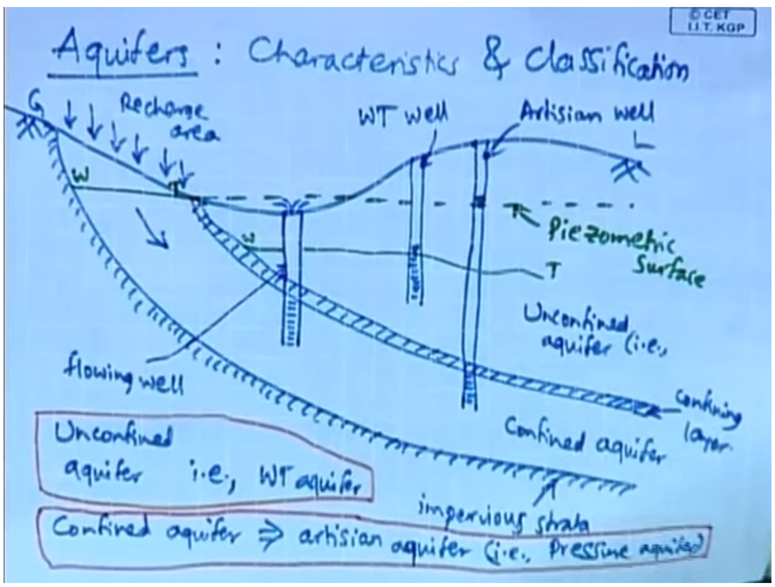
Ground Water Hydrology
Prof. Dr.Venkappayya R. Desai
Department of Civil Engineering
Indian Institute of Technology – Kharaghpur

Module No # 02
Lecture No # 07
Aquifer Classification (Contd.), Ground water Basins and Springs; Dorcy's Law; Permeability

Welcome to this lecture number 7 on continuation of this aquifer classification.

(Refer Slide Time: 00:46)

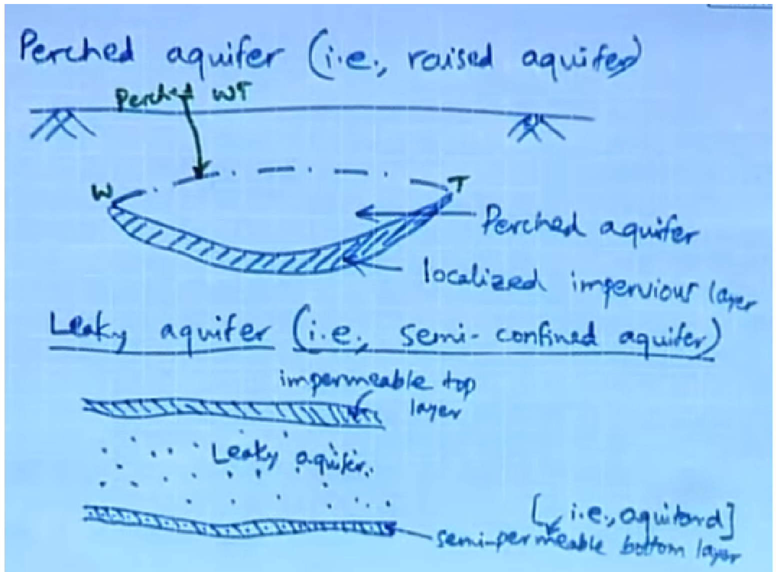


So we had in the previous lecture we were discussing about the aquifer characteristics and classification and specifically we discussed about it say two types of aquifer the first one is the unconfined or table aquifer and we also discussed about confined aquifer which is also known as artesian aquifer or pressure aquifer.

This unconfined is having a impervious stratum only at the bottom and it has a variable top it does not have any confining layer and water table which is variable depending upon various factors. So that forms the upper flexible boundary of the unconfined aquifers on the other hand so this confined aquifer it is known as artesian aquifer or pressure aquifer it has two confining layer one at the top as well as the one at the bottom as shown here.

