Ground Water Hydrology
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Module No # 01
Lecture No # 02
Ground Water in Hydrologic Cycle (Contd.), Ground Water Budget

In last class we discussed about the roll of ground water in hydrological cycle so today we will continue our discussion this ground water represents the important one of the three importance systems if hydrological cycle which can be referred to as a subsurface system of hydrological cycle that means all the activities all the components of hydrological cycle which are taking place below the ground level.

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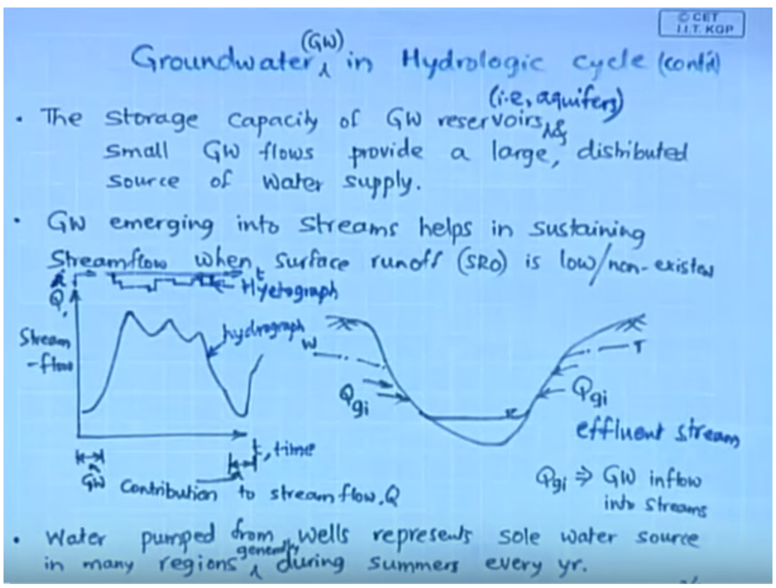

And here let us go to this one so the ground water is stored in the below the ground in water barring layers which are known as aquifers. So this storage capacity of these reservoirs so that is which are commonly referred to aquifers as well as the small ground water flow because when these aquifers gets saturated.

So then excess water from these aquifers flow from the from below the ground on to the ground wherever there are streams and other surface water bodies and these storage capacity in aquifers that is the ground waters as well as the small ground water flows so they ensure a larger as well as distributed source of water supply. So therefore what happens is the water supply the spatial extent gets increased as well as the temporal extent also gets increased.

So that is the major contribution of a ground work now let us also see the ground water emerging into the steams so this helps in sustaining the steam flow over a large space as well as time when the surface runoff is either low or non-existent. Say for example let me refer to you here the hydrograph where in the clot of this stream flow the queue is shown against the time T. So this is the time T. So this is the time T along the horizontal axis and stream flow Q along the vertical axis and just above that.

So there is a what is known as the hyetograph so this is known as the hyetograph which is a plot of rainfall intensity I versus the time T and here the hyetograph is a plot of the steam flow this is the hyetograph. So even though the rainfall is discontinuous that means hyetograph start at this point of time and hence here but still we see that in the hydrograph there is continuous stream flow. So here this portion that means this time duration as well as this time duration after the stoppage of this rainfall precipitation.

So that is the due to the confidential to the stream flow has this been not there so then this hydrograph would have been just shown with some lag with respect to this hydrograph but actually it does not happen. So therefore so this groundwater flow groundwater provides necessary spatial and as well as temporal extent and here what happens is so this one because of the here we can see so this is the cross section of a stream and the groundwater is entering and such a stream is known as effluent stream.

Where in the ground water is entering from the banks as well as little bit through the beds also maybe into the stream through this what is known as the groundwater inflow which is denoted as QGI. So here the water table is above the water level in the steam and this difference in the water table will results in the flow of groundwater from the banks into the stream.

So here these through these this this hyetograph as well as hydrograph as well as effluent stream it is evident that this ground water provides the necessary spatial as well as temporal of distribution of water supply. And also it is well known that the in many places there are wells and these wells represent the sole source of groundwater in many regions of the world especially during summer when there is practically no other source of surface water.

