Ground Water Hydrology
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Module No # 01
Lecture No # 03
Ground Water Level Fluctuations and Environmental Influence (Contd.) Literature

Welcome to this lecture number 3 which is in which I am going to continue from where i stopped in the previous lecture.

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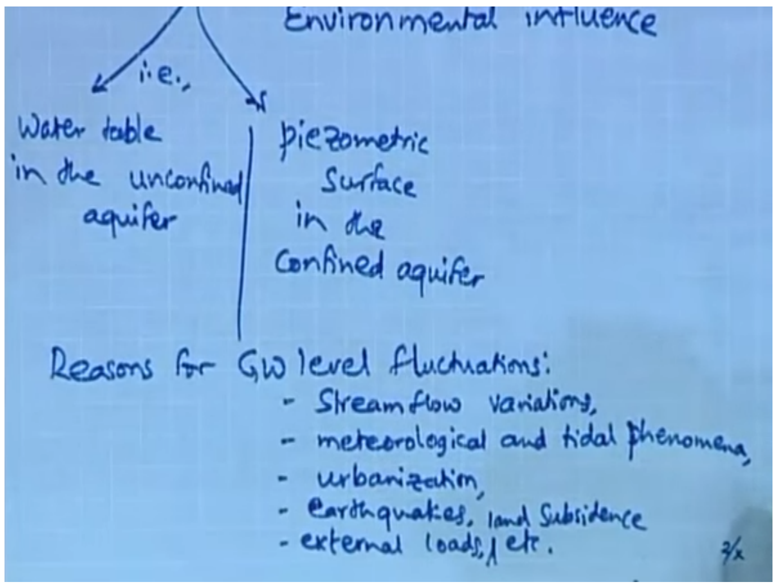

That is on ground water level fluctuation and environmental influence and here we know that it should be our endeavor to maintain the ground water level it may be water table in case of an unconfined aquifer or it is known as piezometric surface in case of a confined aquifer.

So this ground water level should be maintained at the optimum range it should not be it should neither be too shallow nor should it be too deep and to maintain this optimum level of ground water during all the times. So we need study the reason for where reasons based on which the ground water level fluctuates.

So some of the reasons are listed here the first one is stream flow variations flowed by metrological tidal phenomena and urbanization is also one of the parameter which influences the ground water level fluctuation followed by earth quakes external. And so here land subsidence here let me also write land subsidence etc.

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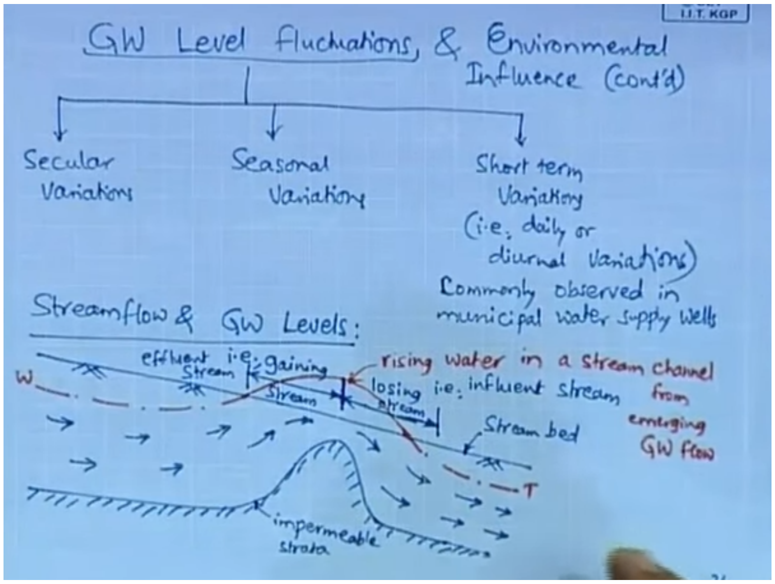

So these are some of the reasons or causes for ground water level fluctuations and let me also continue so in the previous class we were discussing about the secular as well as seasonal variations while the secular variation represents the variation in the ground water level over a period of more than a year. Seasonal variations they represent the variation in the ground water level within one year over the different seasons.

