Computational Hydraulics
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Lecture 1
Introduction to Computational Hydraulics: Overview

Welcome to this first lecture of the course computational hydraulics and this particular course we have this first module introduction to computational hydraulics and this first unit is overview unit.

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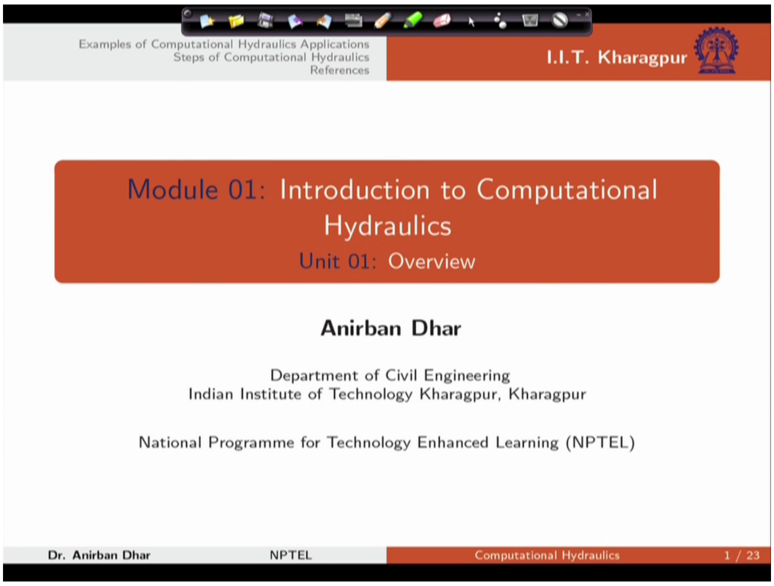

So what are the learning objective of this particular unit? In this particular unit we will try to define this computational hydraulic that means at the end of this unit students will be able to define computational hydraulics and they we will be able to recognize the difference between physical experiment and computational approach.

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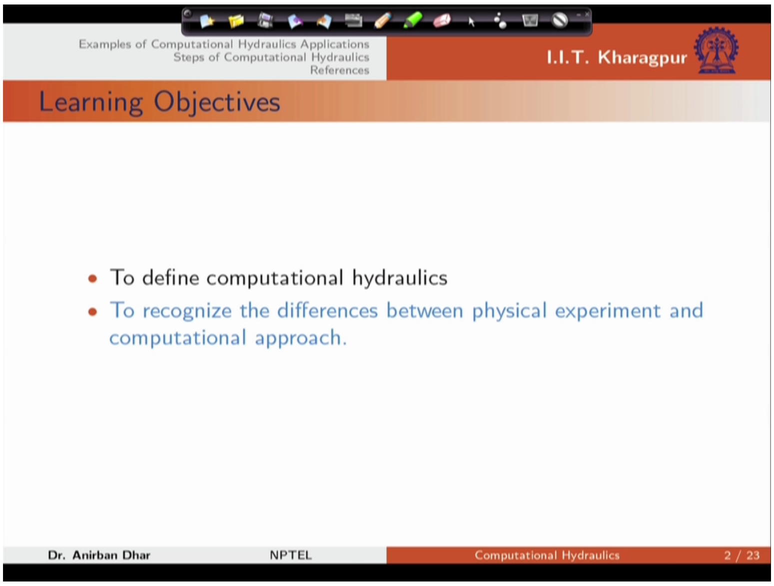

This is the introduction. Fluid flows and moments in hydraulic systems are generally governed by differential equations or partial differential equations. Either they are ordinary differential equation or partial differential equations.

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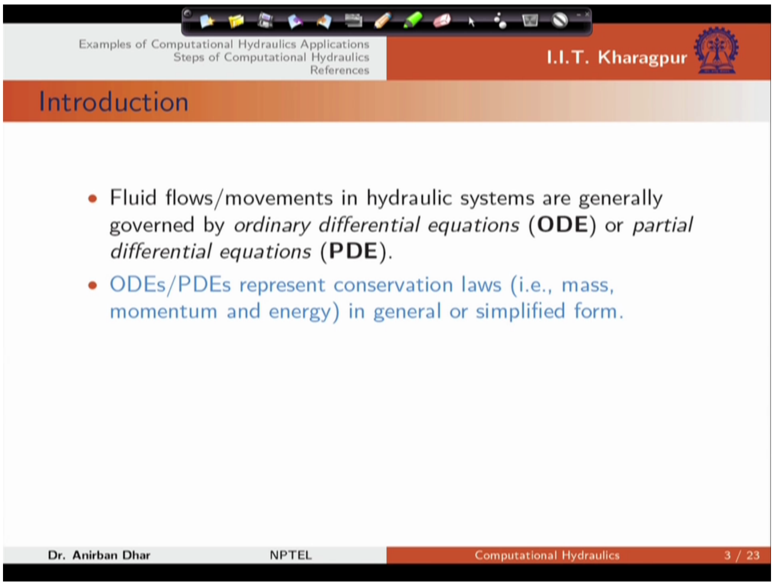

Ordinary or partial differential equations represent the conversation laws, mass momentum and energy in more or less simplified form. And this computational hydraulics is the art of representing (comp) ordinary or partial differential equations in the form of algebraic equations. And overall aim of this computational hydraulics is to reduce the experimental that means physical cost by solving the algebraic equations using our simple computers.

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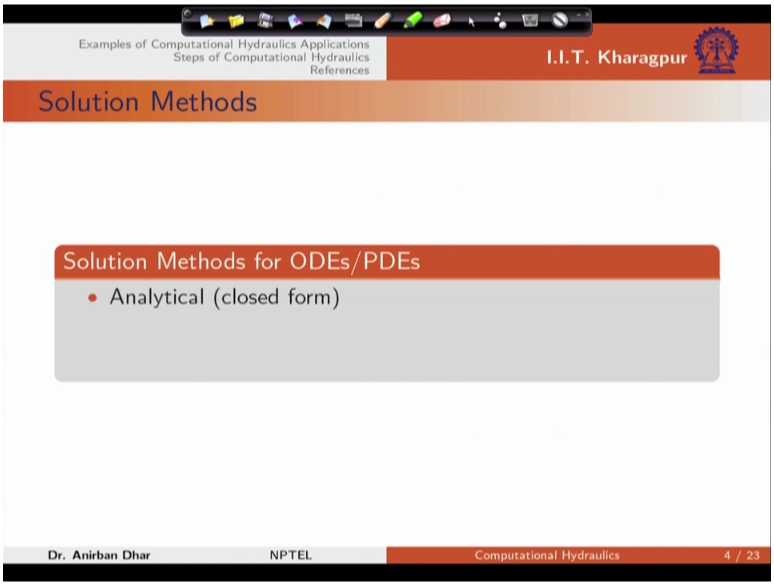

So, what are the solution methods to solve this ordinary or partial differential equation? Either we can utilize analytical form or closed form solutions or semi analytical or part of that is analytical and part is numerically solving the things and complete numerical or approximate form of the ordinary and partial differential equation.

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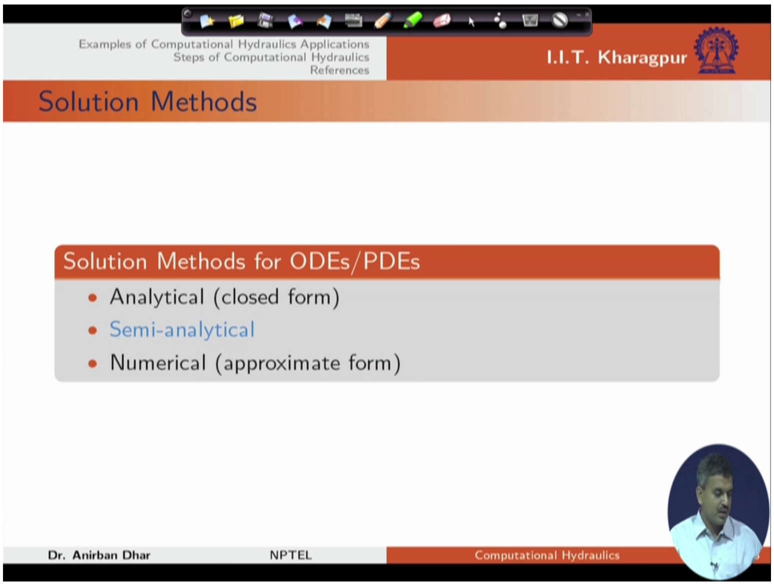

Now what is computational hydraulics? If we consider the definition so computational hydraulics provides a quantitative description of hydraulic systems by means of numerical methods under budgetary constraints. This term of budgetary is important because we can have limited computational facilities available and at the same time with that limited computational budget we need to solve the actual physical problem.