And so this happens generally in almost all years continuously that means every summer so the surface which is available in the form of surface bodies like tanks, lakes or reservoirs. So that goes dry so then it is the ground water which is especially in the wells which will serve as the soul water source in these regions.

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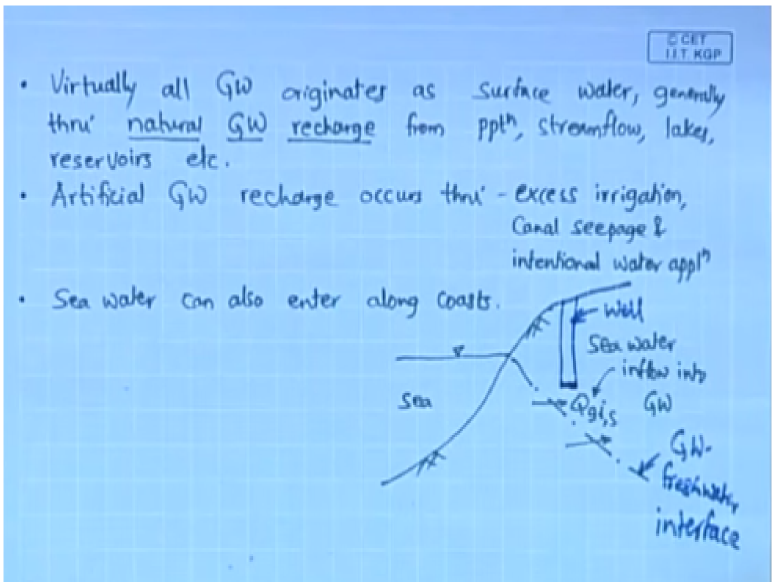

Now let me also let us also discuss about the origin of ground water which provides necessary spatial and temporal sustainability and addition distribution.

So this practically all the ground water originates as surface water through infiltration through this lateral ground water in flow and so this is known as the natural ground water recharge. So this by this process the ground water gets the supply and this supply is from precipitation it is also from stream flow and it is also from infiltration or seepage from the lakes and reservoirs. Now many times so this natural ground water recharge is insufficient in that case we go in for what is known as artificial ground water recharge.

And this artificial groundwater recharge occurs mainly through access irrigation it also occurs through canal seepage and it also occurs through intentional water application. So here so this artificial ground water recharge will bring about the balance between the ground water supply and the ground water demand. So wherever the supply is insufficient compare to the water demand.

So we artificially enhance the ground water supply through water known as the artificial groundwater recharge structures. Many times the sea water also enters through the coast into the ground which may be undesirable but this also represents the ground water recharge so here you can see this is the groundwater fresh water interface and this is the sea water level and this is the coast.

This is below the sea water level this is above the sea water level and here what happens is sea water flows into the ground water below the through this QGIS which represents the sea water inflow and this is undesirable because we know that the sea water is brackish or salty and but what we need for most for many of our activities this is a fresh water. So therefor this is undesirable so in such cases we need to take precautions by extracting the ground water.

In from the wells which are not close to this ground water fresh water interface so therefore in such case if we need to dig a well or a ground water extraction. So here this is the well we need to see that the bottom of the well is much about the interface between ground water and fresh water. Only in such cases we can extract fresh water otherwise what happens is through if the depth of this well is more so that it is very close to this interface of fresh water and ground water.

Then in addition to extracting the fresh water it will also start extracting the brackish or salt water of the sea which has in filtered through the interface. So therefore we should take precautions so that only the fresh water extracted through the wells whose depth is much above the interface. Now let me also refer to you about this the ground water and here so this ground water volume is a much smaller compare to the annual circulation.

So it is said that on an average the ground water whose residence time is the ratio of the volume divided by the flow rate or the annual circulation okay. So the residence time for the shallow ground water that means I refer to a depth of say below the ground. So in this range that means from the ground surface to eight hundred meters below ground so in this shallow ring.

