Ground Water Hydrology
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Module No # 07
Lecture No # 31
Saline Water Intrusion in Aquifers: - Occurrence, Features Affecting Aquifers – Bodon – Ghyben – Hergberg Principle

Welcome to this ground water hydrology course and will be delivering this lecture number 31 in which I will discuss about saline water intrusion in aquifers.

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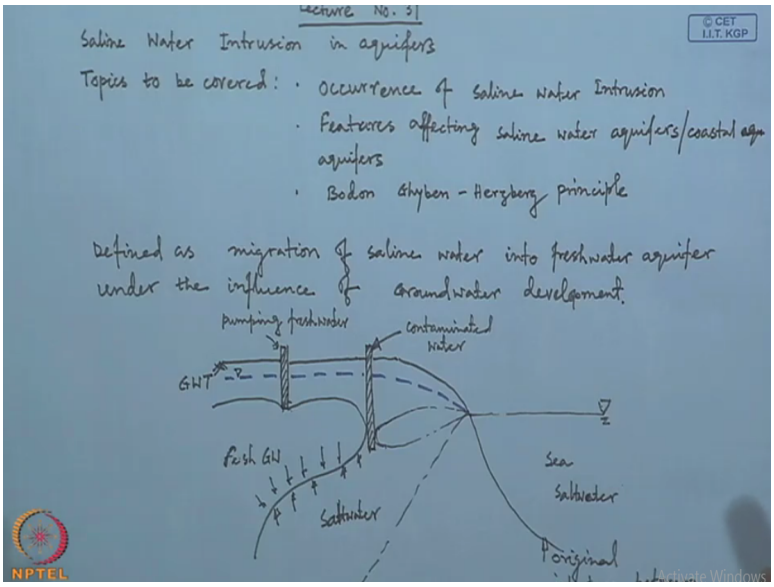

So this is lecture number 31 and our main topic is saline water intrusion in aquifer and topics to be covered under this particular lecture class are occurrence of saline water intrusion. Second are features affecting saline water aquifers or coastal aquifers and third one is BODON GHYBEN HERGEBRG principle.

So first thing what is this saline water intrusion what is this saline water intrusion saline water intrusion is defined by fries and cherry as the migration of salt water into fresh water aquifer under influence of ground water development. So this is basically defined as defined as defined as migration of migration of saline water into fresh water aquifer under the influence of ground water development.

So sometimes we use this ground water word a single word out in this particular course we are using separate words ground water so what is this influence of saline water effect in fresh water aquifers. If you see our coastal aquifers then you will see that let us see we have one pumping well which is pumping fresh water from or which is drawing fresh water from the coastal aquifers.

Another one is the well which is already contaminated. So if you see this is our effective so we have ground water table located here and this is pour ground surface so this particular well is pumping fresh water and this one is pumping contaminated water this is our sea surface or this is your sea and basically this is the position of salt water.

And this is our original interface between salt water and fresh water fresh water aquifer. And this is our location for fresh ground water and this is salt water and this is our interface location so there will be exchange of fresh water and saline water in this region. Due to pumping there will be effect of there will be effect of there will be effect of our pumping within our coastal aquifer.

And there will be lowering of ground water table or GWT. In this region so this is basically a typical coastal aquifer and in which due to pumping effect there will be there will be contamination due to salt water. And now we will try to discuss what are the features are the occurrence or what are the possible reasons for occurrence of saline water intrusion.

