Water Supply Engineering
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Module No # 10
Lecture No # 52
Software of Water Distribution Networks Design and Analysis

Welcome friend's in continuation to our earlier discussion as we have been talking about the advances in water distribution network design this week so we did talk about earlier concepts of 24 7 systems and DMA now we are going to discuss some of the software's available for this water distribution network design and analysis purpose.

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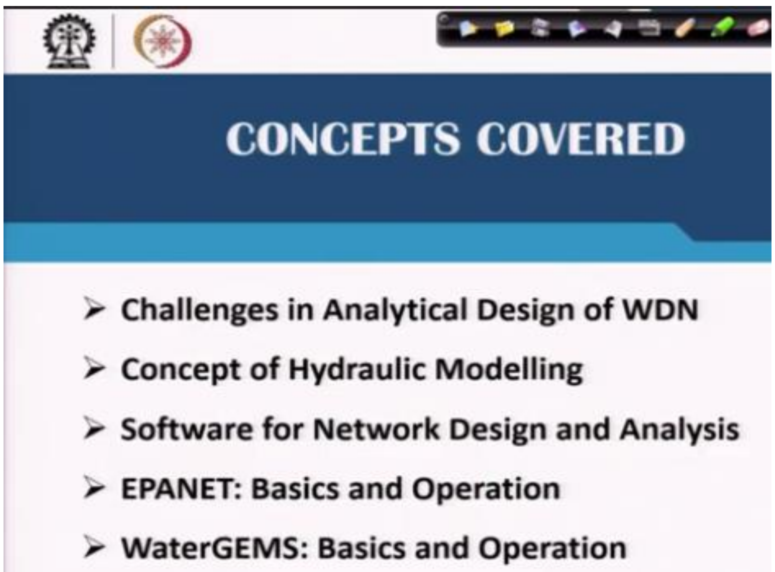

So what particular we are going to cover in this class is the challenges in the analytical design of the water distribution network we will be talking about the concepts of hydraulic modeling. Software for network design and analysis and 2 software's in particular EPANET and water GEMS we will be talking about their basics and operation.

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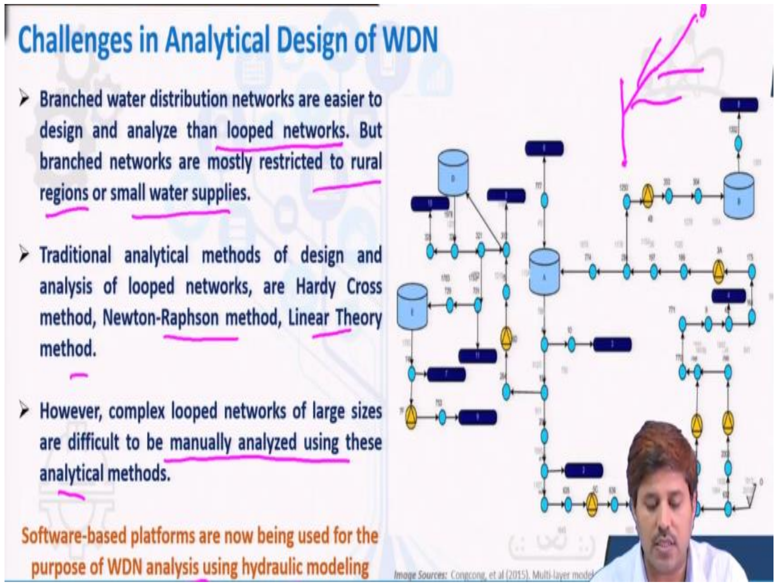

So the branch distribution networks are much easier to design and analyze because as we understand that we have 1 pipe and then going from 1 place to another place so as we discussed earlier that we can keep on accounting the flow from the tail end and pressure drop from the starting and easily kind of analyze the pressure and flow in the branched pipe network but loop network are much more complex okay.

So they posed much bigger challenge in terms of the design and the analysis of the network. Branch networks are although easier but they are only restricted to the rural areas or very small water supplies. So the much like uses are more for the looped network and which is complex to design. The traditional analytical methods of design generally use to the Hardy Cross method, Newton-Raphson method or Linear theory method.

We discussed this earlier also there are complex looped network of very large sizes and they are very difficult to analyze manually or using simple analytical methods. So for these networks software based platforms are being used and they are like very helpful tool in designing as well as analysis or hydraulic modeling of the water distribution networks in particularly the large looped networks.

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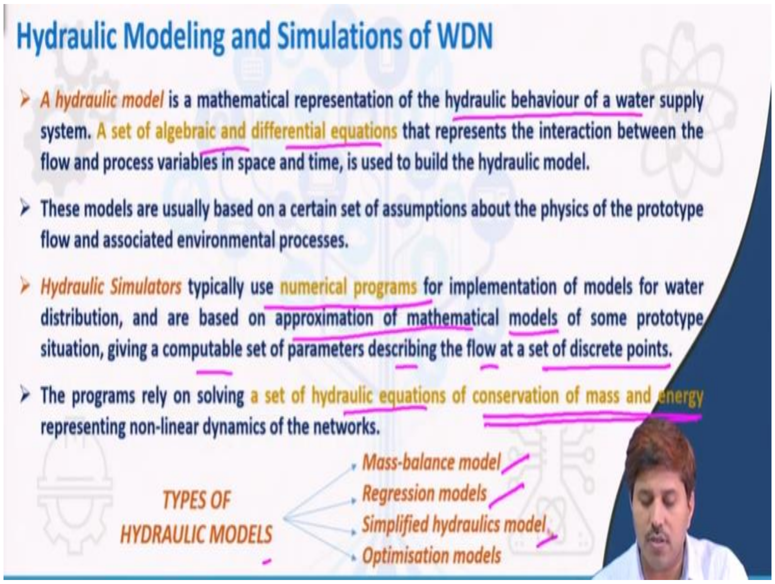

So when we talk about the hydraulic modeling and simulation of water distribution network we are essentially talking about a mathematical system which can simulate or which can kind of represent the actual system in the field. So hydraulic model is typically a mathematical representation of the hydraulic behavior of the various water supply components within a system it essentially uses a set of algebraic and differential equations and these equations represents the interaction between the flow and processes that takes place within the network in the frame of variable space and variability in the time.

So that is what is represented through a hydrological or hydraulic model; not hydrological hydraulic models. These models are very useful okay but works on certain set of assumptions okay we have to because when we want to convert a physical system into a mathematical system or we want to represent a physical system with a set of equations then we of course have to take certain assumption in order to like we can facilitate the conversion of the processes that are happening in the system into a form of equation.

So it works with a certain set of assumptions this hydraulic simulators typically use numerical programs for implementation of this model okay and they are generally based on the approximation of mathematical models of some kind of prototype situation and that way they give a computable set of parameters which describes the flow at a set of discrete points. So that is what generally hydraulic simulators do okay. These programs rely on this set of hydraulic equations and these equations are essentially based on the conservation of mass and energy.

So basic principles still remains the same we are still talking about the conservation of mass and energy but like in terms of just manual calculation or analysis or using simple tools we move on to the software's. So type of hydraulic models that are available they are mass balanced model, regression models there are simplified hydraulic models available or optimization models available for the purpose of hydraulic analysis.

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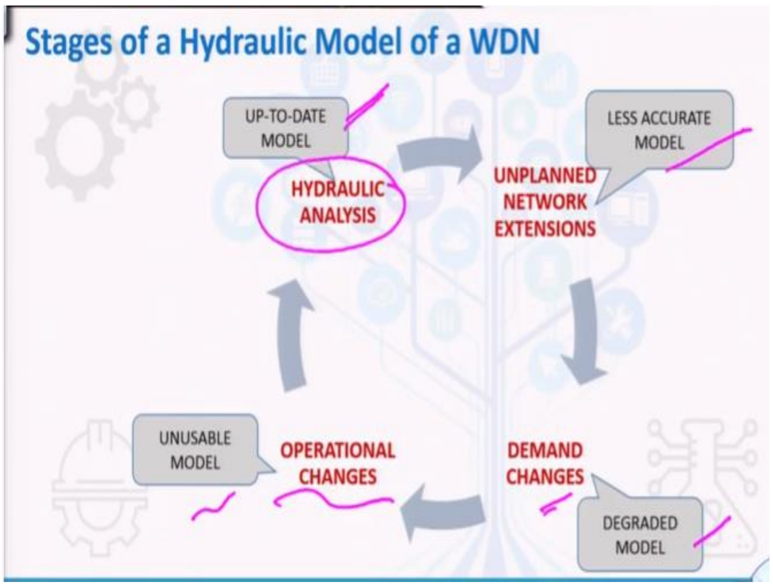

There are various stages in the hydraulic model of a water distribution network we may have unplanned network analysis which is obviously going to give us a less accurate model okay. We can actually set up the demand changes in a degraded model we can look for the operational changes again that if the changes the operational changes are being made continuously the model is going to be unstable and we can do a comprehensive hydraulic analysis which are obtained with the up to date hydraulic models.