So this ground water has residence time nearly 200 years therefore this you can see so this provides the necessary the water security compares to this the soil moisture which is there from the ground to say 1 meter below the ground it has a residence time of just say 20% the year or say nearly about 70 or 75 days say roughly 2 to 2 and half months. So after that through this soil moisture will not be there.

So then but this ground water the shallow ground water will be which is existing in the ground water layer between the ground and the 800 to 1000 meters. Some people refer to the depth as the 1 kilo meter or 1000 meters some people refer to this depth as 800 meters. So therefore so this ground water provides the necessary that is distribution of this extra distribution of this water supply over time.

And it also because we can extract down water through many this sources which as wells which we can dig in various areas where expect ground water in aquifers. So therefore so this provides the necessary that is addition distribution of water supply which is spread over time and space. So this is how this ground water is so important to provide that additional amount of water for additional time in addition areas. So now let us go to the next item of the next article which is the ground water budget.

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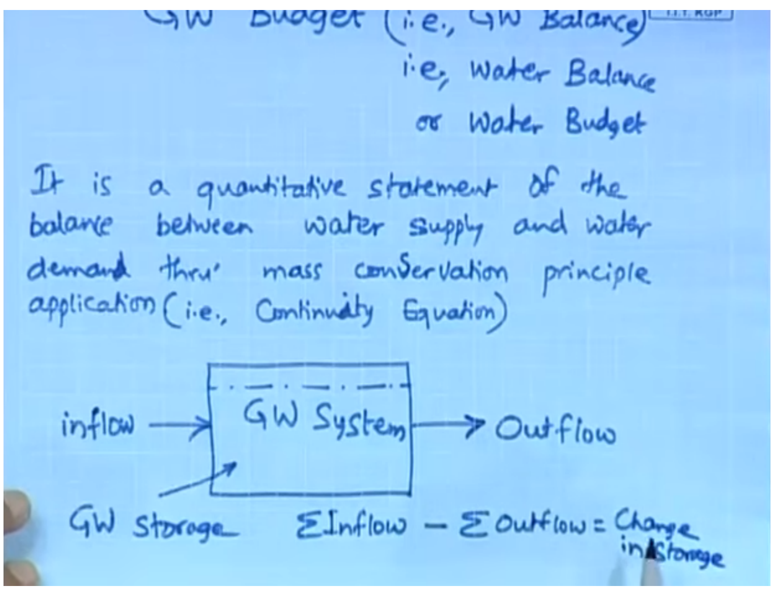

So this is also refer to as the ground water balance even though it is mentioned here as ground water budget essentially it is water balance or water budget in this case basically what we do is we mathematically express the all the water which is available as water as a supply as well as all the water which is consumed through our water demand.

So through this what is known as the water balance equation so therefore so this water balance or water budget here we can also writing this as the water balance or water budget. So here essentially this is so it is a quantitative statement of the balance between water supply and water demand.

Now here through mass conservation principle application so here what we do is in this fluid mechanics there are three conservation principles and water is important fluid for sustaining life and these three conservation principles are the conservation of mass the conservation of energy the conservation of moment. So here this conservation of mass it is also refer to as the continuity equation continuity equation.

So even though we call here it has a groundwater budget or ground water balance essentially it is water balance or water budget because in this ground water we cannot simply segregate ground water completely from the surface water. The simply reason is that so there is always interaction between the surface water and ground water and that is why here what happens is so through various activities.

So the various quantities of a supply as well as demand are estimated so here we can also through mass conservation it is a quantitative statement of the balance between the water supply and water demand through conservation principle application. So here essentially this ground water budget equation is form of that is the total supply that is existing and the total demand that is existing.

So the difference between the supply and the demand will appear as a change in storage say for example if the supply is more than the demand then there will be an increase in the storage. So essentially if we take a system and in the system there will some inflow into the system there will be some outflow from the system and let us take some example for ground water system. So which is bound spatially and here what happens is so the inflows to this ground water system.