And there is also a third type of variation which can list it has a short term variation so in this case so it is basically daily or diurnal variations which is very commonly observed in municipal water supply wells. So essentially here we can say this short term variation is daily represents daily or diagonal variation. Seasonal variation represent the average annual variation average variation within a year and secular variation represents the variation in the ground in the water level over a period more than a year.

So we need to consider all the three and during the all the period ranging from less than a day to a period which is say around a year to a period which is greater than that maybe a number of years could be 5 or 8 or 10 okay. So all these thing we need to consider now let us consider firstly the stream flow and its impact in the ground water levels.

So let us consider this figure a stream with bed shown alone the sloping bed shown here and then there is an impermeable strata let that impermeable strata consist of a hump here I shown here in the middle and because of this hump in the impermeable strata. So the water stream lines the ground water stream lines will show an upward trend and especially in the hump so where the height of the impermeable strata is at its highest.

So this some of this three the ground water stream line they will be above the ground so they become surface water stream lines and so in this portions so that is say from here to here. So this water table will be above the ground level whereas to this left of this the water table is below the ground as well as the right of this section the water table is below the ground level or in this case it is stream bed level.

So here what happens is so this portion that means from the hump to the portion where the ground water stream lines have transforms themselves in surface water stream lines. So it will be acting like a effluent stream or a gaming stream because here what happens is so the all the groundwater will contribute as a effluent or as a contribute to the stream flow. Similarly the downstream of the hump what happens is because the downstream part of the hump.

So here what happens is the surface stream line which where appearing here they again develop a downward orientation and then they get transformed into ground water stream lines. So therefore from this point onwards downstream the water table is again below the ground level and this portion between the hump and the location where the surface stream lines again get converted into groundwater stream lines.

So that will be behave like a losing stream or an influence stream so in this case what happens is because of the water table is higher than the water table in the adjacent testament. So the stream will lose through infiltration as well as the infiltration at the bed desert of the banks. So therefore it will be active like a losing stream as influence stream and in this in middle portion.

So it is the rising water in the stream channel from the emerging ground water flow so this is how the stream flow will affect the ground water level. So many times this stream flow this effect of stream flow on the ground water level is also visible especially in case of floods the flood wave.

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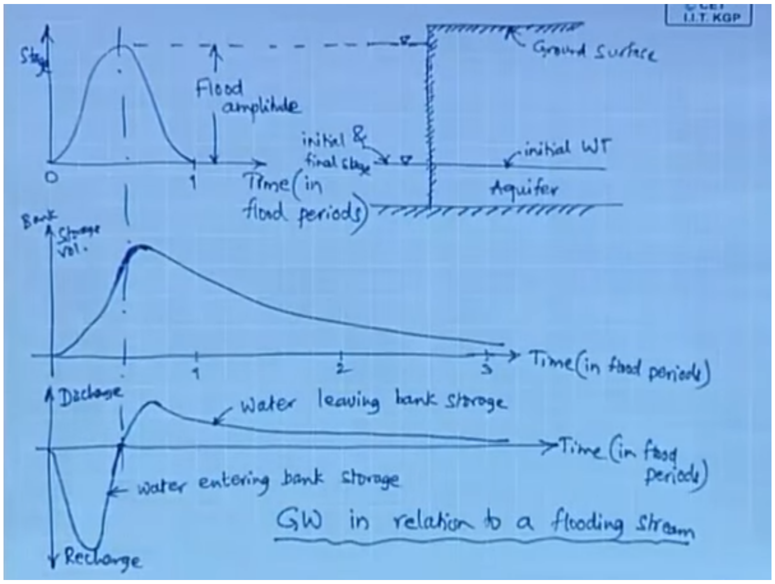

Let us consider in this case a flood stage hydrograph which represents the variation of the stage which is essentially the water level in the stream at a particular location with respect to a standardized datum such as the mean sea level and it is variation with time and in this case the time values are represented in terms of flood period.

So flood period is the period basically its starts from the duration from the time instant when the stream flow or the discharge goes on increasing abruptly above the base flow which is basically ground water contribution. And then again reaching the peak flood during which time there will be peak stage so this is the peak stage here again it starts the flood waves starts receding. So the flood level as well as flood discharge gets reducing and finally it reaches the normal level.