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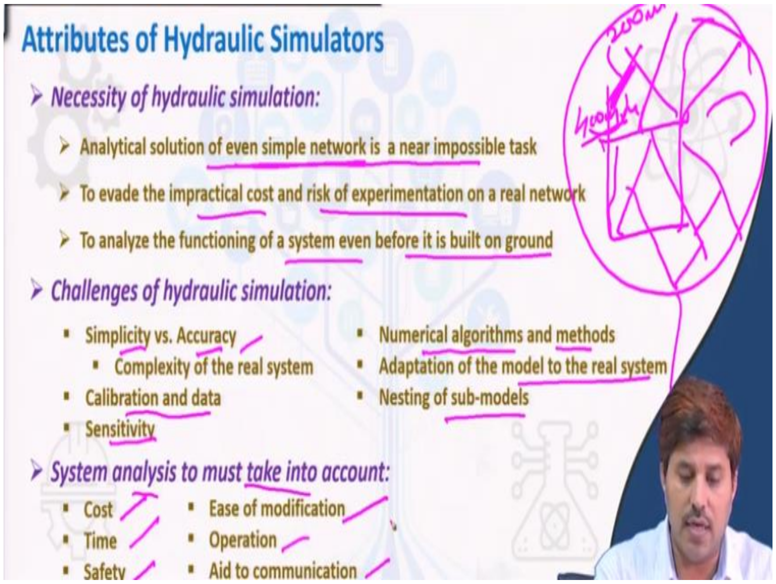

Now if you see the various attributes of hydraulic simulator so first thing why we need hydraulic simulation? What is the necessity for hydraulic simulation? Because analytical solution of given simple like of even simple networks is in near impossible task. That is why we move on to the numerical simulations or numerical solutions of the set of equations because even let us say you randomly make a network okay and say there is practically a looped network with several connections.

Now if you want to write a set of equations for each pipe each node it becomes so complicated a system that is very difficult very challenging to solve it by analytical methods and there the numerical approaches help further to evade the empirical cost and risk of the experimentation on a real network.

So simulation help in that way also we can create several set of conditions and see the behavior of the system okay we can simulate the behavior of the system that way otherwise if you do not have any such feature available if you want to try and test anything say in a network if you want to see what happens if I place here a 200 MM dia pipe or what happens if I place here a 400 MM dia pipe.

So what is the way? How you are going to do that in a complex network again manual analysis by replacing pipe too complicated. So network facilitate doing these things you can pick the pipe and run a simulation again and see how it is affecting the performance okay overall performance of the distribution network or other parameters and features of the network. In absence of such system the other option is to kind of like is physically experimented but you realize that doing this kind of experimentation in real field is so difficult.

It is not a easy job to like go and replace one pipe and fix it other pipe so there this simulation works very well. Also it helps in analyzing the functions of a system even before it is built on a ground. So through a simulation you can say okay if you are going to lay out this kind of network how it is going to function. So that kind of analysis also can be achieved through these hydraulic simulators.

Now there are various challenges associated to this simplicity versus accuracy whether the simulator is simple or simulator is more accurate of course if you go on to more accuracy. So you have to relax certain assumptions and that is going to make the like network complex so complexity of the real system will guide whether what kind of network you want to go for whereas you can make the simulator simple by taking certain set of assumption but if those assumptions are not valid then you are going to compromise on the accuracy part.

So what we like whether we go for simplicity or we go for accuracy then calibration in data if we are trying to build up a network how we are going to calibrate it how we are going to parameterize it how we are going to get data for calibration purpose. Then sensitivity analysis this sensitivity of different parameters what kind of numerical algorithm and method we are using because the different there are different numerical approaches available and some of them are very robust and give a good solutions but takes lot of time okay and lot more complicacy is there.

Whereas some are simple approaches but then again the accuracy level might be lesser then adaptation of the model to the real system is again a challenge because it is still running a virtual model a system where is in real field there might be some other issues coming in or those assumptions what we have make may not be valid and in that case the performance of the system might actually be different than what we observed though simulation and what we actually see in the real systems okay.

And then there are nesting of sub models also can be there when we go for the system analysis we must take in to the account the cost of the analysis time, safety consideration, ease of modification in this simulation process then the operation and kind of aid to communication how we are able to communicate the findings.

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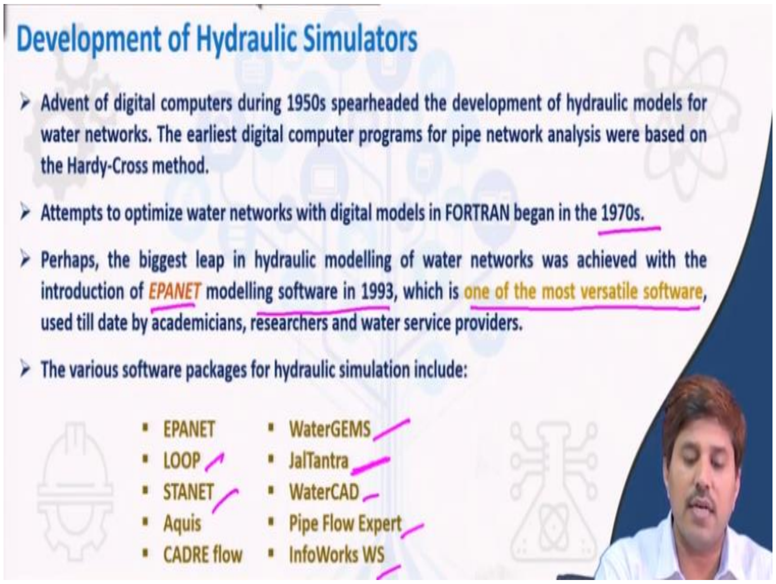

So the hydraulic simulators were started coming in basically after we have developed the digital computing facilities in the late 1950's and these have started basically like since the use of computer started becoming more and more popular in other fields. So was, the hydraulic models started being developed for the water network using the soft computing systems. The earlier digital computer programs were for simple pipe network analysis based on the traditional hardy cross methods.

And there were like attempts being made to optimize the water network with digital models in the photon program which began as early as in around 1970 okay. The biggest leap in kind of a hydraulic modeling in water network was came with EPANET okay so EPANET is a software from the EPA environmental protection agency of the united states. So this modeling software was developed in 1993 and it is still considered one of the most versatile software's okay.

And used by the academician, researchers and water industry people there are various other software package for hydraulic simulation are also available okay they apart from EPANET we have water GEMS as one of the popular software loop is there JalTantra which is recently being developed at IIT Bombay. Then STANET, waterCAD, Aquis, Cadre flow pipe flow expert, infoWorks so there are variety of software's available some of them are free some of them are basically commercial software's.

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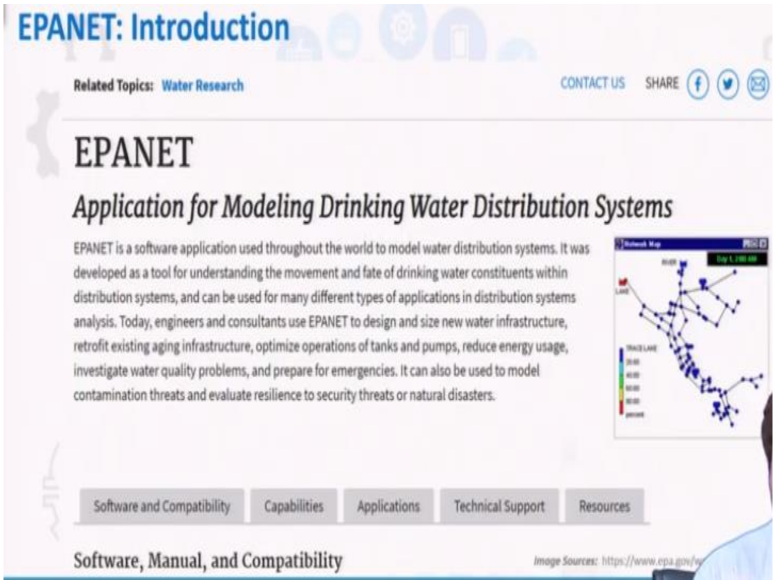

Now EPANET which is as just we are saying is one of the most popular and versatile software is from the United States environmental protection agency okay. This software is basically like is for application of the modeling drinking water distribution system okay.