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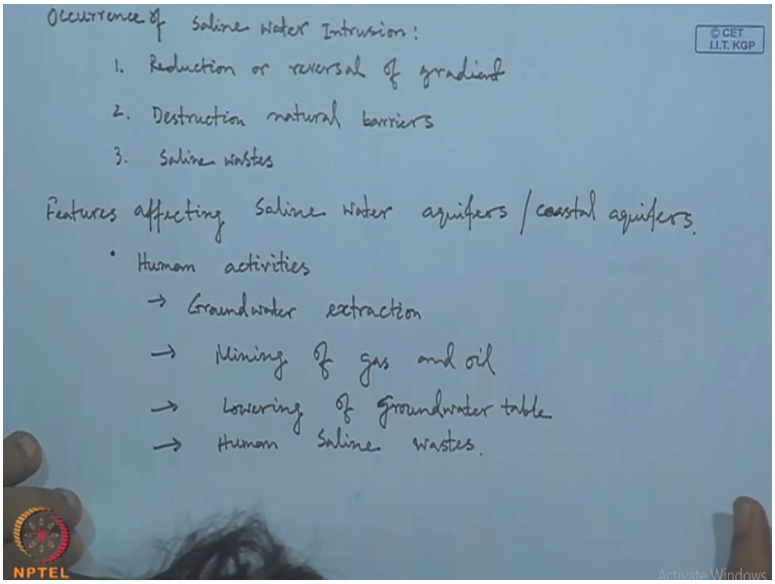

There are three mechanisms which are responsible for occurrence of saline water intrusion first one is reduction or reversal of gradient general perception is that there will be flow from fresh water aquifer towards the sea. But when we have higher pumping case in the fresh water region there will the reversal of gradient in that particular case.

Second one is this is basically destruction of natural barriers destruction of natural barriers this is another important reason for saline water intrusion. What are this barriers maybe we can say are sundarban region we have mangroves and destruction of mangroves can cause saline water intrusion in this coastal region.

Third one is totally human intervention and this is due to pumping of saline waste this is due to saline wastes saline waste and due to this saline waste there it can cause inland salinity or near the region of a coastal aquifer it can cause some kind of extra effect of salinity near coastal aquifers. So now we will try to figure out the features which are affecting saline water aquifers or coastal aquifers saline water aquifers or coastal aquifers.

So first one we can say this is due to human activities human activities what are these human activities first one we can say that ground water extraction second one is mining of gas and oil second one if mining of gas and oil third one is lowering of ground water table and fourth one we can say that human saline wastes. So what is this ground water extraction what is this ground water extraction.

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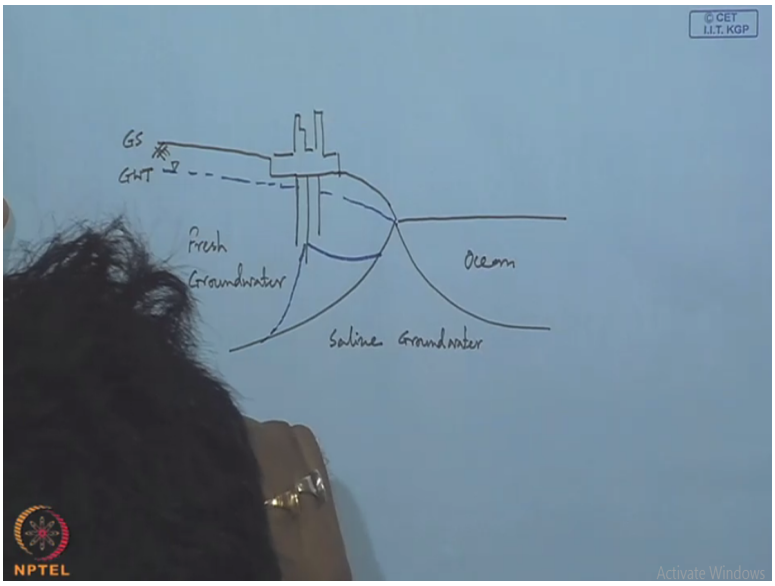

Let us say that we have some city well field which is drawing water from the nearby coastal aquifers and this is our ocean and this is saline ground water and we can denote this thing as fresh ground water. So what is happening due to this is our GS or ground surface and this is again ground water table. What happens due to constant pumping from well field there will be a gradual movement of this interface towards these wells.

