Availability and Management of Groundwater Resources
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Lecture - 30
Estimation of Subsurface Runoff, Types of Wells, Well Hydraulics

Welcome you all; in the part one of the modules 7 estimation of subsurface runoff, type of wells and well hydraulics. We have started the hydrological cycle from the concept that precipitation is the only recharge source of the groundwater is an aquifer. So, since precipitation is the only recharge source so it is contributing water to the aquifer as well as it is contributing water surplus rainfall amount is contributing to the earth surface water source that is the river water.

So, here inside the earth surface we have seen that precipitated water first infiltrated down and then percolated and then it reaches to the aquifer the formation which holds the groundwater. But the surplus rainfall amount means; those amounts of water which is not entering as a per infiltration of percolation they straight forward move through the topography of the earth's surface and ultimately reaching to the stream channel. So, this is that time also we had discussed this is called as runoff.

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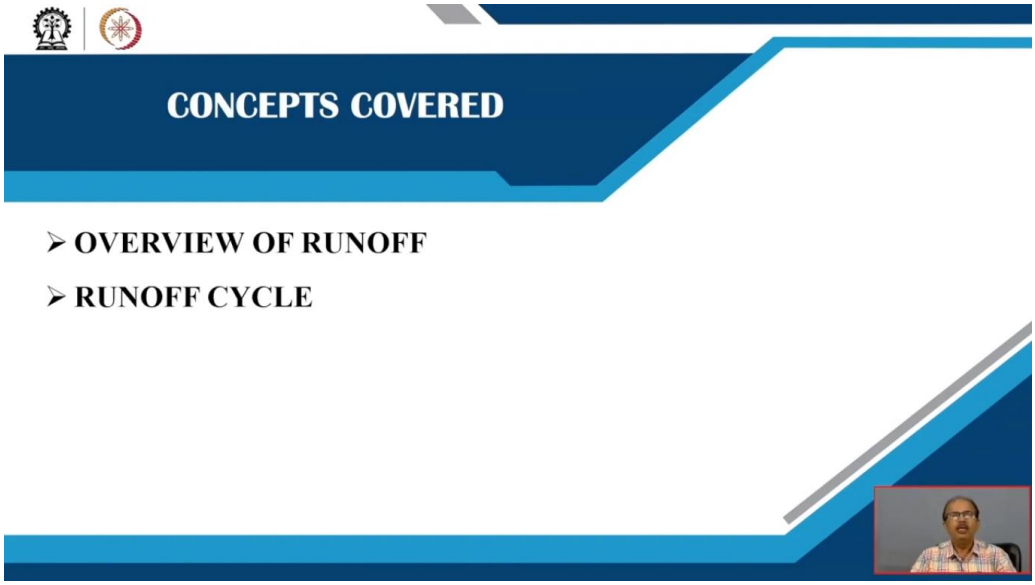

So, in this lecture we will concentrate on the topics that is overview of runoff as well as the runoff cycle. So, these two thing we will discuss in greater detail because now we have covered almost

in detail about the formations which are the known as an aquifer, then the vadose zone, then the confined and unconfined aquifer, then the porosity permeability and we have also seen the law of groundwater movement that is the Darcy's law.

After this just we have entered into the overview of runoff because runoff is a very important component of hydrological cycle; it contributes groundwater to the aquifer underneath the earth's surface. So, now we will first discuss what is run off.

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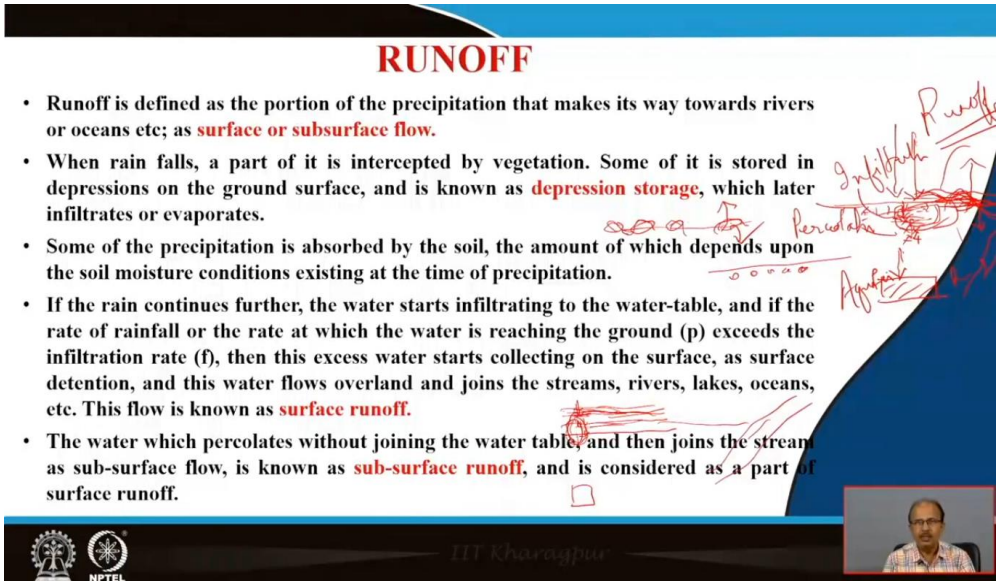