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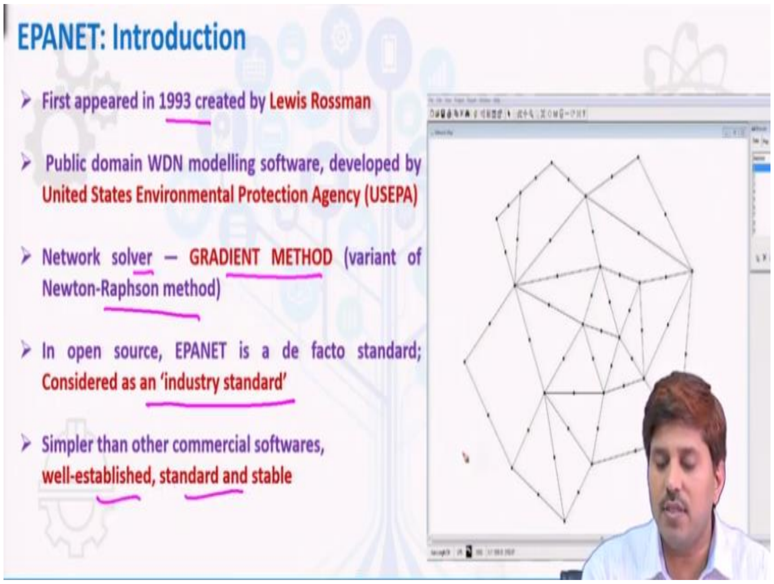

This software first appeared in 1993 it was created by the Lewis it is basically kind of a uses network solvent gradient method for network solving which is a variation of Newton-Raphson method. So basically Newton- Raphson method is used for solving the network it is open source okay and it is basically considered as industry standard. So various industries also use it is simpler than various other commercial software's and very well established standard and available this is the interface of the EPANET.

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The various function available here in the EPANET are the extended period simulation for hydraulic and water quality behavior within the pressurized pipe network it also works faster destate simulation but the uses are limited for steady state so mostly like used feature is the extended period simulation which is used by the designer. The basic hydraulic calculations of the pressure and flow it will provide it will model the water quality parameters as well but this features are very limited though.

The basic energy modeling capability is also there and the equations used for head loss calculations are the Darcy-Weisbach, Hazen-Williams or Chezy-Mannings equations and it can work in metric unit or the United States unit where (()) (13:49) are used.

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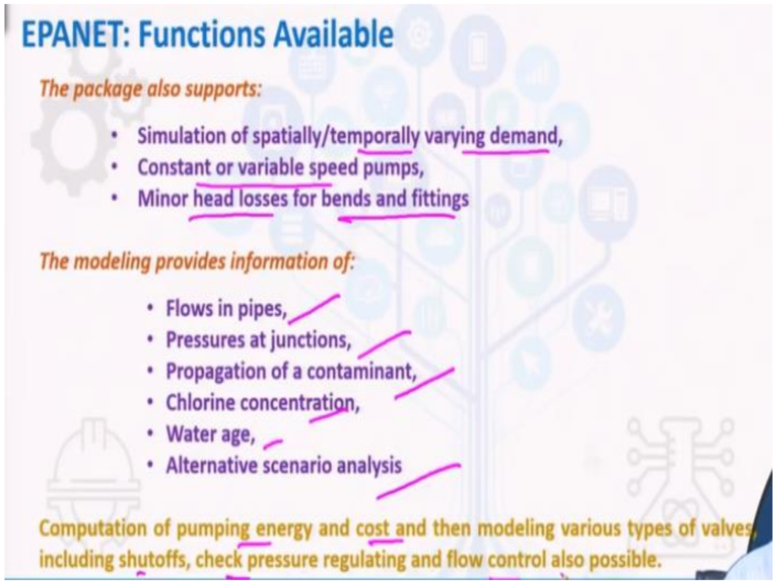

Then the various functions available in the software so the package supports the simulations of spatially or temporarily varying demand it is basically constant or variable speed pump can be used and the minor head loss for bend and fittings can also be determined over here. Modeling also provides the information of the flow in pipes pressure at junctions then propagation of a contaminant how a contaminant propagates in the system chlorine concentration, age of water and various alternative analysis scenarios.

So we can build several alternatives and analyze and compare them okay. It also helps in computing of the pumping energy and cost and then modeling various types of valves including shut of valves check pressures okay and various other type of flow control measures are also possible which can be modeled using these type of software's.

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If we talk about the compatibility so the official versions of EPANET which are available EPANET2w is for windows version 2d also windows version MSX is basically advanced quality modeling purpose. The EPANET toolkit DLL is for developers then Z is for which integrates with the Google Earth and EPANET L is for the Linux okay. So it is compatible to various this thing GIS integrations are also available with the using certain design extensions okay we can use the GIS extension as well.

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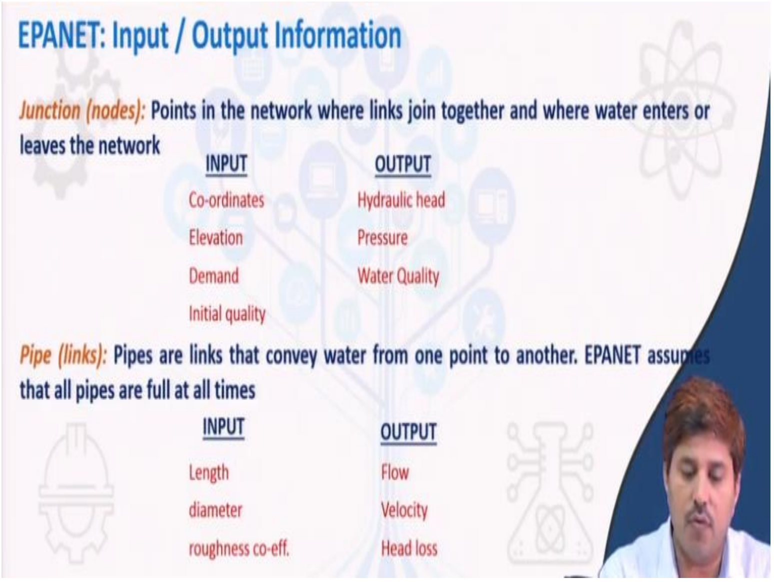

The input and output which the software provides so in terms of input there are input for junctions it will use the junction coordinate it will use the elevation, demand and initial quality in the output it will give the hydraulic head pressure and water quality at junctions for pipes again length dia and roughness coefficient and it will actually require the flow velocity and head loss as an output actually it will give the flow velocity and head loss as an output.

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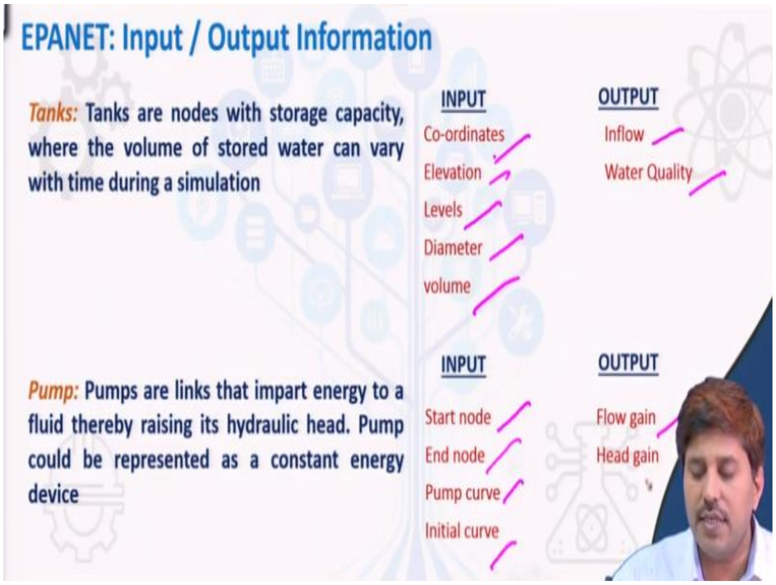

In tanks in the input it will require the co-ordinates then elevation of the tanks, levels, diameter, volume of the tank and output it will give the inflow and water quality. The inputs at the pumps it will give the start node, end node, pump curve and initial curves and it will gain give the flow and head gain through the pumps so how much is the gain in the flow or how much is gain in the head.

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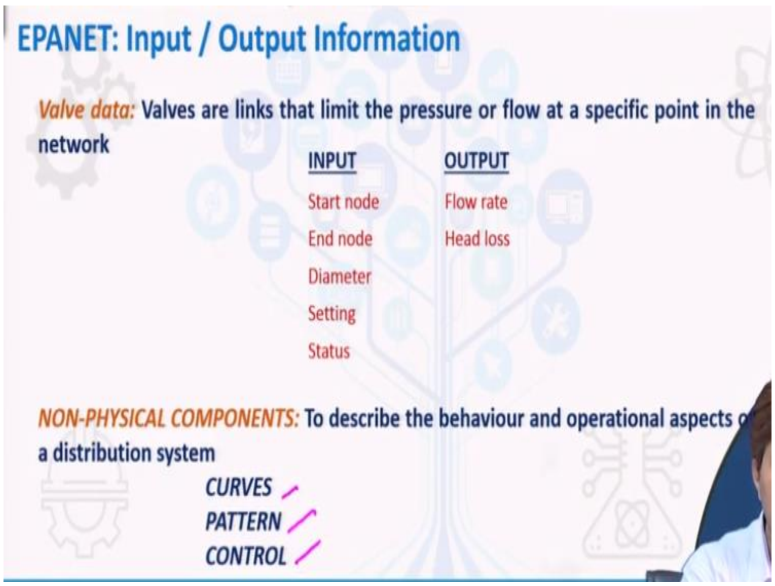

For values again it will required inputs like start node, end node diameter, setting, status all those things and flow rate and head loss can be taken as an output from the valve data. For non-physical components it will be basically describing behavior of the operational aspect of the distribution system it can use curves, patterns or the controls. So these are the some of the input output features.