So this period from the increase from the instant when they the flood wave started increasing to the time instant when the flood wave started decreasing. So this is known as a flood period so here it is indicated as the time instant between 0 and 1. So here this is a stage flood stage hydrograph and the difference between the initial water which is the here in Indian Terminology it is known as the no flood level or the danger level and also the highest flood level that is the final water level that is the water level during the flood peak.

And this one this initial stage of flood is also the final stage because after the flood wave recedes it again goes back to this one and here this is the ground surface which is slightly above the flood stage flood peak stage and in this case now let us consider how the bank storage volume as well as the recharge and the discharge vary in case of a flooding steam and so now let us consider the bank storage.

So essentially this bank storage volume is the volume of flood water which gets stored in the banks of course which includes beds also and here what happens is so this as the flood stage goes on increasing from the initial level to the flood peak stage. So the bank storage volume also goes on increasing and when the flood stage is at its peak the bank storage volume it also at its peak and as the flood stage goes on decreasing the bank storage goes on also goes on decreasing but more gradually not as abruptly as deferred flood wave.

So here in this case if the received time for the receding flood stage hydrograph is may be of the order of say 40 to 50 % of the flood period whereas in this case the time for reduction in the bank storage volume it may be after order of 40 to 50 % of the flood period. Whereas in this case the time for the reduction in the bank storage it may be almost say 2 and half at least two and half times the flood period.

So it is more gradual here and now let us consider the recharge and discharge volume so which occur due to the water entering the bank storage and the water leaving the bank storage. So here initially when the flood wave starts and the food stage goes on increasing from the initial level to the flood peak stage. So the recharge goes on increasing and it reaches the maximum and again so this recharge then the recharge goes on when the flood stage is stage at its peak and the bank storage volume also at its peak.

So here the recharge volume which essentially is represented by the volume bound by this curve. So this recharge volume is also the maximum. So here this is the peak recharge intensity and this recharge intensity goes on decreasing and the recharge volume. So this is the area here so that is maximum and once the recharge is maximum when what happens is the water starts leaving the bank storage and so that will appear as a discharge.

So this discharge which starts from the time instance of the flood peak stage it starts increasing initially reaches peak somewhere between the flood peak stage and the and the first time flood time period. So somewhere in between so this discharge volume is this the discharge intensity is maximum and then so like the bank storage volume. So then onwards water leaving the bank storage will also be gradual.

So essentially this area which goes on increasing represents that is the water leaving the bank storage and again so in about the two and half to three times this one. So it shows it again comes back to original value. So this is the impact of stream so previously in the previous case we studied we discussed about the ground water level in case of a river which is having an impermeable bed with central raised portion and hump.

And in this case number 2 we studied the variation of the flood volume especially the bank storage volume as well as the water entering the bank storage during the recharge process and water leaving the bank during the discharge process. So these are some of this one the cases of stream flow influencing the ground water level.

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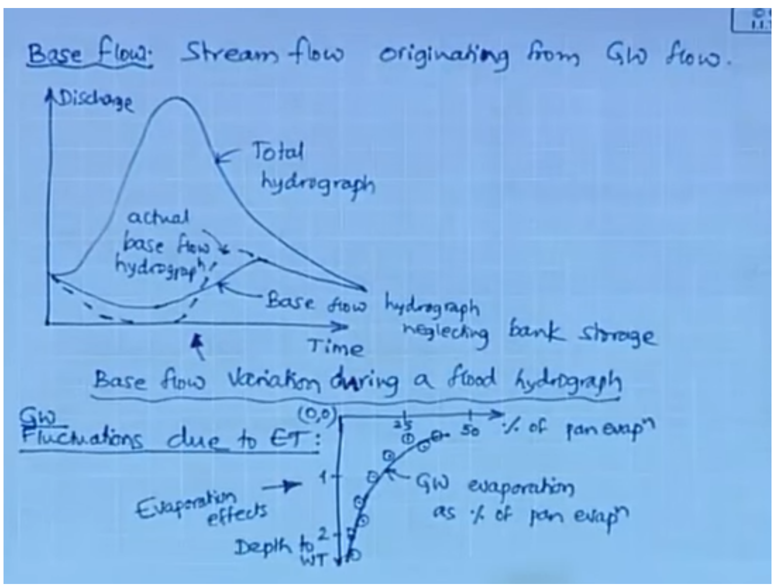

Now let us come to what is known as the base flow and this base flow has a name itself says. So it is the flow which is existing in a stream due to extended contribution of ground water so obviously this stream flow originates from the ground water flow. So this base flow is the stream flow portion which originates from the ground water flow.