And finally if this wells these wells draw significant of water from this fresh water aquifers it can cause saline water intrusion in ground water aquifer. So we can say that pumping is a responsible point for saline water intrusion or an important feature for this effect in fresh water aquifer for coastal regions. Second one we talk about this mining gas and oil.

So in most of the cases we see that mining operation is usually carried out near coastal regions. That can affect significantly these all fresh ground water aquifers. Third one is lowering of ground water table there may be a different causes due to which there can be lowering of lowering of ground water table. And another thing is that human saline waste that can also cause saline water intrusion in coastal aquifers.

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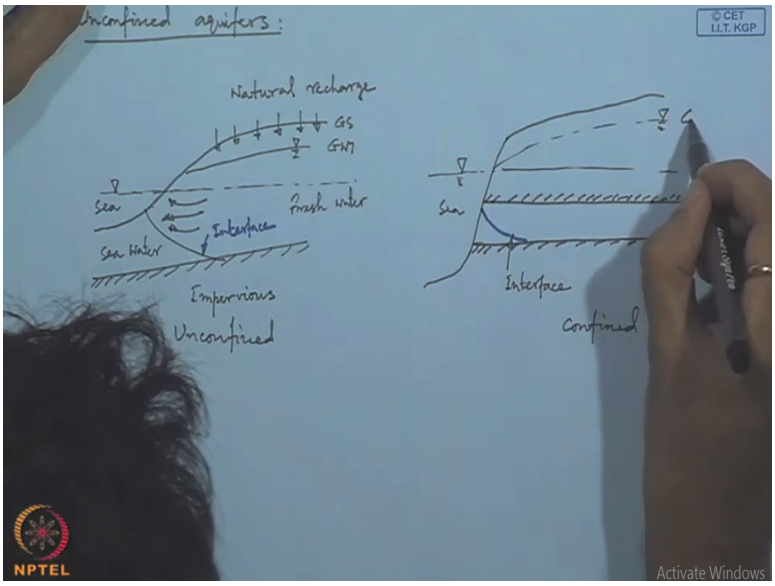

So if we distinctly see different things so for unconfined and confined aquifers for unconfined aquifers we can have different situations first one is your bate condition which is impervious in nature. Then this is sea level and natural recharge or natural recharge is offering from the top this is our ground water table GWT this is our GS our ground surface.

So this is common thing that there will be movement of water from fresh water fresh water aquifer. And this is basically this is basically our interface location second case if we have some kind of confined aquifer situation this is again impervious this is our sea level another impervious region.

So this is the location of interface this is for unconfined and this is for confined aquifers again this is ground water table and this is ground surface. We have fresh water here so these are two examples of for interface movement in confined and unconfined aquifers. And we can say that this is our piezometric surface piezometric surface for unconfined confined aquifer.

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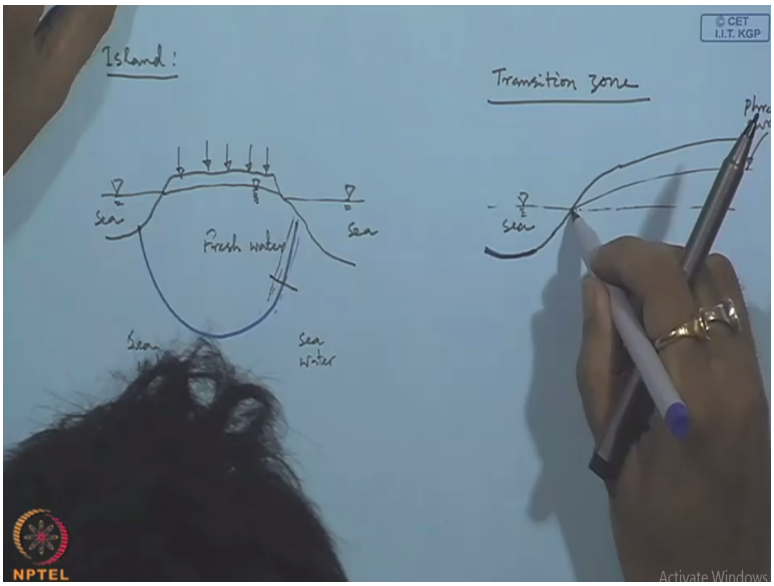

Another situation we can have that is island situation that is for island aquifers fresh water interesting for island aquifer. We have different settings which on the top we have fresh water and from the bottom we have this saline water and this is our normal ground water table and in islands only source of water are fresh water is natural recharge natural recharge is the only source of water.