So they are essentially from say precipitation or they are also from other water supply such as irrigation and may be there could be into this system there may be some lateral inflows. So these are all the terms which represents inflow likewise in terms of this outflow. So we can say it is pumping say for example if I say draw this ground water system and here and so these are the inflow and this is the outflow and here let me say represent.

So this so this let me this is the ground water storage so here so this is the system diagram for the ground water and it will have the inflow from one side of course there can be more the many times inflow from more than one side also and there is outflow also from many sides and then depending upon this one I can write the expression as a sum of inflow minus sum of outflow is equal to that is the change in storage.

So here so coming to this one so therefore what we need to do so this is essentially one equation. So therefore we can at the most determine one unknown okay so here as I said the this equation that is the ground water budget equation or the water budget equation.

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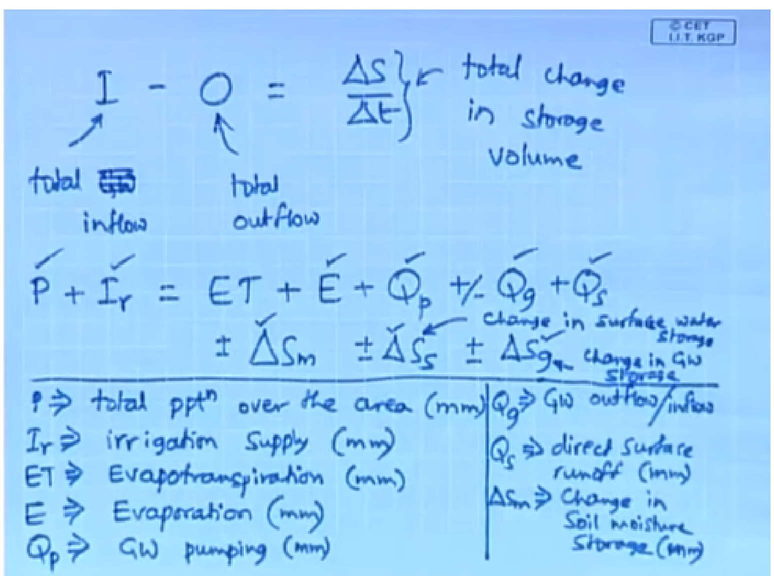

So can be written as I – O = Delta S / Delta T so this is the ground water inflow or let us say this is total inflow and this O represents the total outflow and this delta S / delta T represents this total change in storage volume. The same thing we can write it as this as P + IR = ET so here the P represents let me write all this P represents the precipitation.

IR represents the irrigation this ET represents the evapotranspiration + E + QP + - QG + QS + - delta SM + - delta SS + - delta SG. So here P represents total precipitation over the area so certain depth so here if P is in terms of certain depth then all the terms also must be in terms of the depth units okay. So this may be certain depth millimeters and then this IR represents the irrigation supply for that area and that is expressed as certain depth over the entire area.

Next it is the ET which is evapotranspiration again expressed as depth from this area in as depth in millimeters next is the evaporation. So this is evaporation over that area again expressed as depth so next is this QP. This QP represents so this is the ground water pumping so that is also expressed as certain depth in millimeter and then this QG represents so this is the ground water outflow or inflow if it is outflow it will have a positive sign.

If it is inflow from the neighboring areas it will have a negative sign next is QS which represents the direct surface and all again it is expressed in terms of depth and this delta SM represents change in soil moisture storage again in as a depth in millimeters and so this delta SS so here am writing. So this is the change in surface water storage okay and lastly this delta SG represents change in ground water storage.

So essentially here suppose we need to estimate say that is suppose we have the surface component surface zone of the corp. So here in this case because we are dealing with the surface zone of the crop so it is required it is required for us to estimate this a evapotranspiration which takes place through this crop through this surface zone.

So therefore in here we need to make either estimate or actually measure the precipitation the irrigation supply the evaporation which takes place over that area then the ground water the water which has been pumped which his QP. And this ground water outflow whether it is there in that area then QS is the direct surface runoff in that area then the change in the soil moisture through various instruments such as a limiter or etc.

