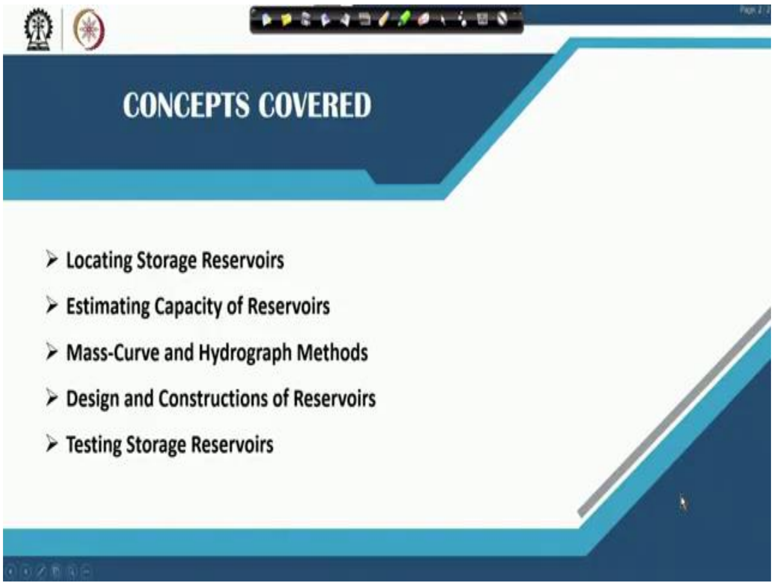
Water Supply Engineering
Prof. Manoj Kumar Tiwari
School of Water Resources
Indian Institute of Technology - Kharagpur

Lecture 20
Placement, Design and Construction of Storage Reservoirs

Hello friends and welcome back so we have been talking about water storage structure this week and so far we did talk about the basics and the ground storage structures and elevated storage structures and that too we did talk about the raw water as well as treated water storage structures. So, this lecture we are going to discuss about the placement design and construction of some of this storage reservoirs mostly for treated water.

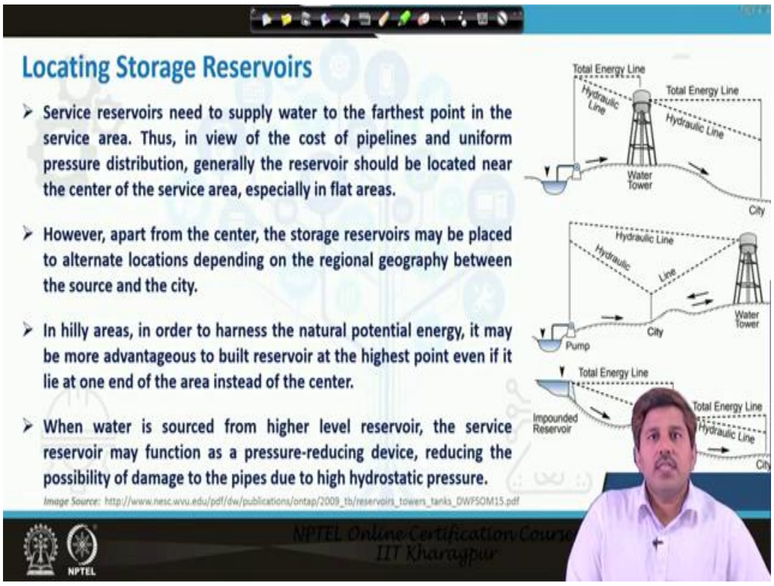
(Refer Slide Time: 00:47)



Because raw water storage reservoirs as we discussed are generally either in the form of dam so that is to be in line or the offline storage structures in the form of reservoirs near the treatment plant or near the intake itself or before the intake. But the treated water storage structures which we discussed in the last class we need to talk about how or where we should locate that preferably and what else we are going to cover in this lecture is the estimating capacity of these reservoirs.

There are mass curve and hydrograph methods both graphical and tabular methods will be discussing. And then some of the considerations provided for design and construction of these reservoirs. And I will conclude this lecture with testing of storage reservoirs.

(Refer Slide Time: 01:46)



So, to start with where to locate these reservoirs, so service reservoirs particularly the treated water reservoirs need to be located at a point which gives is the best possible economy. Now we know that the service reservoirs or storage reservoirs treated water reservoirs the basic function is to provide the water supply at desired pressure level to all the consumers. So, it should be able to supply water to the consumer at the farthest point in the service area with adequate pressure level so that there should not be much of the pressure drop by the time water reaches to that consumer.

So with that concept the best possible location is usually in the center of the this service area somewhere near the center of the service area. So, that is what is the preferable location of the storage reservoirs or service reservoirs and this is practically good for the flat areas where we do not have much of a problem we can select the area where we want to locate a reservoir and in the middle of the service area wherever we find out somewhere in the center of the service area wherever we find the adequate space we can actually locate these reservoirs.