So these are of all unconfined confined and for island aquifers. These cases we have considered a sharp interface between our fresh water and sea water or ocean water in reality this sharp interface does not exist. This is basically our one kind of approximation to real world problem or what exists in reality is some kind of diffused interface in fresh water. We have less density and in case of sea water we have high density.

So there exist some kind of density gradient between this fresh water to sea water region and in between we will have some kind of diffused region or diffused interface or position. So we can say this region has transition zone transition zone and this existence of transition zone is due to molecular diffusion and dispersion process that occurs during mixing of sea water and fresh water.

So what is this thing so like previous figure will draw same so this is our sea region and this is our phreatic surface this is fresh water and this is saline water in between there exist something

called transition zone. Thus density of fluid within this transition zone is in between saline water and fresh water.

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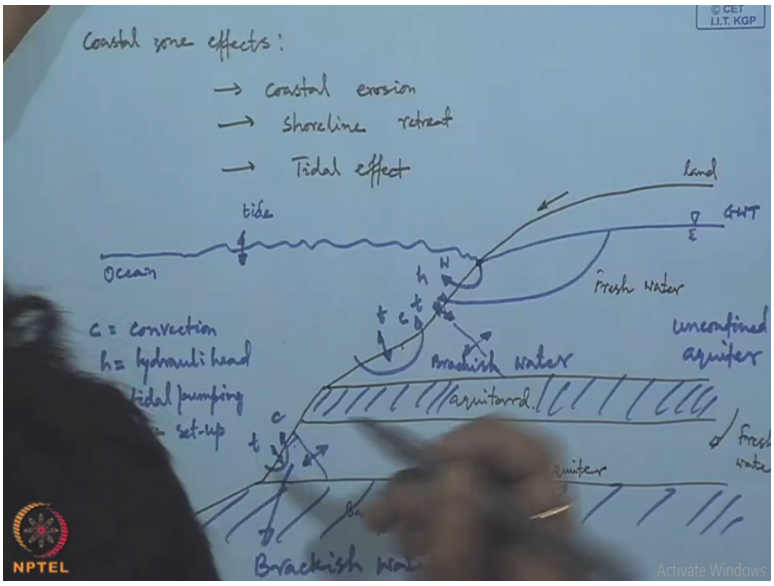

So next thing or next point for this features affecting our saline aquifers is coastal zone effects in coastal zone effects we have coastal coastal erosion process next is shore line retreat and tidal effect. What is this coastal erosion due to decrease in the number of the mangrove tree in this coastal regions or we can say this coconut trees there is a some kind of coastal erosion occurs in the coastal shore line and due to that.

Coastal erosion is one important thing that effects our saline water intrusion in our coastal aquifers. Next one is this shore line retreat shore line retreat is a common problem and one example of this is cape attires this light house in US that has been shifted towards inland somewhat 2870 feets 200 and 200 and 2870 feets inland due to this shoreline retreat effect.

And third one is tidal effect tidal effect or wave effect. This tidal effect or wave effect is generally generated due to water waves and during tsunami or high water wave or natural tidal fluctuations there are will be some kind of effect within the costal aquifers. So what are the influencing things during this process so this is again our ground water table and this is our land region.

So land region we have this overland flow and from ocean we can have some kind of wavy effect wavy effect due to this tides and for this fresh water thing next we have some kind of let us say some kind of acquitard region. And finally this is base some kind of impermeable base this is our confined aquifer and fresh water comes from some upstream side this is our acquitard this is our base so there will be intrusion of brackish water.