Then the change in the soil moisture through various instruments such as limiter or etc then change in the surface water storage as well as change in the ground water. If all this terms are estimated then the only unknown in this case will be this vapor transpiration. So here this is known this is known this is known this known this is known this is known this is known this is known this is known. So the only unknown is the evapo-transportation which we can estimate provided all our estimates are the estimates or measurements are reasonably correct.

Similarly let us say the wee need to estimate this deep percolation so in this case so s here all other terms so deep percolation were estimated we are we need to estimate so therefore we should have the idea about all other terms so therefore here in this case that is the change in the ground water storage okay. So this represents deep percolation so here only this SG is unknown whereas all other terms we need to estimate.

So all other terms this is the two supply side terms and then seven demand side times terms that is evapo-transportation, evaporation the QP QG, QS, Delta SM as well as the Delta SS. If all these either we can estimate or measure with reasonable amount of precision and accuracy then we can estimate the change in ground water storage and in this again if we deduct the change in the ground water storage in the top aquifers then we can estimate the deep percolation.

So like this so this ground water budget it helps us in providing the in applying the mass conservation principle and thereby what we do is we estimate the unknown parameter. It may be whether in case of it may be for a on the surface or it may be below the surface so here therefore this estimation of this change in the storage the ground water storage okay.

So that is one which is very much so on once we do a reasonable estimate of the change in ground water storage then we can do realistic estimate of ground water supply and based on that we decide whether this change in the ground water whether it is increasing over that area over time or whether it is decrease.

So accordingly we decide the strategy if it is increasing then we need to this water the ground water storage is within the satisfactory zone that means the water table depth is within the satisfactory range of fluctuation. And so accordingly we may design proper land drainage system as well as subsurface drainage system and then take out the excess water which is very much required which is very much the case in case of the systems where there is there is flooding water logging and things like that.

Likewise suppose due to other reason other causes in a particular area over a particular period of time. So there is a decrease in the ground water storage so then that need to be properly estimated and then there we need to go for say the augmentation measure through artificial ground water recharge. So that the water table or the piezometer depth is maintained in within the permissible range it is not too deep.

So that extraction of ground water will become unfeasible will become infeasible or will become too expensive. So therefore depending upon this Delta SG whether that is change in the ground water storage in a particular area over a particular period of time. So need to decide whether we need to have a drainage system their or this whether we need to have an artificial ground water recharge system there.

So this ground water budget or which essentially water budget or water balance or ground water balance equation. So here we are using this continuity principle, continuity equation or the mass conservation principles and thereby measuring actually measuring through field test or through realistic estimation of certain terms of water supply or water demand. So we estimate the change in the ground water storage in general or we may student other thing also like the evapo-transportation as I mentioned earlier.

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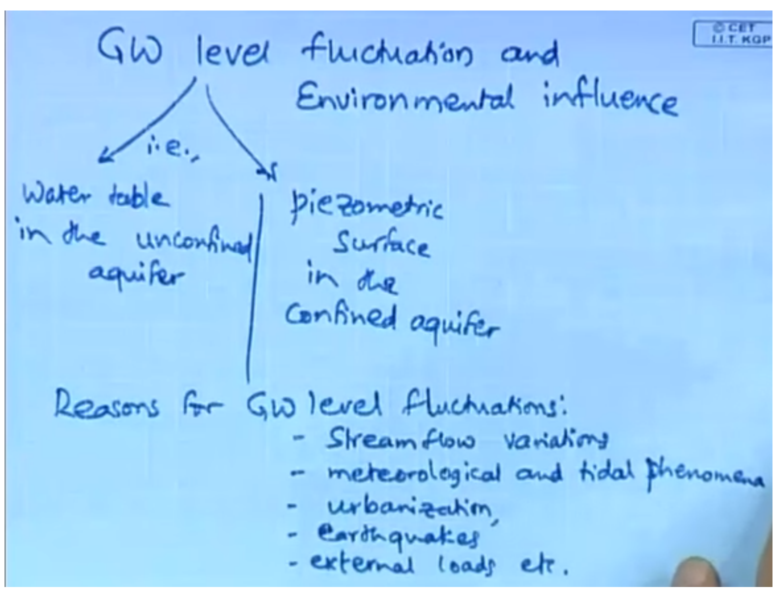