Now let us consider a flood hydrograph as I was mentioning here so this is the total hydrograph which you can also call it flood hydrograph say somewhere here this during this period there is a precipitation and rainfall and then because of the so there is surface runoff increase and then it starts the flood hydrograph and it reaches the peak.

So this is the peak discharge of the peak flood recharge and after that it goes on decreasing and again it will reach the total discharge will be equal to the base flow wherein entirely it is the base flow which contributes total flow from this time and beyond. So now here let us study the variation of the base flow. As we discussed in the previous case so because during this period recharge is taking place the ground water recharge is taking place and unless the ground water gets saturated.

So there cannot be any discharge so therefore this is this essentially the dotted line from here to here this represents the recharge phase and then there is no this one and if we from this point onwards discharge starts. So this discharge goes on increasing reaches the peak and then it starts decreasing and so finally it starts gradually decreasing and it reaches from this point onwards it is only the base flow which is contributed this to the stream flow there is no other contribution to the stream flow beyond this point.

But if we consider if you neglect the bank storage then what happens is so the base flow hydrograph which is essentially the plot of base flow with time it shows less fluctuation. So because so here what happens is so this base flow hydrograph in this we are neglecting the bank storage and because of this one. So it is showing the minimum base flow does not reach zero because there will be always some margin but this is the not the actual case.

So this is just the base flow hydrograph when we neglect the bank storage so here the minimum base flow is also less is also slightly more than the 0 which is the 0 which is the actual minimum base flow and the maximum base flow is slightly less than the actual maximum base flow which occurs somewhere here so like this so it is the base flow which essentially is the one which provides the this one which provides the extended ground water distribution over space and time.

And it is essentially this base flow in the hydrology which is represented by the various infiltrations indices like the Phi index the W index. So which represent essentially the infiltration part and then so especially that this W index the initially attractions area also and so essentially so the base flow represents the minimum total flow which exists the during the period wherein there is no flooding.

Now this is this represents the base flow variation during a flood hydrograph the actual variation from the dotted line and the base flow hydrograph neglecting the bank storage shown by this line which shows the higher minimum and a lower maximum. Now let us consider the other factors such as the impact of evapo-transportation on the ground water fluctuation. So in the previous class we mentioned that even though ground water it is below the ground.

So always there is some small portion of ground water which is closer to the surface which is very close to the surface level and it is affected it is subjected to evaporation and so therefore what happens is. So because of this small that is the portion of this ground flow is directly which is directly subject to evaporation near the surface. So there the in the surface near the surface so the evaporation expressed as a percentage of panning operation is very high.

As we can see here say this is say some in the range between a the surface and say 0.5 meters or say may by 1.45 meter which is which is a one and half feet. So around this range in this top layer so the ground water evaporation which will be almost 25 to the it is more than 25 % and even it reaches as high as say 50% of Pan evaporation rate there.

But as we deeper and deeper so this the evaporation effect it will be less and less visible on the ground water fluctuation because what happens is so this is a the ground water is at a depth below this 0.5 or say 0.45 meters and therefore what happens is the ground water evaporation of ground water expressed as a percentage of pan evaporation it goes on decreasing and even it may be so at deeper depths it may be practically negligible it may be of the order of say 5% or even less than that.

So this is how the ground water fluctuates due to the effect of evaporation so the effect is significant in the ground water layer which is at the top that means from the surface to say 0.45 to 0.5 meter below the ground and below that fluctuation let off ground water level. Due to evaporation so that will be significantly less.

Now let us also consider the effect of transpiration because as you know evapo-transpiration consists of evaporation which is occurring at the open surface or the water open water bodies or the bare soil moisture gets evaporated there. And transpiration is basically the water which gets which transforms into the vapor form due to the metabolic activity of the plants. So the plants they during the process of metabolism so through this stomata openings.