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For water quality simulations it can model the water age and predict the flow of non-reactive and reactive materials. So how a non-reactive or conservative material is going to flow in the water and how a reactive material which is going to degrade with time or with which might react with something? So how that is going to flow generally the kinetics of the reactive material is chosen as first order it may be used to predict the chlorine residual with water distribution system so that is another feature where it can used.

For internal water quality simulation only kind of evaluates the decay or growth of a single constituent okay the rate of material as it grows it basically tracks the percentage of flow from the given nodes. Then there is a extension package which EPANET MSX which allow modeling of interaction between the different constituents also. So if you are trying to model a multi parameter kind of system where more than 1 water quality parameters are more than 1 water contaminants you want to consider.

So EPANET MSX can be used for that purpose it implies the global reaction rate coefficient which modified on a pipe to pipe basis and storage tank models are as a complete mixed or plug flow reactor type.

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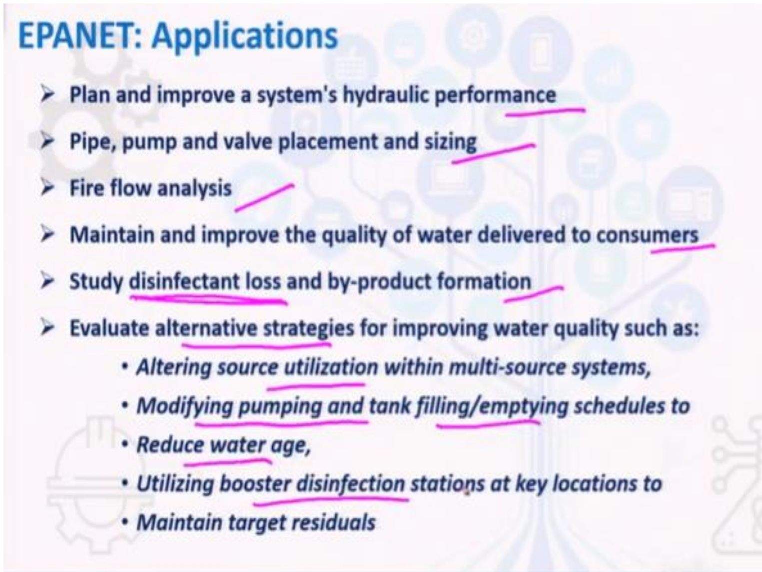

So this is the features options available for water quality simulation. It as a wide variety of application as we discussed earlier also it can plan and improve the system's hydraulic performance at pipe pump and valve placement and sizing is another option then fire flow analysis it can maintain and improve the quality of water delivered to the consumers it can study the deficient losses and byproduct formation so particularly the disinfectant how the disinfectant is performing the chlorine residual chlorine concentrations.

And it can also do the strategy modeling so it can evaluate the alternate strategies by altering the source the utilization, modifying pumping and tank filling reducing the water age utilizing booster disinfection stations and maintaining the target residuals. So these are variety of things which also can be modeled.

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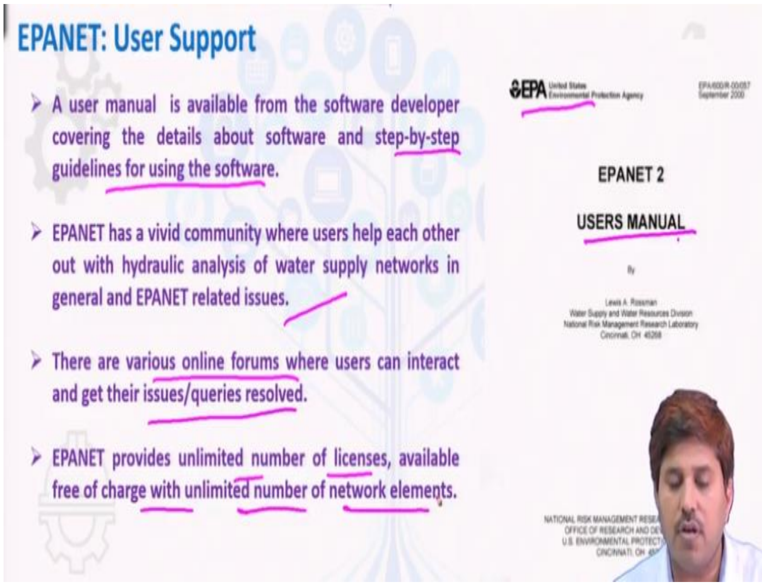

There are supports available there are very good and detailed user manual is available from the software developers EPA. So there is a very good step by step guidelines are available in this user manual also it has a vivid community where basically there are various user which interact and help each other in the official forums of EPANET and then various other online forums are available where user can interact with each other post their quires, questions or issues while running the software and then experts or other users might intervene and guide them onto how to like how to work on these issues or the operational issues problems.

It also provide unlimited number of licenses available free of charge with unlimited number of network elements. So there is no limitation on size this is the completely free software from the USEPA.

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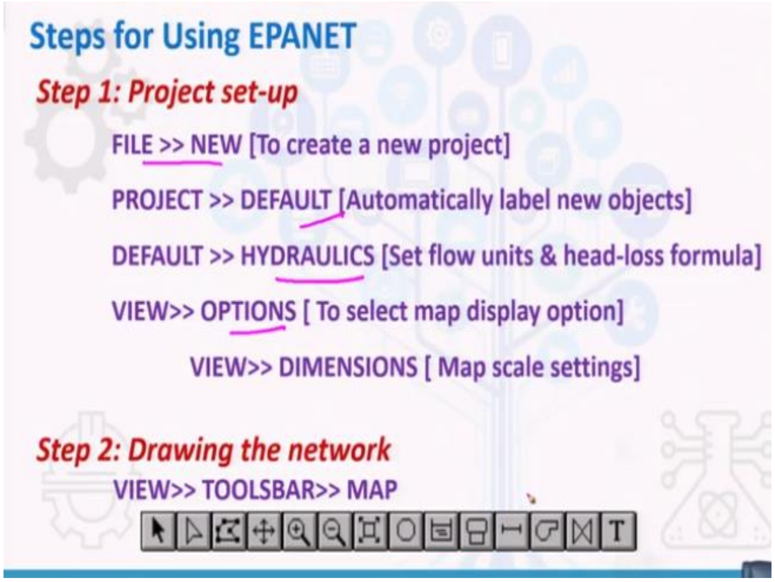

This steps are typically used in the EPANET is the first step is to project setup so we can go for file we can create a new file or default and then the default setup will be hydraulic in the options we can select various options. And then for drawing the network we can use this tool bars. So this tool bars help in various way we can kind of draw pump or pipe length or various other features using the tool bar.

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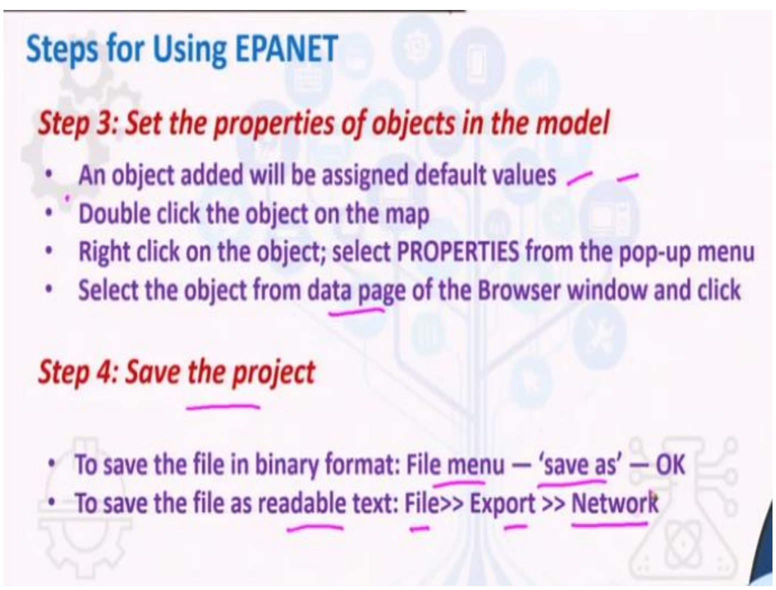

We can set the properties of the object in the model so we can add an object so we can add as a reservoir a pump a pipe by double clicking on the map and then click on the object and select the properties of the object from the popup menu that we will be getting. We select an object from the data page then we can get the properties of that we can save the project so for saving we can go to the file menu and save as and if you want to get the readable text so we can export that file as a network for a getting a readable text.