However there are issues when we try to do this in the other type of terrain. So, if we are placing where the regional geography is not flat the source and the city are at different elevations then we will have to think about what could be the best place for putting these storage reservoirs. Now as we said that economy would be something to govern this and there could be the multiple options for that.

So, in hilly areas like in order to harness the natural potential energy hilly areas generally we get some place elevated. So, in order to harness that we may place our storage reservoir at some elevation and pump water there even if the source is at lower we pump water there and from that away point we harness that natural potential energy and then make sure that water reaches the consumer mostly by the gravity also there could be conditions when the source is at higher elevation.

So if water is being say sourced from a higher elevation then we can place the reservoir somewhere in between and then the purpose of reservoir is not only to kind of store the water for emergency and all that it also helps in reducing the pressure. Because if the natural elevation is quite high then that means the water pressure in the pipe is going to be enormously high and we may see the problem of the higher h8 like the bursting of pipes and those kind of problem you may see due to high hydrostatic pressure.

So, then these reservoirs put in between can act as a pressure reducing devices as well. So, like we may have a case where basically say our source is as lower elevation then somewhere we get higher elevation before city. So, a place or reservoir here then pump water to this and then from here it usually goes to the city by the gravity. Or many times we get cases like this when the city is in between and the elevation is on the other side of the source then also we can actually pump water to the water tower or reservoir and from there we can get the city.

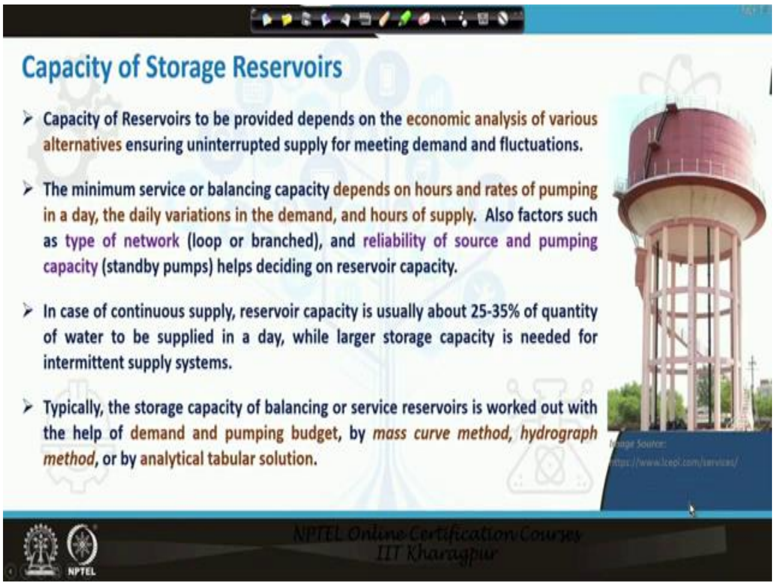
But in this case what happens like in such cases it is advisable to that we pump the water first to city and the some of the direct demand can be tapped directly pumping from the source. And we pump only additional water to the reservoir which can serve as in backup. So, the size of the reservoir here would be small whereas the size of here size of the reservoir here should be pretty large because all the water would be pumped to the reservoir first.

And then from reservoir it would actually be going to the city and more so over like in in a case like this when we consider a case like this then we can have different scenarios. How much head is to be provided through the pumping can be determined because we will have a pipe system from here to city then we will have a pipe system from city to the means from city to here or you can say directly from here to the tower.

And we will have a pipe system from here to this place or you can see that 3 pipes one is this one is this and one is this. So, all will have friction losses when our pumping is higher than the demand then after meeting the demand additional water will be pumped to the tower. When pumping is smaller than the demand then there would not be any water pumping here. So, this route will be off the city will get water from here as well as reservoir because demand is higher than the pumping and in case demand is equal to the pumping exactly balancing.

So, then this and both these routes will be off only water will be pumped from the source to the city and it will meet the entire demand of the city so no water going to the reservoir or no water coming from the reservoir. So, under these 3 extreme cases we can have different scenarios.

(Refer Slide Time: 08:12)



Now how we determine the capacity of these reservoirs. So, capacity of reservoir whatever we plan to provide is typically depends on the economic analysis of all the alternatives available. So, as we said that we can have a different placement scenario we can have a different sizing also. So, like in one case if we are putting planning a reservoir between city and the source. You want all your water to go to the reservoir so you are looking for a very big capacity of reservoir.

If you want to go for a balancing reservoir then like which actually gets the balanced water only then you will need a smaller capacity of reservoir. So, eventually the capacity will be depending on trying and testing various alternatives and the idea should be that what you ensure is uninterrupted supply for meeting all the demands and fluctuations. And whatever best possible and most economical alternative you can get for a reservoir placement in capacity would be the best.