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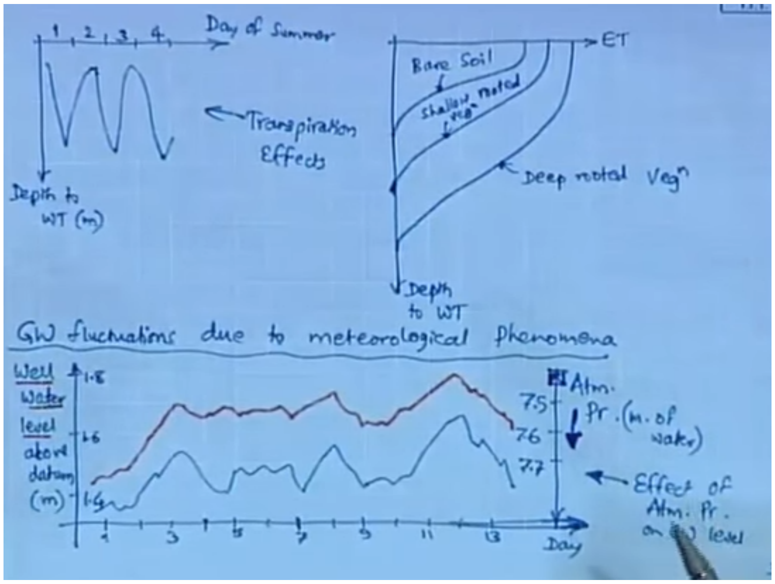

So they give out water in the form of water vapor which is known as transpiration and here say let us consider a day in few days in summer and the depth of water table and as you can see here so this day one represents a 24 hour period similarly day to day 3, day 4 all of the represent the 24 hour period and as we all know so the temperature is maximum sometime immediately after day.

So therefore during that period the transpiration rate will also be maximum so therefore the depth of water table will be the highest that means the water table will be deepest at that. And again as the evening approaches and then as they at the midnight and then so beyond that so what happens is so due to the reduction in the transpiration activity the depth of water table it shows a slight increase.

So it may be of the order say a few centimeters may something like less than definitely less than 10 centimeters generally of the part of say around 5 centimeters then again the next day it happens the same thing what happens so here somewhere immediately after the midday okay.

The transpiration is maximum the rate of transpiration is the maximum so the water table depth is maximum.

So this kind of daily variation of the water table depth due to transpiration it follows the you cans say this is a sinusoidal wave now let us consider the effect of the vegetation evapo-transportation essentially because it is extremely difficult to measure evaporation or transpiration separately because when we plants on the ground so there are some areas where there are plants which planted artificially or plants which grow out naturally whereas in the neighboring areas.

So there may not be any plants so essentially so in such case there will be loss of water from evaporation in the bare soil or the soil or the or the area where water is the plants are watered by say flooding and other similarly process. So here what happens so therefore it is a well know practice to express this total loss due to evaporation and transportation together as evapo-transpiration.

So here see in case of bare soil so the evapo-transportation is the depth to water table the part of depth water table versus evapo-transportation it follow this curve. So at this one so at this depth so there is a 0 evapo-transportation so this could be say a few meter may be 2 or 3, 2 to 5 meters or so depending upon the type of soil and the presence of the impervious strata below and on the other hand say wherever the shallow routed vegetation.

So this consists of plants whose roots they do not spread more than say 1 meter or from the ground surface. So in such case what happens is so the at the ground surface the evapo-transportation is the maximum and then as we go deeper and obviously this depth wherein the evapo-transpiration will be practically 0. So this depth will be higher than the depth due to the depth observed in case of a bare soil.

So here the variation of evapo-transportation and the depth water table in areas having having shallow routed plants or crops or vegetation it follows this say one obviously here this the and here you see the bare soil. So this evapo-transpiration is entirely due to evaporation whereas in this case. So if you can say this is due to evaporation and this is due to transpiration so and at this depth which may be say something like say 1 to 2 meters.

So here at this depth and beyond so the evapo-transpiration becomes practically 0 and now let us consider deep rooted vegetation like such as the large trees. So for example we can give this banyan tree so this banyan tree it is one of this in the roots. So they also grow they also reach the ground then they grow bigger and bigger and thereby giving addition stability to the banyan tree and in this case the roots may go even few meters deep also.