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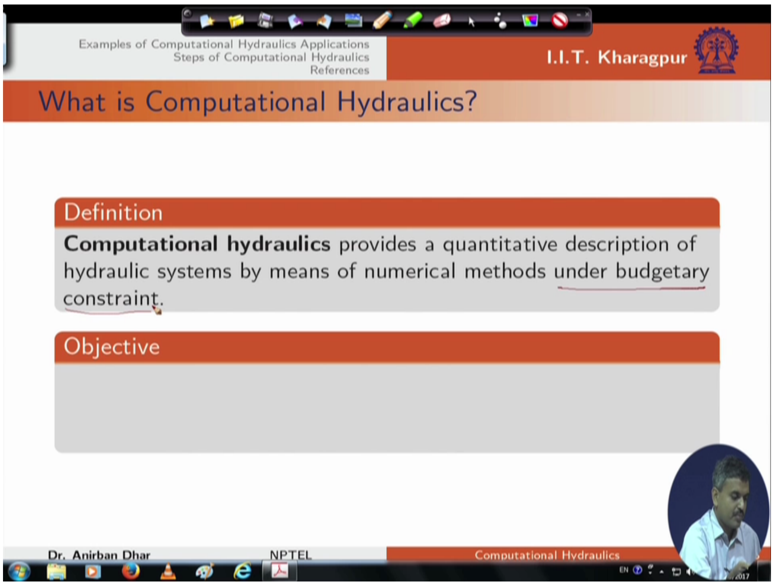

So what is the objective of this thing? Objective is to empower scientists or engineers to perform numerical experiments in a virtual laboratory before experimenting physically. So computers with the computers we can try to solve the problem in a virtual laboratory and then we can perform the experiments.

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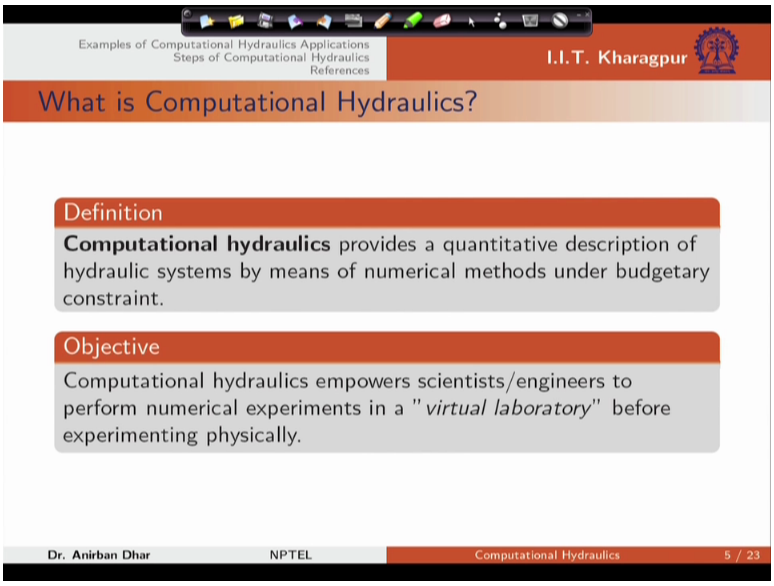

So let us consider one example. We have this high density fluid on the left hand side and right hand side we have low density fluid. Left hand side it is representing the experimental configuration and right hand side it is numerical configuration. So if we have a gate between this high with density and low density fluid and we remove that gate there will be mixing of this high density and low density fluid.

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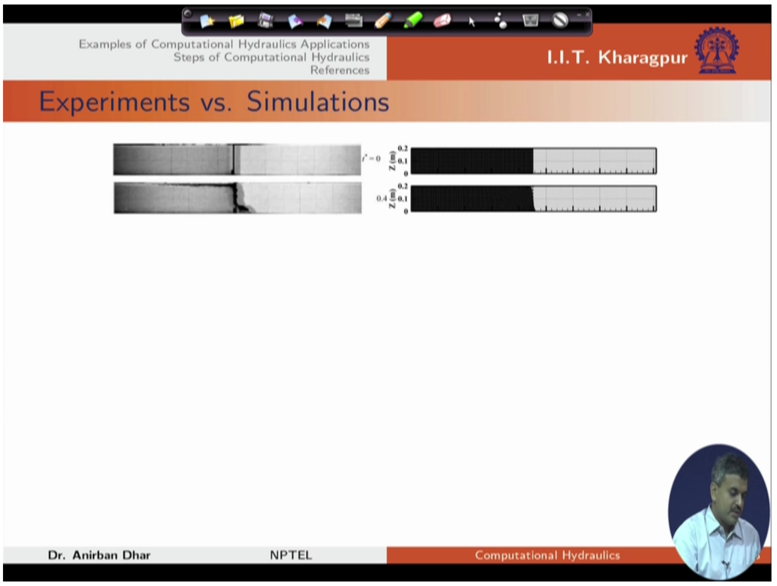

If we with time if we capture the mixing process then we can see this kind of configuration. So with time we can see that there is mixing which is occurring in the system. This is called as lock exchange flow.

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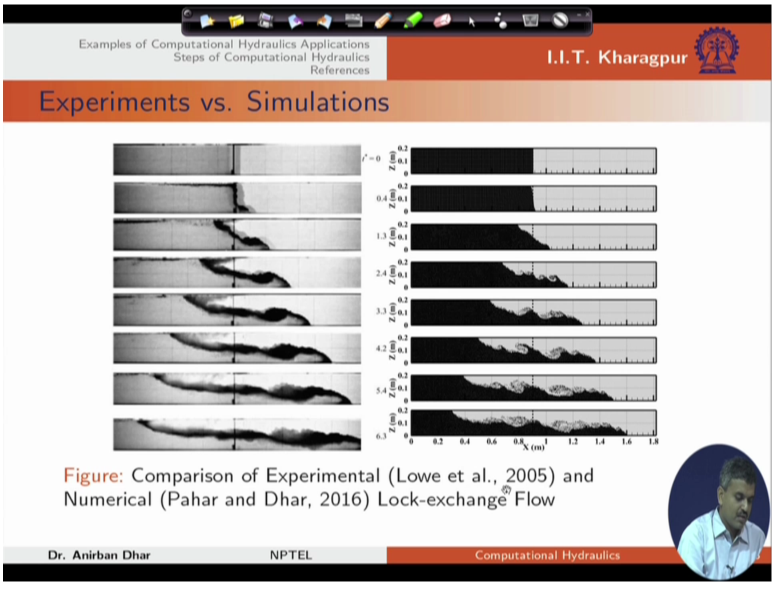

Now in experiments the information about physical phenomena on representative spatiotemporal observation points depending on techno economic feasibility. So in our experiments we try to get information at certain observation points either it is in space and in time. But in simulations, prediction about physical phenomena on discretize nodes depending on again techno economic feasibility.