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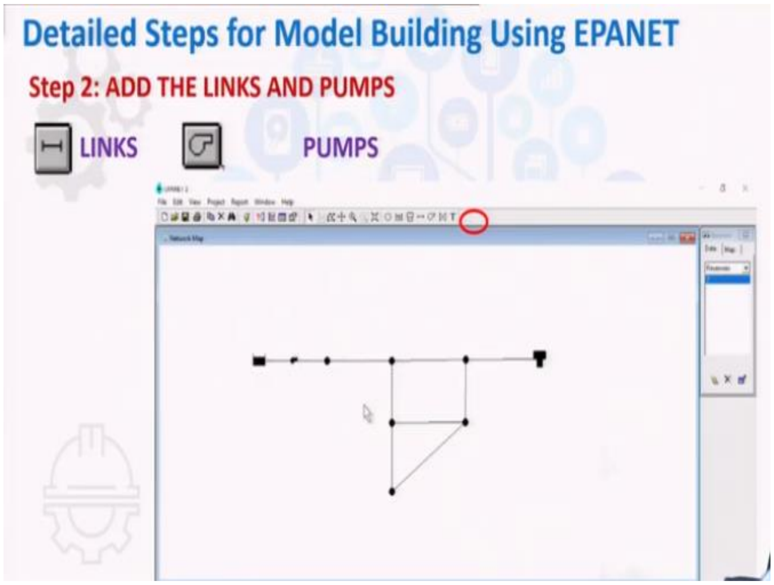

So this how it is done typically we open a file and then add the notes so we can use the reservoir junctions or tanks this is the feature for reservoir this is for kind of junction so we can put nodes, junctions and, reservoirs okay. And similarly we can add the links so links is basically the through pipe between the 2 nodes or 2 other components and we can add pump wherever we want so that is another feature that one may actually use okay.

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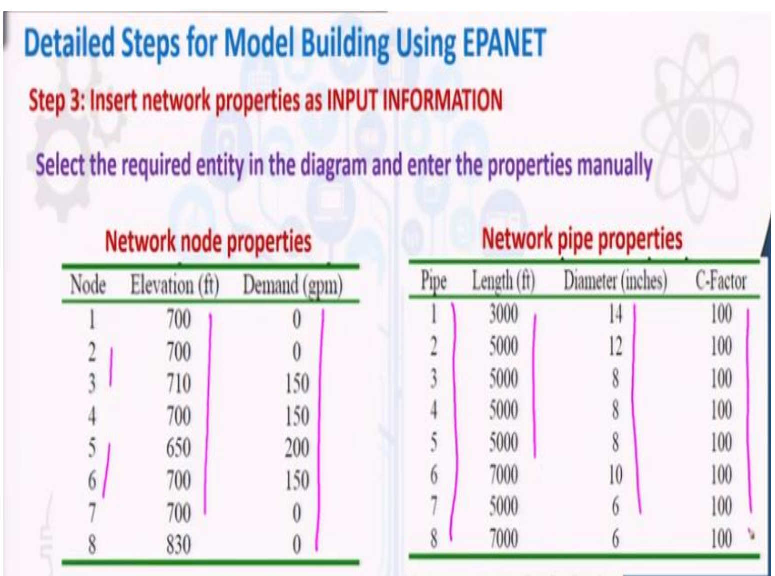

Then we can insert the network properties as a input information so for the difference let us say how many nodes the nodes we are having so for the different nodes what are the elevation what are the demand at the different nodes and we can add the network property. So for each pipe because nodes are connected with the pipes for each pipe what is the length of the pipe? What is the diameter of the pipe? What is the Hazen coefficient okay?

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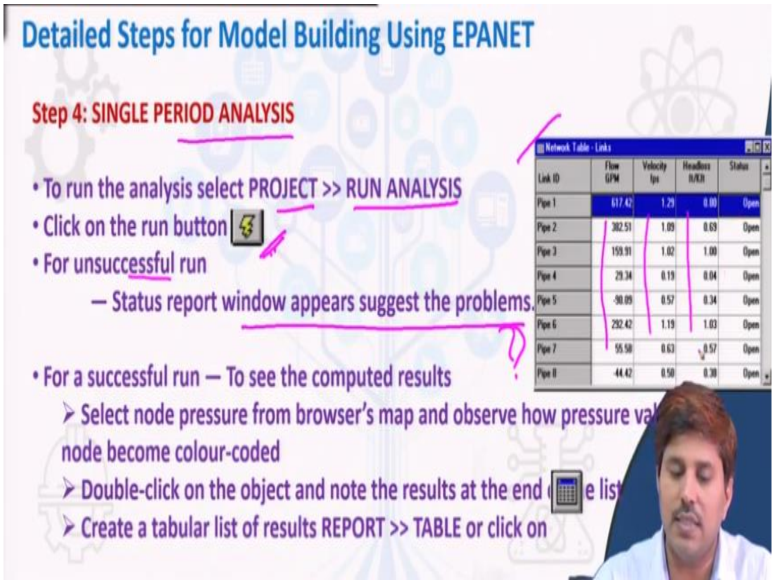

Or whatever model we are using if we are using Hazen William coefficient so what is Hazen William coefficient there? And then we can go for a single period analysis so to run this analysis we can select the project and run analysis which can be done by clicking this button if there any problem. So then we will get a message of unsuccessful run and then window will appear which will suggest what is the problem?

So we resolve that problem and once the problem is resolved or say we do not have problem then the run will be successful and we can see the results in say this form also. So we will get a table with showing the flow through different pipes, velocity head loss so all this analysis can be achieved using the steady state run.

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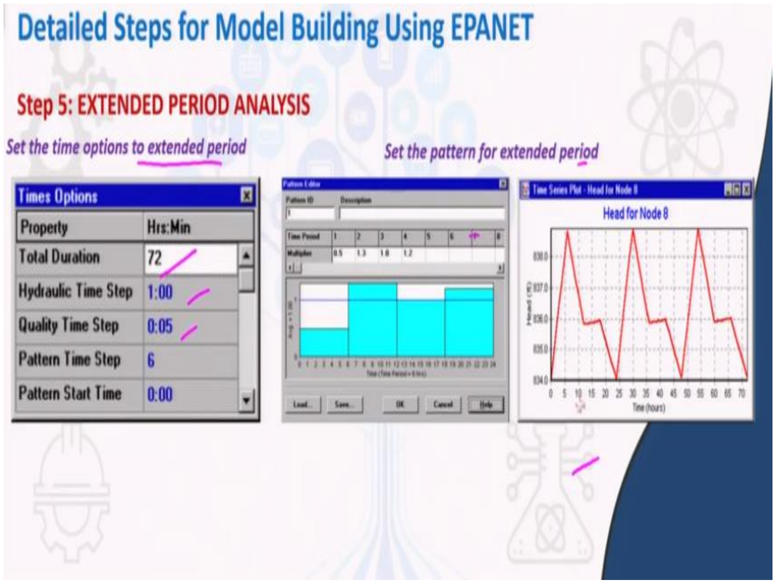

But steady state run is our single period analysis is a lesser use the extended period analysis is more important so because then here we can set up the time of the extended period let us say we want to run it for 72 hours or whatever time we give the time step unit and every other thing pattern and then we basically set the pattern for the extended period and then we can get the results say this is head loss for one particular node or like how the pattern has achieved for the different time period for the different component of the network. So those kind of results may be obtained.

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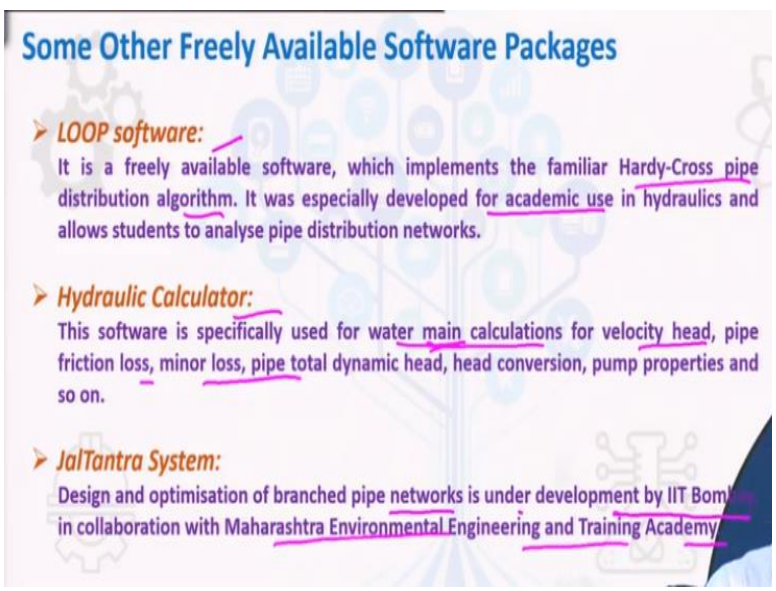

So that was about water GEMS we will have a demonstration of this in the next class okay when we will see how we can use this are just a step by step guide but more demonstration kind of setup will see in the next class. There are various other freely available software packages like the loop software which is again software which is implements Hardy cross pipe distribution algorithm.

This is especially developed for academic use then there is a hydraulic calculator this software is used for water mains calculation of the velocity head pipe friction minor loss so mostly for the like water main. JalTanra is newer system which is developed this in fact a very good system for branched pipe network and it is basically being developed by IIT Bombay in collaboration with the Maharashtra environmental engineering and training academy. So they are also in a process of developing this.