Sometimes even may be tens of meters deep rarely so here what happens is this the plot of evapo-transpiration and they the depth to the water table. So it will follow a curve which is even which is having a at the ground level the evapo-transpiration is even more because it is a deep rooted vegetation and the when it is deep rooted vegetation it also has a large number of leaves as well as stem through which this transpiration takes place.

So therefore the evapo-transpiration takes place at the ground level is larger and also so up to this basically it represents the root under depth which may be of the order of say 5 to 10 meters. So only beyond that the evapo-transpiration becomes 0 so therefore so this is the diagram show the variations of evapo-transpiration with the depth ground with the depth water table for bare soil.

Shallow rooted vegetation so wherein we can say the vegetation is the root zone depth is say less below less than 1 meter also or so less than 1 meter whereas deep rooted vegetation where in the root zone depth is even up to say 8 to 10 meters or so this case this is the variation. So now let us come to variation or fluctuation in the ground water table due to other metallurgical phenomena such as the atmospheric pressure.

And we know that so it is the atmospheric pressure which is the prerequisite for a mow atmospheric pressure here is a prerequisite for precipitation when there wherever there is lower pressure formation. So there what is that the water the atmospheric moisture which is as well as moisture which is in the clouds it has a tendency to precipitate and this precipitated clouds with water atmospheric moisture condensed in them become heavy and then the precipitation starts in various forms of precipitation.

So here what happens is so as they as the atmospheric pressure decreases so the here these peaks because that atmospheric pressure which is shown to be in the graduates it is the higher atmospheric pressure is shown in the downward direction. So therefore this as the atmospheric pressure increases so there is no possibility of precipitation. So therefore the ground water the well water level which essentially represents the groundwater level in unconfined aquifer it will at its lowest slip and as the atmospheric decreases.

So it represents so these points so here so the there is a possibility of precipitation and then due to precipitation the well water level which represents which also represents the ground water level in unconfined aquifer increases. So like that this is the effect of atmospheric pressure on the ground water fluctuation in case in this case we have considered only the unconfined aquifer.

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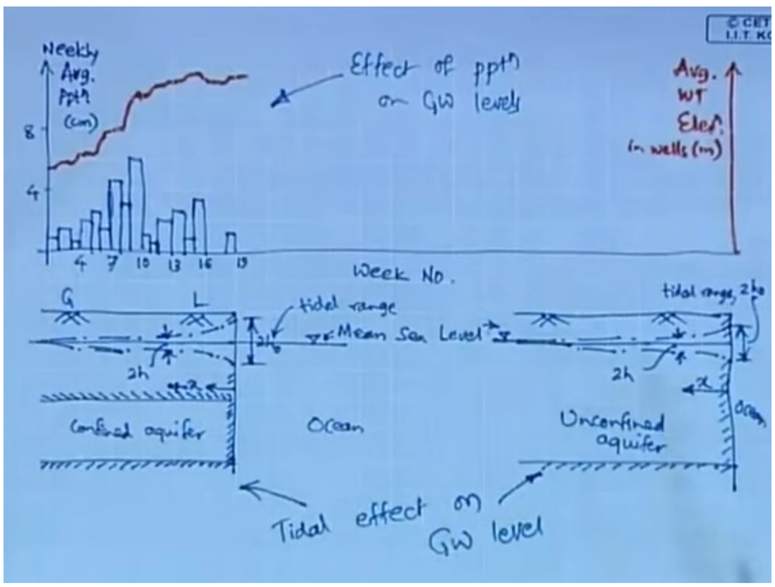

Now let us come to the effect of precipitation in general and say rainfall in particular in the ground water level fluctuation. So here let us consider the weekly hyetograph which represents the amount of precipitation which has taken place during the particular week. So in this case this rectangle represents the precipitation depth in the week number one similarly this represents the precipitation depth in week number 2 like.

So like that so this basically a stacked bar graph with the width of each of the stack stacked bar equal to the duration of 1 week and this case now in the in red color the average water table elevation in the wells which represents the ground water level in and unconfined aquifer okay is represented in this case as you can see here. So this is basically K here we can say this is we can consider to the monsoon season in a region say in India where the monsoon is significant and this one.

So here what happens is as long it is some amount of average weekly precipitation so this results and this average weekly evapo-transpiration is somewhat less than this. So this the ground water the average water table elevation will go on increasing and there are some places where the average water table elevation is almost stacked in.