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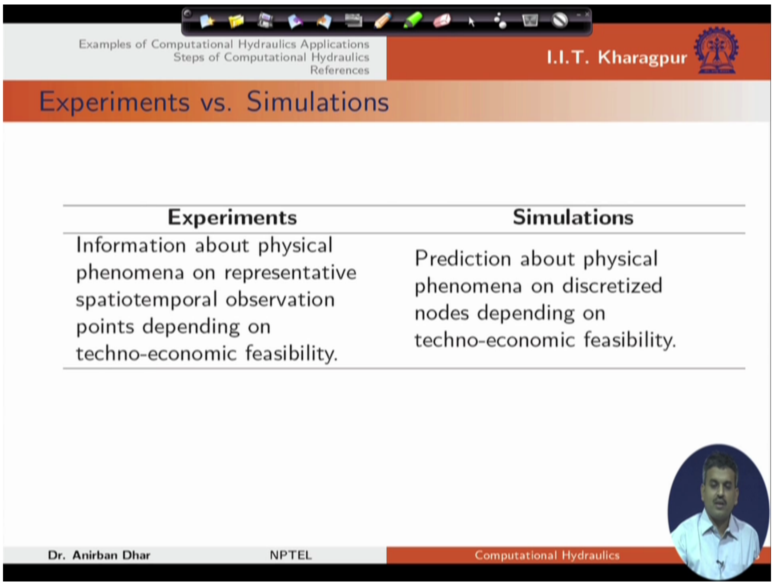

If we have a final mesh, then mesh or gridding system we can get a good approximation of the system and we can get more information or find information about the system. With experiments measurement error is important in simulations conceptualization in terms of mathematical equations that is mathematical description of physical phenomena and numerical errors are important.

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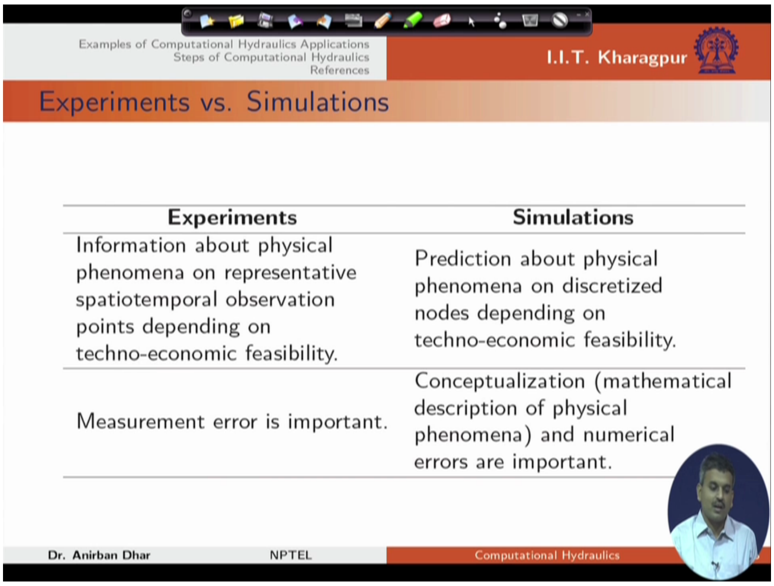

So types of fluid flow is and moments. Fluid flows and moments in hydraulic systems include groundwater movement and contaminant transport in aquifers. Surface water flows it can be a flow in open channels, surface flooding, flow over hydraulic structures or pressurized conduits or pipe flow system or it can be interaction between surface water and groundwater flows.

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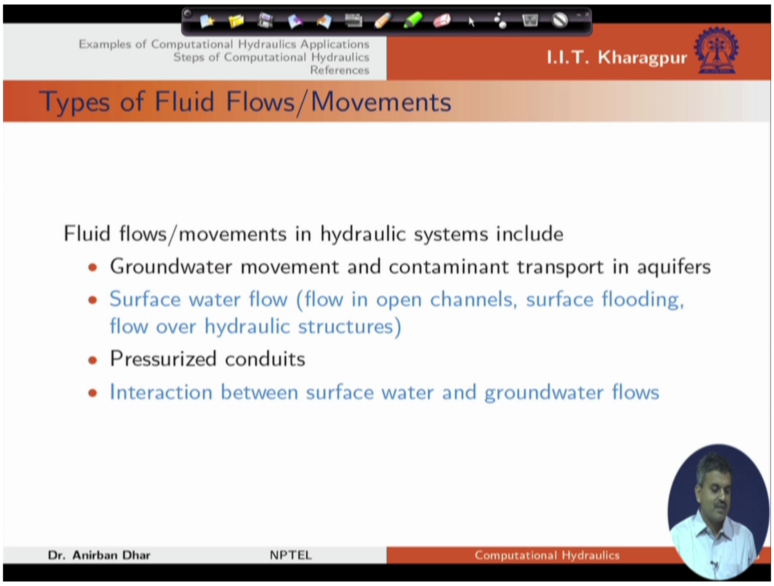

So let us consider first example on groundwater movement in aquifers.

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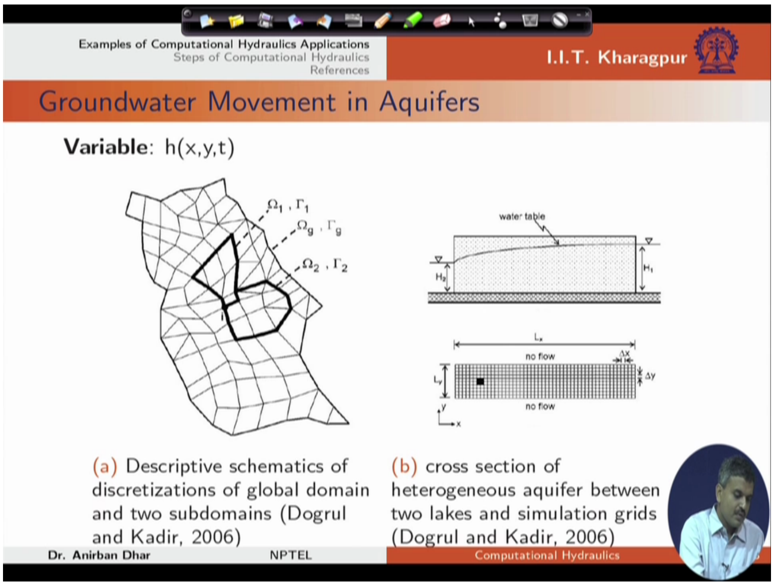

We can consider this system where this is your boundary and we can divide the whole system into parts and we can have some subdomains and we try to discretize or divide the whole system into different parts.

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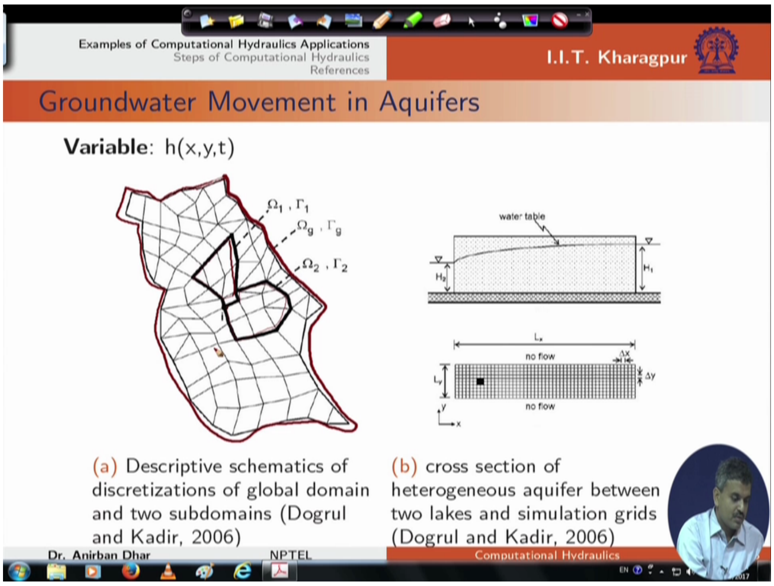

So these are called as our elements or cells. And this particular problem is groundwater movement in aquifers. So variable is head variation for x, y and t.