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In the commercial grade the water GEMS is one of the popular packages as just we were discussing earlier also like EPANET is for free and then commercial grade water GEMS is considered as one of the best packages available. Okay this is actually water GEMS is from Bentley groups okay.

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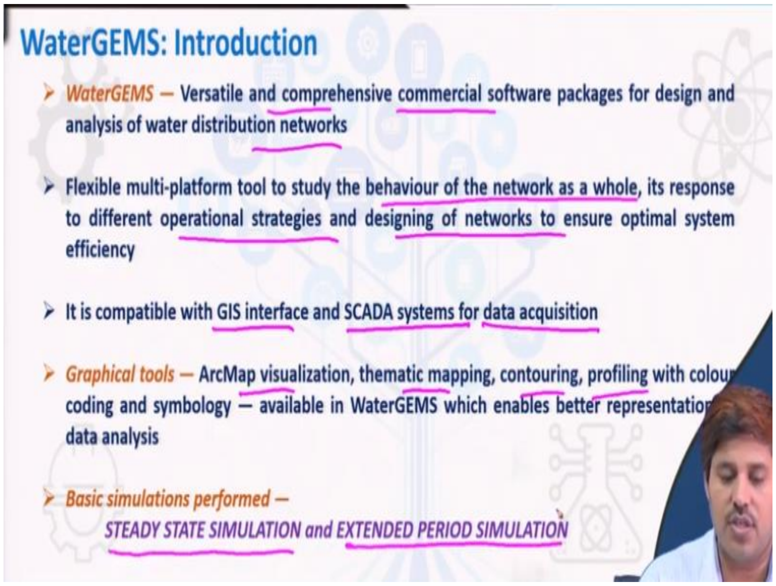

So this is in fact of versatile and comprehensive commercial software package for design and analysis of water distribution network. It is a flexible multi-platform tool we can use in whatever platform we wish to and it studies the behavior of a network as a whole and it responds to like different operational studies and we can design the network to ensure a kind of optimal efficiency.

It is compatible with GIS interface and SCADA system for data acquisition and the graphical tools there are various graphical tools like ArcMap visualization, thematic mapping, contouring, profiling with the color coding these are all available in water GEMS. The basic simulation as performed either steady state simulation or extended period simulation. Again steady state simulation has a limited use the extended period simulation is the one which is most commonly used.

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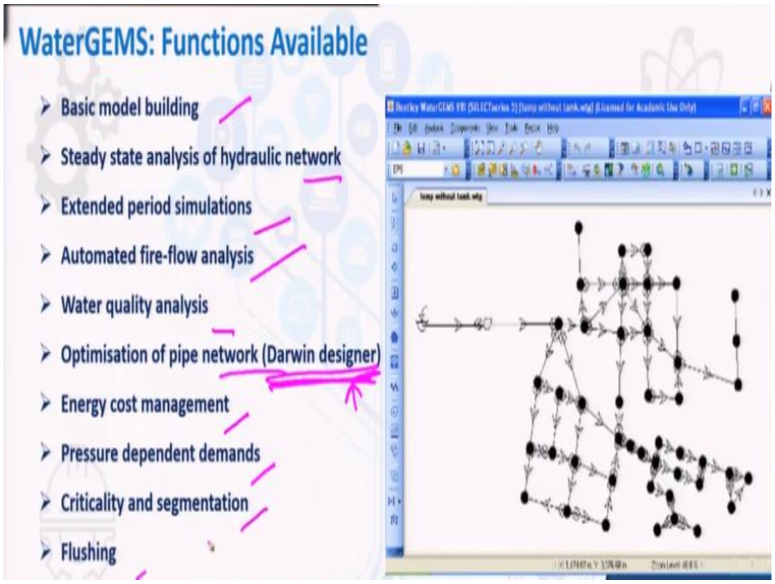

The functions that, are available here so the basic model building then steady state analysis of hydraulic network steady extended period simulations then automated fire flow analysis water quality analysis then optimization of the network through the Darwin designers. So this optimization feature can also is in fact one the very, highlighted feature of water GEMS which is not available in majority of the other packages. Then energy cost management pressure dependent demand and criticality and segmentation and the flushing. This is a typical interface of water GEMS.

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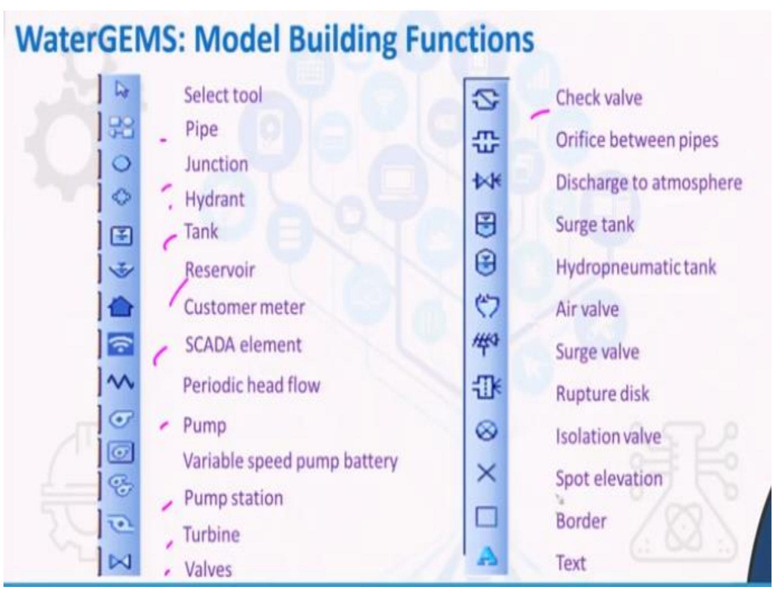

These are some of the models building function okay so various tools how we like set up pipe junction, hydrant, tanks, reservoir. So then SCADA element if we have pump, pumping stations, turbine, valves, check valve. So, all these features are there in the model building as a model building functions.

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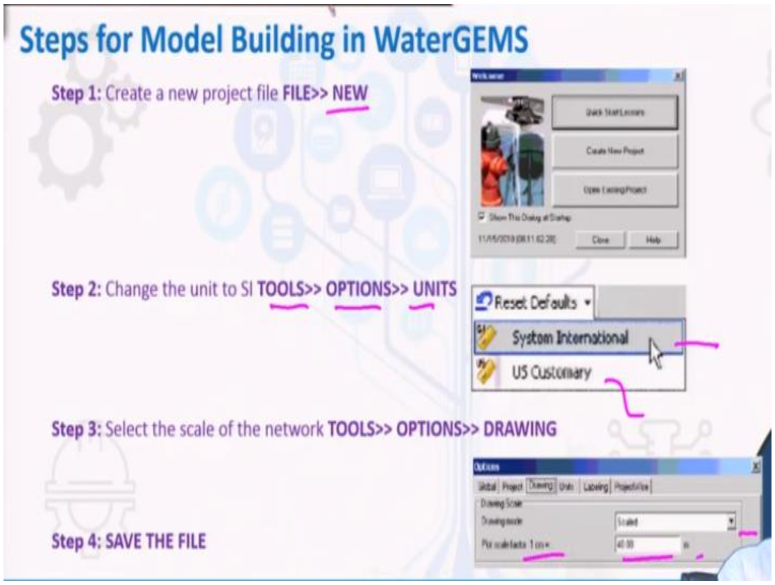

If we see the steps so again we can use go to a new file for creating a file okay. And then in the tools we can choose options and units so we go for internationally units or US customary units which is in the fit one kind of system. And we can select the tools options and drawing so like drawing more we can select whether we want to give any scale for the drawing. So if you want to select a scale we can also give here and we can save the file that way.

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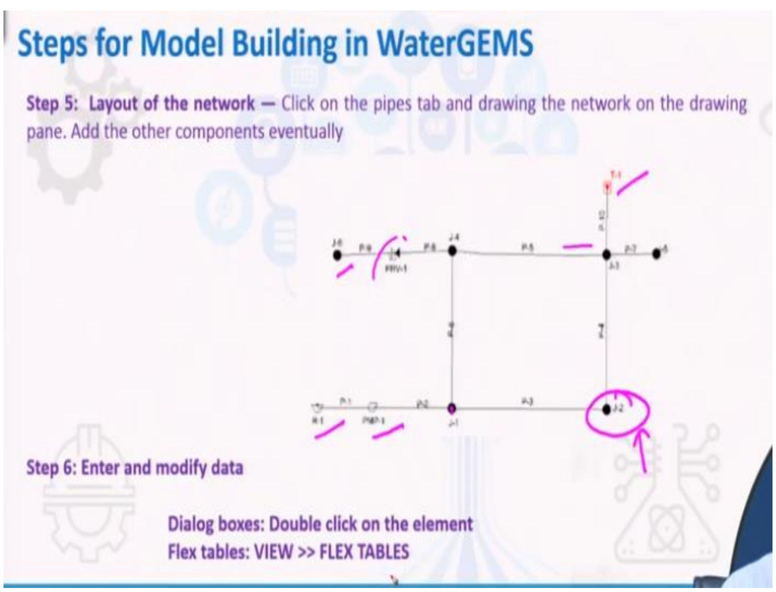

Then we can go to the next step which is a layout of the network okay. So we can click on the pipe tabs and drawing network in a plane we can add other component eventually so this is similar to that of the EPANET okay we can use the junctions we can use the pipe we can use the valves we can use the tank okay. We can use the pump in a similar way reservoir so all those features can be added here and then we can like enter and then modify the data saved that okay.