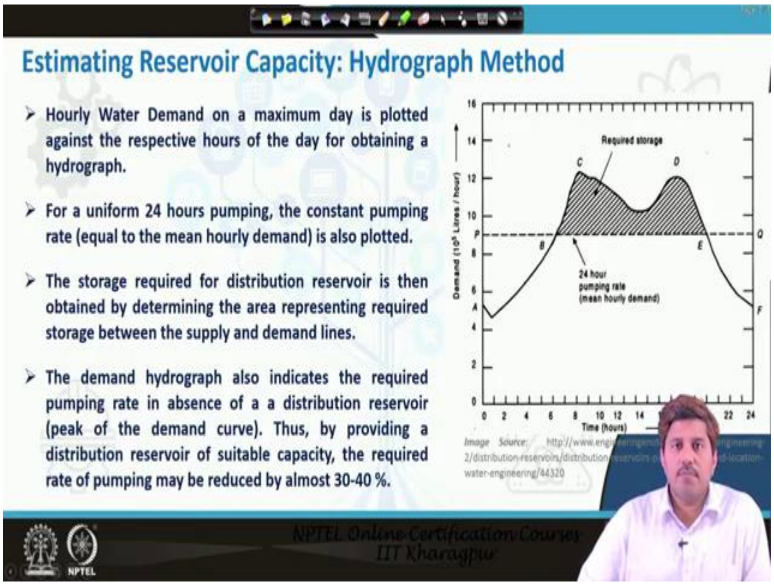
The minimum service basically or balancing capacity will depend on the hours and rates of pumping in a day. And what are the variations in the demand and what are the hours of supply. So, factors such as what type of ne2rk is there whether is a loop or branch Ne2rk for branch ne2rk of course because you do not have interconnection in the ne2rk so one reservoir water you cannot connect to the other.

So in these kind of branch ne2rk you have to you basically would be having looking for a higher capacity whereas in lube ne2rk you can work out with the lower capacity as well. Similarly reliability of the source and pumping capacities so pumping capacity in a sense drivability or pumping capacity means how many standbys you are providing. So, as we discussed in the last week that whatever is the bhp or black horse power needed we provide additional as a backup.

Because some pump fail then what you will be doing so normally 100% backup is recommended but for larger plants we do not go for 100% backup. So, if you do not have 100% backup then you will be actually looking for a larger storage because your backup has to be compensated from there. If you are having 100% backup so the and you have you are having a reliable source that means you can compromise on the reservoir capacity.

So these are some of the factors which govern the capacity of the reservoir. In case of continuous supply reservoir capacity is usually 25 to 35 cent of the quantity of water which is supplied in a day. And we may go for larger capacities in case of it is an intermittent supply system. The storage capacity of balancing or service reservoir is determined typically by the demand and pumping budget so we set out the total demand and set out the total pumping rate. So, basically inflow and outflow into the reservoir and then we do a mass curve analysis or a hydrograph analysis either graphically or by the tabular methods and we then determine the capacity.

(Refer Slide Time: 11:53)



So, how it is done so if let us say if you want to use a hydrograph method so what is done here that actually the hourly water demand on a maximum day is plotted against the respective hours. So, these are the hours of the day and if you want to plot hourly water demand as say so basically what is the demand at 0 hour demand at 2 hour 4 our 6 hour 8 hours. So, this is specific hourly water demand and we plot it like this right.

Now we know that total demand in a day and if it is a 24 uniform pumping if it is a 24 hour pumping so the total demand divided by 24 gives us the constant pumping rate. so, our pumping rate is constant the demand rate is basically fluctuating. So, what we get is that basically this is my demand rate and this is my pumping rate which is constant. so, with this constant pumping rate and this thing idea has to be like area under this curve has to be equal to area under the this curve the constant curve.

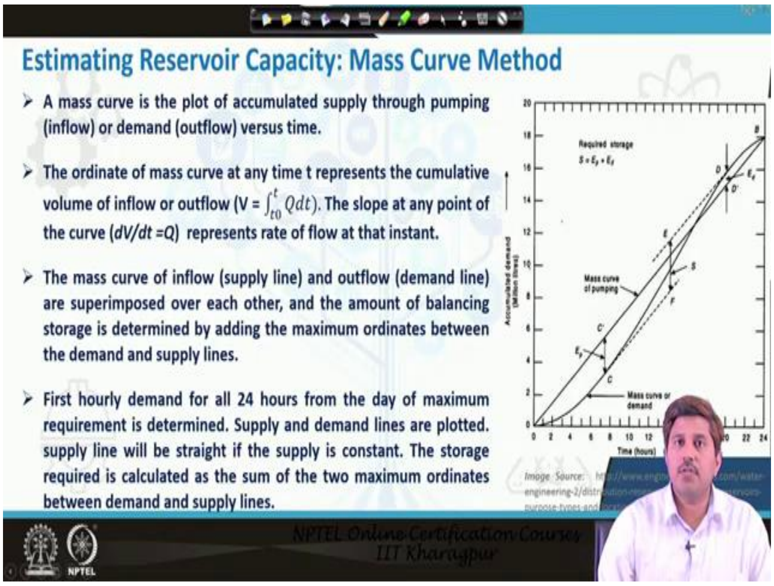
So all the area has to be the same under both the curves but what we see here that one place here particularly if you see this zone this zone so then your supply is higher demand is lower this zone demand is again demand is lower and supply is higher but in this zone let us say in this zone what you have is the higher demand and lesser supply. So, in such scenarios what basically these extra supply would have to compensate these extra demand over here ok.