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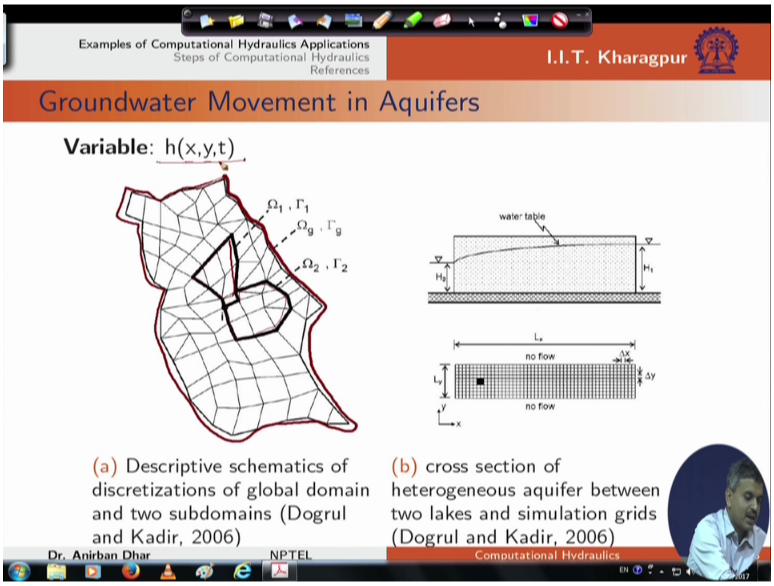

So special variation and temporal variation but there is no change in z direction. So simple example is left and right side we have two water levels and this is your, inplan view. This is your plan view and this is elevation.

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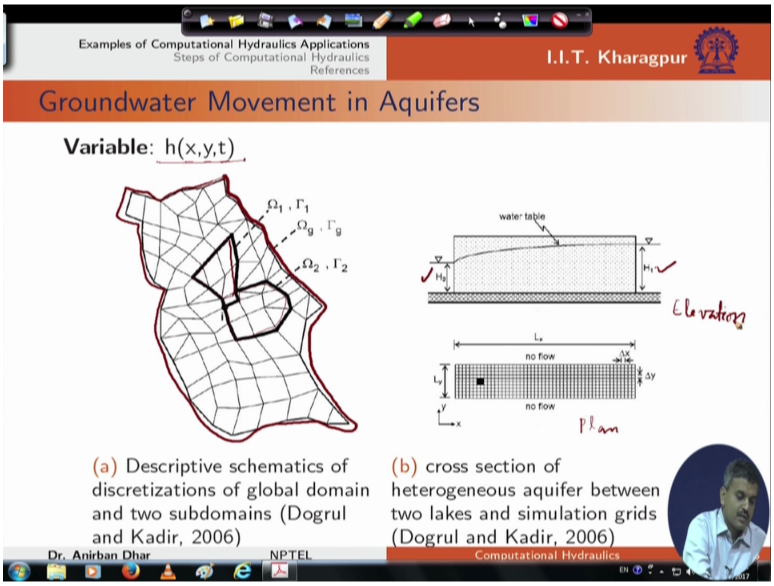

We have specified heads these two sides and no flow on this top and bottom one. So with this configuration we can try to find out the position of water table.

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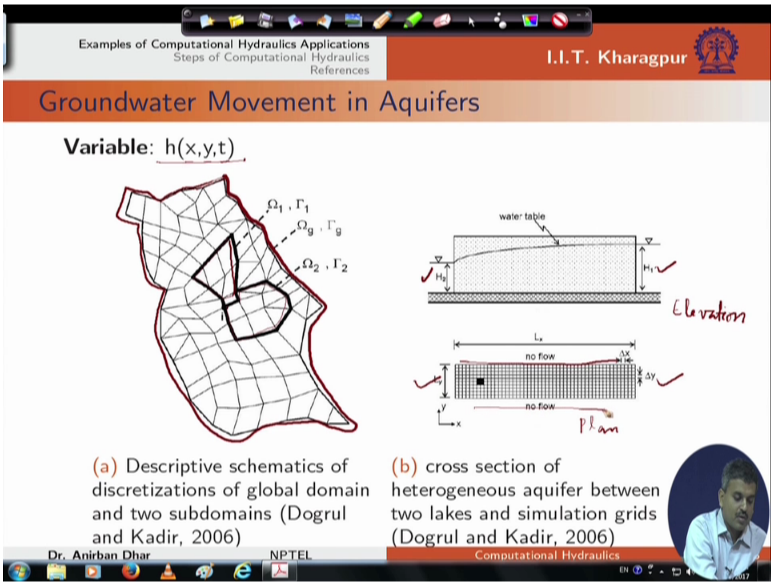

So water table is varying with x and y and with time if there is variation in h2 and h1. Otherwise if h2 and h1 are fixed with time then we will get steady state configuration in this system or steady state water level in this particular system.

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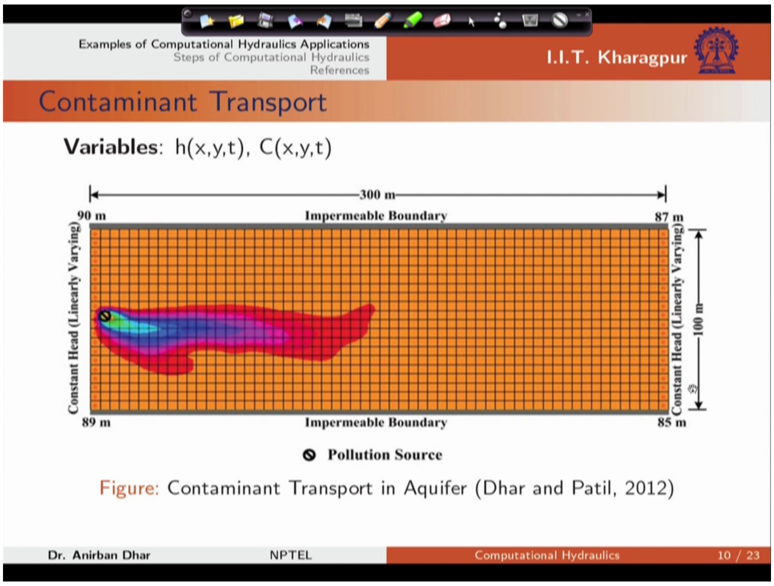

Next is contaminant transport in aquifer system. Again we have impermeable boundary and top and bottom and left hand side and right hand side we have constant head boundary condition. So what are the variables? Variable are hydraulic head h which is varying with x, y and t. And concentration again for two dimensional aquifer system it is x, y and t.

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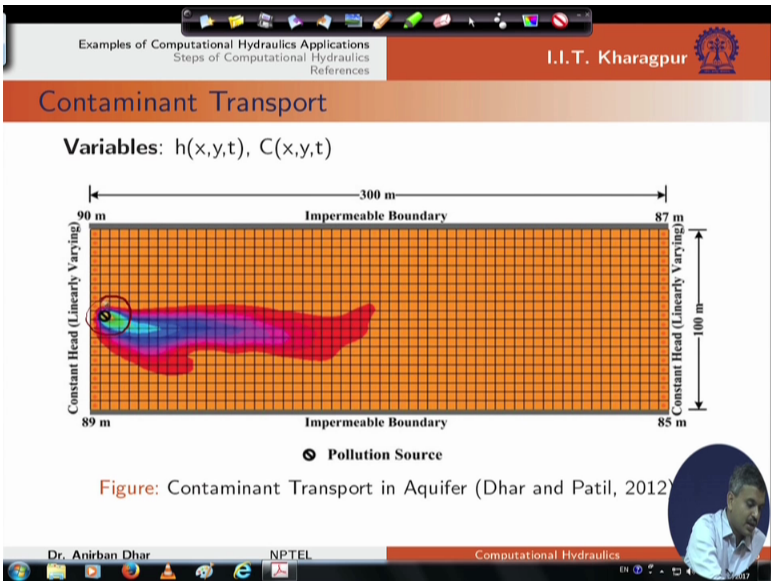

If you have some injection point at this location or we are injecting some water or pollutant from this system, due to hydraulic head it is moving right ward. So with time we can find out what is the concentration level within the aquifer system.