And there will be interaction between fresh water and this brackish water and flow is generally towards sea so what are the other this we have if we denote sea as convection H as hydraulic head T as tidal pumping and W as wave setup then we can how that there will be discharge from the fresh water towards the sea due to these four components.

These four components this is directly this is wave setup next one is due to hydraulic head and we have this tidal effect which is occurring near to this interface between aquifer and sea and our convection process. That occurs in this brackish water or this region brackish water region and also some kind of tidal pumping setup occurs in this region.

Similarly for confined aquifer this is our unconfined aquifer and this is our confined one so in this brackish region again we have convection which dominates the flow conditions and the tidal thing which dominates the flow condition near brackish region. And this is governed by the hydraulic head.

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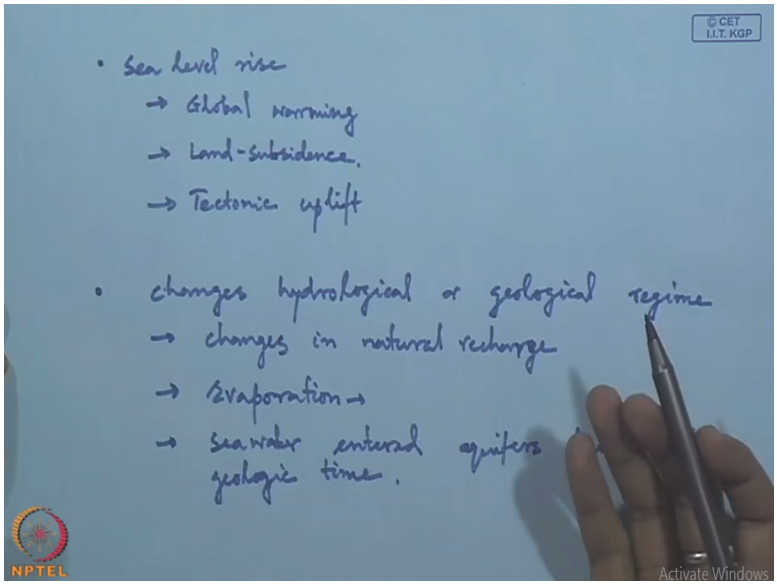

So the next feature that is affecting saline water intrusion is sea level rise or rise in sea level. This particular point is somewhat debatable point because some people have neglected the effect of sea level rise for sea water intrusion in coastal aquifers. But sea level rise significantly affects the salt water intrusion near to coast only near to coast. Its effect may not be that much inwards or line wards region but it is surely affects the region which is near to shore line.

And what are the sub points under this is one is global warming which affects sea level rise and it is indirectly affecting salt water intrusion. Next is land subsidence there may be sea level rise and also due to some kind of tectonic uplift due to some tectonic uplift there can rise in sea level so next point is changes hydrological or geological region hydrological or geological region individual point.

We can discuss under this thing is changes in natural recharge changes in natural recharge next is evaporation what is the effect of changes in natural recharge there may be reduction in rainfall pattern or increase in rain fall pattern that can affect our sea level this salt water intrusion. Next one is evaporation due to the evaporation water. There may be concentrated amount of salt may be available near the creeks or any other region near to the coastal aquifers.

That can cause salt water intrusion and third one we can discuss that is sea water entered aquifers during passed geologic time. So sea water that is that is already entered in lower aquifers or deeper aquifers during passed geologic time that can significantly affect our inland part inland salinity or near to the coast.

Also sometimes what happens due to different kind of stratification your fresh water may be at the lower strata compared to sea water which is at the top most strata are due to some effect or we can have situations where this sea water is located in the deeper aquifers due to some geological event in the past.

