation that is also termed as the continuity equation.

So, what is it? It can be in the case of a particular catchment this equation can be utilized, for getting an idea about the estimate of the quantity of water. So, it can be applied to any phase of hydrological cycle. There is no mandatory rule that it can be applied to liquid phase or vapor phase, nothing like that. This is a general equation which can be applied to any of the phases, the general expression is given by

$$I - O = \Delta S$$

What is I? I is the inflow volume into the catchment within a particular time duration is considered as I, O is the outflow volume in the catchment during that same time period Δt. And consider catchment or drainage area, whenever some water is falling on that some inflow is there, some outflow is there. Some amount of water will be stored within that particular area, it will not be flowing as runoff. So, some water which is stored within that particular area is termed as the storage. So, when some rainfall is occurring, there will be changes taking place regarding the water stored within the catchment. So, that is represented by ΔS, that is change in storage in that catchment during the same time duration Δt.

And this Δt depends on the analysis. If we are going to find out the estimate for a day that Δt will be a day, if it is on the weekly basis it will be a week and if it is on a monthly basis or on a yearly basis then Δt will be changing. But only one condition is that all these terms that is inflow, outflow and change in storage, all quantities should be measured during that time interval Δt.

So, this can be applied to a small lake, it can be applied to a wetland, it can be applied to a big catchment. So, anywhere you can apply this equation. Reservoir, dam, in the case of groundwater, whatever be the entity which you are considering you can apply this water balance equation. Now, let us see how can it be applied to a catchment.

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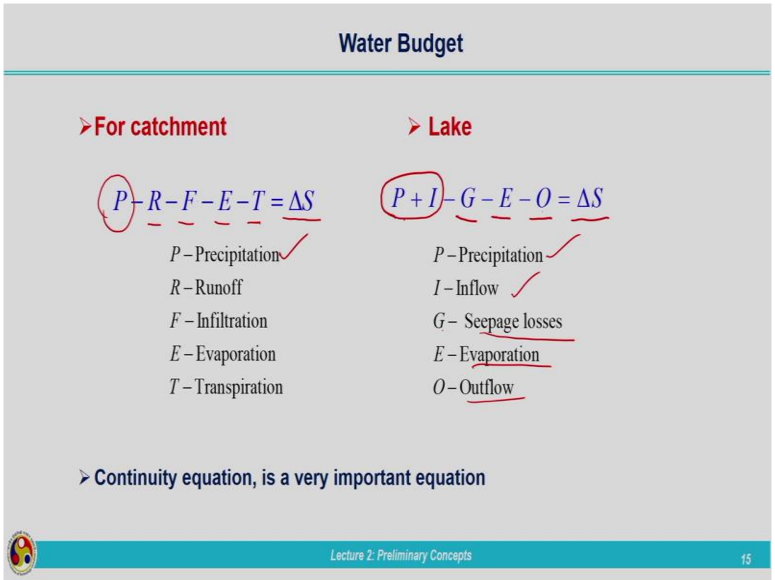

For a catchment if you are applying that particular formula, inflow minus outflow is equal to change in storage, change in storage is here on the right hand side, inflow in a catchment if we talk about it is nothing but our precipitation.

$$P - R - F - E - T = \Delta S$$

Whenever the precipitation is occurring, we are having so many losses. Runoff is there, infiltration losses is there, evaporation, transpiration all those are losses. So, inflow minus outflow, all these losses are considered as the outflow. So, you can see precipitation minus runoff, infiltration, evaporation and transpiration. That difference, the amount, how much is a difference between inflow and outflow, where it can go, it can be added to the storage only.

So, that is the ΔS component in the case of a catchment. So, when we are doing the water budgeting of a catchment, we need to quantify precipitation, runoff, infiltration, evaporation, transpiration. Sometimes we may be neglecting some of the losses, that is depending on the area. Other than that, you need to have a quantified value corresponding to all these and that you can substitute and do the water budgeting.

Now, in the case of a water body for example, if you are considering the lake, the same formula we are going to apply. So, here in this case, if we are having a lake, you will be having a inflow to the lake coming, some tributary or some stream is joining there. So, in addition to the precipitation, you are having some other inflow which is joining the lake, so, all together will be considered as the inflow.

$$P + I - G - E - O = \Delta S$$

Now, if we are grouping terms corresponding to outflow, these are groundwater seepage (within the ground some amount will be going inside that is considered as the seepage), evaporation from the lake and outflow from the lake. If some water is taken for some purposes or some stream is starting from that particular lake or that way some other outflow will be there.

That will be considered under this term and the difference between this inflow together and outflow is taken as the, considered as the change in storage of that particular lake. So, here P is again precipitation, I inflow to the lake, it may be in the form of a stream or some other connecting channel or whatever be present there which is added to the lake water is added to the lake. So, that is coming under this inflow component and there will be seepage losses which is considered as G and evaporation and outflow. Together we can write the water budget equation in this form.

So, for different, different hydrological entities, we can make use of this formula and we can have a water budget. This equation is very very important, whenever we are talking about the mass conservation principle, that is from the fundamental principles when we are going to estimate the quantity of water we will be making use of this equation. You will be coming to know about this particular equation in detail later on. This is a very simple form of equation which we have seen now. So, the details related to this particular equation by taking into account of the temporal variation, spatial variation, all these things we will come to know in the coming lectures.

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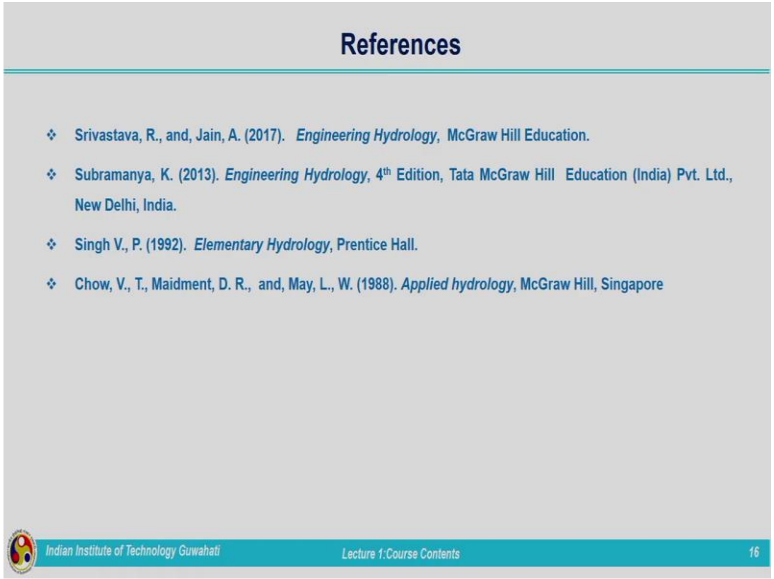

So, these are some of the references. So, in order to summarize this lecture, we have started with the hydrologic cycle, different hydrologic processes we have seen and after that we have come to the global water budgeting and how much is the total amount of water existing on the earth we have seen and then we have seen the residence time, how long water will be present in a particular phase. How much is the time spent by the water particle either in vapor form, liquid form, on the surface of ground or within the ground surface. These things we can understand by means of residence time.

After that we have seen for the quantitative assessment or analysis of these processes, we need to have an area on which these processes have been applied. That we have seen by means of a catchment or watershed or basin. Then we have seen, how we can do the water budgeting for a catchment and lake. So, here I am stopping now. Thank you.