So, runoff is defined as the portion of the precipitation that makes its way towards the river or ocean as surface flow, we have seen that this is the earth's surface and, on the earth surface, we are having the precipitation, precipitated water falls on the earth's surface then it first in enter into the top layer of the soil layer which we called it as a infiltration, this is infiltration. Then the first layer of the soil just entering into the second layer of the soil so we called it as a percolation.

So, percolation and then by gravity it reaches populated water reaches to rock formation which we generally called as aquifer, so this is an aquifer. So, now this is the earth's surface and we are having the rainfall water, so this water first, it will satisfy the moisture, the soil layers satisfy the soil layer first. And once the soil layer; will become concentrated with water then it would not infiltrate and percolate down rather it will move through the topography of the earth's surface.

And this movement of surplus amount of rainwater which is not being able to go down because of the saturation in this layer then this amount of water and water is called as runoff, so this is called as a runoff. So, this runoff we will discuss in greater detail one cycle also plays for runoff which is called as runoff cycle just like the hydrological cycle. So, runoff is defined as the portion of precipitation which makes its way towards reverse.

So, ultimately where the water will go; water will meet to; certain river, if some river is flowing so, it will reach us to certain river. When rain falls a part of it is intercepted by vegetation very interesting. So, what is happening on the earth's surface; we are having tall trees, tall buildings etcetera. So, first of all when the rain starts it is being intercepted by the; tall buildings or tall trees that is by vegetation.

Some of it is stored in the depression, storage depression means some storage structure remains on the earth surface some void remain on the earth surface. So, this amount of water is known as depression storage which later on may evaporate again to the atmosphere or may infiltrate down to the earth surface. So, this stage comes when the rain falls on the earth's surface, first of all it is being intercepted by the tall trees and tall buildings.

Then from the tall trees and tall buildings the water moves to the earth's surface. On the earth surface we are having the number of voids so it tries to fills the void first. This is known as the depression storage and this amount of water which is being filled in the depression storage may evaporate up to the atmosphere or may influence trade down to the earth's surface. So, this happens during the rain.

Some of the precipitation is absorbed by the soil layer, so underneath the earth's surface is the soil layer we have seen underneath the earth's surface is the soil layer. So, this precipitation is a; precipitated water will be absorbed by the soil layer. The amount of which depends upon the soil moisture condition existing at the time of precipitation. So, it varies at some place; suppose the soil is having moisture so it will receive a lesser amount of precipitated water.

At some places the soil is totally dry so it will receive the more amount of your infiltrated water. If the rain continues further now, rain is continuing, then what happens the water starts infiltrating to the water table as I have told you that the infiltrated water we percolate inside and then it will reach us to the water table. Water table is the upper layer of any aquifer especially the unconfined aquifer.

So, this surplus amount of water is reaching to the ground and exceeding the infiltration rate and then this excess water starts collecting on the earth surface as surface detention and this water flows over lane. Because the water is at the land surface, overland and ultimately joins the streams, river, lakes, oceans these all are the example of the earth surface water sources streams river lakes is ocean etcetera.

This surplus amount of water which remains on the land surface which flows through the topography of the land surface is generally known as surface runoff. This is known as surface runoff. But the water which percolates without joining the water table now, this is called a surface runoff which is flowing through the earth surface. But when the rain starts some amount of water infiltrates down again it is after infiltrating down the; suppose this is the first layer of the soil. Then this is the second layer of the soil, then this is the third layer of the soil so once the first layer of the soil will saturate here definitely it would not allow water to move down. Again, from this saturated portion the water will reach to the second layer and from this to the third layer. So, again the rain water will enter and saturate this layer. So, once all the three layers; different layers may be several layers of the soil will become saturated.