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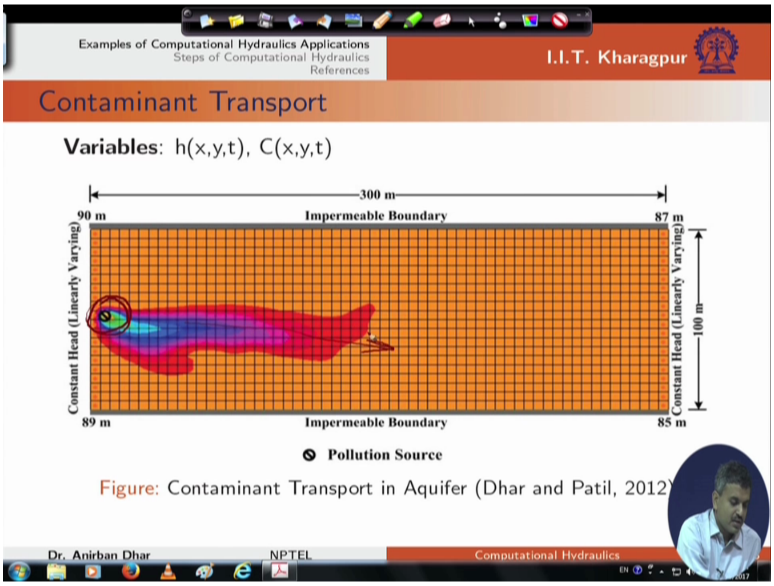

Next problem is problem of channel network. Here the variable is q, x which is varying with x and t and again h which is varying with x and t. Q is the discharge in channel and h is the depth of flow within the channel system.

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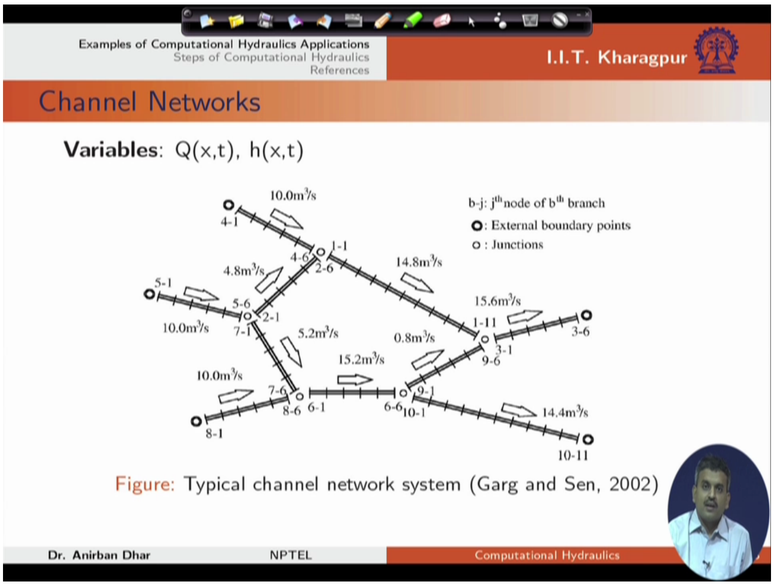

So in this case we have some inner nodes I.

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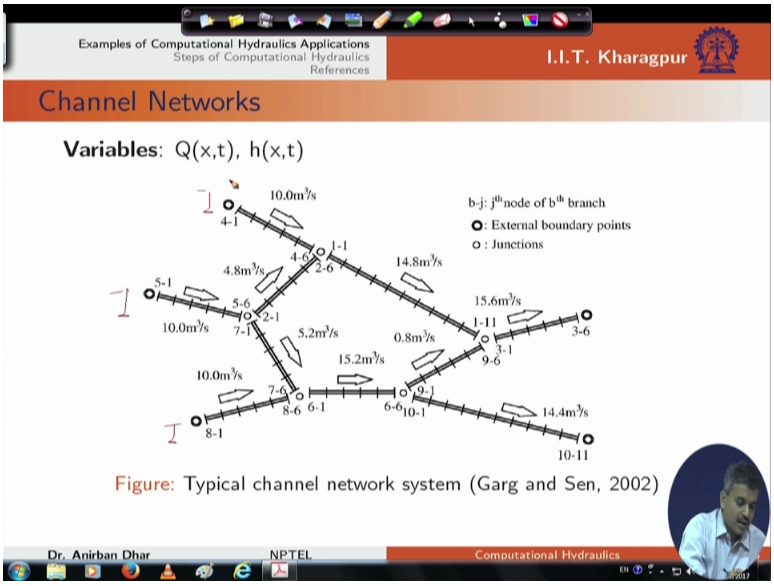

And this is our outlet points. So with this inflow condition and outflow condition, what will be the hydraulic head and discharge within the system that we have to find out.

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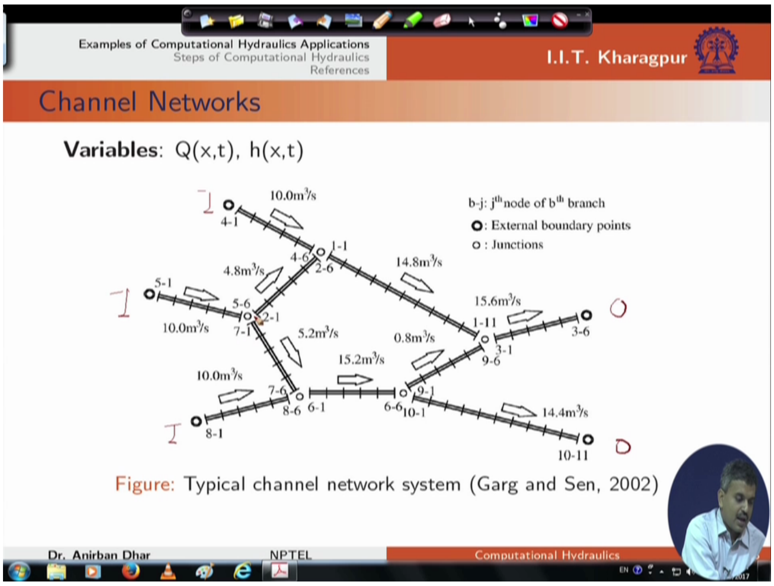

So next one is surface flooding. We need to figure out what is the depth of surface flow within our maybe irrigation commands.

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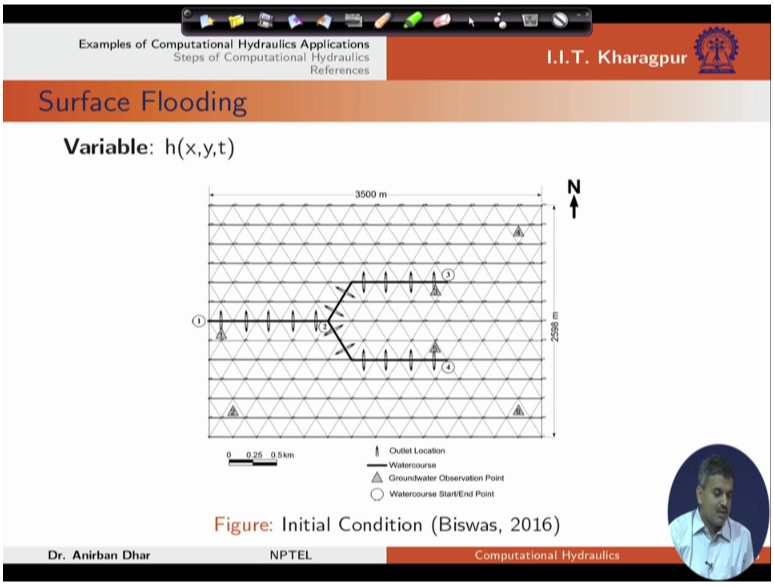

Let us say, this is our channel system and from channel there is flow towards the field. So with this flow there will be surface flooding and we need to find out what will be the depth of flooding within this area or surface flooding for each cells.

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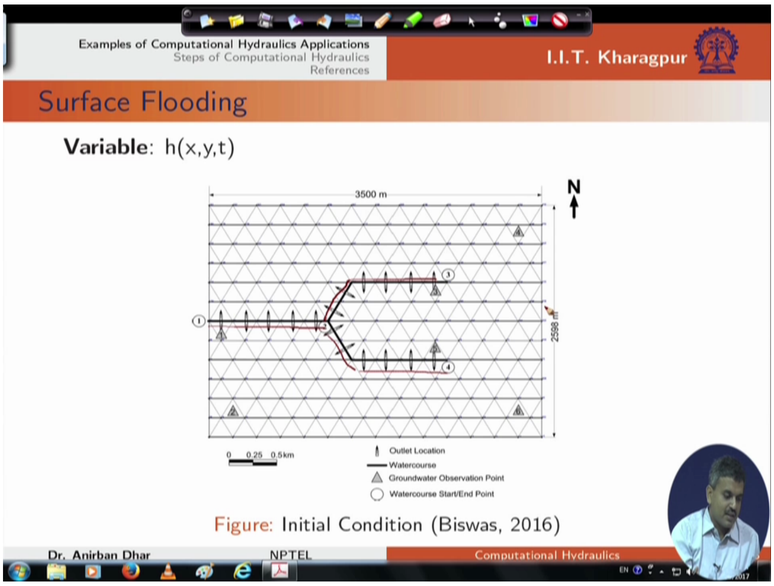

So if we consider flow in this channel system obviously the cells which are closer to this channel configuration that will get maximum water initially.

