Geotechnical Measurements and Explorations

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Lecture No. # 32

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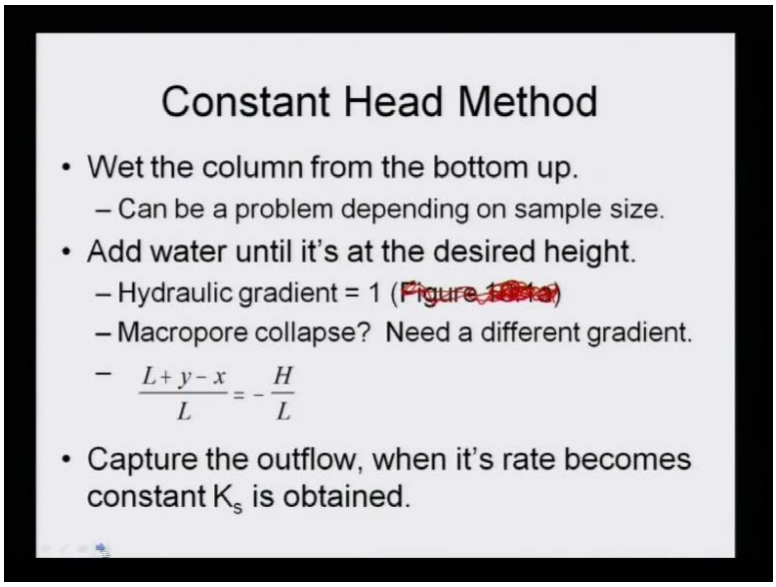

So, next part is your constant head method to determine coefficient of permeability, as I said last class. So, there are two methods one is your constant head method, other is your variable head method. In this method generally you add water and collect at the outflow when the rate becomes constant that means how do you know that? Add water until it is hydraulic gradient become one that means, rate becomes constant that means you collect water in a stipulated time. So, same water you are getting regular time interval, then you can say that the rate becomes constant. So, at that condition you find it out. What is the difference means coefficient of permeability of soil.

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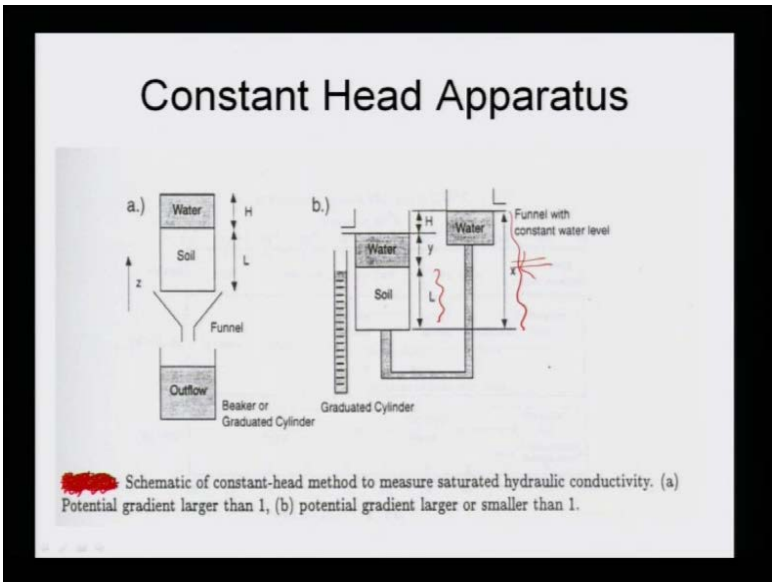

If look at this constant head apparatus, generally what happen there is a soil and water has been allowed to flow through the soil in a constant head. That means, this head is fix, this height of the water fixed from the soil, So that the head is fixed. So, water allows to pass through the soil. So, then you will collect amount of water in the outflow passing through the outflow water discharge for time based on the time, you can find it out your coefficient of permeability. So, L is the length through the soil. If you look at here means, water passing through the soil from here to here this is called length.

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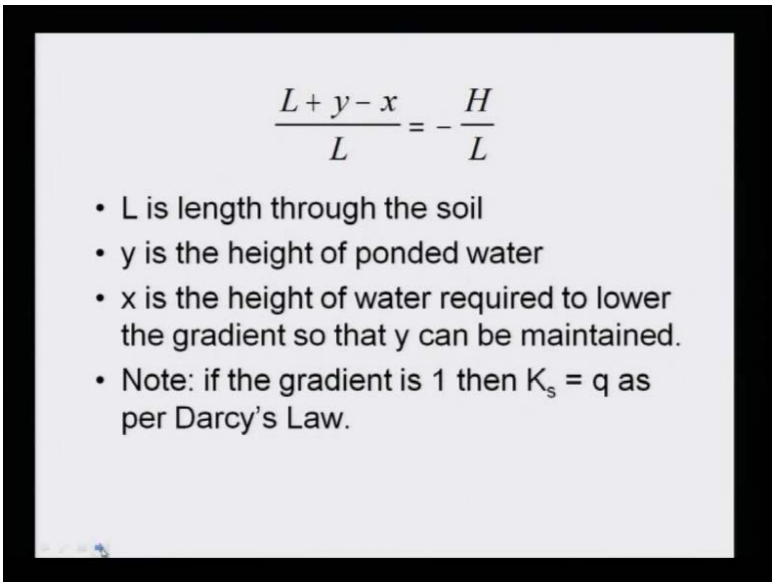

Y is the height of ponded water that means, height of the water above the soil. x is the height of water require to lower the gradients so that y can be maintained. x is the height of the water required to be lowered so that y should be always maintained. If gradient is one then K s is equal to q as per Darcy's law.

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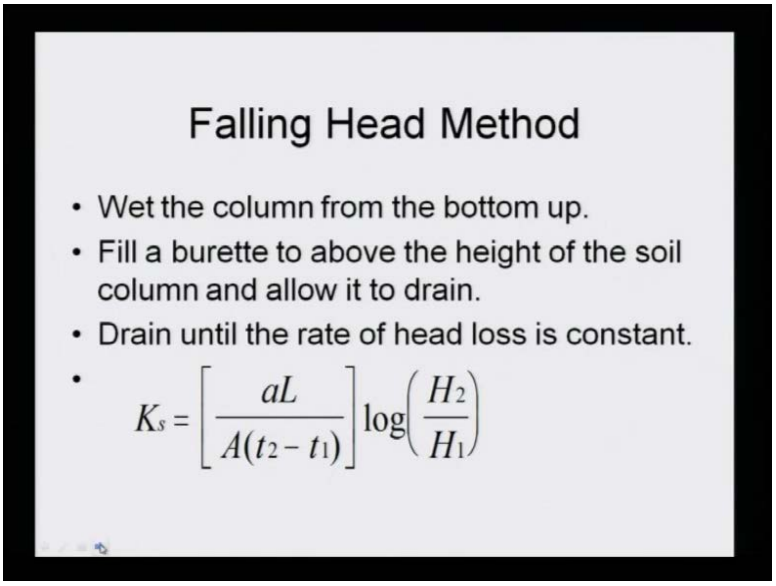

Now, come back to falling head method, in this falling head method wet the column from the bottom up fill a burette to above the height of the soil column and allow it to drain. Drain until rate of head loss is constant means; rate of head loss is constant. So,

coefficient of permeability of soil you can find it out a L by a into t 2 minus t 1 log H 2 by H 1. It is called falling head that means the head has to vary; where this falling head had been used this falling head used for the soil of fine-grained soil generally or constant head method has been used to find it out, coefficient of permeability of coarse-grained soil.

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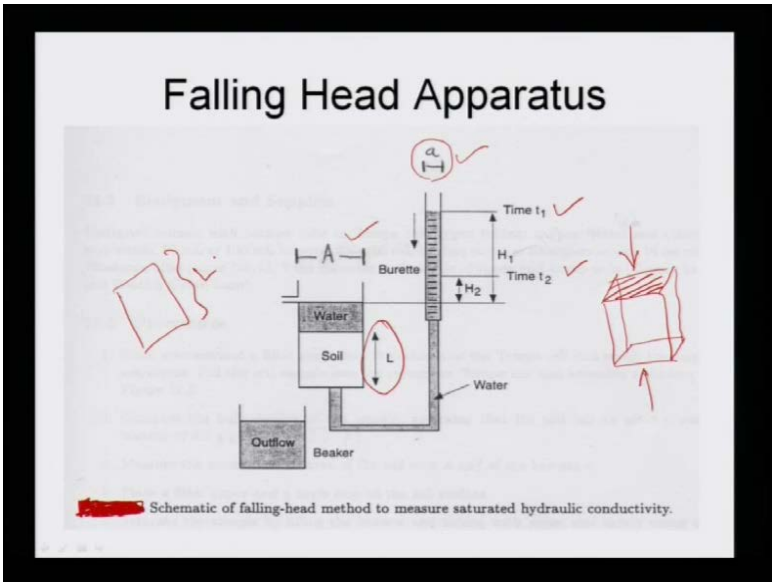

Now, if you look at this falling head apparatus this is soil. So, this is a burette water is there means initially, you pour water inside the burette then a is your diameter of the burette and find it out what is your time interval, time t 1 then after certain height H 2 find it out time t 2, L is your length of the soil where it is passing through. Now, area of cross section the movement I say area of the cross section, if this is my soil sample how water flow through this water is flowing through this in this direction or in this directions that means, this is the area of cross section through which water passes.