We can for particularly setting up the properties of anything we can just double click that particular element let us say if we want to setup properties of this junction. We double click that element and then basically we put in properties or see whatever is the information provided.

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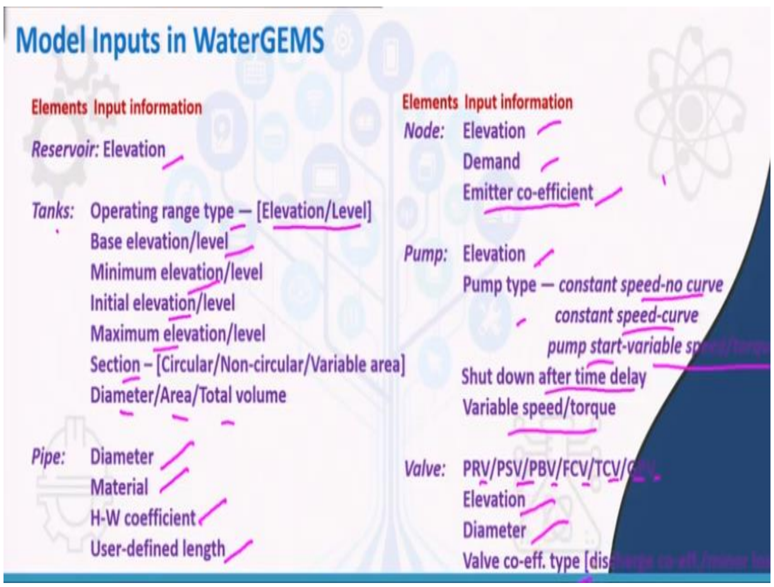

The various input information's for the different elements here so for reservoir we need to provide elevation for tanks we need to provide the operating range type whether it is working on elevation or level the base calculation or the minimal evaluation then initial evaluation maximum evaluation then section circular non circular or variable area, diameter area total volume all these options can be given.

For pipe we need to provide diameter, material Hazen William coefficient and user define length for node elevation demand and emitter coefficient. Emitter coefficient is basically kind of like how much flow can be emitted from that particular node then elevation for pumps what is the elevation of pump types. So the different type of pump option are available constant speed no curve constant speed curve then pump start variable speed variable speed or torque and shutdown after time delay.

So there are variety of options then value again which particular type of valve we want to put and then elevation diameter and the value coefficient type of the valve so all these are the different input elements.

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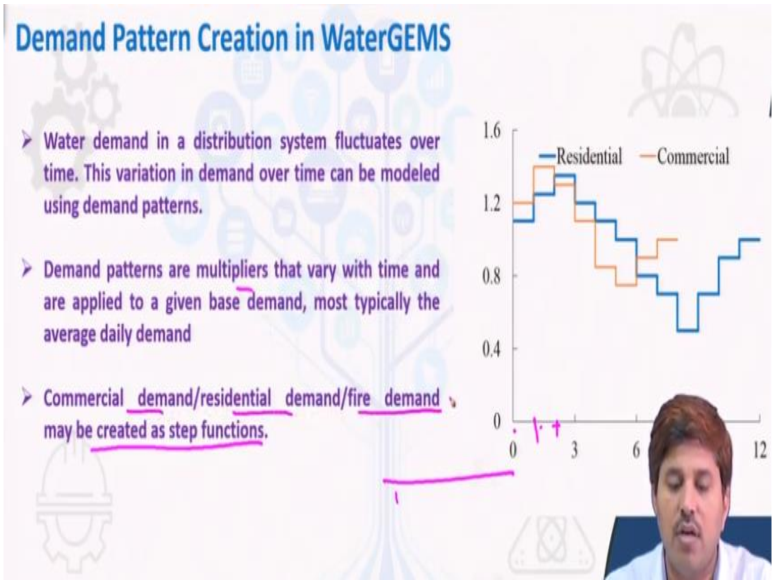

We need to provide demand pattern also we can give us straight average demand or we have the flexibility of giving demand as the step functions. So demand patterns are generally the multipliers that vary with the time so with the average demand we can have different multipliers which will vary with times. So let us say for 1 like 0 to 1 hour we have a multiple 1 to 2 hour we have another multiplier. So it eventually gives us as a kind of step functions for commercial residential or fire demand that can be inserted.

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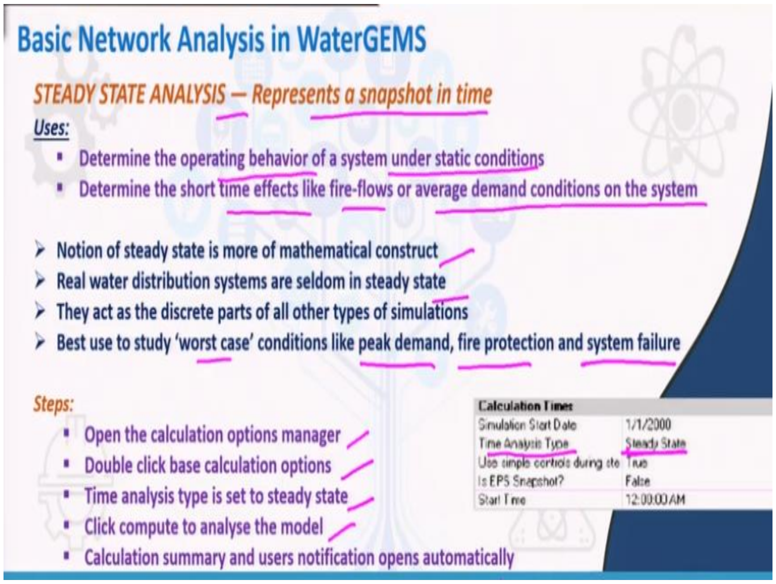

For analysis purpose the basic network analysis is done either in the steady state analysis or in the extended period analysis. The steady state analysis represents snapshot in a time because it considers the system as a static and running at that particular thing. So it used generally for seeing operating behavior of a system under the static conditions and it determine the short time effects like fire flow or average demand conditions on the system.

Generally it is not that much used is less used because the system usually does not run in a steady state the distribution systems usually run in a kind of transient state so we do not have the like this steady state analysis as that limited uses it is best used for the worst case conditions like. Say if you are having a peak demand or fire protection or system failure. So simulating that in a extended period run becomes much more complex we can straight away say that okay during a fire this is going to be the flow so we have a fixed flow and we can run a steady state analysis for these kind of conditions okay.

It is basically notion of steady state which is more of a mathematical concept the real water distribution systems are seldom in steady state they act as a discrete part of the other type of simulations. So the steps is that we open the calculation option manager double click the base calculation options and then time analyze type is set to steady state. And so here basically like this time analysis tape and need to be set to the steady state okay. And then we click at compute to analyze the model and then we will get the calculation summary automatically.

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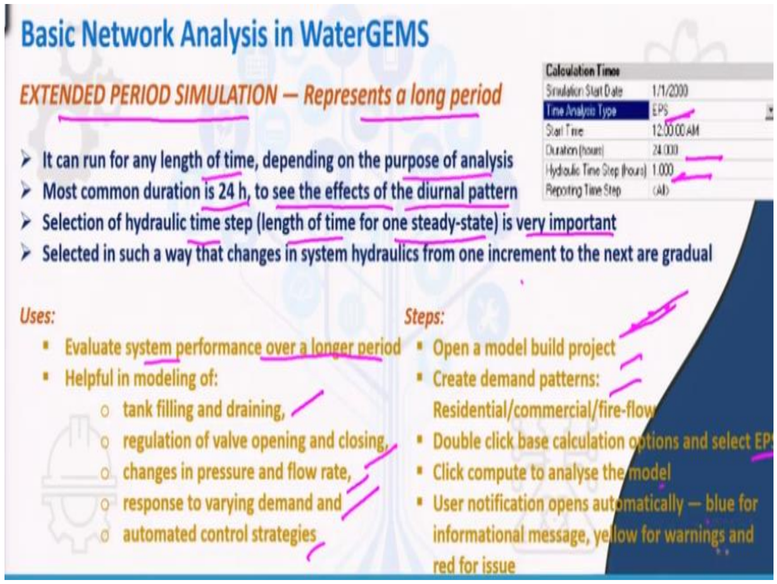

So that is how we run the steady state however the more used is the extended period analysis which represents a long period in most common duration is 24 hours to see the effect of the diurnal pattern but we can have an another optional as well. It can run for any length of time depending on the purpose of analysis. If you want to analyze it for longer duration we can run it. Then selection of hydraulic time steps so length of time for like one steady state is very important so how much hydraulic time steps we are consider say 1 hours so it will get a step in each 1 hour and see what is the situation there.