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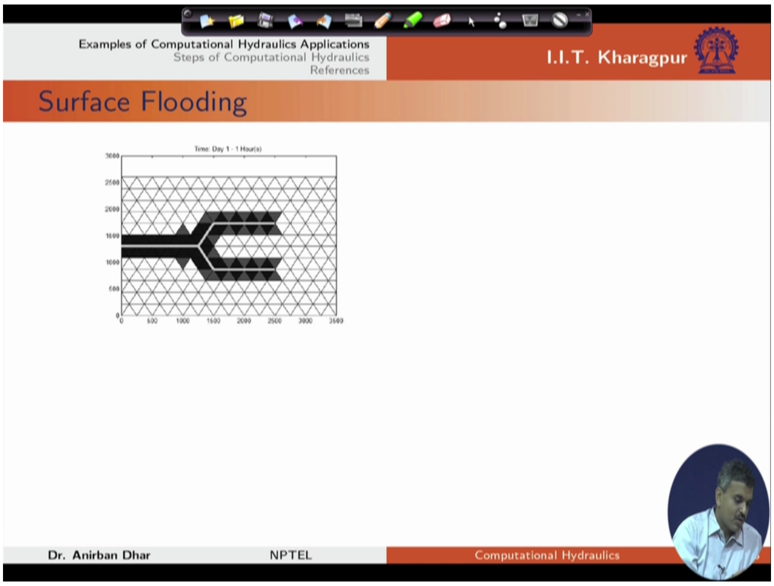

And with time there will be moment of water towards other cells and with time there will be further expansion. And in this case grey cells are representing partially filled cells and black cells are actually completely filled cells and white cells are empty cells. So we can see that overtime there is moment of water from one cell to another cell.

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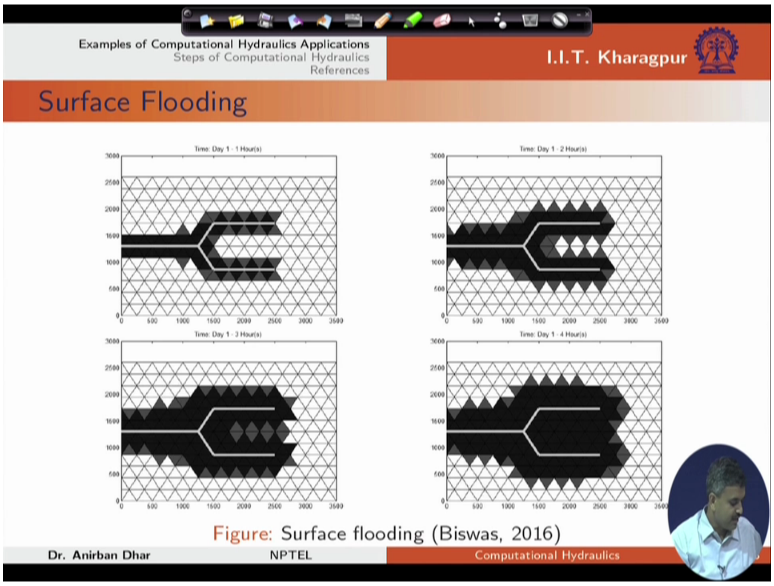

Next example is for open channel flow or hydraulic jump. Initial configuration is that inflow and outflow we havesame velocity level and initial condition is u is equal to u2 and w that is vertical velocity is 0 and h1 is the depth on both the sides.

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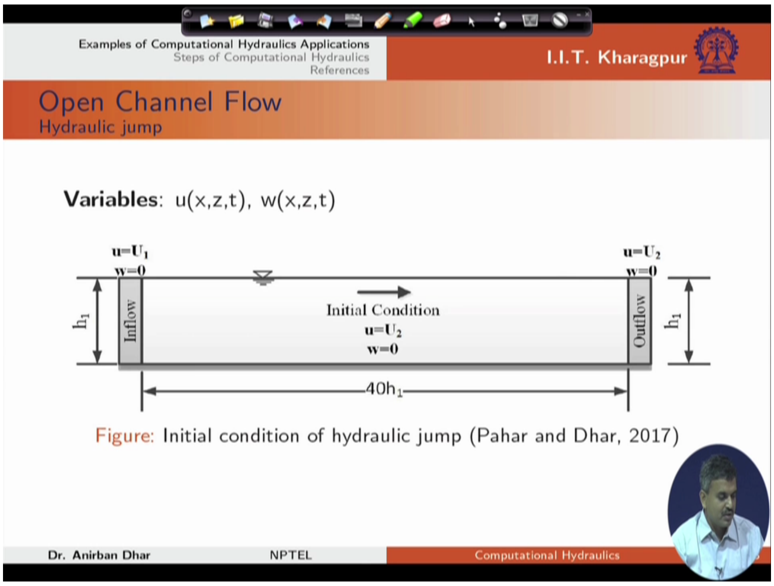

So what we need to find out in this case, we need to find out the u which is our longitudinal velocity which is varying with x, z and t and w which is vertical velocity. That we need to calculate from this system.

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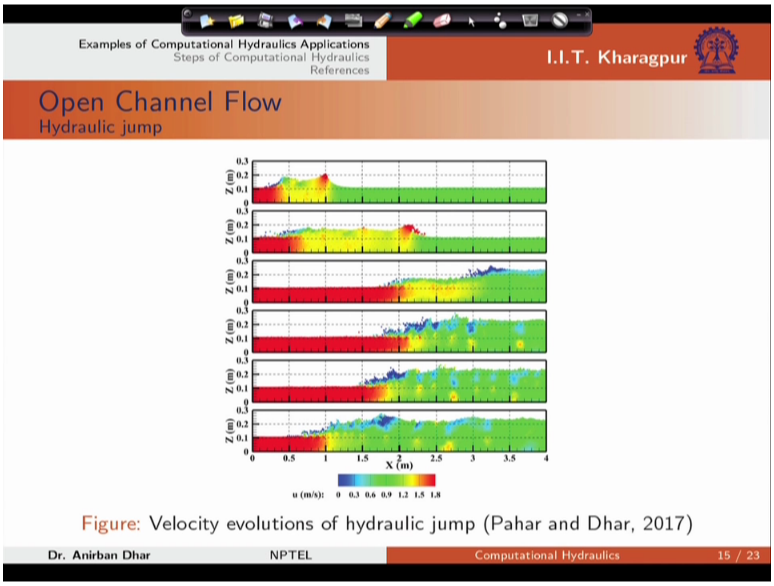

So if we solve this problem we can see what is the longitudinal velocity variation within system? We can easily see that there is hydraulic jump occurring within the system.

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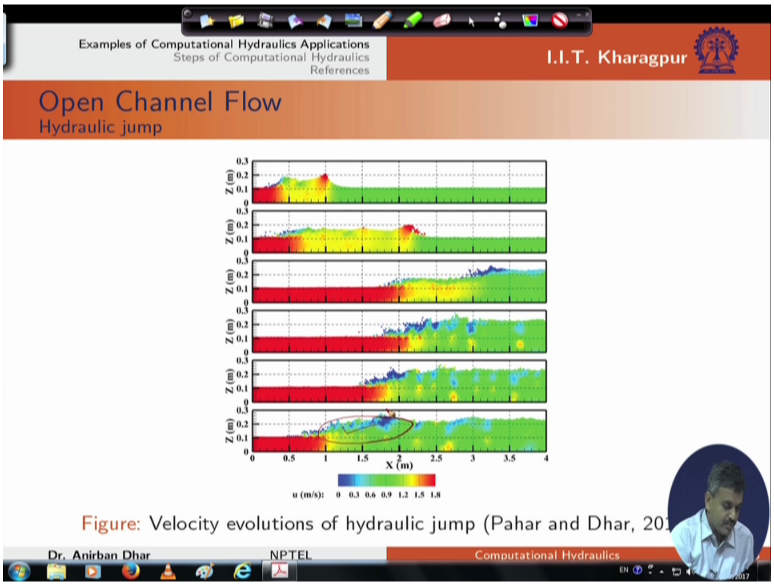

There can be a situation where pressurized conduitscan be there. So what it is the variables are h, x,t. It's only variation in one direction and with time that is x and t and q x and t which is the discharge.