So, A is your area of cross section if you know the change in water collected with a time t 1 as well as t 2 and these are your fixed parameter. That means a is your diameter of burette cross-sectional area of soil. You know length of the soil, you know in that mould what is that length of the soil that you know. Then if you collect the outflow that means discharge with respect to time t 1 and t 2 then only you can find it out. What is your coefficient of permeability for falling head apparatus? That means

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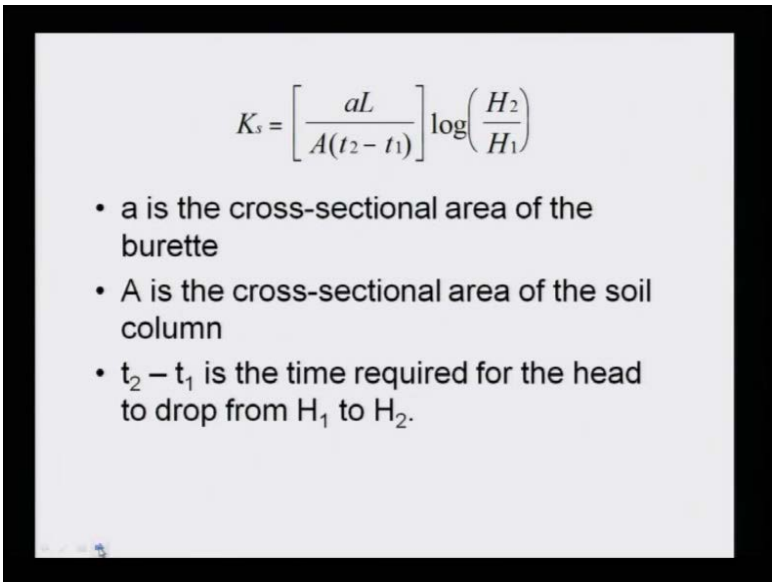

for fine-grained soil, if you look at a is your diameter of burette, L is your length of the soil specimen A is your area of cross section, t 2minus t 1with this time t 2and t 1 and H 2 by H 1 is nothing, but your head or height, if you look at here H 1 with time t 1 with time t 2 with this. What is your head? This is your H 2 from there you can find it out coefficient of permeability by means of falling head method.

This is I explained. Now,

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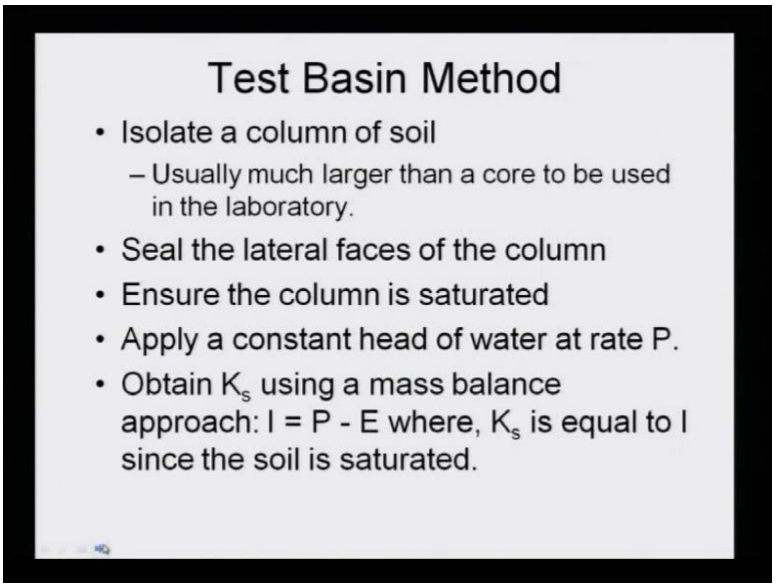

another one is called test basin method. That means, isolate a column of soil usually

much larger than a core to be used in the laboratory seal. The lateral faces of the column ensure the column is saturated apply a constant head of water at rate P obtained K s using a mass balance approach. That means I is equal to P minus E where K s is equal to I since, soil is saturated this is called test basin method.

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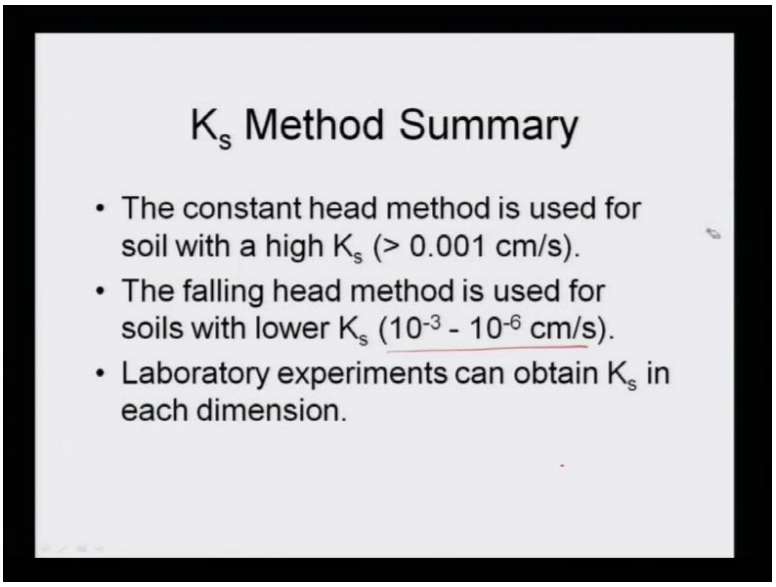

So, K s finding out coefficient of permeability of soil. The constant head method is used for soil with a height with a with a high K s means high coefficient of permeability that means the soil whose coefficient of permeability is greater than 0.001 cm per second, 0.001 cm per second. That means high coefficient of permeability from where you will get it. You will get it for cohesion less soil high coefficient of permeability because these are the sandy soil. So, here you are going to or you are expecting high coefficient of permeability.

The range is given if K s coefficient of permeability of soil is greater than 0.001 cm per second then constant head method is to be used somewhere else. Coefficient of permeability is written K, some people they write it K s, some will write capital K. So, it depends upon the notation, how they are using. The falling head method is used for soil with lower permeability that means, if coefficient of permeability is varying between 10 to the power minus 3 to 10 to the power minus 6 cm per second that means, this is for your fine-grained soil. Then the falling head method to be used. Falling head method indirectly it says that it is for fine-grained soil. This is for coarse-grained soil laboratory

experiment can obtained K s in each dimensions, both the dimensions you can find it out means coefficient of permeability.

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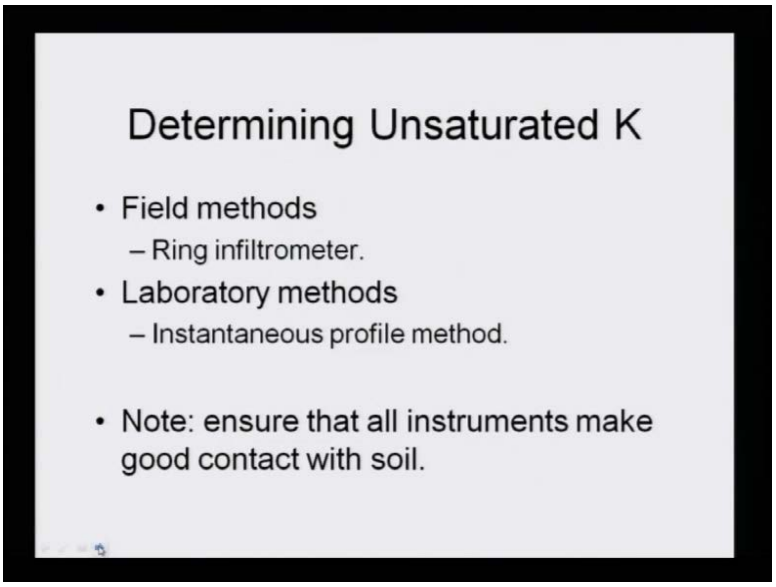

Before I start this determining this unsaturated K.

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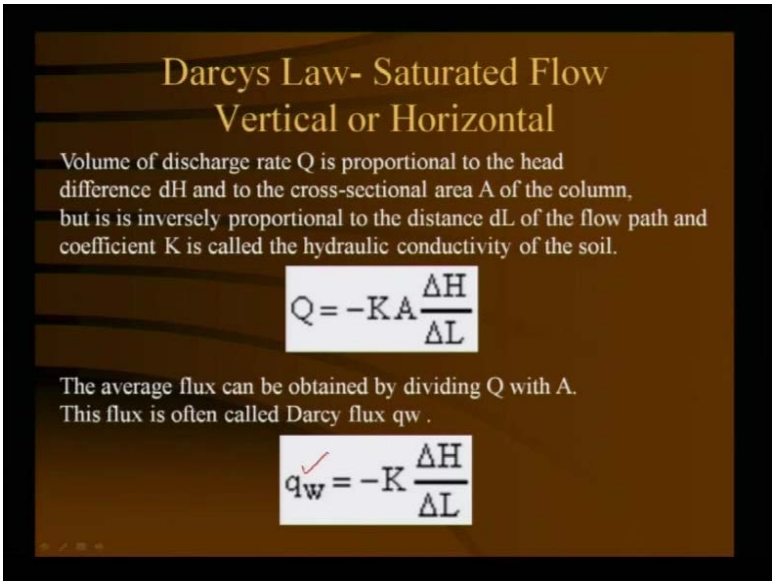

Now, if you look at here this Darcy's law saturated flow vertical or horizontal, if I go back to theory volume of discharge rate Q is proportional to head difference d H and to the cross-sectional area A of the column, but is inversely proportional to the distance d L or L. We say L or d L or H or d H of the flow path and coefficient of permeability K is

called coefficient of permeability or coefficient of means Conductivity sometimes hydraulic conductivity of soil it say is Q is equal to minus K A delta H by L. The average flux can be obtained by dividing Q with A, the flux is often called Darcy's flux q w, Darcy's flux q w.