Now if you do not have in case you do not have a storage system then you will have to pump at the highest rate. Now if say C is your highest rate for say which is more than 12 or here if C is your highest rate then you will have to pump or you will have to have a system which can pump at the rate C but if you are going for a storage reservoir then for all these like all the area under the curve the maximum demand what you can actually see a flat rate of pumping.

And this flat rate of pumping will be let us say instead of around 12 it would be around 9. So, you are still able to save some basically save on to the pumping cost. Because you are or you are providing a system which are of smaller capacity by 30 to 40% instead of providing a system of capacity more than 12 you are going to provide a system of capacity around 9 ok. so, that way substantial saving in installation you can get in laying down the other system but you will have to invest on putting up a storage reservoir.

So, how you are going to determine the capacity of the storage reservoir well actually your storage reservoir has to fulfill these extra demand. So, the area under this curve area under this curve is to be determined and that is what will be your storage capacity. So, that way we can determine the balancing story of a reservoir using this method.

(Refer Slide Time: 15:41)



However the more popular method because getting an area under the discrete curve might be challenging. So the more popular method is actually the mass curve method. The mass curve is the plot of accumulated supply through pumping K or demand versus time so we can have either way. So, a mass curve is basically accumulation over time how much mass because we do pumping in terms of rate meter cube per hour meter cube per second we estimate demand also million liters per day or say liters per hour million liters per hour.

So, our demand and our pumping is in the form of rate we convert that to the mass by multiplying it with the time. so, we basically get an accumulated mass over time and then we plot that. so, any odd means if you see a typical mass curve so it will represent T versus the cumulative volume or you can say in terms of mass also. So, if this is my time and this is my accumulated volume so in say our first hour this was the demand in second hour the demand increased a little or did not increase whatever.

So if the same demand is there if say I have a in the first hour demand is 2 in second hour demand is 2 in third our demand is 3 in 4th our demand is 5. So, let us say this is my hours one 2 3 4 then what will happen the cumulative demand in first hour still remains 2 cumulative demand till in the first 2 hours becomes 4 cumulative demand in the first 3 hours become 2 + 2 4 + 3 7 cumulative demand in first 4 hours becomes 7 + 5 which is 12.

So, I get this cumulative demand so I plot one 2 3 4 5 versus these numbers 2 4 7 12. So, that way I basically get a plot total mass curve. So, this is how we basically plot and when we plot so it is actually what we are plotting is from p0 means from initial time that is my t0 to p time whatever time I am taking and the discharge into the time whatever time I have considered. The slope of this at any point will give me the basically discharge because it V is equal to integration of Q dt so we know that dv by dt will let me actually equal to Q.

So, we actually plot to mass curves in this method one would be the mass curve for demand which is basically the outflow from the reservoir how much demand that reservoir needs to meet or how much water that reservoir needs to supply. So, this is actually a supply curve. So, we have a supply line which is basically the mass curve of demand. Now let us say you get a typical mass curve of demand like this.

Now in the mass curve of demand as it is a cumulative so when basically it is more or more flat that means the demand is increasing at very slow rate and when the curve is more and more steep means demand is raising at very rapid rate. So, we will get a mass curve which is from 0 to 24 hours again this is done for a maximum day when the demand is maximum. Now wherever this ends we want if you want to have a system with a constant supply so that means if say the total cumulative demand reaches 18 for say as in this case.

If total cumulative demand reaches 18 then we want to have a system which supplies 18 million liters of water in 24 hours. Now if we select a constant pumping rate there that means we will have to supply 18 in 24 hours. So, hourly pumping rate will be this and then we can actually meet 0-0 to that point and this will give us a mass curve or the pumping rate or cumulative pumping rate for the hour inflow line so the water which will be sent to the reservoir.