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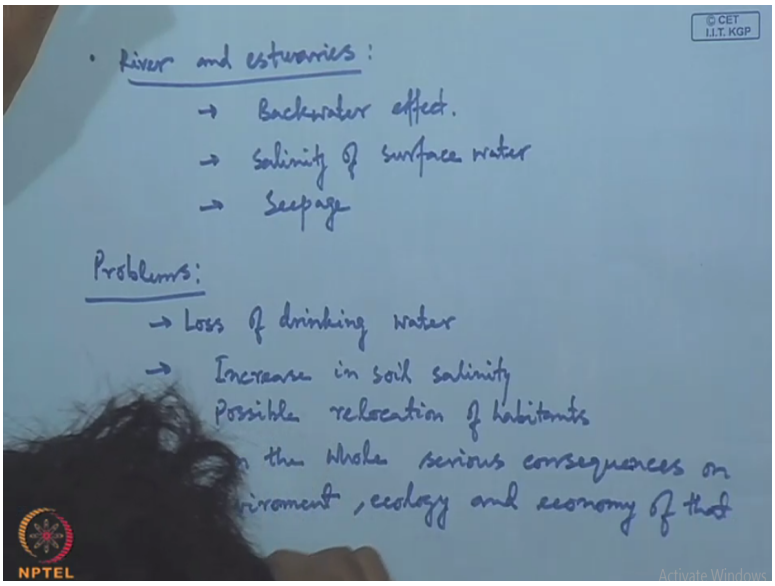

And last point under this particular thing is effect of river and Estuaries River and estuaries one point we can say that is backwater effect salinity of surface water and final thing is seepage. So what is this backwater effect due to these rivers which are connected to the sea there may be backwater effect and due to tidal variation it can affect significant portion of the river.

And in turn this salinity of surface water can cause saline water intrusion in coastal aquifers or inland aquifers along with other effects like heavy extraction or heavy pumping from this particular aquifer and seepage is another reason for saline water intrusion. So if we summarize this features that are affecting our saline water intrusion then what are the effects or problems due to this saline water intrusion. First one is loss of drinking water loss of drinking water.

Next is due to loss of drinking water. There will be a problem in related to habitant. Next is increase in soil salinity due to this increase in soil salinity there may be problem related to agriculture. Third one is possible relocation of habitants this is another important point so on the whole serious consequences on environment ecology and economy of that region so these are the effects due to or these are the problems due to saline water intrusion in aquifers.

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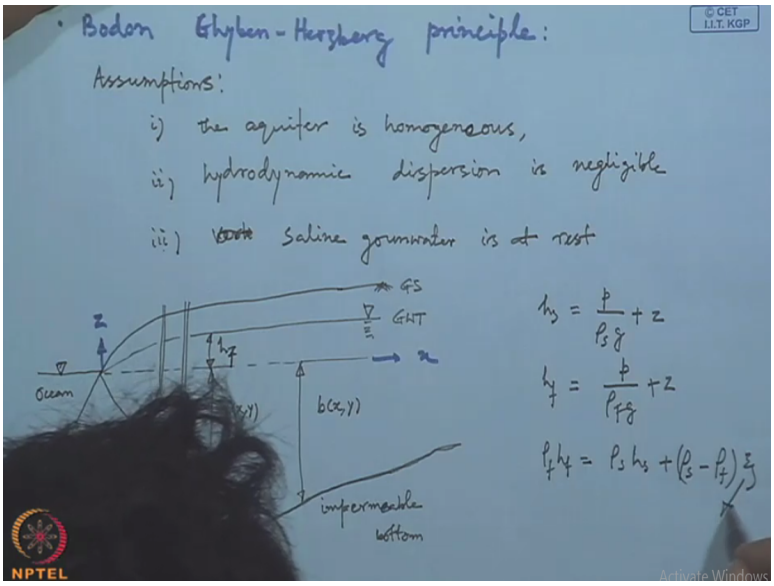

So next point will discuss about this BODOB GHYBEN HERGBERG principle so this is the most simple approximation of the interface for modeling the saline water intrusion in coastal aquifers. So what are the inherent assumption for this particular principle first one assumptions first one is that the aquifer is homogenous next one is hydrodynamic dispersion is negligible.