And so here this water in the ground water will be under pressure much above the atmospheric pressure that why it is also known as pressure aquifer or artesian aquifer.

(Refer Slide Time: 02:41)



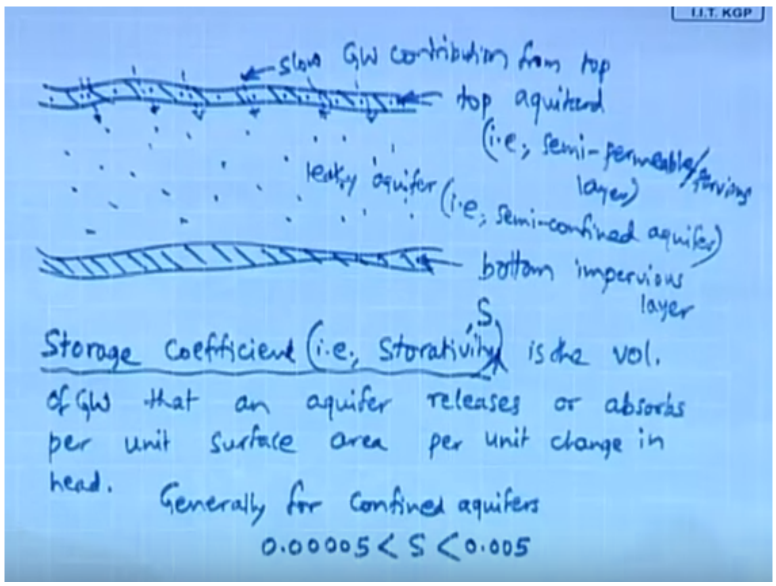
Now let us also learn about say two more aquifers so the first one is the perched aquifer. So this perched means a raised aquifers essentially it is a locally raised aquifer suppose in a particular area below the ground there is a small saucer like impervious layer for a limited extent and over this this impervious layer some amount of ground water gets stored. So this represents the water table so here this represents a zone of aeration and below that so this represent the zone of saturation.

So this one represents the perched aquifer so the perched actually say this is the perched water table and this one is the perched aquifer. So here we should bear in mind that the impervious layer let me write it as a localized impervious layer as a very limited areal extent and therefore the amount of ground water stored in a perched aquifer is also limited and so therefore it is available only for a small period of time.

And of course because so above the perched water table there is zone of variation and below the water table there is zone of saturation. So it also is included as one of the maybe here you can call it as localized aquifer localized unconventional aquifer. So that is what the perched aquifer represents so this forms the third type of aquifer and the last the fourth and last type of aquifer that we are going to discuss is the leaky aquifer which can also be called semi confined aquifer.

In this case it has it is a confined aquifer the only difference is one of the layers either the bottom layer and in this case the top layer. So this is impermeable top layer say this is a semi permeable bottom layer or it can be either other way also. And of course so this is the other name for this semi permeable bottom layer is aqui tude I am sorry aqui tard. And this is the leaky aquifer it can be the other way also that is the top layer maybe semi confined semi permeable or aqui tard.

(Refer Slide Time: 08: 03)



And the bottom layer so this case so this is the top aqui tard that is semi permeable layer and this is the bottom semi permeable or semi pervious, impervious layer and here this is the leaky aquifer also known as semi confined aquifer. So in this case so since the top layer is semi pervious permeable or say pervious so from the top layer there will be a slow contribution of ground water into this leaky aquifer.

Slow ground water contribution from top likewise as mentioning here the semi permeable or semi-pervious bottom layer in this case there will be so this represents slow ground water leakage at the bottom so it is for this reason. So these are known as semi confined aquifer so basically here you can say it is one end either one at the end or at the bottom there is a confined there is a confining layer which is fully impervious and at the other end the either at in this case here it is at the bottom and in this case here it is at the top.