Then what will happen the; earth surface runoff starts; it will start from this place runoff will start from this place. We have seen also, we up after few minutes of the duration of the intense rainfall; what happens then; we show the rain water moves through the topography of the earth surface which is called as surface runoff. But this here also the amount of water is here. So, this water again moves laterally, it moves laterally it is not going down to reach to the aquifer.

It moves laterally and this lateral point lateral movement of the precipitated water ultimately joining any river it is ultimately joining any river channel. So, this amount of water is called as

subsurface run out. This is the earth surface runoff and just beneath the earth surface the from the soil layer from the different soil layers from the different formations inside the earth surface the water moves laterally and ultimately joining to the stream or your channel which is known as subsurface runoff.

And it is concentrated as a part of the earth surface runoff it is also a part of the earth surface runoff. So, I hope that you have got the idea about the earth surface runoff and subsurface runoff.

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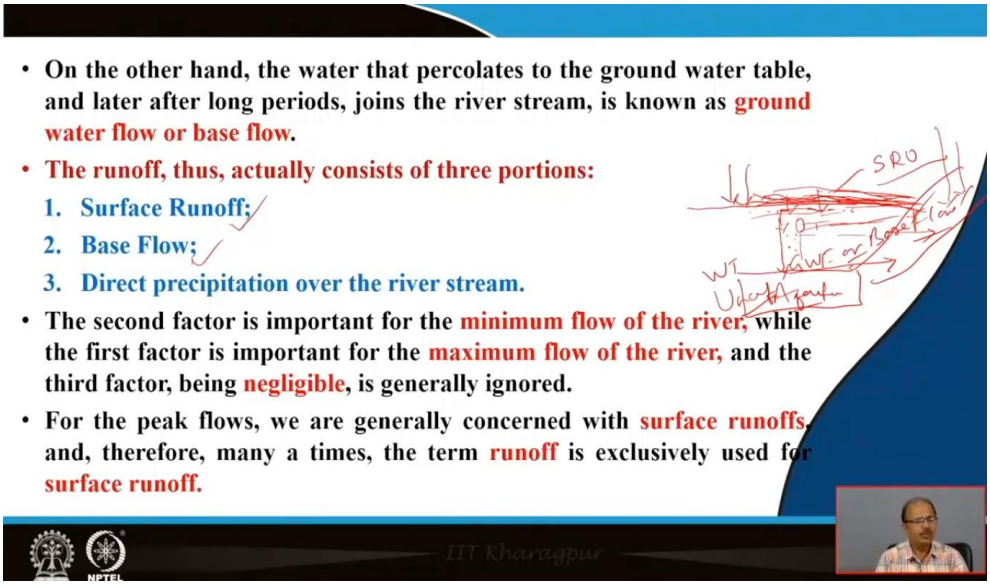

Now on the other hand the water that percolates to the groundwater table because now after the precipitation surface runoff will move towards the river channel this is the river channel. So, it will move towards the river channel, ultimately joins to the river channel. The water which percolates down will reach to the groundwater table this is the water table means this is a formation which is called as aquifer especially the unconfined aquifer we have read previously.

So, the water that percolates to the water table and later after long periods joins the river streams is known as groundwater flow or base flow, this is very important base flow. So, base flow is contributing water to the river channels. So, the water that percolates to the groundwater table and after a long period of time if it is joining to the river stream then such amount of water is known as groundwater flow or base flow, this is the concept.

So, this runoff; what we have discussed just now actually consists of three portions. First the surface runoff which is we have understood why surface runoff is taking place because the bottom layer of the soil has become saturated. Once it will become saturated definitely it would not allow the water to come down. So, what will happen; the water will move through the earth surface; where it will go it will reach to the river channel.

It will move reach to the ultimately it is to the river channel, so this is called as surface runoff. Then base flow the water which have already precipitated in then infiltrated then percolated which reached to the water table, so some amount of water from this area laterally moves and ultimately joins to the river channel which is known as the base flow. So, one see in a river first the earth surface runoff is contributing water to the river.