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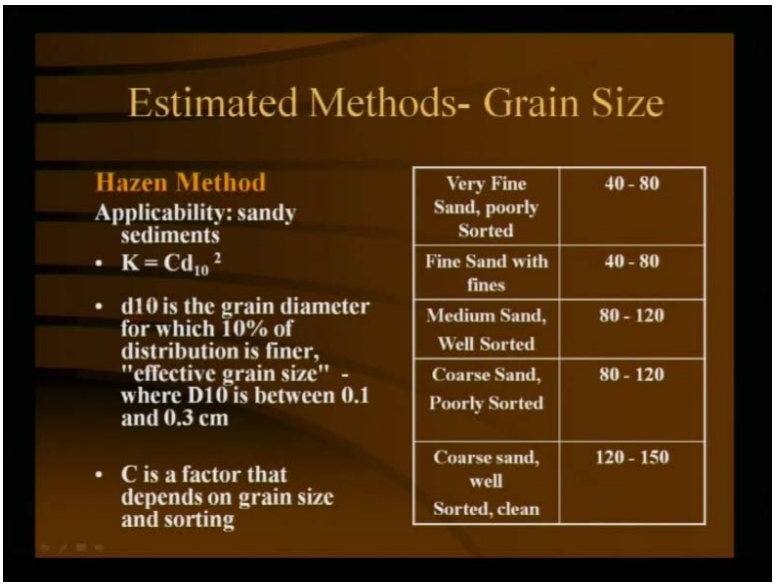

Now, if you look at these estimated methods grain size very fine sand or poorly sorted means, it will be 40 to 80 percent means applicability is sand sediments. So, K is equal to c into d 10 square, d 10 is your grain diameter for which 10 percent of distribution is finer. That means, effective grain size where d 10 is between 0.1 and 0.3 centimeter. C is a factor that depends upon grain size and ssorting C is your factor and medium sand well graded these are all tabulated form it is given.

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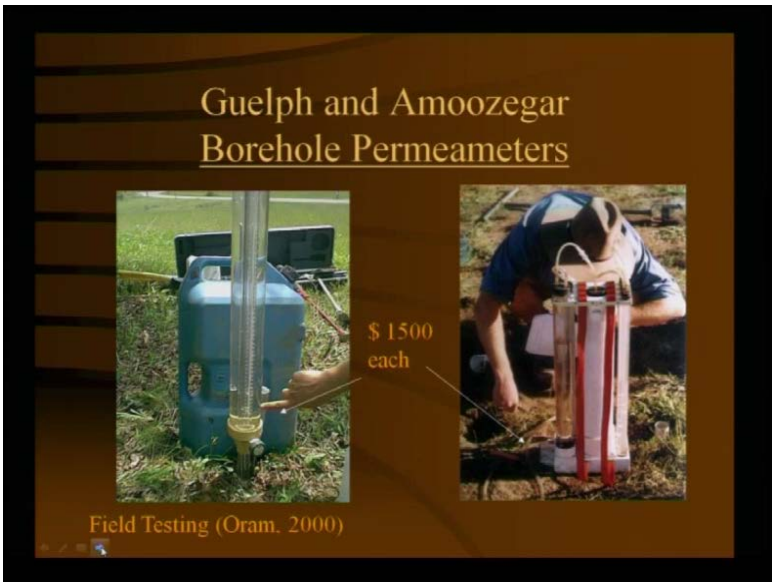

Field testing, if you look at this field testing this is called Borehole Permeameter one of the testing as I said, earlier in the field permeability. How do you find it out? One is method is your pumping in, pumping out other is your by means of tracer, third is your by means of Borehole method and this is one of the field test that is called Borehole Permeameter or permeability test. If you look at here these are all testing arrangements of this field testing for Borehole.

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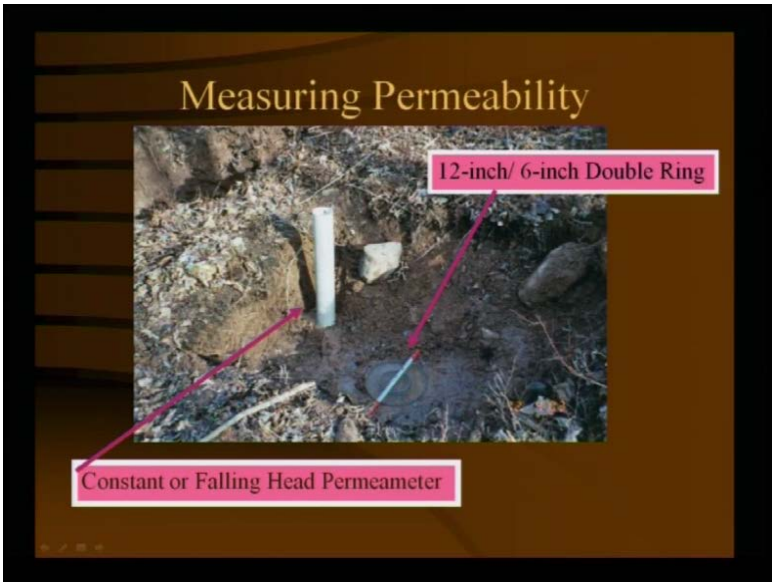

You see 12 inch to 6 inch Double ring has to be provided here and by means of borehole

constant or Falling Head Permeameter you can measure.

If I go back to this Double ring.

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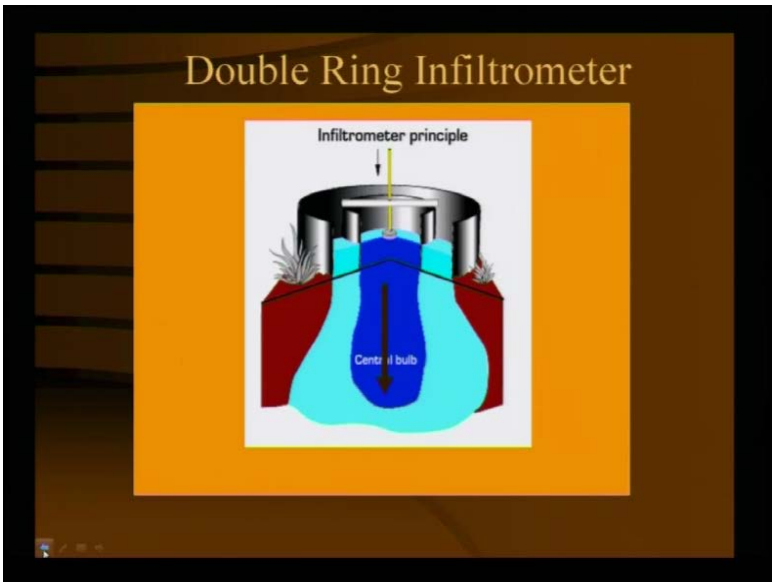

Double Ring Infiltrometer, its a central bulb with this infiltrometer principle is as per this.

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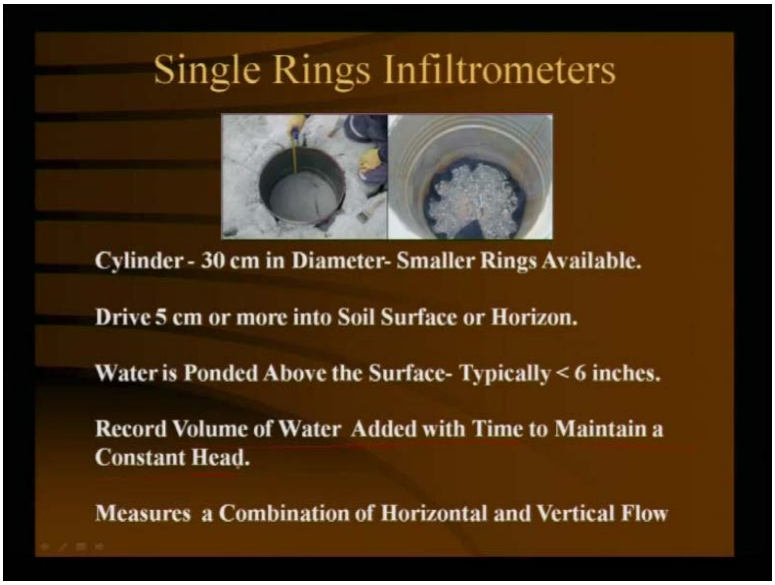

Cylinder of 30 centimeter in diameter smaller rings are available also, drive 5 centimeter or more into soil structure or horizon. Water is ponded above the surface typically less

than 6 inch record volume of water added with time to maintain a constant head. How much of volume of water require to maintain a constant head?