So this completes the ground water budget and now let us go to this ground water level fluctuation as I was mentioning groundwater level fluctuation and environmental influence. As I was mentioning this ground water provides a necessary water security extended over space and time. Therefore we should see that the level of groundwater in unconfined aquifer it is known as the water table.

So this ground water level this is referred to as so water table in the unconfined aquifer or it is refer to as the peizometric surface in the confined aquifer. So this we should see that the ground water level fluctuation is within the permissible limits and there are various reasons for this ground water level fluctuation okay. So the reason for ground water level fluctuations they are that is the stream flow variation that means the flow in the rain streams or river it varies with time and that results in the ground water level fluctuation.

And there they are meteorological and tidal influences and tidal phenomena also urbanization earthquakes and external loads. So here the stream flow variation as I was mentioning there will variation in the rate of flow in the stream and that results in the fluctuation in the ground water level in the neighboring areas. Similarly the meteorological and the tidal phenomena areas. So suppose there is a rainfall or a flooding or may be the discharge of water from upstream area or this may be gather as surface flooding or even tidal phenomena in the coastal areas.

So there will be coastal area so there will be due to the sea waves so what happens is the there will be fluctuation sea water level and then this fluctuation in the sea water level will give rise to the tidal phenomena and then therefore there will be variation in the ground water level. Similarly urbanization so because of this urbanization so people tend to have more tube wells or extracts more ground water through other wells as well as other sources and therefore there is a possibility there is a result in the ground water level falling down.

So similarly this earth quake so these earthquake what they do is because of this earth quake so there will be cracks in the earth surface and due to this cracks what happens is the surface water in a stream or from a bed or from the banks it took this carried it infiltrates or percolates easily into the through this cracks developed due to the earthquakes and thereby so there it may results in the at some places it may results in the lowering of ground water table.

And some other places it may results in the raise of the ground water table due to additional due to excessive it is a the deposition excessive storage of ground water which has grown through this cracks developed due to the earth quake. And largely these external loads so these external also may be due to this say for example if there is a dam or other barrage or such hydraulic structure.

So there what happens is so due to this water load so there will be the raise in the water table or the ground water and so in the downstream of the dam so there may be lowering of the water table so these are some of the examples of the water table fluctuation.

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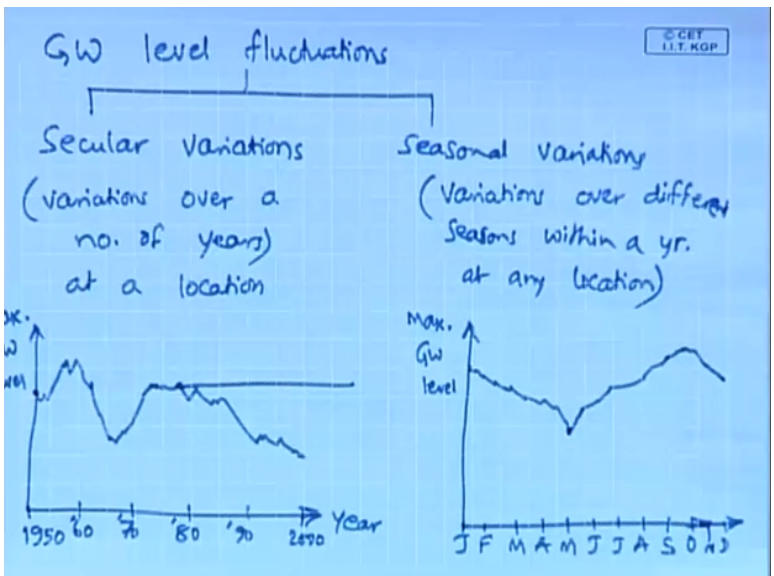

And now let us see a little bit about the ground water level fluctuations here we can make we can classify into two categories the first one is the secular variation the second is the seasonal variation. So the secular variations are variations over a number of years at a location.