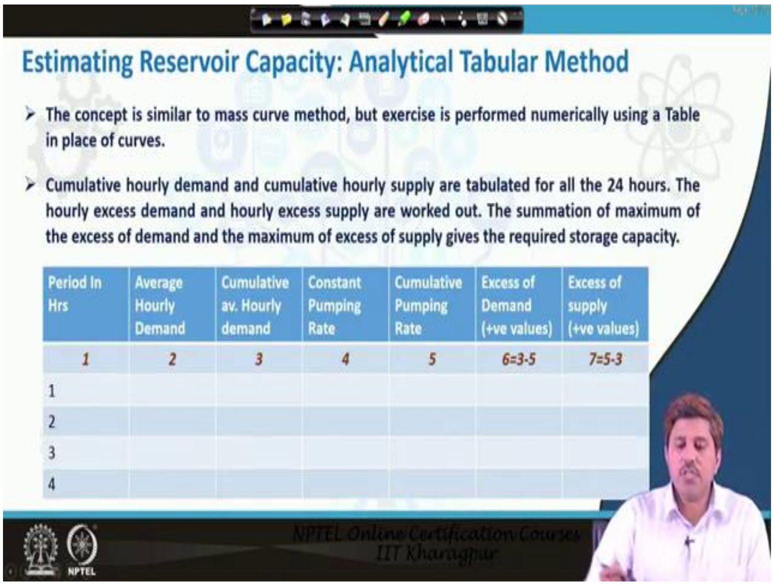
So we pump water at this rate to the reservoir and then from reservoir it will meet the demand as the demand curve is there. So, that way we can actually have a constant pumping line constant mass curve of pumping it is constant because in unit time the increase is unit. so, it will be actually a straight line. Whereas here in unit time the demand change in the demand is not unit some time it is more some time it is less and as a result what we will see that it is not a straight line.

So, we will get a mass curve like this and we will get a mass curve for pumping which is straight line. So, now we get these 2 mass curves what we do is that we take the maximum positive and negative ordinates so this is basically the here pumping is more than the demand, so this becomes whatever wherever it is the maximum this becomes the basically extra volume required due to stored the water when the pumping is more so this is excess pumping case pumping is more than the demand, so excess pumping.

Now there are all these cases are excess pumping but this case represents the maximum excess pumping. So, maximum excess pumping is going to be this much volume after that it will actually start reducing the excess volume starts reducing. Now and this is the maximum deficit. So, this is the excess demand which is denoted by the IDE here. So, this is excess pumping and this is excess demand so excess demand means when the pumping rate is lower demand rate is high we again take the maximum ordinate here and this becomes the ED and summation of these 2 gives us the storage capacity of the reservoir.

So first we will basically take a 24-hour demand on a maximum day and then we plot a constant supply line see where the maximum positive and negative differences are occurring. So, maximum positive difference is basically EP and our excess pumping and negative difference is actually access demand we sum these 2 in order to get the capacity of the reservoir.

(Refer Slide Time: 22:58)



So, this is the typical masker method and same can be used for using basically the analytical tables. So, the concept remains the same here it is basically the exercise which will be done numerically using tables instead of plotting graphs. So, what we can have we can basically frame a table where we write period in hours so 1 2 3 4 5 that hours will be listed here. Average hourly demand what are the demand over here cumulative hourly demand. So, we will be basically summing these 2.

So, like this is equal to this and then here this plus this will come here this plus this will come here this plus this will come here. so, that we will get cumulative constant pumping rate we can determine and similarly we will get the cumulative pumping rate. Now what we determine the excess of the demand so this is the demand and this is the sort of cumulative pumping. So, we substrate 5 minus we subtract 5 from 3 so, 3 - 5 will give us the excess pumping demand and we will take all positive values only here.

So, wherever it is positive we will list all those values excess of supply now we do the reverse because this is the supply and this is the demand so excess supply means 5 is greater than 3 so 5 - 3 and all positive numbers we list out here. So, wherever there is a positive it will be blank here wherever there is basically negative or blank generally there will be a positive number over here. So, we actually list all these over a period of 24 hours and then take the maximum positive from here and maximum positive from here and add these 2 in order to get the total demand.

So, it is basically similar to mass curve method on instead of only plotting we are doing it in a tabular form. Again this is a case or this all say the mass curve earlier that we saw are the cases when we are actually when we are considering that it is that it is a 24 hour pumping there might be cases when we have just say 8 hours pumping ok or 12 hours pumping. So, for same problem if you are having just 12 hours pumping instead of say 8 hours pumping.