So there was they those represent the weeks where in the total weekly precipitation as well as the totally total weekly evapo-transportation is more or less same or slightly less in that case it also shows like decreasing 10 and in this case so here say this during week number 17 and 18 absolutely no precipitation. So in this case the precipitation among the weekly precipitation amount is 0 whereas the weekly evapo-transpiration amount is significant.

So therefore it shows it the water table it shows a lowering trend so that is shown by this and then again on the nineteen week so the some precipitation and because of that the water table again as long as this the depth of precipitation is slightly more than the average weekly evapo-transpiration. So this water table goes on show a slight increase so like this the various metrological phenomena okay will impact the ground water level fluctuation.

Now let us consider the tidal range the effects of tides on the ground water level in this case we know that in English we say that time and tide wait for none. So this tide are essentially our daily tides which occur with a time period of say 12 hours am sorry 24 hours and 50 minutes there are also the spring tides and so in a during of say 24 hour 50 minutes.

So point on earth will be closest to another point of moon essentially this tide occur due to the attraction between the earth sun attraction earth sun, earth moon as well as sun and moon. So obviously of course sun and moon it won't have any effect on earth but at least the attraction between earth and sun as well as attraction between earth and moon. It earth and moon so this attraction results in the daily tides so which will so in a period of say 24 hours 50 minutes there will be two spring tides there will be two high tides and there were two low tides.

And then similarly during summer and then during winter spring as well as autumn there will be so tides so here let us consider so the tidal effect on the ground water level and in the left hand side in the figure were considering the confined aquifer. So here this is the ground water level so here although the ground slope will not be as steep like this generally. So for simplicity so the interface between land and ocean represented by this vertical line.

And so this represent a confined aquifer and here so this tidal range represented at 2 H0 where H0 is the height of the water surface above in sea level at that particular tidal location or coastal location and then at a general distance X measured from the coast. So this is the coast here which has been approximated as a vertical line so at general distance X the tidal height = 2H. So here what happens is because of the tidal effect so when the water level in the sea is maximum.

So obviously the groundwater level at the level will also reach will also be reaching the maximum and of course as you move away from there from the coast. So this variation will also be decreasing an eventually at some distance upstream from the cost so this tidal variation will be practically negligible and so this is case of confined aquifer and because of this so there will also be this represents the variation of the piezometric surface in case of a confined aquifer.

Now on the left hand side let us consider the tidal effect ground water level in unconfined aquifer so here so there is an unconfined aquifer which essentially is spreading from the ground level here. So this is the ground level all the way up to the so the impervious strata. So this is the impervious layer and similarly this is the impervious layer.

Incase of a confined aquifer and of course this is also the impervious layer the top confining layer which is also an impervious layer and in this case what happens is the same phenomena is observed and the when the tide reaches its maximum range at its maximum level. So the ground water level will also the fluctuation and it will show the maximum level which is H0 times above the main sea level and here in this case this represents the main sea level.

And at any distance X upstream of the coast so this ground water table will be having an increase in the depth in elevation given by H which is less than H0 and at some distance upstream of the groundwater level. So it will be 0 the ground water fluctuation is 0. So this is the impact of the tidal water level on the ground water level fluctuation.

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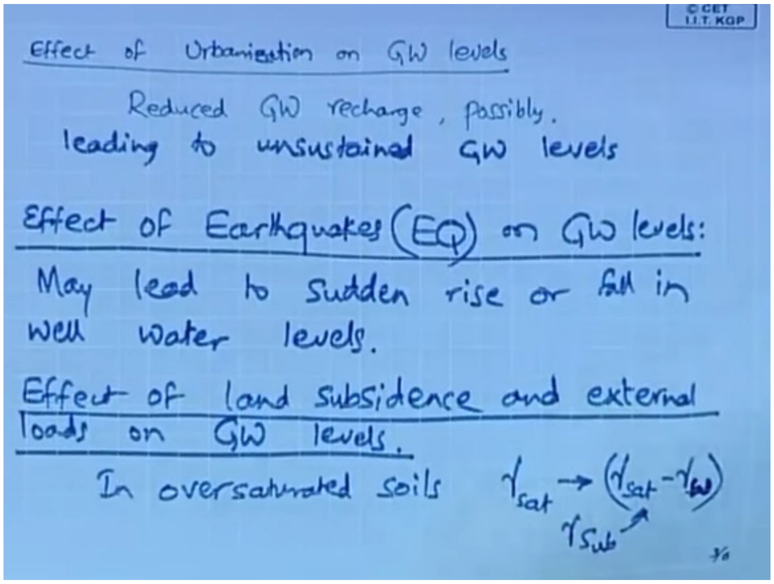