Second, the base flow of groundwater flow is contributing water to the river and thirdly the direct precipitation over the river is also contributing water to the river. So, generally the river accepts water from the surface runoff from the base flow and from the direct precipitation over the river stream. Now one second factor is also, very important minimum flow of the river, see the earth surface runoff will contribute to the minimum flow of river.

Because that much amount of water which will not enter into the earth surface; only that amount of water will move to the river channel. So, surface runoff of part is contributing very little amount of water to the river whereas the sorry the base flow is contributing very little amount of water very because second factor, the base flow. So, the second factor is contributing a very minimum amount of water to the river.

Because only those amounts of water which will remain here will ultimately laterally move and join the this one; whereas the surface runoff is contributing to the maximum flow of river because surplus amount of rain water will go ultimately to the river channel. So, the point is that the second factor base flow is contributing very little amount of water to the river channel. This is surface runoff is contributing very high amount of water to the river channel.

And this third one is generally we are ignoring it negative is just a negligible amount because only the area of the stream will receive rain water. So, the point is that the surface runoff a base flow both are contributing water to the river. For the peak flows we are generally concerned with the surface runoff and therefore many a times the term runoff is exclusively used for surface runoff generally runoff means surface runoff.

And peak flows time when the river is having peak flow sufficient maximum amount of water is there then definitely the contributor is the surface runoff. So, this is the concept regarding the runoff.

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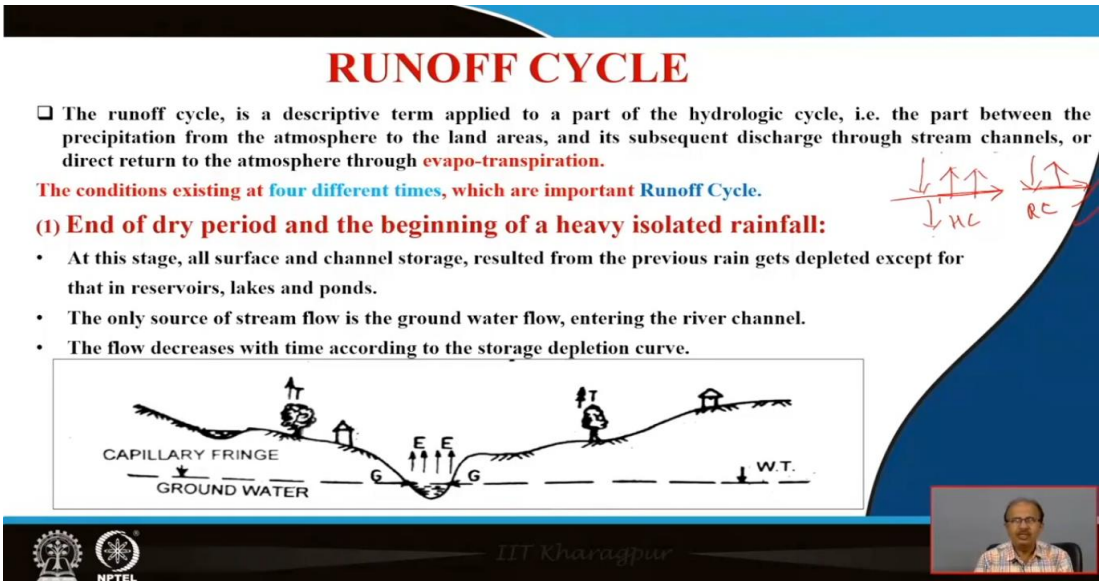

Now runoff cycle, so we have we should understand the runoff cycle also because we have seen that the runoff is contributing the maximum on water to the stream channel. See just like the groundwater, surface water is also one of the important sources of water. So, runoff cycle is a descriptive term applied to a part of the hydrological cycle it is a part of the hydrological cycle because the part between the precipitation from the atmosphere to the land areas and its subsequent discharge through stream channels.

So, in the runoffs in the hydrological cycle we have seen that the precipitation was there then the evapotranspiration was there evaporation was there transpiration was there, then the surface runoff was there then the groundwater runoff will be there. Here what we are seeing that the it is also a

part of the hydrological cycle and this precipitated water is coming to the land surface then it is ultimately reaching to the stream channel.