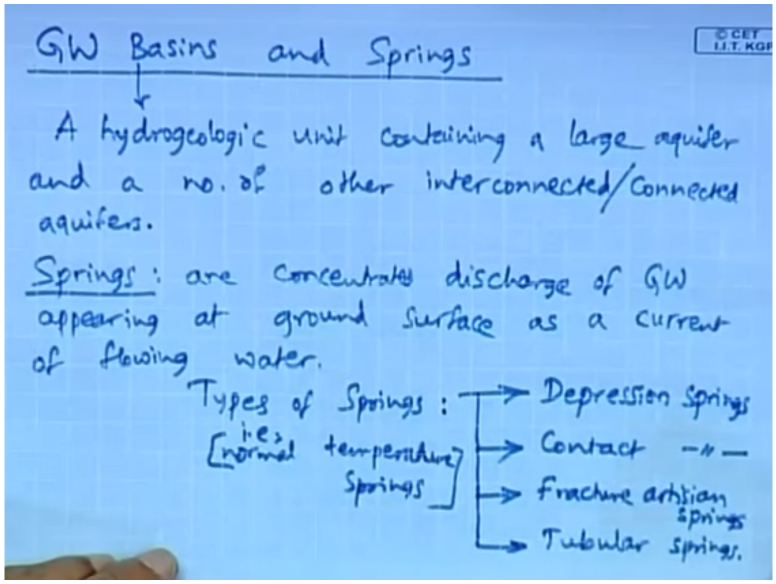
So the layer is an aqui tard which is semi pervious okay so these the unconfined aquifer or the water table aquifer the confined aquifer or the artesian or the pressure aquifer and thirdly the perched aquifer or raised aquifer we may also refer to as a localized raised unconfined and fourthly it is leaky aquifer or say semi confined aquifer. So these are the four types of aquifers and each one of them will be here yield ground water depending upon the various factors.

And among this one of the important factors which determines this ground water yield from aquifer is known as the storage co efficient also known as storativity and this storativity is the volume of water you can say volume of ground water that an aquifer releases or absorbs per unit surface area per unit change in in a head. Obviously head is measured perpendicular to the surface area so this is known as the storage coefficient or storativity.

And generally so the for confined aquifer and this denoted by the letter S generally for confined aquifer it is a unitless basically because it represent ratio of two volumes for confined aquifers so this is a this storativity will be in the range of 5 into 10 to the power of – 5 to 5 into 10 to the power – 3. So this is the storage coefficient and it the specific yield or ground water yield from an aquifer very much depends upon this parameters.

And this so this storage coefficient is considered as one of the three important formation constants of aquifer the other two being the hydraulic conductivity or permeability and transmissivity or transmissibility which of course will discuss sometime later in this lecture.

(Refer Slide Time: 16:40)



So now we will discuss little bit about the ground water basins and springs so just like the water basin which is which essentially represents a particular area on the surface of earth which holds water and there will be say there will be specific drainage pattern. So in this case the ground water basin is also some kind of physical entity which has a certain aerial extent and this this ground water basin consists of one large aquifer as well as the number of small aquifer.

Just like in the surface water basin there will be a main course main stream channel or main course and it is there will be number of other courses. So in this case also of ground water so there will be a main aquifer and a number of inter related aquifer. So here we can this ground water basin so we may define it has a hydrologic or hydro geologic unit containing a large aquifer and a number of other inter connected aquifers.