Now let us come to the effect of urbanization on the ground water level in this case. We all know that in case of urbanize locality so there will be this large amount of households surface or finished surface and so which result in a significant increase in the surface or now at the same time significant decrease in the total groundwater recharge unless and until so there are some specific artificial groundwater recharge structures designed and installed.

So the groundwater recharge will be highly insufficient so therefore will be highly insufficient. So therefore so this reduced groundwater recharge will results in gradual lowering of the groundwater level unless until we take measures to have appropriate artificially groundwater recharge measures. So therefore the effect of urbanization in general in the areas is very what I should say is the reduce ground water discharge possibly.

So here this is a leading to sustained groundwater levels that means eventually the groundwater level will be. So deep that extraction of known water will be will become feasible and will not be feasible any more now. So this is the effect of the urbanization now let us also consider the effect of earthquake it is EQ on groundwater levels. So here what happens in case of earthquake there will be a variety of effects as I mentioned in my previous class the earth shakes and due to this shaking of earth and there will be this various in the fault zone as well as in the various one.

So there will be significant amount of damage of the earth and especially case of structures such as building and other engineering structures and so because of this cracks which developed on the in the buildings which also continue along the ground. So here what happen is they there will be sudden rise or fall of what level in the wells so if there is a sudden rise in the water level in a well.

So may lead to certain level rise or fall in well water levels if there is a sudden rise in the well water level immediately after earthquake then we should realize that there is a possibly some additional very high ground water recharge taking place due to the change in the sub surface soil layers due to earthquake. And similarly if there is a sudden fall in the well water level then it is indication that so the water from the particular well is flowing into say neighboring locations neighboring areas.

So thereby there is a certain fall in the water level of the well so these are some of the impacts of first one and now let us also consider and say the impact of the land subsidence as well as external loads. So these external loads as well as the impact of land subsidence on ground water levels. So in this case both these land subsidence as well as its external loads they result in significant variation in the ground water level.

So there what happens is wherever there is a external load applied so this load may be due to a particular hydraulic structure such as it may be a hydrostatic load or it may be some other load. So here what happens is due to the application of load the ground shows certain amount of deflection they ground the soil above the aquifer shows certain amount of deflection and when we this load is removed.

So this reflection does not really get removed for the simple reason that soil is not perfectly elastic and so there is a lot of plasticity involved in the soil and because of this so there will be fluctuations there will be impact on the ground water level. So and then similarly and the land subsidence and many places this wherever there is external this one external wherever there is a say over saturation of ground water.

So there the land becomes the soil it is a unique rate will decrease from gamma set to gamma sub. So in this case in case of over saturates soils so this is a gamma sat changes to gamma sat -

gamma sub gamma W which is the unit weight of water and this gamma sat – gamma W is the submerged unit weight of a water. So therefore when the just below just when then unit weight of the soil is at or slightly below the gamma sat.

So it will have the optimum moisture content and it will have the optimum moisture strength and as its unit weight falls. So it strength also falls so this strength the fall in the strength is many times so significant so that there will be land subsidence and so this land subsidence may be this land stead is an example of that and so because of that so this what happens is ground water level fluctuates.

So these are some of the impact of the earth quake external loads as well as land subsidence and so this 1 we will now in this so this is a how so the ground water level fluctuates practically due to various causes various reasons and so this fluctuation will result in the ground water level which is either too shallow or to this one or to deep. So that were in the extraction of ground water level or harnessing or ground water level becomes unsustainable becomes costly.

So therefore we should see that so by adopting appropriate measures we should be analyzing the ground water fluctuation we should ensure that the water table in case of the unconfined aquifer or the piezometric surface in case of the confined aquifer it is maintained at the optimum depth and so in the so we will stop here and we will continue all though we mentioned in the title of this one the literature data sources as well as internet sources in this lecture so we will continue it in next class thank you.