So, this and then a few amounts of water again going back to the atmosphere. So, this is the hydrological cycle, this is the runoff cycle. So, runoff cycle is having four different times just the different types of the runoff cycle we are discussing now. The condition exists if we will just assume that the rain has just started. So, the first condition is, end of the dry period means summer season.

After the summer season the monsoon has reached and during the monsoon season the first rain has taken place, so the end of the dry period and beginning of a heavy isolated rainfall. So, what is happening? At this stage all surface and channel storage all surface and channel storage means the small ditches on the earth's surface resulted from the previous rain gets depleted means they are totally dried except few structure that is lakes, reservoirs, ponds etcetera in which the water remains for some duration otherwise, all other portions are totally dry; rain has just started. The only source of stream flow is the groundwater flow in this time because rain is not there before the rain we are discussing. So, but the river is having some amount of water, where is the source? Source is the stream flow that is the base flow what we have discussed in the previous slides.

So, base flow is contributing water groundwater flow is contributing water to the river channel. The flow decreases with time according to the storage depletion curve because; totally dry period is there, so flow generally decreases with; as the same will pass the flow decreases and this condition exist end of the dry period and beginning of a heavy isolated rainfall.

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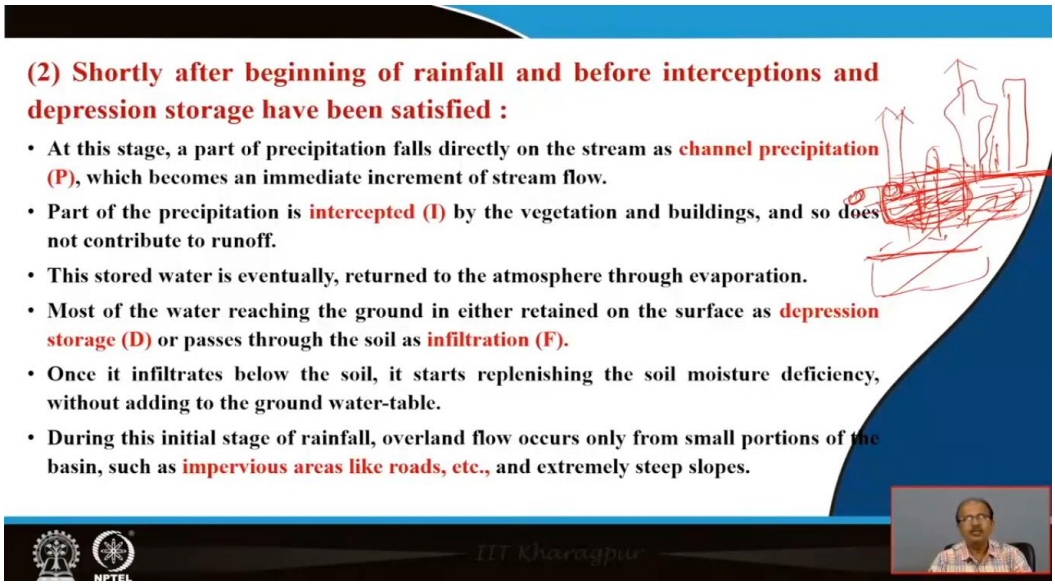

So, now in the second cycle; we see shortly after; beginning of rainfall; now the rain has started and before interceptions and depression storage have been satisfied. Means just that the rain falling drop reaches to the tall building tall trees and reaches to the small ditches ponds whatever on the surface of the earth. So, what is happening at this stage, a part of precipitation falls directory on the stream channel.

So, if this is the stream channel so precipitation is falling on the stream channel then this; after reaching to the stream channel it becomes an intermediate increment of stream flow not too much but to some increment of the stream flow take place. Part of the precipitation is intercepted; what we have seen; that the tall trees was there tall buildings were there. So, it is tall trees and tall buildings are just restricting the rainfall amount to raise to the earth's surface.

These are intercepted by building and vegetation. So, they are just at this point they are not contributing to runoff. Now this water is again falling down to the earth surface small ditches are on the earth surface this is the earth surface this is the earth surface, so this is the river channel so small details are there on the earth surface. So, what is happening; your stored water is eventually returned to the atmosphere through evapotranspiration.

So, whatever water is being run in the depression storage they will ultimately go back to the atmosphere which will be generally known as evaporation. So, evaporation from these small

details of ponds and transpiration from the plant surface, so these water again move back to your atmosphere. Now most of the water reaching the ground in either retained on the surface as depression storage or passes through the soil as infiltration.