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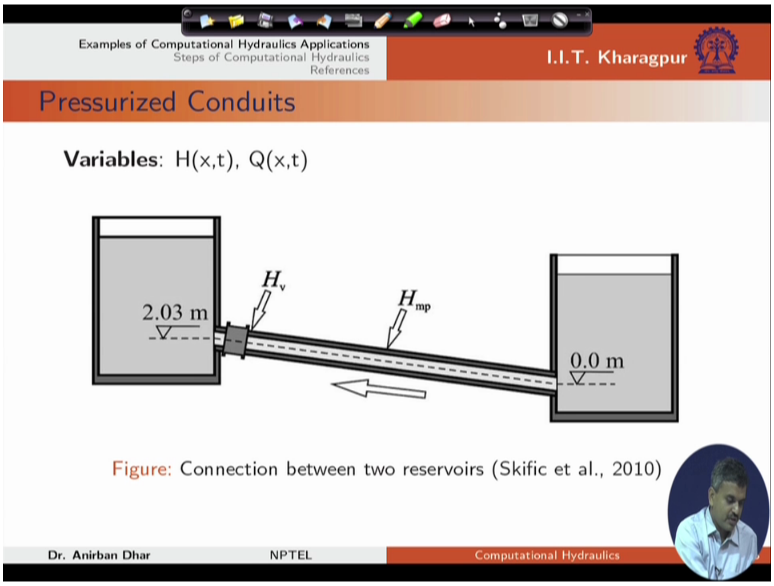

If we suddenly close the valve at this location so they will be changed in the piezo metric head h and discharge within the system. So we need to find out what will be the variation with time.

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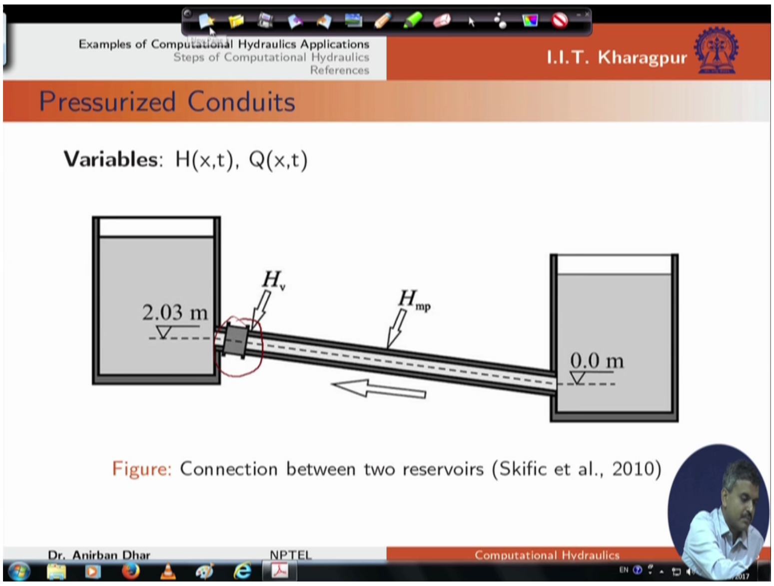

And there can be system where p is your pressure and q is the discharge within pipe network system. So within this network we need to find out what is the pressure and discharge for each of these pipes. This is a common problem for urban or city like situation.

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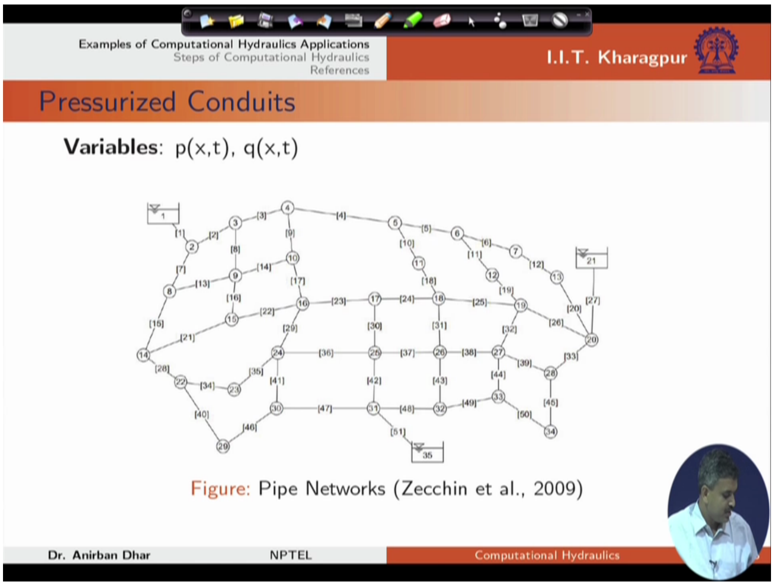

Then there can be problems for surface water and groundwater interaction. We can have zeta x, t that is our level. In this case the water level and in this case this is the ground level and zeta s this is the water level or surface water level and ps is the discharge through the (()) (19:28) fluid domain and pg is the discharge in the pores domain or saturated pores domain. We can use the concept of dry and wet cells to solve this type of groundwater surface water interaction problem.

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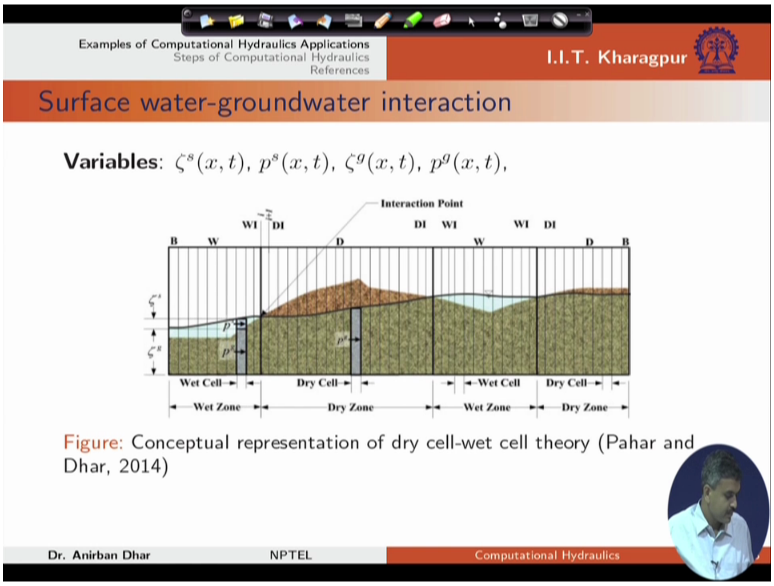

Then there can be regional scale problem, where we have a channel network.

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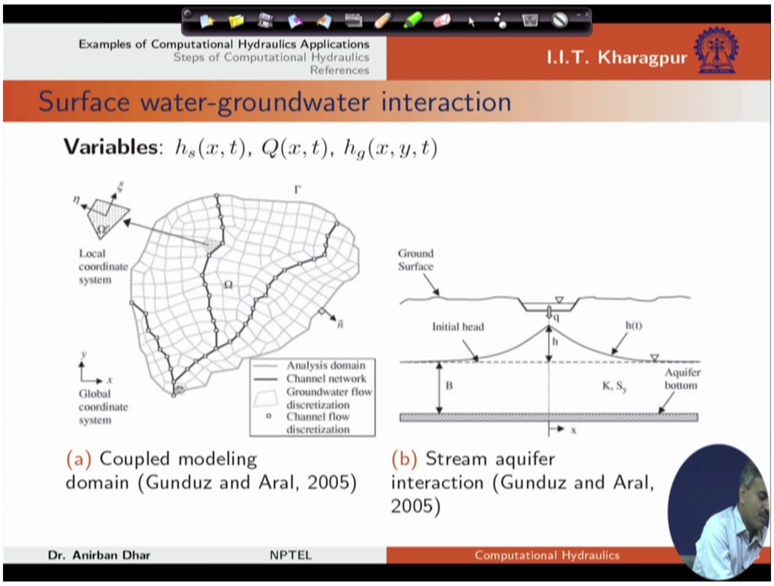

And let us say this is our outlet point for the attachment of river basin. So there will be interaction between the channel flow or river flow with the aquifers.