It can measures a combination of horizontal, as well as vertical flow. This is a single ring infiltrometer. So, you in that infiltrometer allow water so, measure the volume of water with time to maintain the constant head. That means equal amount of water passes through this borehole with equal time difference at where the, it will achieve a constant head. That means how much volume of water require to achieve your constant head. That is in case of this both single as well as double ring infiltrometer. This advantage is this by borehole method you can measure both a combination of horizontal as well as vertical flow, in case of in field testing method or in situ conditions.

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Now, A S T M Double Infiltrometer means, if you look at this A S T M double infiltrometer, this is your infiltrometer and outer ring are means particularly, this is your outer ring. This outer ring is about 6 to 24 inch in diameter and A S T M recommend 12 to 24 inches and Marriotte bottle can be used to maintain constant head, this is a bottle to be used to maintain constant head and the rings driven 5 centimeter to 6 inches in the soil and if necessary to be sealed. Basically, in this ring what will happen?

It should be inserted inside the soil and from here water should be added to the ring. So, it allowed to flow through this once it allow flow through this then you can find it out, how much water pass through the soil in equal interval of time. So, that a constant head

has to be measured means, maintain once a constant head has been maintained then you can find it out, what is your coefficient of permeability. So, particularly very difficult to install and seal A S T M double rings, single rings are easy to install and easy to seal particularly, very difficult in double ring because this enter is has to go inside because this is pipeline from where there, but in case of single ring there is nothing you can add water from the top.

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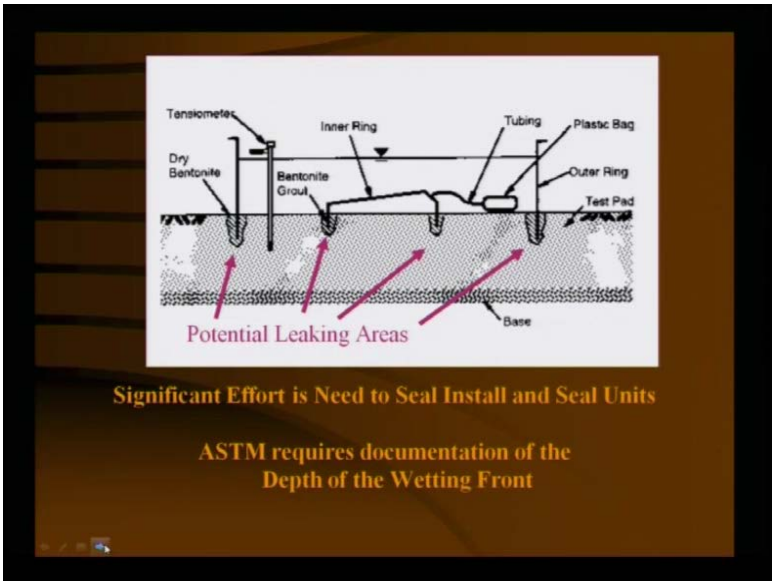

You see significant effort is needed to seal the, seal install and seal units that means A S T M requires documentation of depth of wetting front. There might be a chance of leakage here potential leaking area here may be leaking, here may be leaking it has to be sealed by means of bentonite slurry.

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Other double ring, small diameter are easier to install or repeat the testing. This is 6 inch to 12 inch double ring, 3 inch to 5 inch double ring in 12 inch diameter look at this how it has been installed.

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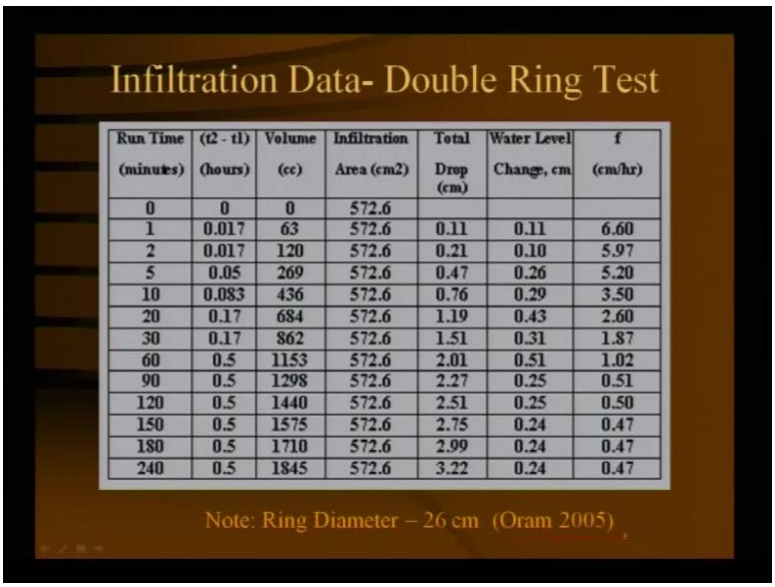

Means, these are all your infiltration data of this test has been made by Oram 2005.

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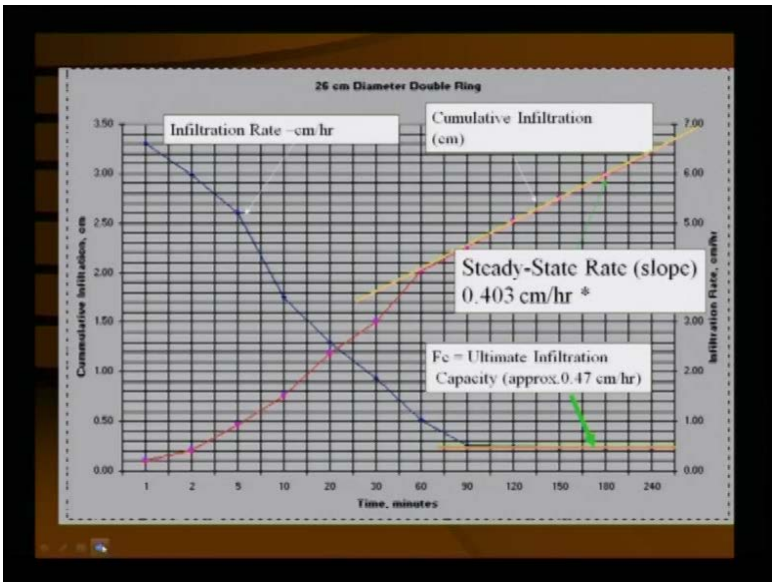

Now, come back to this field test.

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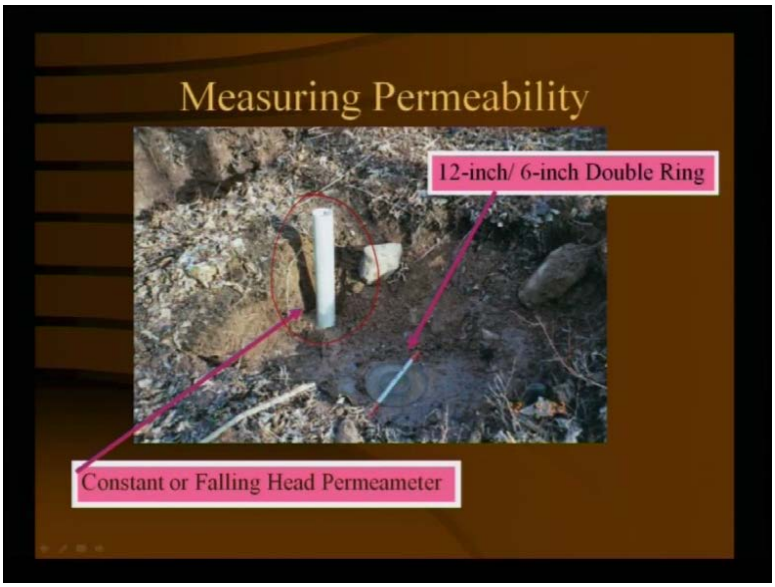

look at this, by means of boring in situ method means this is your borehole. You made the borehole here and boring pipe has been inserted here by means of single ring 12 inch to or 6 inch or single ring or double ring you allow water to flow inside. So, that a constant head has to be achieved once a constant head has to be achieved that means delta H by delta L amount of soil, where you are considering inside this borehole with the time you can find it out your coefficient of permeability in situ at vertical, as well as

also laterally.

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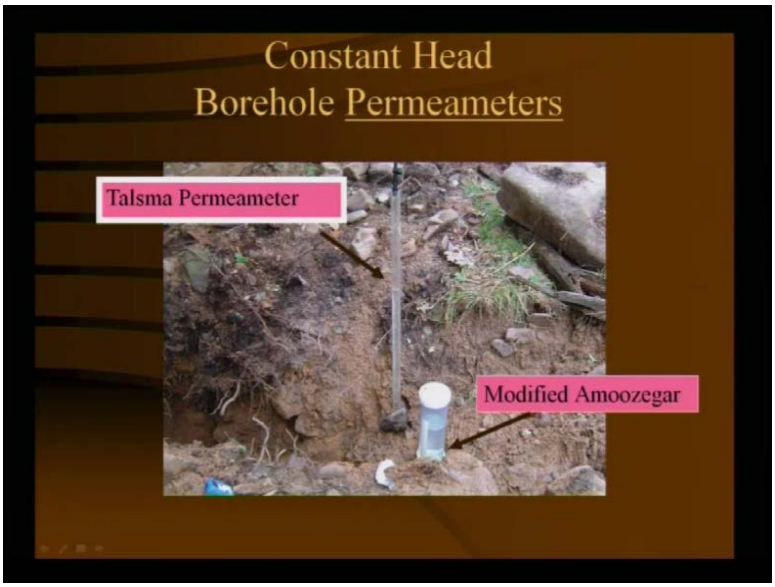

Another one is it has a different permeameter, you see sometimes it is given naming Talsma Permeameter, where you see here you modified Amoozegar. So, here water you add it how much water pass through this, you can find it out. So, this is a constant head borehole permeameter.