So, now the rain amounts will fill up these voids storage structure on the earth surface and then it will allow water to move down because this soil is totally dry so definitely it will take water from the earth surface as the rain will start. Now once it infiltrates below the soil it starts replacing the soil moisture deficiency, so here the soil moisture deficiency was there earlier but once the infiltration starts definitely it will fulfill the soil water at this layer.

So, now the soil has become wet and now at this time this water because they have become just saturated so these water are not reaching to the water table. It is not reaching so what is happening it is just adding water to this soil layer and here. Now during the initial stage of rainfall overland flow occurs. Now this layer has become saturated so definitely the rainfall amount will not remain inside not go move inside.

So, where it will go it will move toward the; your surface moves towards the topographer through the topography of the land surface and ultimately join the river channel. So, during this initial stage of rainfall overland flow occurs only from small portion of the basin see only this portion because here only the soil has become saturated. This layer is remain unsaturated, now so just assume assumption is there definitely the water will fall here.

So, this layer here will but if the portion of our land surface is too much, so where there will be good amount of water first the soil moisture deficiency will reduce at this place only and where the trees remain dries definitely it will if the rain will start then again the overland flow will take place after the fulfilling of the soil moisture deficiency of the so underneath soil layer. So, this usually happens during the initial stage of the rainfall, overland flow occurs only from small portions of the basin.

Such as impervious areas where this example roads is the imperious areas and if the water will fall in on the extremely steep slope. So, this amount of water will just convert into the form of runoff

because it is having no chance to infiltrate or percolate down to the surface. So, since it is impervious so definitely it will not allow water to go inside the surface. So, what will happen this amount of rain water will convert into runoff or the rain water will fall on the steep slope.

So, as soon as it will fall on the steep slopes definitely the water will not enter as infiltration or percolation rather it will go down and ultimately meet to the river channel. So, this is the second stage absolutely after the beginning of the rainfall and before the interception and depression storage are being fulfilled also being satisfied.

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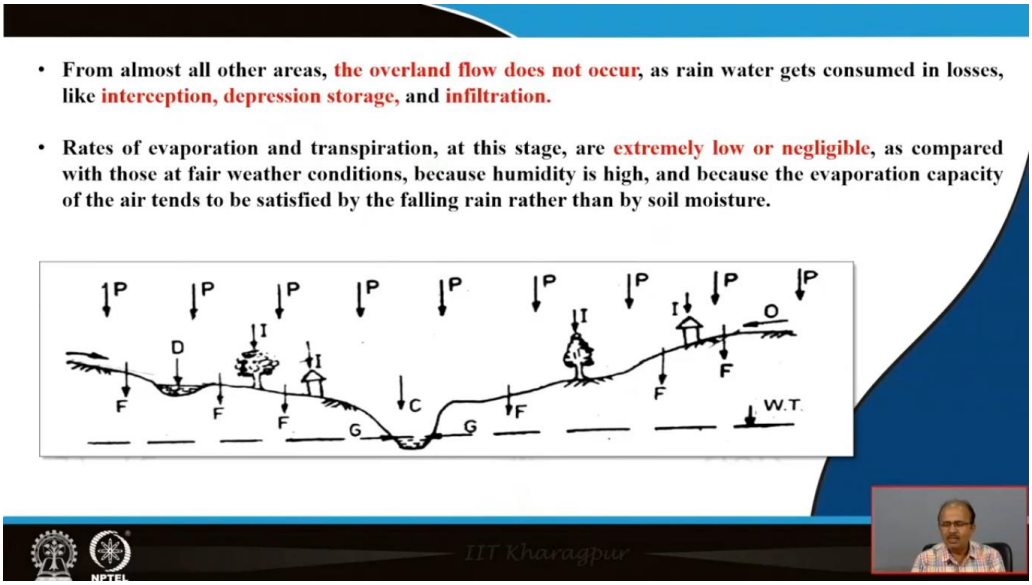

Now third stage now some more on this from almost all other areas the overland flow does not occur as rainwater gets consumed in losses. So, losses are also, there your interceptions are there, then depression storage are there, then infiltration are there. So, throughout the area you would not get large amount of overland flow why? because these will take some amount of water intercepted water depression storage water infiltrated water.