Third one is that vertical third one is that saline water saline ground water is at rest saline ground water is at rest. So to derive this thing we can use we can use our hydrostatic principles of fluid mechanics. And we can directly imply those pressure related relationship for derivation of BODOB GHYBEN HERGBERG principle.

So first we can sketch our geometry so that is this is our ocean and we having interface like this and this is our impermeable base impermeable base for this problem. This is ground surface this is ground water table and this particular location we have our Z axis this is our X axis so this depth from the sea level. We can denote it as XY is a function of X and Y again this depth of interfaces this is as XY.

And from the ocean surface to our ground water table we have HF depth. So this is our interface and this is our salt water and this is the location of toe and we have impermeable bottom. So from this one we can write that HS = Rho SG +Z and HF = P Rho FG / Z where Rho S is the density of salt water and Rho F is the density of fresh water. So during dynamic equilibrium there should be pressure continuity at the interface.

So what we can do we can equate the pressure from these two equations and if we equate the pressure from these two equations we can directly write HF Rho S HS + Rho S – F. So what is this is calculated this is calculated from the X axis and this is the depth of this location. So basically our function is - Z so we have replaced this -Z with this thing now if we equate these equations then we will finally get Rho F / Rho S - Rho F into HF HS Rho S Rho F and HS.

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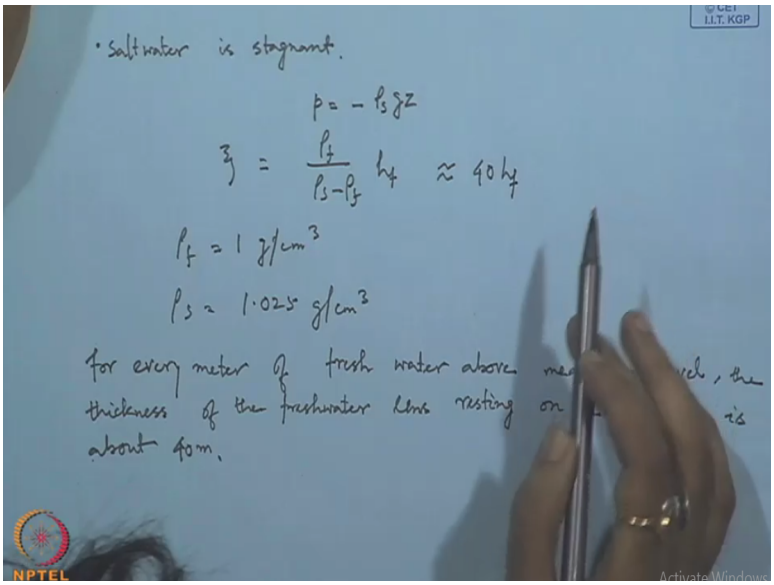

GHYBEN HERGBERG they have further simplified that the salt water is stagnant salt water is stagnant thus we can directly use hydrostatic principles and Rho SG we can directly write it so further from our previous equation. We can write that Rho F / Rho S - Rho F into HF. If we consider our Rho F = 1 gram centimeter cube and Rho S as 1.025 gram centimeter cube.

Then we will see that this value is approximately 40 times HF. So we can say that for every meter of fresh water above mean sea level the thickness of the fresh water lens resting in salt water is about 40 meters. So we can see that for every meter of fresh water above mean sea level the thickness of fresh water lens resting on salt water is about 40 meters.

And for this GHYBEN HERGBERG principle it is mandatory that it should have some depth above mean sea level otherwise there will be reversal of flow from this region. So we can say that this is one important historical development for saline water intrusion saline water intrusion measurement and it depends on sharp interface principle.

So today's lecture we are concluding with this GHYBEN HERGBERG principle. Next lecture we will discuss the application of GHYBEN HERGBERG principle for identification of salt water intrusion in coastal region thank you.