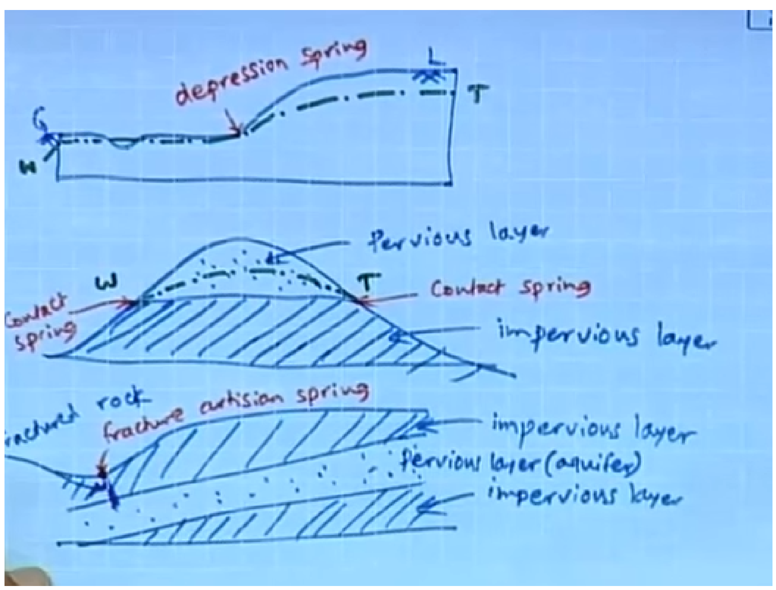
Inter connected or say connected aquifers and like this surface water basin a catchment which is also referred to as watershed. So this ground water basin also has storage and this transport ground water transport both are involved and many times. So this ground water basins consist of large area aerial extent as well as depth which can yield a significant amount of ground water.

Now let us come to this springs so this spring is it is basically water gushing out from the ground surface is generally known as the spring. So we can write this is as concentrated discharge of ground water appearing it ground surface as a current of flowing water so here you can say spring it is basically at the ground surface it represents an interface and upstream of the spring the water is in ground water form and downstream of the spring the isn’t water comes on earth so it is a surface water form.

And these springs may be of different types such as here we can say this is types of springs and of course this this springs in this the water may come out as a current either in the normal temperature or it may come out as a current of hot or higher temperature. So like this so this spring can be a either a normal water spring or a hot water spring so in this in the normal water spring the temperature is the normal temperature and which are generally refer to as a simply springs.

So these are let me write here so this is the normal temperature springs so the various types us discuss few of them among the normal temperature springs is the depression springs followed by contact springs followed by artesian springs or say fraction artesian springs then there is a tubular spring so these are the four important types of springs.

(Refer Slide Time: 24:32)



Now let us discuss briefly about each one of them so here let us consider say suppose this is a ground water sub surface layer and in this say let us say so this is the ground level and then this is the water table. So here at this table the water table meets the ground level and so therefore here this we have what is known as depression spring? Through which the water gushes out from suppose there is some normal even if we create very small depression.

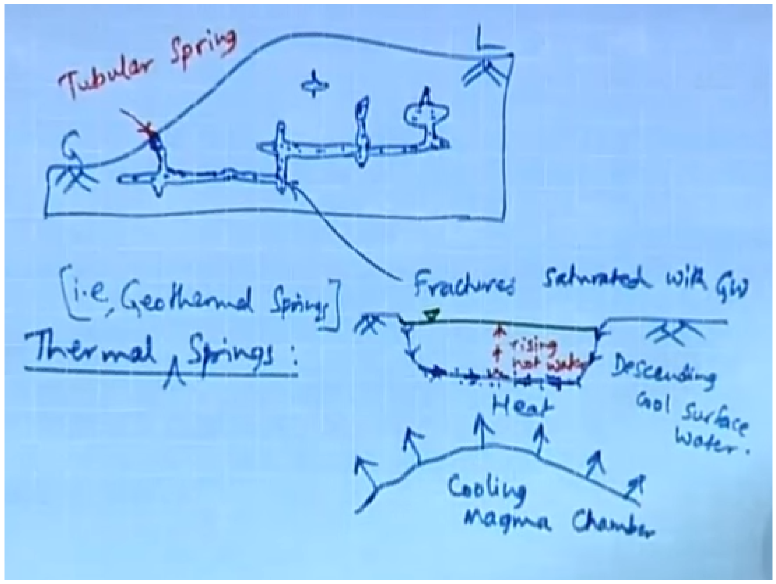
So the water gushes out through that so this is the first type of spring next we have what is known as the contact spring and in this contact spring suppose we have a ground water mount and with this is an impervious layer and here it is overlaid by a pervious layer and in this so this is a and this represents the water table. And this water table is in contact with the ground profile at these two points where we have will get a contact springs.