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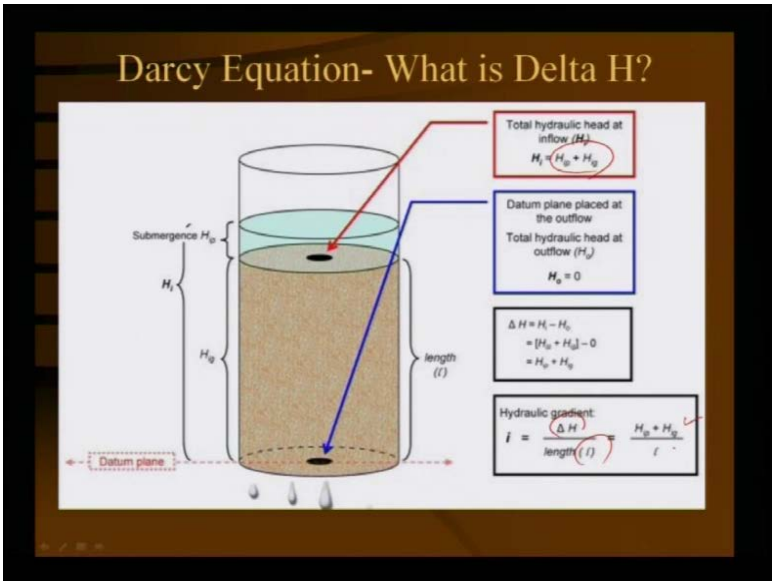

What is delta H? If you look at delta H is if you look at the total hydraulic head at inflow, at point of inflow total hydraulic head is your at this point. At this point total hydraulic

head is if it is H I that means, H I row plus H j p. What is H I row? Means, if you look at here this is your length of the soil, soil plus this is your water. So, datum plane placed at the outflow that means, where this outflow will be there datum plane has to be places it this is my datum plane.

So, total hydraulic head that outflow H 0 is equal to 0 because datum plane has been placed here. So, delta H change in hydraulic head is H I minus H 0, H I is nothing, but your it has come from here soil with water minus 0. So, this will so hydraulic gradient I is equal to change in hydraulic head by length. So, this is your change in hydraulic head and this is your length.

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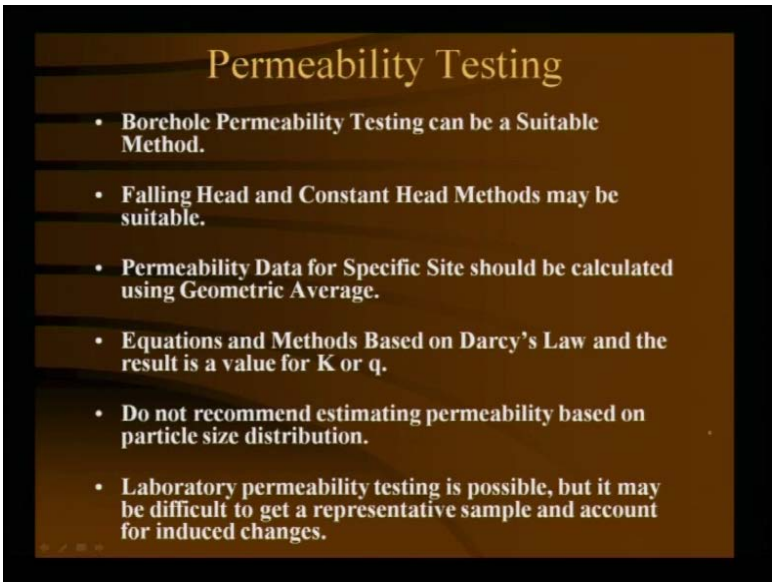

Borehole permeability testing can be a suitable method falling head and constant head method, may be suitable permeability data for specific site should be calculated using geometric average means, specific data, specific site, permeability data suppose, specific site is this site is there .so, how do you find it out in geometric average you consider one borehole here find it out permeability, one borehole here find it out permeability, one borehole here find it out permeability, one borehole here find it out permeability with these once you find it out the permeability.

Then you can take its average equations and methods based on Darcy's law and the result is a value for K or q always do not recommend estimating permeability based on particle size distribution, do not recommend it laboratory permeability testing is also possible,

but it may be difficult to get representative sample and account for induced changes. So, best is you go for borehole permeability testing in the field in situ condition, then you record it and that site record it three, four places and take this average.

This average value has to be reported to find it out means particularly, this geometric average value of this K has to be reported for your final value of coefficient of permeability of soil.

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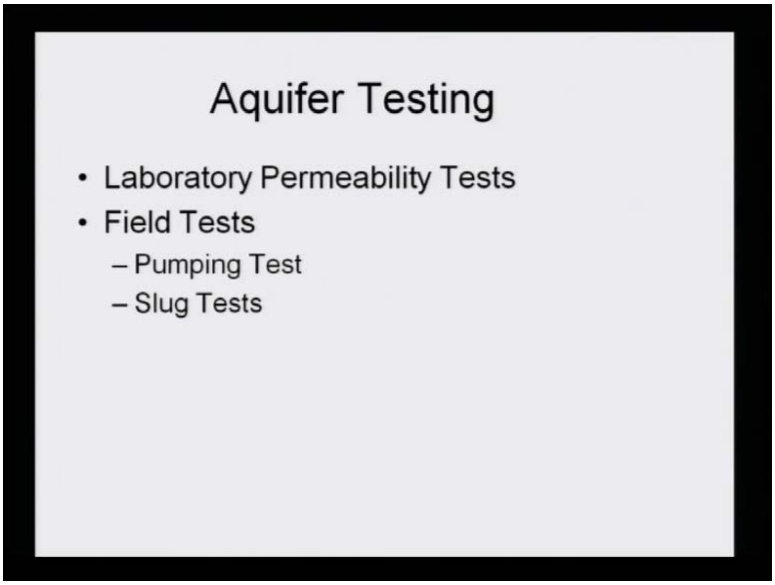

Let me start with this Aquifer testing, laboratory permeability test and field test after this borehole test, field test also pumping test also slug test also remaining. So,

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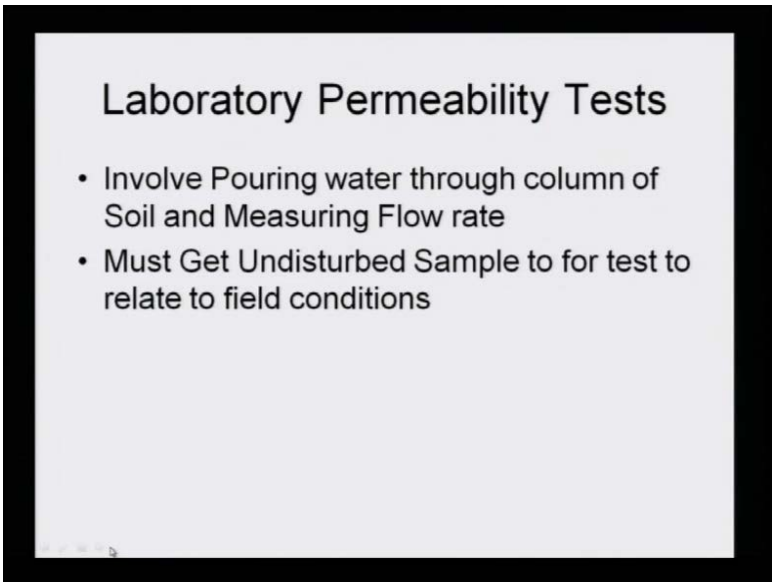

Let me finish then, I will go to that means as I said as I discussed last class in laboratory permeability test. It involves pouring water through the column of soil and measuring flow rate and you should get undisturbed sample for the test to relate the field condition. Undisturbed sample of the soil column you have to collect from the field so, that whatever permeability in the laboratory you are going to get, it has to be co-related to the field condition.

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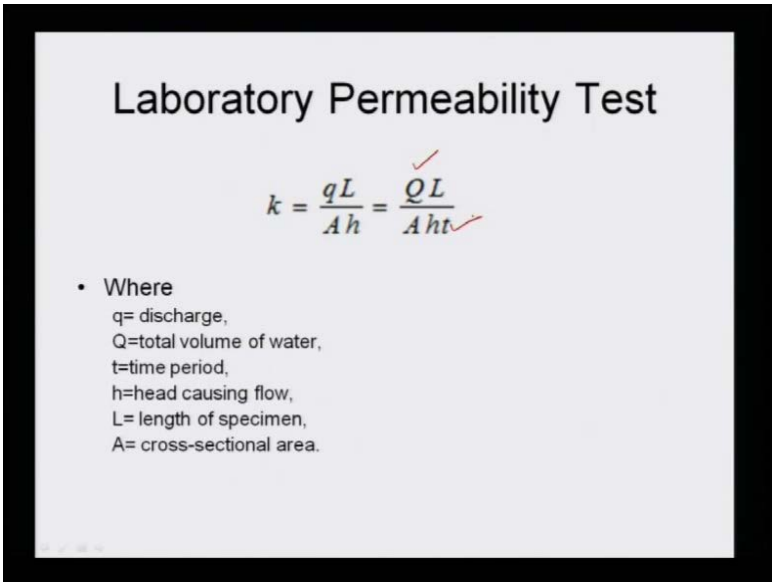

Laboratory permeability test as I said, with your constant head k is equal to q L by A h.