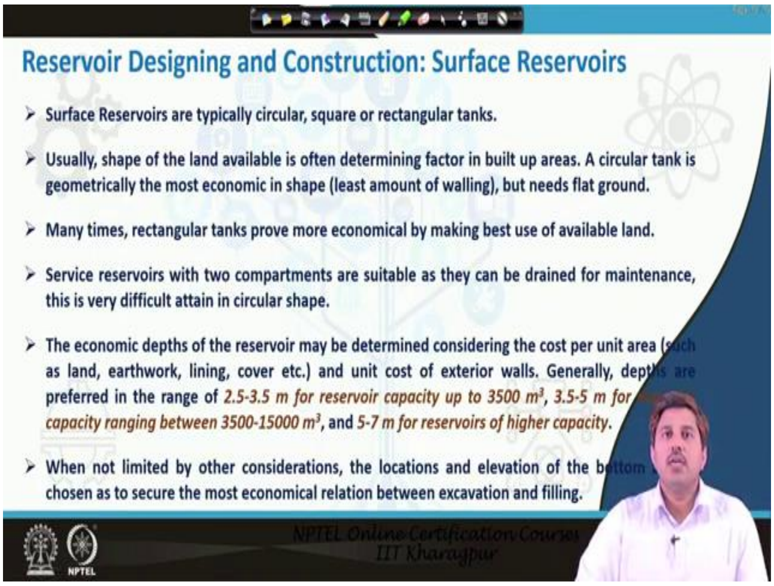
And you decide you are pumping hour went well robber you are going to pump. So, let us say you are going to pump from 6:00 in the morning to the 18 in the evening ok if you are pumping from 6:00 in the morning to 8 in the evening then you are then in that case your demand line is not going to be like you are basically mass curve about pumping is not going to be like this of course you have to pump the same volume over here.

So this will remain one point and this will remain one point and you will get a line like this ok. So, instead of using this line then you will have to see the maximum difference from this line and this line. Now it is possible that maximum difference is at this point or maximum difference is at some other point if maximum difference is at this point you consider this and maximum difference here is at say this point then you consider this.

So, this becomes my EP and or in fact it is a deficit other way also this becomes my EP now because pumping is more than here and this becomes my excess demand so then I will take the sum of these 2 and get the value. Same thing can be done in a tabular form also so if constant pumping rate is the rate is constant but if it is a not at period of supply one we just have say 0 here.

Here also we have 0 here also we have 0 we here also from 6th onwards we are going to start at some pumping rate and then we will be accumulating that. Similarly accumulating accumulation also it will be 0 and then from 6 onwards will start the value. so, accordingly we can get the excess demand and supply when we are pumping for a intermittent times and not be round-the-clock.

(Refer Slide Time: 27:27)



Now that was about determining the capacities but how we go for designing and construction of these reservoirs. So, for surface reservoirs typically circular square or rectangular tanks are used. However the shape of land available will be actually one of the most important factor and should be used in determining what kind of shape would be ideal. A circular tank is geometrically the most economical because the periphery you know that a circle has the least periphery so the work over the walls will is going to be the limited for the same amount of area or same amount the cap of the capacity.

But then a circular tank will actually be requiring flat ground so if you are having a flat ground it is fine if you are not then many times in fact the rectangular tank proved to be the more economical by making best use of the available land. Generally particularly for the ground reservoirs we should go for more than one compartment. So, 2 or more compartments are suitable as when we are operating one compartment the other can be put through clean or maintenance.

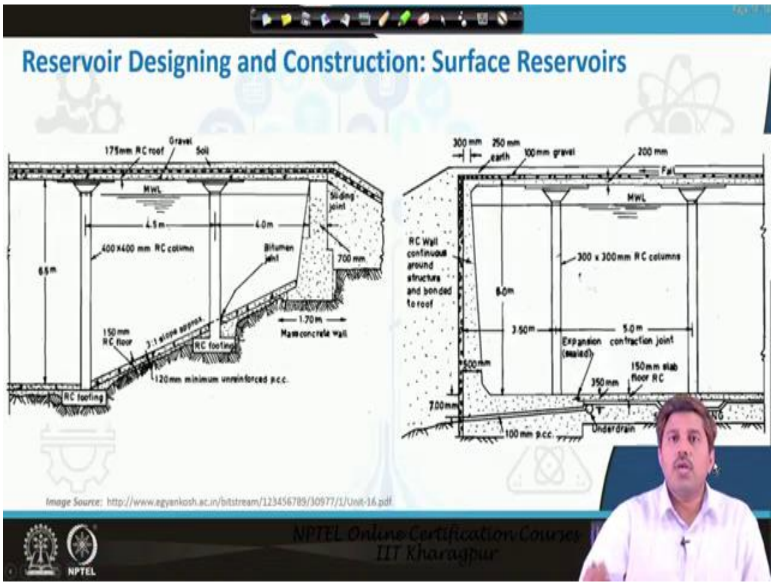
But in circular shape it difficult to basically get more than one compartment easily. The depth also is a very important factor depth is again determined by the economic criteria. So, the most economical depth can be determined by considering what is the cost per unit area such as land? Earth work lining cover which is to be provided per unit area and then there is a unit cost of the exterior walls. So, if we take the like both this and then we can actually say you know that unit cost of wall unit cost of so for same volume what length width or what area into depth is to be provided.