And we basically selected in such a way that change is in the system hydraulic from one increment to the next are gradual. So from 1 hour to 2 hour to 3 hour all the changes has to be gradual it is not like it is abrupt changes. So how we do that? It basically in the time analysis step we select the EPS which is extended period analysis okay select the duration select the hydraulic time step and then that way we analyze.

It helps in evaluating the system performance over a longer period it is helpful in modeling of tank filling and draining regulation of valve opening and closing it helps in the kind of setting up the changes in the pressure and flow rate response to the varying demand and automated control strategies. The step is the similar like we select the EPS so we open a model bill create the demand pattern and then double click the calculation option and select the extended period analysis we click compute analysis the model and then user notification will open automatically blue for the informational message yellow for the warning and red for any issue if there is any issue in the model.

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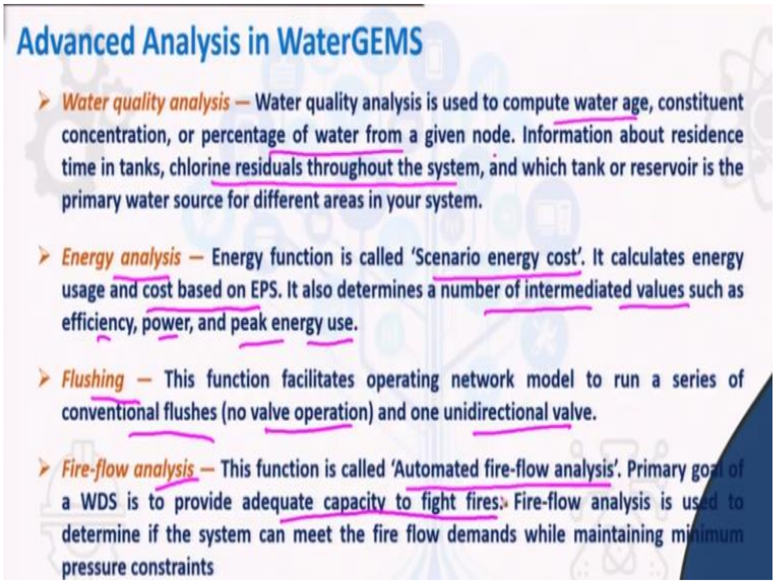

There are various advanced analysis features also available in water GEMS like water quality analysis which is basically helps to compute water age and the constituent concentration percentage of water from the given node so. Then the chlorine residual throughout the systems; so these kind of system so these kind of features can also be analyzed. It also helps in energy analysis so function is called Scenario energy cost.

It calculates the energy uses and cost based on the extended period simulations it also determines kind of the number of intermediate valves such as efficiency, power, peak, energy uses. So this values will be kind of suggested using or can be monitored can be determined using the energy analysis tool. It also can be used for flushing purpose when basically the flow is just unidirectional.

There is no valve operation all the network is open and runs in a series of conventional flushes so in turn network is actually being flushed off. It helps in a fire flow analysis as well which is there is a feature called automated fire flow analysis okay and this kind of see if it provides the adequate capacity for fire fights. So these are some of the advanced features.

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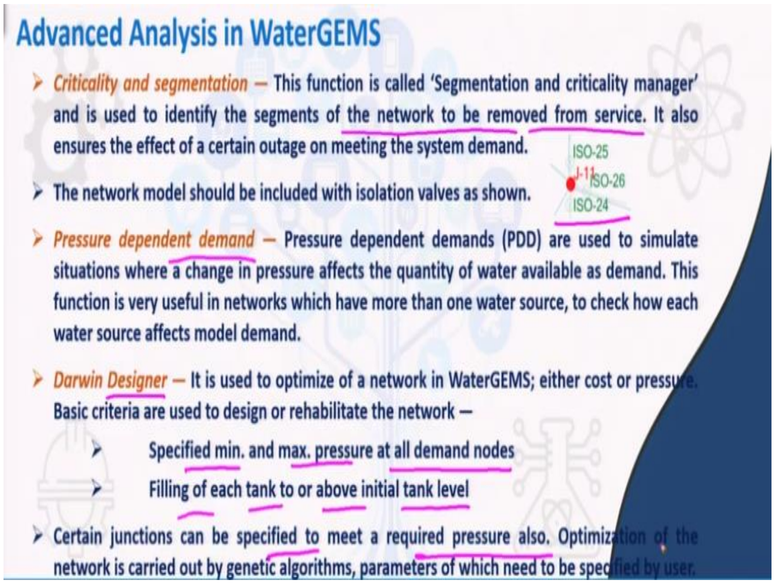

It also like can be used for criticality and segmentation through a feature called segmentation and criticality manager which is uses to identify the segments of the network which is to be remove from the service based on criticality of this system okay. So that way it is very helpful the network model should be a kind of included with isolation valve and then this is how we may include the isolation valves.

Then it is used for pressure dependent demand as well so a pressure dependent demand which is PDD are used to simulate the situations when there is a change in pressure which is effecting the quantity of water available as a demand. So how the pressure changes is going to kind of affect demand that is basically analyzed using the PDD function pressure dependent demand function. The Darwin designer is for the optimization purpose so it uses basically the network to optimize; and it can take as a cost for optimization or pressure for optimization.

So the basic criteria the design that includes is it is specified minimum and maximum pressure at all the demand notes and filling each tank or above initial level tank level so all this features can be analyzed okay. It also kind of helps in creating certain junctions and they it can be specified to meet the required pressure for these junctions okay. Optimization of the network is generally carried out by the GA genetic algorithm and parameter of this, needs to be specified by the user.

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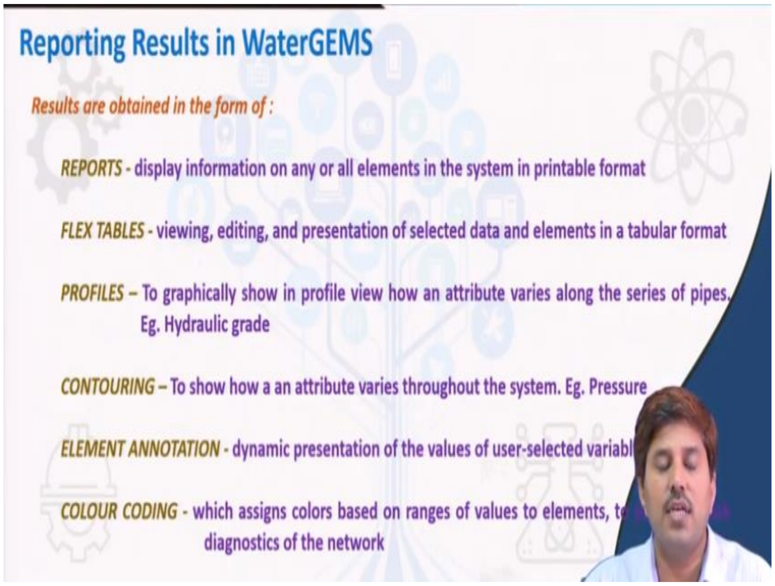

After we like complete the run so results are reported either in the form of reports or flex tables or profiles or contouring or kind of element annotation specifically and the color coding options is also available.

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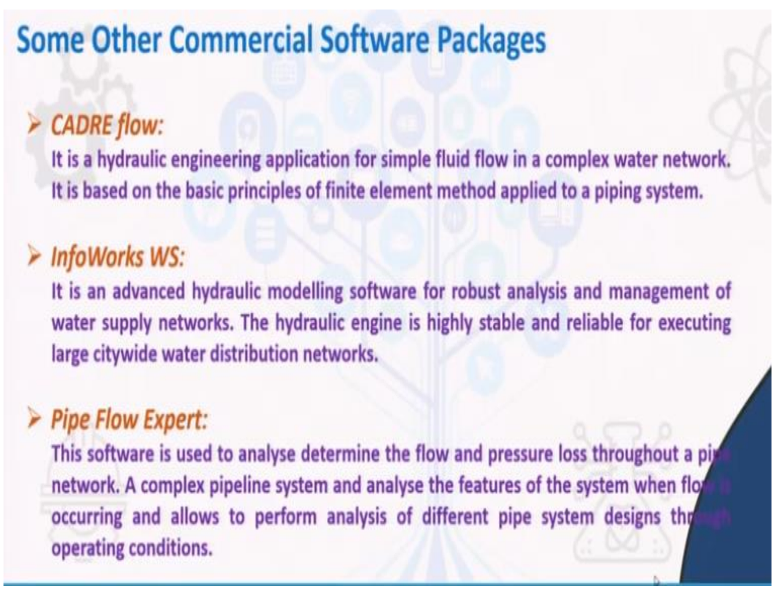

Then that is about water GEMS there are some other commercial popular packages available like CADRE flow infoworks, pipe flow and few more are available there in fact many software's available but as we discussed that water GEMS is by far regarded as the most robust commercial software package available. So with this we conclude the discussions here we will see in the next class about how we use EPANET and water GEMS through a demonstration so thank you for joining and see you in the next class.