So this is again a so essentially here what happens so the water slowly little get released from the contact spring and then it flows along the impervious layer of this soil or rock mount and eventually so it may join the stream or it may join a lake or any other surface storage area like that. So essentially this contact spring is found and of course in this case unlike the depression spring so generally the water the current velocity will be slightly less.

Now the third one let us is the fracture artesian spring wherein we have suppose a pervious layer which is over laid by an impervious layer. So this is impervious layer again this also an impervious layer in between the pervious layer there is an aquifer. So this is a and there is a fracture so here this we can say this is a fractured rock over the impervious layer which is lying above the previous layer and through this fracture the water gushes through what is known as fracture artesian spring.

So essentially so this is a the part of this there is a fracture in the impervious layer which is over and above the aquifer and through this fracture so the water gushes out through what is known as the artesian spring. And the last one so this are the three types of springs the last one let us discuss is the tubular spring.

(Refer Slide Time: 32:16)



And in this tubular spring we have suppose this is the fractured rock so these are the fractures in the rock and suppose this is the level up to which the ground water is stored. And obviously the same level is maintained here also and here at this point so this is a tubular spring and here we can say so these are the fractures saturated with ground water and of course so this is the ground level so because here the fracture continues up to the ground.

And then the ground water stored in these fractured the level of ground water stored in these structures is above this the level of tubular spring so the water gushes out as a spring. So these are four types of springs and also let us also discuss about the high temperature springs which are known as say thermal springs they are also known as geothermal springs.

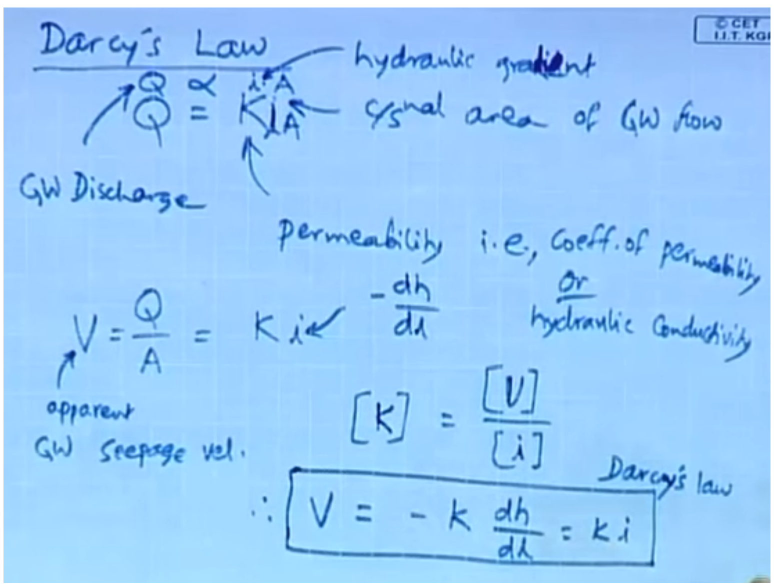
So in this case what happens is so the because of the large temperature the hot temperature through this cooling magma chamber. So this is the heat getting released and what this does is suppose this is the so here the surface water gets released so this is the descending cool surface water. And here of course we have a so this descending cool surface water comes in contact with the heat release through the cooling magma and then here.

So this is the level of water and this is the rising hot water so when this descending cool water cold water sold surface water comes in contact with the heat released by the cooling magma chamber. So it is temperature gets increased and then it comes as a rising hot water so here so this is the hot spring or geezer.