So, what we are seeing; that the rates of evaporation and transpiration at this stage are extremely low or negligible as compared with those at fair weather conditions. Definitely during the summer season, the evaporation and transpiration will be more but since the water rain has started so the area has become saturated with the water. So, at this time the your condition weather conditions

are also where so, this evaporation and transpiration remaining near about negligible from small areas.

Because humidity is high and because the evaporation capacity of the air tends to be satisfied by the falling rain rather than by the soil moisture. So, this we are seeing precipitation we are seeing precipitation is there than infiltration infiltrating then depression storage having the water and in the water table is there so this is the second stage cycle.

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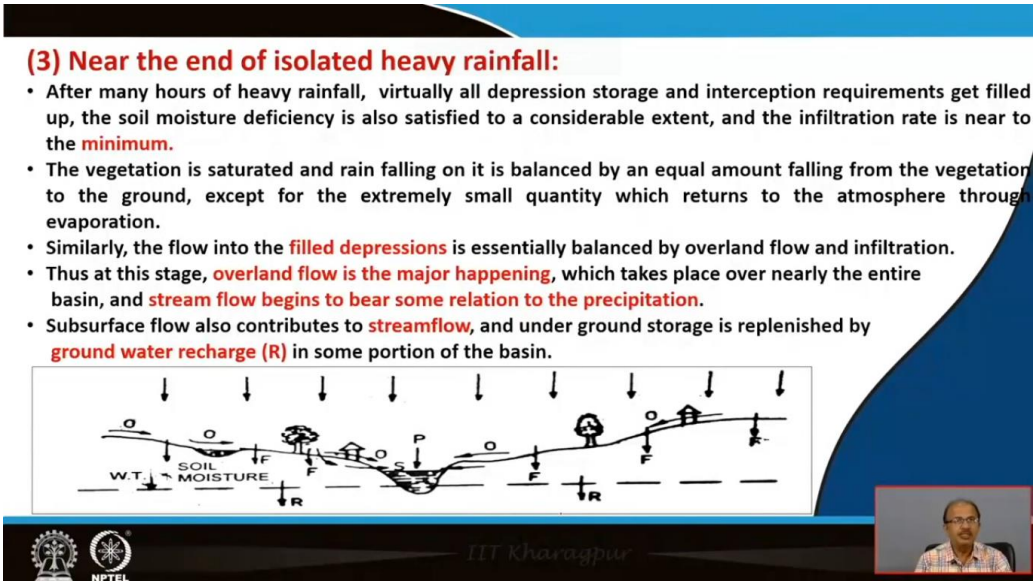

Now third is the near the end, now the rain is about to end so near the end of the isolated heavy rainfall. What is happening at this time? After many hours of heavy rainfall virtually all depression storage whatever on the earth's surface and interception requirements get full filled up. The soil moisture deficiency is also satisfied to a considerable extent and the infiltration rate is near to the minimum.

Now since soil moisture deficiency has also satisfied. So, definitely infiltration rate will become low that is near about to minimum. The vegetation is saturated and rain falling on it is balanced by an equal amount falling from the vegetation to the ground from vegetation or tall trees again the rain water will fall to the ground except for extremely small quantity which returns to the atmosphere through evaporation.

Small quantity of rain water which is being intercepted by the tall trees are again goes back to the atmosphere in the form of evaporation but very small quantity. Similarly, the flow into the field depletion is essentially balanced by overland flow and infiltration. So, we have seen also after the end of the heavy rainfall some amount of water remains in the depression storage means what it is just balancing the overland flow and infiltration.

So, this is being balanced after the rain stops. So, at this stage overland flow is the major happening which takes place over nearly the entire basin and the stream flow begins to bear some relation to the precipitation. So, as the rain will just end what will happen the only contributor will remain at that time that will be the overland flow because we have seen infiltration no infiltration because the soil has become saturated.

So, only the runoff will play a very, very important role at the end of the isolation rated heavy rainfall. And then what is happening the subsurface flow also contributes to the surface stream flow and underground storage is replenished by groundwater recharge in some portion of the basin. So, now what is happening surface runoff will take starts at this time probably have seen also just at the end of the rain we are seeing that the rain water is moving towards the slope and going down to the distant river also.

So, runoff place at that time maximum amount, then what is happening inside the earth's surface since water has become saturated in the underneath layer. So, ground water stream flow will take place underground storage will replenish by the groundwater recharge. Because now the water will reach towards the your aquifer also so groundwater recharge will take place. You have seen this is the water table and beneath it the water is have become as they started to reach to the aquifer.