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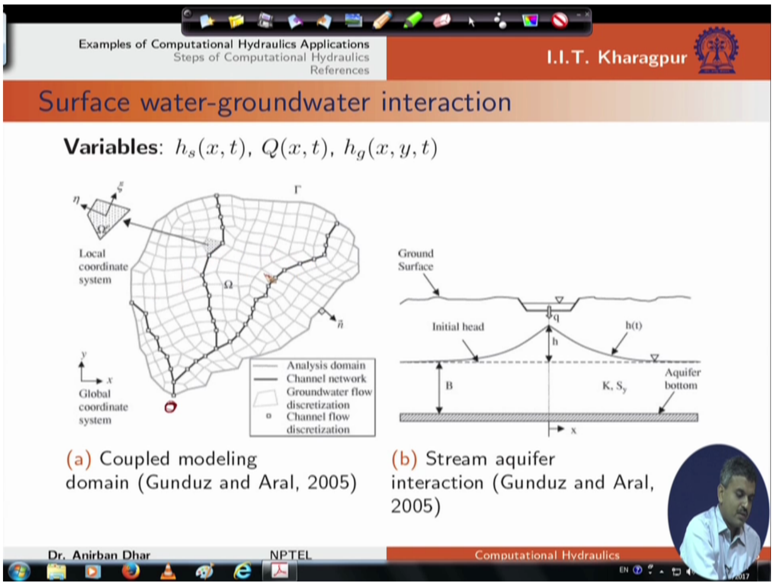

If we have a lower groundwater table so obviously there will be recharge like situation from the bed of this channel.

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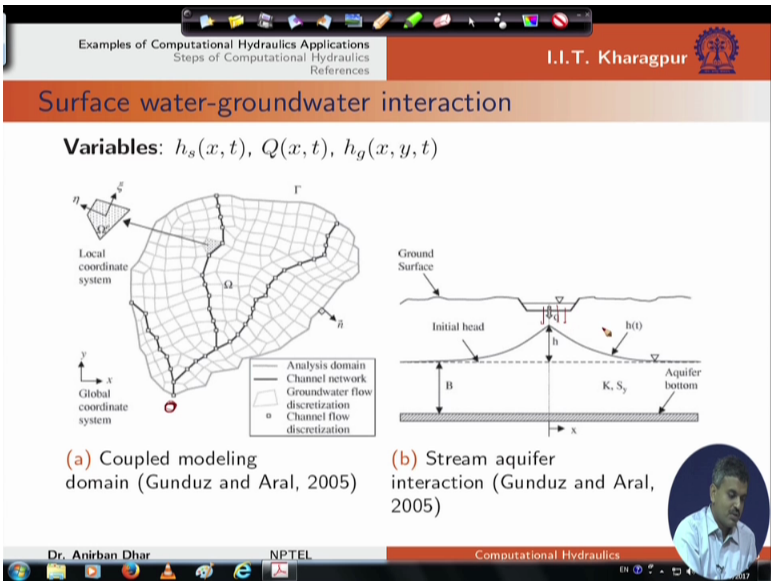

Otherwise there can be losing stream or gain stream kind of situation within the regional frame work. So what are the variables? Variables are hs is the level within the our channel network and q is the discharge within the channel network. That is also varying with x and t and hg is the groundwater table variation or groundwater level that is a piezo metric head and that is varying with x, y and t. So we can solve this stream aquifer interaction kind of problem using computational hydraulics.

So next kind of problem there we have flooding kind of situation and we have 1D system and 2D system which can be used for flooding like situation. So 1D is channel flow and 2D is for surface flooding, hc is the canal head which is varying with x and t. Qc is canal discharge which is x and t varying with x and t, hf is the flood level within the two dimensional system and that is also varying with x, y and t. Uf and vf these ares two associated velocities corresponding to co-ordinate system.

Sowe can solve this problem of 1D 2D integrated surface flooding kind of situation using computational hydraulics. So we can divide the system into one dimensional and two dimensional configuration with elements and we can solve this problems.

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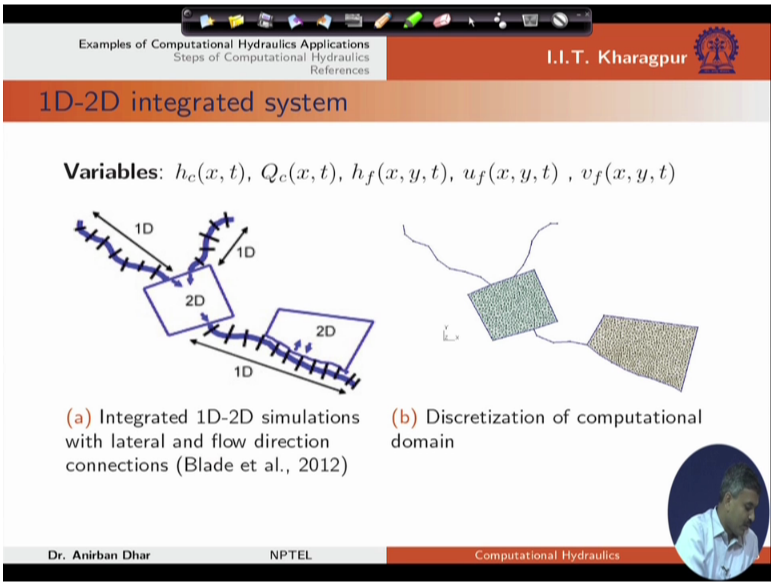

So what are the steps for this computational hydraulics? So first we need to define the problem. There is problem definition. Next is the conceptualization in terms of mathematical governing equations. Then comes this domain representation in terms of discrete nodes and cells. And then comes this discretization of governing equations using some numerical techniques and with this discretize equations we can form the algebraic equations or representation in terms of algebraic equations.

And then this solution of algebraic equations. And finally this post processing of solution results. We need to verify our computational result with experimental or analytical values or results which are available in the literature.

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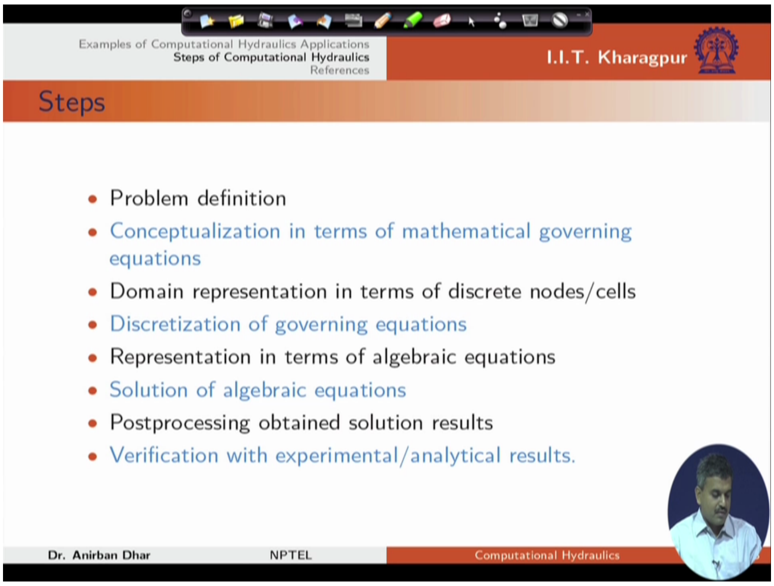

So this is the overview lecture or unit lecture for our first module, introduction to computational hydraulics. Thank you.