So, q is your discharge, L is your length, A is your area of cross section, h is equal to head causing the flow, if I make it into q total q into L, A into h into t. So, q is your total volume of water and t is the time period required to cause the head causing flow and L is your length of the soil specimen, as I said A is your cross-sectional area.

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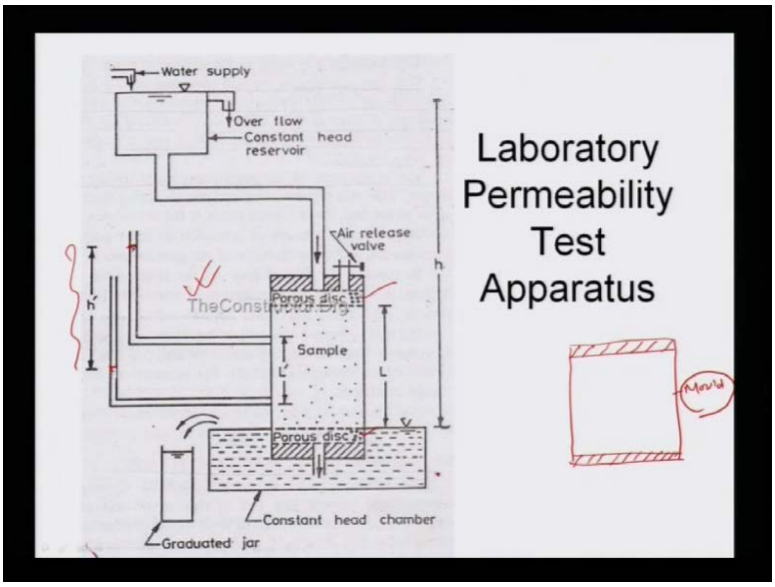

Now, constant head method just a bigger picture I want to show this water tank has been placed above the soil sample earlier just, I show this means. What is the principle, how it has been done? This is the laboratory test equipment. Now, this soil sample has been put inside a mould it cannot stand inside a mould with this mould. If you look at this top part is connected with porous stone also bottom part is connected with this you can connect means, place your porous stone both has the top and bottom and here, it is your porous stone or porous disc.

Why porous disc? The movement you allow water only porous stones are only allow water to pass. That means the movement water is here it passes through top of the soil sample. So, water is allow to pass through the porous stone along the soil sample, then at the bottom. What will happen? Porous stone will only allow water to flow not allow soil sample to flow through here. So, this is mould inside this mould your soil sample is there and with this soil sample connect it by means, of piezometer.

So, you can you can find it out. How much is your hydraulic head develop h prime, how much is your hydraulic head develop? Then here at this here, there is a graduated jar is

there from there you collect your water basically, if a constant head permeability this is your constant head permeability method.

What will happen? Water passed you allow from the tank it should be placed over the soil. So, that the head has to be maintained so water will pass inside. So, how water will pass water will flow from higher head to lower head so, head loss or head with your difference at head you will observe by means, of piezometer.

This piezometer will be at the top. So, how much water will be here you can find it out this is your water. This is piezometer at the bottom of the soil sample, you will find it out water level here with this water level top and bottom then you can find it out h prime. What is your head loss and with this help of head loss you will find it out constant head permeability you can find it out, what is your coefficient of permeability?

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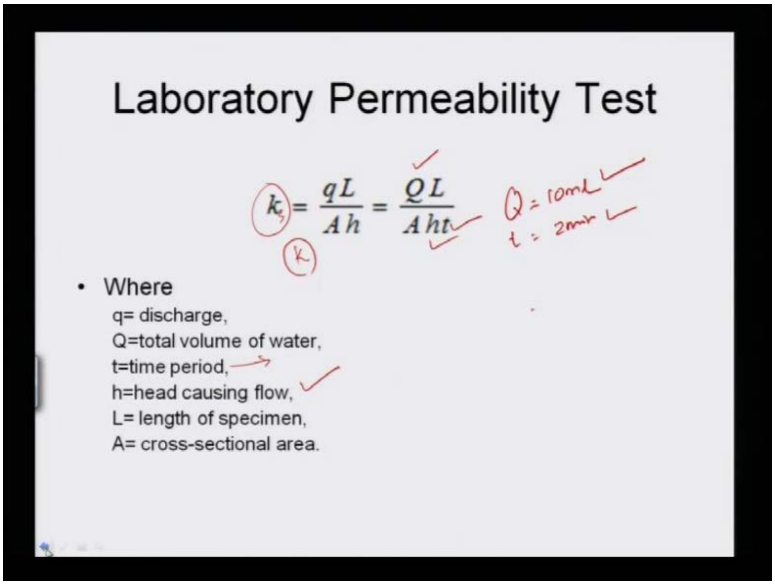

You see sometimes, we write K s sometimes some people write K. So, S earlier slides are K s here it is K it is nothing, but coefficient of permeability.

Now, this total volume of water can you measure it. How much volume passing through this? Yes, I can measure how you will measure look at here the movement you allow water to pass through this here and collected in a graduated jar. That means, you take a stop watch allow for suppose, say time t is equal to 1 minute initially, you start time t is equal to 1 minute then, with this stop watch take time t is equal to 4 minute with 4

minute time t interval collect the water.

How much water you are collecting? Then second step with time you start t is equal to 4 minute then, allow another time interval say 4 minute that means, next step of 4 minute plus 4 minute at 8 minute time, then you collect your water and stop the collection of water means, at regular interval of time how much water collected that you can measure from there, you can find it out your discharge or total volume of water, where it has been collected in this graduated or measuring jar.

How much amount of volume of water you can collect you can find it out? Then head causing the flow, you can find it out from here by means of measuring the piezometer, you can find it out head causing the flow. Then time period how much time period as I said initial, time sort t, t 1 is equal to so say zero t 2 is equal to 2 minute, how much time period with this two minute of time period of time, you have collected. Discharge of this m l say 10 m l with 2 minute time interval, you get the discharge say q is equal to 10 m l and time interval t is equal to with 2 minutes that means, you will get q you will get t h you will find it out as I said, h you will get it from here.

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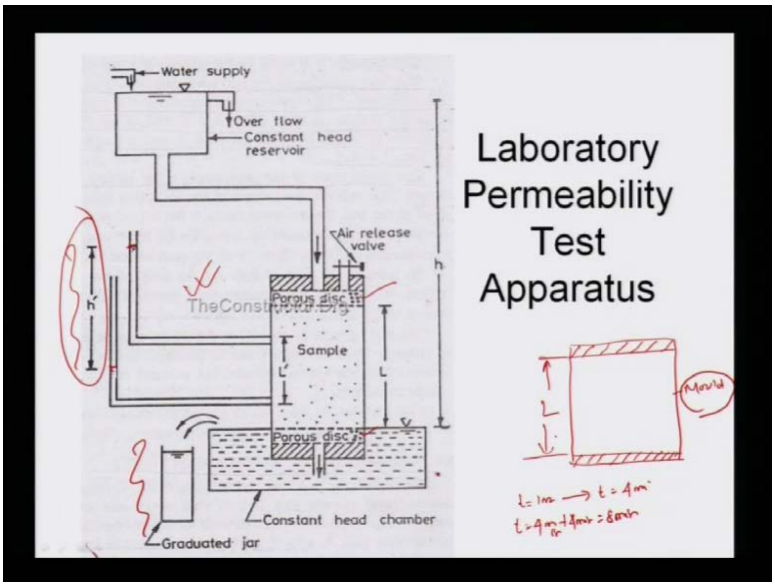

What is your hydraulic head? From there you can find it out h. So, h you also you get you know length of length of the soil sample from the mould. From the mould you can you know what is that pre-decided length means, this is your fixed length what is your length you know it. So, once you know the length then what else remaining area of cross

section that you can very easily find it out. From there you can find it out coefficient of permeability by means of constant head permeability you can find it out.