So, R is the groundwater recharge, now this is the third condition because rain has just stopped.

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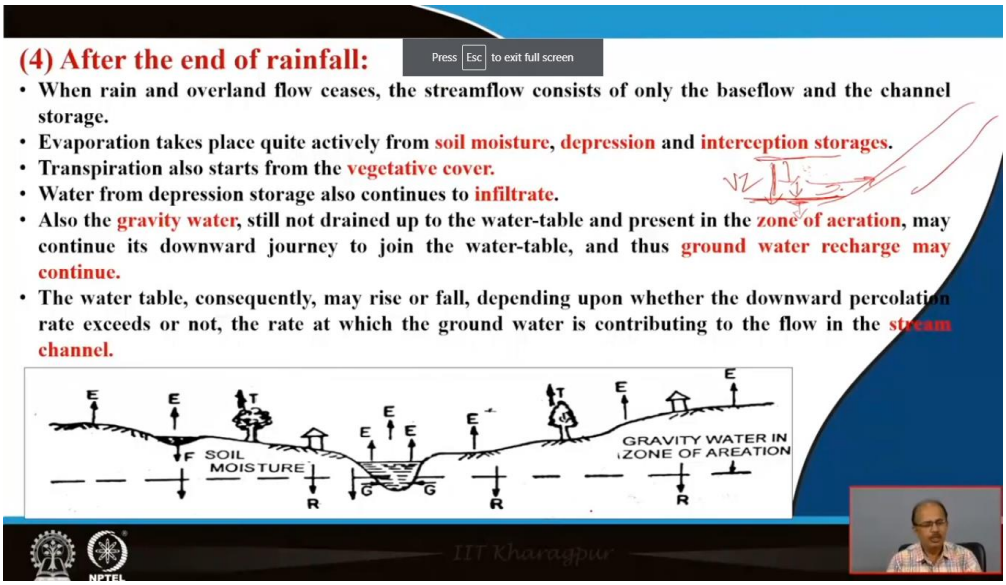

And now the fourth condition after the end of the rainfall so now the fault condition is that rain has totally stopped now which type of conditions remains in the during this time. So, when the rain and overland flow sieges because surface runoff also decreased the amount to what was the on the earth's surface they have reached to the stream flow. So, when the rain and overland flow stops then what is happening the stream flow consists of only the base flow.

Now the river will receive only the base flow base flow means the water which was infiltrated and percolated down to meet the water table. So, this amount of water of the vadose zone this is the vadose zone because the zone if you will recall the underneath the surface to the depth of the water table is the zone is known as vadose zone. So, this vadose zone water surplus water will ultimately move laterally and joins the river channel which is known as the base flow.

So, this base flow plays a very, very important role at this time. Evaporation takes place evaporation from the plants from some ditches, small ditches that start actively from the soil moisture depression and interception storage, suppose some water remains on the buildings top of the buildings so evaporation starts. Transpiration also starts from the vegetative cover because those amount of those drops of rain was still there on the vegetative cover.

So, they are not just reaching to the earth's surface they are from the leaf surface they are again going back to the atmosphere, transpiration also starts. Now water from depression storage also

continues to infiltrate if the moisture deficiency remains still in the underneath the surface. So, infiltration will start and then what is happening the gravity water is still not drained up to the water table and present in the zone operation may continue.

So, what is happening now, the surplus amount of water which remain in the zone of aeration zone of aeration is your vadose zone here. so, what will happen; this may continue to its downward journey to join the water table. So, this water will then starts and will reach to the water table and from there the groundwater recharge may continue, so this will start to come to the aquifer.

The water table consequently may rise or fall it may rise may come up or may go down. Depending upon whether the downward percolating rate exceeds or not, the rate at which the groundwater is contributing to the flow in the steam channel. So, if the groundwater base flow is contributing more amount of water to the stream channel definitely some more amount of water is required to reach to the water table.

So, this variation we have seen or we are seeing when the rain starts and when the rain stops. So, this amount of water which is reaching to the earth's surface not going down to reach to the aquifer is generally known as the runoff and this runoff plays a very, very important role in contributing the water to the stream as well as to the aquifer. So, with this we have learned about the concept of the runoff, thank you very much to all.