And obviously so there will be many so this cooling magma chamber is great depth something like three thousand meter or so and because of that so the thermal springs ad many times. So they will also have say other mineral ingredients and these cooling springs are available in are con be these hot water springs or say thermal springs or geothermal springs can be found in different parts of the world.

In such as say New Zealand there are ample amount of sun and many times so this geo thermal springs area also used in generating electricity. So these some of the springs so initially we saw the four normal temperature springs or simply springs followed by we also discussed briefly about the geo thermal or a thermal spring or hot water spring. Now so this is a so far we discuss about the ground water storage or occurrence part of it.

(Refer Slide Time: 39:46)



Now let us discuss a little about the t he Darcy's law which essentially represents the basic equation or basic law governing the ground water moment. So here so this Darcy's law we can state it as the discharge Q = so firstly it is stated as the discharge is proportional to I into A. So this Q is the discharge so here this is the ground water discharge and this I is known as the hydraulic gradient and this A is known as the is the cross sectional area of flow of ground water flow.

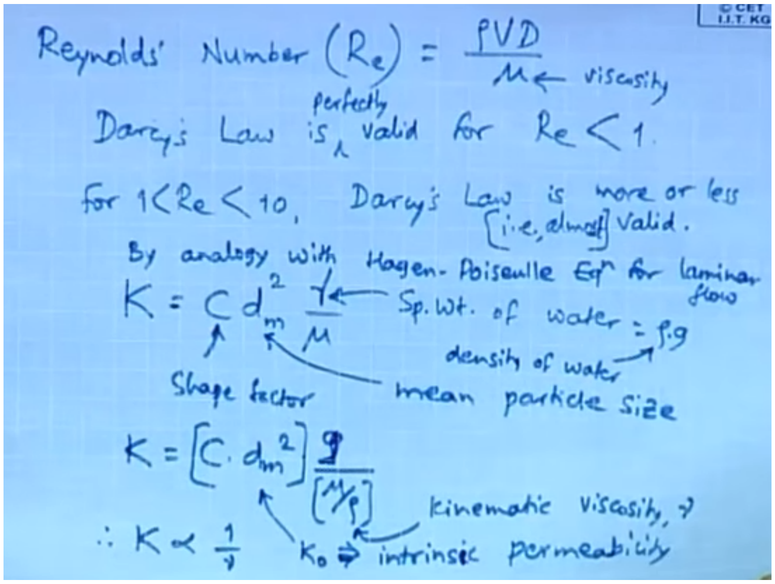
S when Q is proportional to I into A product of I and A so we can as well write this Q = KIA where K is proportionality constant which also known as permeability it is also known as the coefficient of permeability or it is also known as hydraulic conductivity. So here we can write this down as Q over A which is equal to K into I. So this Q over A is also equal to the velocity and in this case it is the here we can take it as the apparent ground water seapage velocity.

And here left hand side the dimensions of velocity so for this equations to be dimensionally homogeneous. So the dimensions of this K which is the coefficient of permeability or it is also simply known as permeability or hydraulic conductivity as equal to the dimensions of velocity divided by the dimensions of this hydraulic gradient. And this hydraulic gradient is a pure number with no units.

So therefore this hydraulic conductivity or permeability or coefficient of permeability has the units of velocity has the dimensions as well as units of velocity. So this is Darcy's law which is stated by the French hydraulic engineer HENRY DARCY in say nineteen sorry 1856. So here this I which is the hydraulic gradient so this is = – DH / DL so there is a negative sign to indicate that as the ground water travel distance L increases the head the ground water head or H decreases.

So therefore this I will have a negative so therefore here we can mention we can state here so this is V = - K into DH / DL so this is which is = simply K into I. So this relationship is popularly known as Darcy' s law which is applicable for say ground water flow and as we can see so this ground water flow it is laminar flow it is highly laminar flow the velocity is a very small so therefore. So the ground water velocity for which the Darcy's Law is applicable so it depends upon the parameter which governs the laminar flow.