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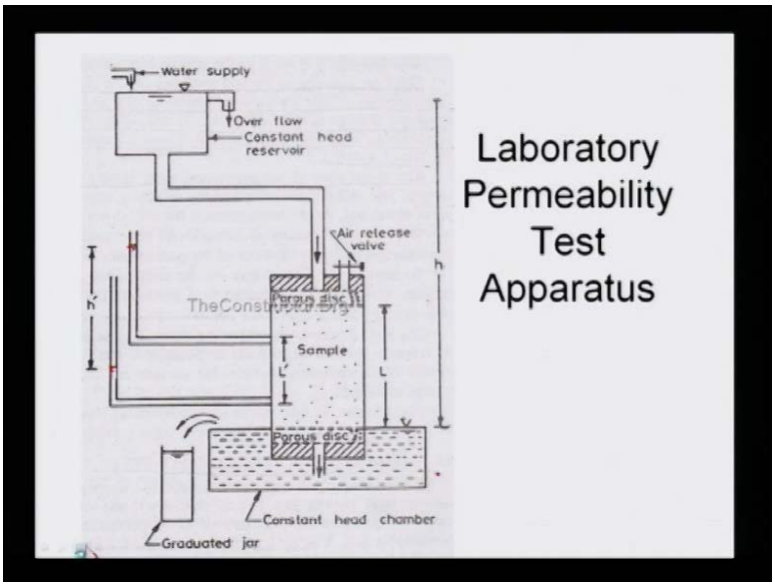

So, this is the earlier slides are how it has been done. What is the physics behind it and this slide is showing coefficient of permeability by constant head method, laboratory equipment and how this laboratory equipment has been placed for this coefficient of permeability by means of constant head method.

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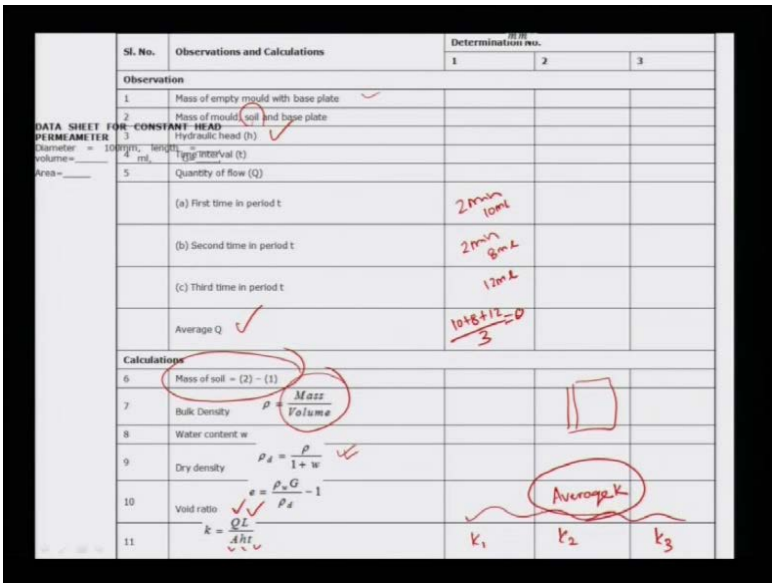

Now, come to next. What are the measurements you are going to do? This is calculation

sheet that means, mass of empty mould with base plate you measure, you have to take at least 3 moulds. So, that average value as I said one coefficient of permeability may not be correct at least 2 to 3 at least 3 mould you will take it a three soil sample, you will take it find it out coefficient of permeability and take the average.

So, initially mass of a empty mould with base plate you measure mass of mould with soil and base plate you can find it out, third is your hydraulic head you can get it then time interval quantity of flow, you can get it. So, first time in period t second time in period t third time period in t. What is mean by first time period in t? Suppose with first time period of two minute. What is your flow? What is the q means? How much water you collected in the measuring jar?

Second time period suppose, say another 2 minute, how much volume of water you collected how much m l you are collected suppose, first 2 minute you collected 10 m l, second 2 minute you collected 8 m l, third you collected suppose, say 12 m l that means, average value of 10 plus 8 plus 12 by 3 this q l has to be reported. This average volume has to be reported do not go by only one value of q only one time interval whatever, you are getting the q that is not to be true because inside the soil to get this, achieve this, constant head it takes time.

So, what will happen you take any two, three interval of time and take the average and report it for your calculations. So, from these from two and one mass of mould soil and base plate, if I deduct mass of a empty mould with base plate I can find it out. What is by mass of the soil? So, mass of the soil you can get it 2 minus 1. So, bulk density you can find it out, mass per volume because mould volume is fixed 1 meter by 1 meter by 1 meter means.

What is the dimension is there it is fixed. Now, water content you can measure it from this bulk density you can find it out, dry density then you can find it out, also void ratio. What is the void ratio? It is also required then from all this value of q average value of q report it length of the sample. Length of the mould you know area of cross section hydraulic head and time interval from there you find it out, this is your k 1 this is your k 2, this is your k 3 for three soil samples, with help of k 1, k 2 and k 3 then 3 permeability, you are getting.

Theoretical they are suppose to be same, but it is not true so, the value will be means the

value will be vary slightly, then you consider report it average value of the k 1, k 2, k 3 this you have to report means, while reporting this because this is a laboratory test, this is a laboratory test more the number of samples you are going to test it more accurate data you will get it, more average value you can interpret it.

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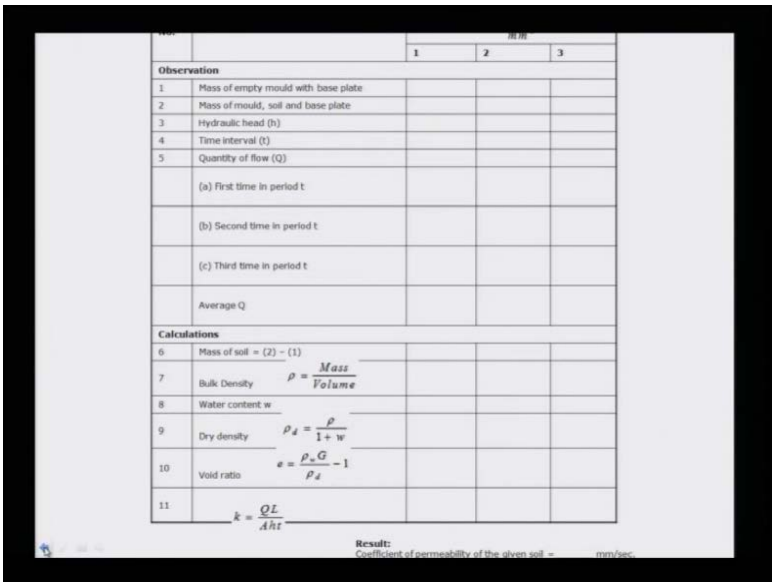

This is the same thing. The coefficient of permeability is the dimension is either centimeter per second or m l per second, if you look at this it is a centimeter per second or mm per second, it depend upon that how you are representing this sample. Now, there are two test as I said, I have shown you justone detail data sheet about the laboratory test data sheet.

What are the measurement you are going to do one, two, three how many samples, what detail data sheets, what you are going to get? Same data sheets can be used for variable head in this variable head, this hydraulic head to be 2h 1 and h 2 with time t 1 and t 2, this two things will come here then calculation, as per the formula you can find it out. What is the value of q and then you can find it out what is the value of k? From this once you are getting.

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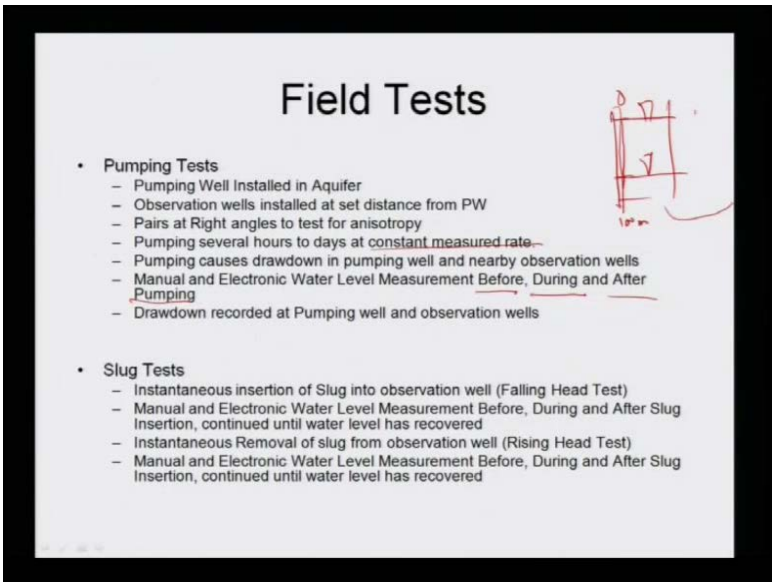

Now, this field test this is your pumping test. Pumping well installed in Aquifer observation wells installed at set distance from pumping well, look at this there are two test I left earlier, I borehole method I said one is called another method is called pumping in or pumping out test. So, pumping wells that means pumping wells should be installed in a Aquifer there are two pumping wells. One pumping well has to be installed in Aquifer other pumping well is called observation well, it should be installed at a certain distance away from your pumping well pairs at right angle to test for anisotropic.

If this is my pumping well means pairs at right angle. So, one pumping well will be here one will be here so, that it should be right angle to each other so that I can find it out anisotropy. Anisotropy means isotropic anisotropy. Anisotropy means the property of permeability in x and y direction, it should not be same isotropic means k x is equal to k y is equal to k z, x, y and z direction. The permeability is same pumping several hours to days at a constant measure rate that means, pumping means you pump it constant rate that means several hours to days it may be four hours, it may be eight hours it may be one day, it may be continuous two to three days.

At a constant measure rate, at a constant measure rate means you decide how much amount of water to be pumped out how much water say suppose, say hundred m l of water. So, may be one thousand m l of water that is called constant measure rate that measure rate should be constant pumping causes draw down in pumping well. The

movement you start pumping water outside this pumping well, if this is a pumping well the water level is here then you are pump out. So, sudden drawdown the water level will be fall down and manual and electronic water level measurements before during and after pumping that means, both manually we can measure it manually.