So, you have a unit cost of area and depth will give you the length of the walls to be are the basically size of the walls to be provided. So, you have unit cost of the unit cost of the exterior walls as well so what eventually at what depth you are going to get an ideal or most economized combination would actually give you the economic depth. Generally for reservoirs of the capacity up to 3,500 meter cube 2.5 to 3.5 meter depth is adopted is considered good in fact.

3.5 to 5 meter depth is considered good for reservoirs where the capacity ranges between 3500 to 15000 meter cube and for higher capacity reservoirs 5 to 7 meter depth should be chosen. Further when there is no limitation of other con sort of considerations the location and elevation will actually be decided based on the most economical relation between the excavation and filling because for ground reservoirs it is mostly excavation and filling.

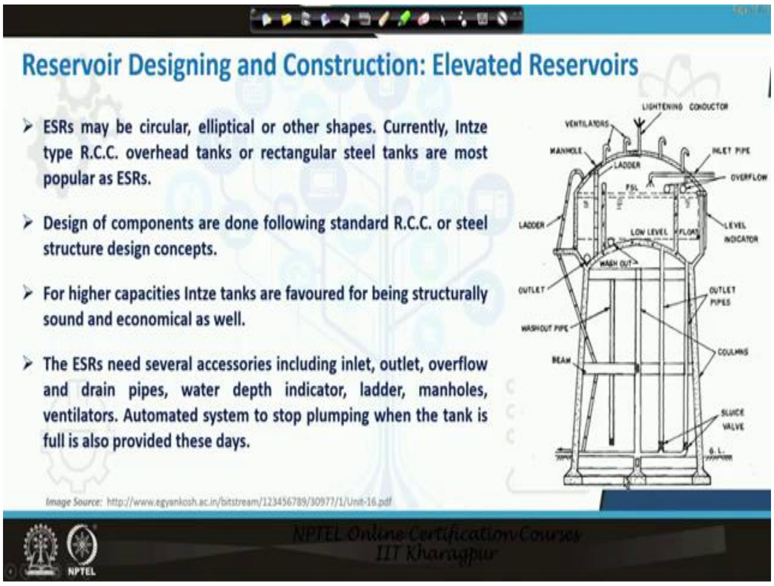
We can go for Argon reservoirs or masonry or RCC reservoirs even for the other than reservoirs or whatever remember we are talking about storage of the treated water. So, there should not be any chance of contamination so we should not like just dig a reservoir and put water into it because then it is going to acquire a lot of sediments. So, proper lining proper top cover must be insured in these reservoirs because we are actually going to store treated water.

(Refer Slide Time: 31:22)



So, we will have to see that water is stored adequately these are couple of designs. So, let us say like in some cases when you have a sloppy ground you can actually use a reservoir like this also where you have stored water the depth actually varies here or for flat systems you can have a reservoir of this kind.

(Refer Slide Time: 31:49)



The standard RCC design practices can be adopted for design and construction of the elevated reservoirs for ESR circular elliptical except or other safe reservoirs are popular. The intze RCC overhead tanks or rectangular steel tanks are generally the most popular ESR. So, for RCC purpose it is basically the in intze tank are more common intze tank means you it will have it will lay on intze this is in tanks are actually named after a scientist who basically discovered this concept.

So, he said that laying the tanks on this shaped structure so these kind of tanks are called in intze. So, here it is it will be the support will be actually on this thing and you will have a portion of the reservoir outside the support in such a fashion and it is a basically curved. So, the weight lies on this and it is kind of gives you the good bearing capacity as well. So, and particularly for the higher capacities instant are more favoured.

So if you are going for a big tanks instincts are more favoured because they are structurally sound and economical as well as opposed to the other designs. Steel tanks are also used and like rectangular steel tanks are more common if you are if someone is planning to go for a steel tank instead of the RCC or concrete tank the design of the tank will be done following standard RCC or steel structure design concept.

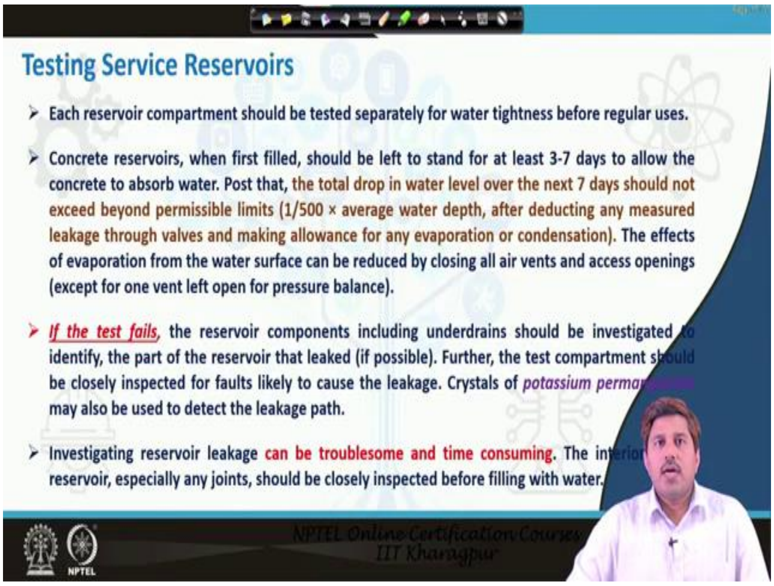
We are not going to go into the detail of those it is available in any standard textbooks. The ESR also has to be accompanied with several accessories. So, there has to be kind of Inlet outlet overflow and drain pipes with all the different purposes Inlet pipe will bring water to the tank outlet pipe will actually be used for supplying supply line. The overflow if the tank is actually getting overflowed so there has there has to be an overflow pipe which takes the water to the drain.