Similarly this seasonal variation are variations over different seasons within a year at any location. So when I consider the groundwater level fluctuation we should focus on this the circular variation as well as we should focus on the seasonal variations. So in this case say suppose I mentioned so this is the so this is the year and then this is the maximum ground water level.

In this case and of course let me also represent in this case say here let me say this is a say 19, 50, 60, 70, 80, 90 and then say this is 2000. In this case at a particular the maximum ground water level in a year from this 1950 onwards it could be it may show a trend like this. So initially and so here from this it is evident that say for example from very close to 1990's.

So there is almost continuous decline in the maximum ground water level during a that particular year so this is just one example of a secular variation and the similarly the seasonal variation so what we do is within a year we represent the variation at any location okay. And so at this case say if I represent say the month of January, March, April, May, June, July, August, September, October, November and then say December.

So in this case at a particular location so this is the again let me take it as the maximum ground water level. So in this case say suppose for the Indian condition so this is the ground water level it may reach the minimum in this one and it may reach the maximum sometime there and then again it may slowly decrease. So this represent the seasonal variation and now let me also so just few minutes back in the influence of ground water in the hydrological cycle.

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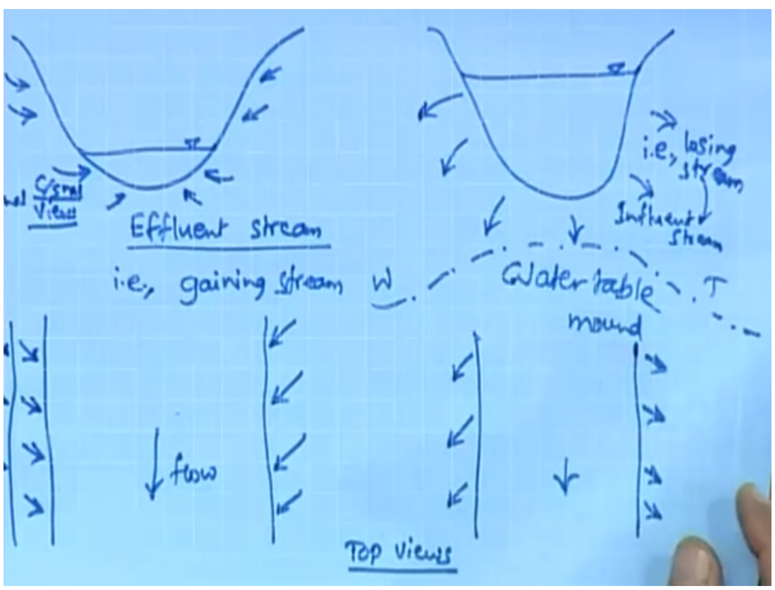

I mentioned type of stream which is known as the effluent stream so this is the effluent stream in this case there may be contribution from the bed as well as banks into the stream. And this is also referred to has a gaming stream similarly there are another type of stream which is known as a losing stream. Wherein this stream is having a high water level and then so because of this there is infiltration from the stream into the ground and this is they refer to as the water table mount.

And if I draw the so this is cross sectional view so this is the here this is the influence stream and this influence stream also refer to as losing stream and this are the cross sectional waves. So this is the cross sectional view and so this are the top view so in this case so incase of this so this is the flow direction in the stream and so the water will be entering from both the banks. On the other hand in case of and influence stream suppose this is the flow direction.

In this case the ground water the surface water in the stream will be leaving and flowing as ground water through beds and banks creating a water table mount. And so this will be the flow lines from this influence stream so effluent stream having the flow line converging and the influence stream having the flow line diverging. So this so we will continue our discussion on the ground water level fluctuation and the environmental influence in the next lecture thank you bye.