How we can measure it? You place a scale from top to bottom you place a scale. Suppose, this is started with 0 this is your 100 mm. So, how much height water you have pumped that you can measure by manually or by electronics device. Electronic device you can place it it can directly give, once the dimension is fixed you know the how much volume of water is there. So, how much has been pumping out that you can electronically, you can measure it you place it so meticulously. So, that you can measure before what is the height and during also what is the height and after the pumping, how much the height has be achieved?

Drawdown recorded at pumping well and observation well both this wells you measure how much drawdown has been achieved.

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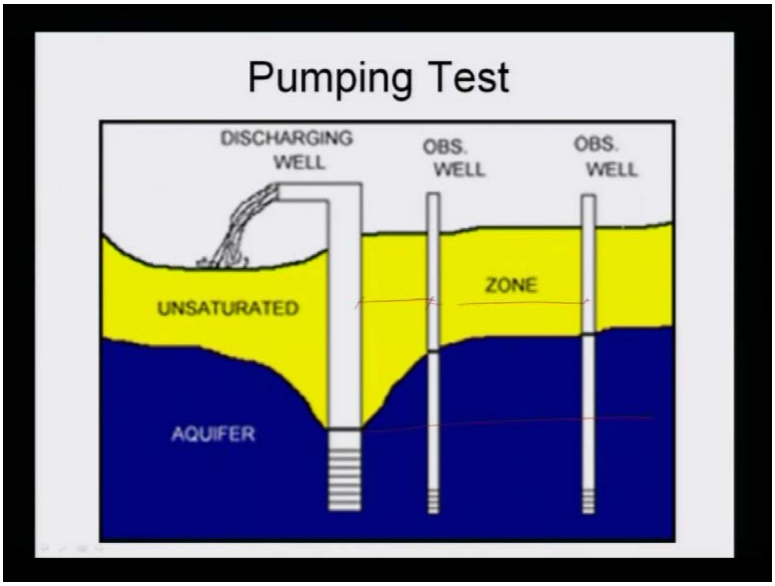

So, another test is your, this I am going to show you also in details.

These are all in field I am going to show you in details. If you look at here this is your aquifer means water table is there, water level is there aquifer in that aquifer means, this is constant aquifer in that case you just a discharge well. This is your discharge well and

nearby at certain distance you know this distance with this distance this is your observed well either one well or two wells you can put it. So, what will happen at a constant rate, this discharge you pump at a constant rate you take out this water from this aquifer.

So, what will happen there will be a certain drawdown sudden drawdown of water so, how much of water from the soil, it is a sudden drawdown with this observed well and as well as here you can measure it. This is how this physics how it looks. If I summaries how it looks outside if I draw a schematic diagram of how it looks.

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But in the field it is different; you see how this pumping in, pumping out, pumping test has been done.

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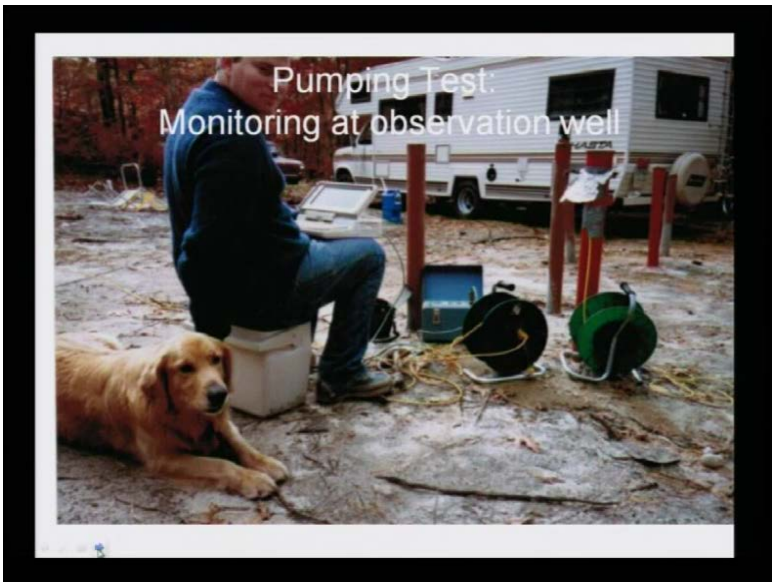

If I take it here pumping test monitoring, this observation well these are my observation well one observation well two, it has been electronically post. So, that you can find it out what is your observation wells also.

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Then you see this by means of, tape also you allow the tape should go inside you can measure the. How much of height of fall? What is the distance the water drawdown is there?

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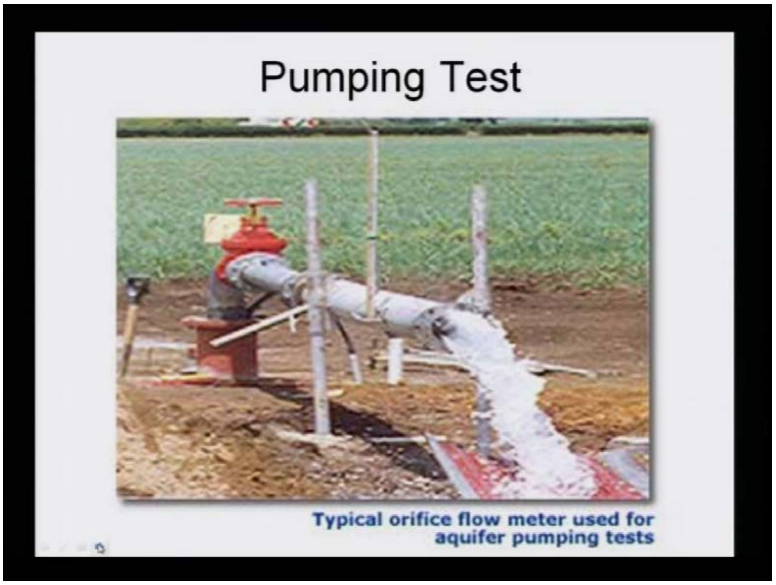

You see how much pumping means by means of constant rate you are taking out the water from the aquifer.

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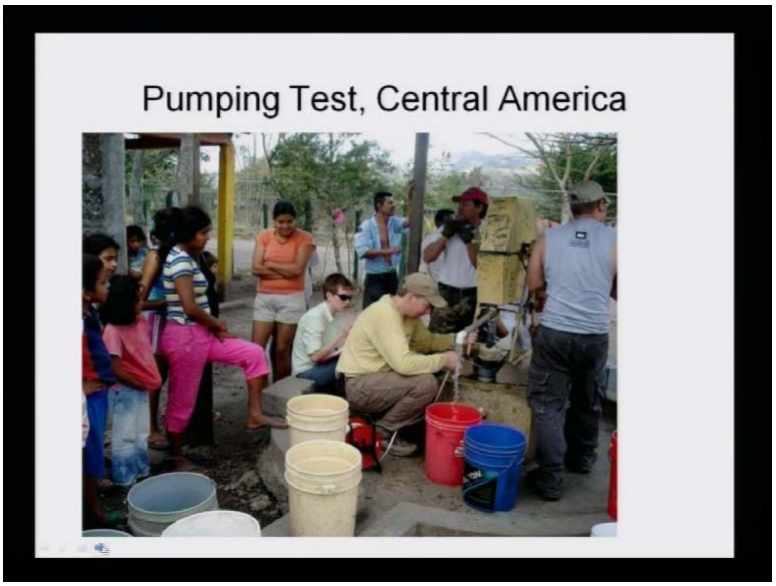

These are pumping test heavy equipments used in the field means portable sometimes some, some people use heavy equipments sometimes some people are using portable equipment.

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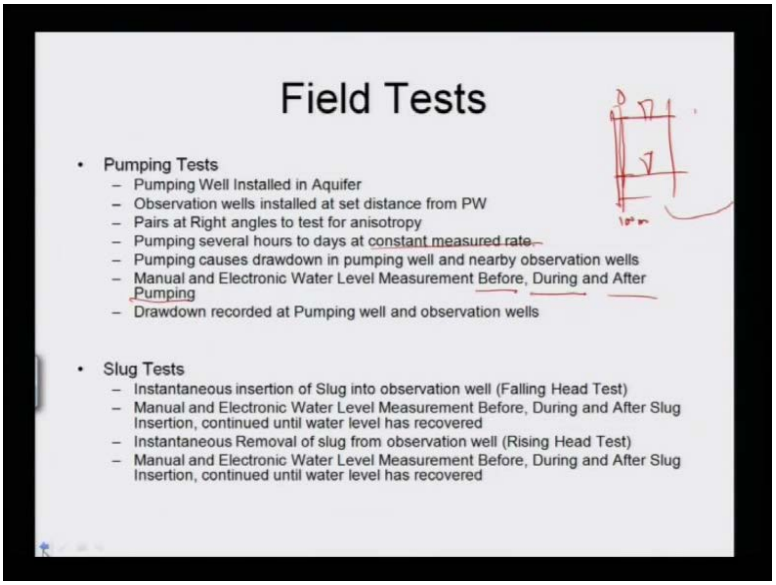

So, then we will go back to our next part of this slug test that we I will discuss in the next class.