And there has to be a drain pipe also in the bottom when we are washing or cleaning tanks. So, we should be able to drain the drain the water which is used for cleaning the tank into the drainage. There has to be water depth indicator it is good that if we have such a water depth indicator so that depth is visible from the base of the tank itself or from far off places so that we can see what is the label in the reservoir.

If you put a micro scale and everybody in the for purpose of looking the depth if one needs to go over the tank level to see the depth then it becomes very difficult. So, we should have a prominent water depth indicator there has to be a ladder for assessing the tank there has to be main holes for servicing repairing cleaning of the tank. So, that using manhole somebody can go inside and basically do the cleanup and maintenance work. There should be ventilators, so these are kind of some of the essential components of these ERS.

These days it is also like common to have an automated system to stop pumping when the tank is full. So, earlier days basically it was not so we had to have no or flow system and then the water might be actually flowing if the tank is fully pump is not switched off. But these days we usually go for automated system so as soon as tank reaches a certain level or is near full it will give a signal and then pumping will be closed. So these are some of the features which would be there in the ESR.

(Refer Slide Time: 36:03)



Now the reservoirs should be tested also so once it is constructed it should be tested and specifically tested for water tightness because the function basic function of reservoir is to hold water. So, we must see that it is water tight it is not leaking water. And it is not that we should just test reservoir as in hole or something even if there is an internal leakage if it is a more than one chamber, one compartment.

So, we have to test each compartment because one compartment might be leaking water to the other compartment and if you do not test that we will never know. So, we should test each compartment while making all other compartments sort of empty. So, for concrete reservoirs when it is first filled it should be basically left to stand for 3 to 7 days so that whatever water concrete needs to adsorb can get it can adsorb in this period 3 to 7 days is a general recommendation.

But many times even the higher periods are used so even up to 21 days could be actually used for some specific designs. But normally 3 to 7 days are good enough for concrete to adsorb water whatever it can. After the concrete heads of the water so means after these 3 to 7 days period whatever we choose upon we should see that total drop in the water level over the next 7 days should not exceed beyond the permissible limit.

So, if we fill tank to certain level the drop in the water should not be beyond the permissible limit and this permissible limit all the varies but normally like it is recommended that 1 to 500 into the average water depth so basically the 500 times of the average water depth is becomes our permissible limit in many cases it is taken 1 to 1000 also so that is not 1 5th 100 but 1000th times of the average water depth.

And while calculating we must ensure that we detect any major leakage through walls or making allowance for the evaporation or condensation those kind of thing. Also we should try to like kind of nullify these effects as far as possible like evaporation and those things we should while testing we should close all the air vents and other openings except one which is for the pressure balance.

Now if test is successful if the loss is within the limit we say that yes tank is good enough watertight and can be put into the use. Now but if the test fails then we should try to identify why it has failed so we should basically then oversee the various reservoir components including the under drain systems and we should properly investigate and identify and see from where this leakage is possibly coming. If we can identify that way it is if not then we will have to kind of go for the test compartments make them empty completely and then closely inspect all the faults that might actually causing the leakage.

Sometime we use the crystals of operation for magnet which is a basically colour, oxidant. So, we use that and then try to detect the leakage path so we fill some water into the tank and put the potassium permanganate and see from which this thing the colour is getting apparent. So, by using this colour treasure we can actually try to track the leakage path also. The point is that investigating reservoir leakage if it is leaking at all it is very troublesome and time consuming process.

So, kind of all the interior of the reservoir especially any joint or those kind of places where walls are there joints are there where pipe connections are there it should be closely inspected before filling the water. So, that as far as if we can pass the test it is the best thing otherwise it is going to get a quite complicated. But anyway so that is step which should be followed and we should ensure that our reservoirs are watertight before putting them into the use.

So with this we conclude this lecture and most of our the discussions also in this week we will have one more lecture in this week where we will be talking about we will be taking in fact some practice problems to see how we can determine the capacity and how we can put the how we can put a size to the reservoir. So, see you in the next class thank you for joining.