(Refer Slide Time: 45:50)



That is the Reynolds number here we can denote this as RE so this for the so the Darcy's law is valid for Reynolds number is let me say perfectly valid for Reynolds number less than 1 and here we know this Reynolds is defined as the ratio of inertia force to viscous force and mathematically = Rho VD / Mu where Rho is the density V is the velocity D is the characteristic dimension and Mu is the viscosity of the coefficient of viscosity.

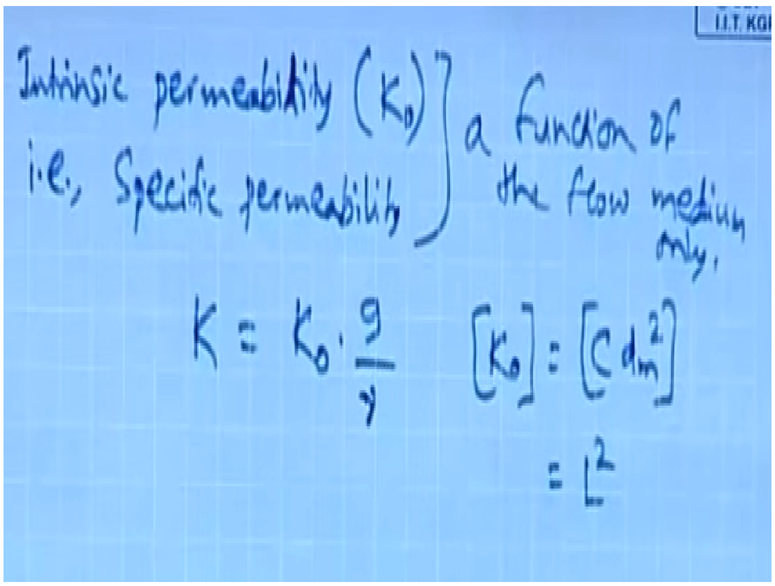
And so for Reynolds number greater than 1 and less than 10 so the Darcy's law is more or less applicable more or less that means it is almost valid. So only when the Reynolds number exceeds this 10 which is very rare in case of ground water then so this Darcy's law will not be valid. And also we know that as per the Hagen Poisel equation for the conductivity so this coefficient of permeability can be expressed by C DM square into gamma / Mu.

So this is by enology with Hegan Posial flow equation for laminar flow so this coefficient of permeability. So here the C is the shape factor and this DM is the mean particle size and this gamma is the specific weight of water fluid and of course in case of ground water it is a water ok. And obviously so this Mu is the viscosity and so this is = Rho into G where Rho is the density of water okay.

Now here we can conclude that so this K = CDM square and this gamma which is row into G and G if we express it as the denominator of the denominator so this will be so this is G I am sorry this gamma if I express is at denominator or denominator so then so this is the kinematic viscosity which is denoted by this small letter Mu. Therefore the hydraulic conductivity or the coefficient of permeability or permeability is inversely proportional to the kinematic viscosity of water

So as the kinematic viscosity changes so the hydraulic conductivity there is a inversely so here this term is CDM square which is denoted by K0 which is the which is known as the intrinsic permeability. So obviously so this CDM square nothing to do with the fluid properties it has only to do with the properties of the flow medium which is the soil or rock in this case.

(Refer Slide Time: 52:58)



So here so this intrinsic of course this intrinsic permeability this is also known as the specific permeability is related with the permeability by the equation K = K0 into G / Mu. So this dimensions of this intrinsic permeability as the dimensions of this dimensionless constant as well as DM square it has a dimensions of say length square. So this is the intrinsic permeability which has a so this is a function of the flow medium only okay.

And the next class we will discuss about the transmissibility or transmissivity as well as other so this transmissibility along with this hydraulic conductivity and storativity and forms what are known as a formation constants of fact refers. So in the next lecture we will discuss further about this hydraulic conductivity tranmissivity and its determination and other related topics thank you.