**Urban Utilities Planning: Water Supply, Sanitation and Drainage**
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**Module - 04**
**Pumping and Storage**
**Lecture - 20**
**Service Reservoir - Part II**

Welcome back, in Lecture 20 we will continue with Service Reservoir, this is Part 2 where we will solve some of the problems.

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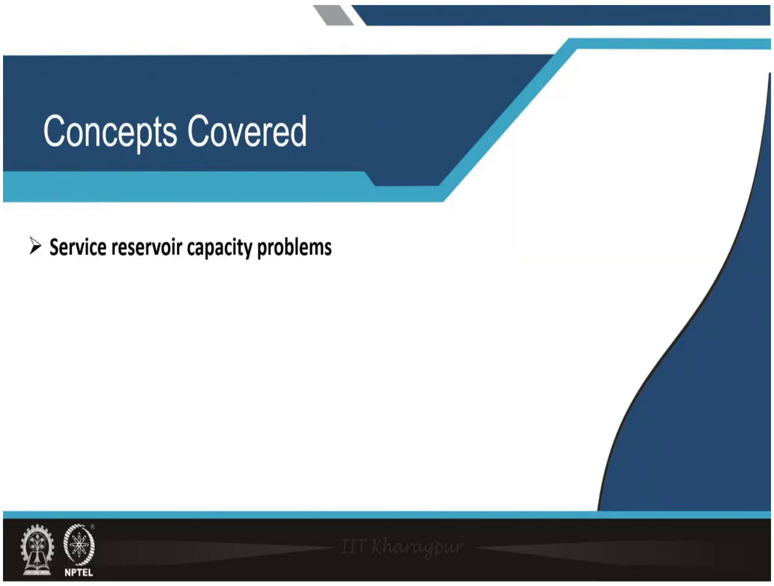


So, we will look into service reservoir capacity problems in this particular lecture.

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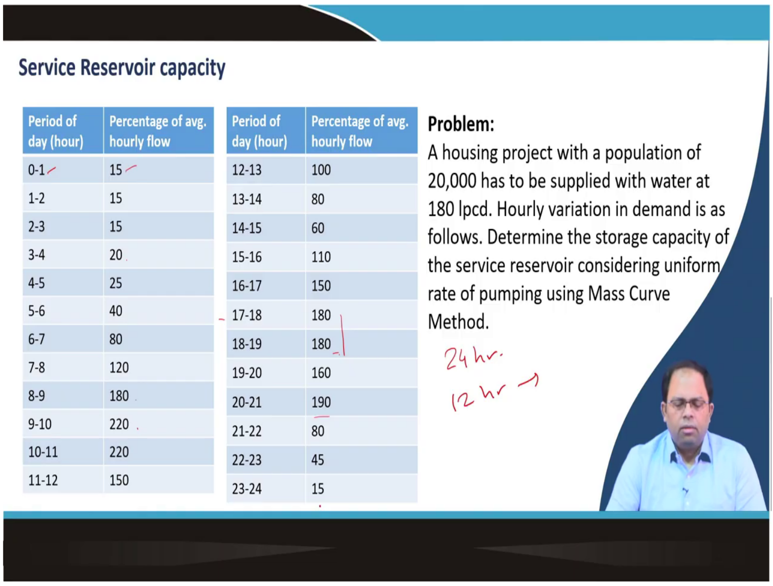


So, first let us look into a problem; A housing project with a population of 20,000 has to be supplied with water at 180 liters per capita per day. Hourly variation in demand is as follows, which is given in this particular table and we need to determine the storage capacity of the service reservoir considering uniform rate of pumping using Mass Curve Method.

And we do it either considering a 24 hour period or a 12 hour period i.e., two time periods one in the morning and one in the evening which is the typical situation in Indian urban areas. So, let us look into the variation in demand. So, we start from 0th hour which is 12 to 1 o' clock and then 1 to 2, 2 to 3 and so on.

And so, in that way we have the figures till the 24th hour. So, we see that at night time maybe at night 1 o' clock the percentage the consumption is around 15 percent of the average flow. So, when we add up all the consumption, and we divide by 24 and take 15 percent of that which gives us the amount of consumption during this time period.

Overall, we can see that in that entire zone or neighborhood we see 15 percent of average consumption during that time period of one hour at 1 o' clock at night. Then the same is observed till around 3 o' clock and then we see that it is increasing so; that means, some people are getting up they are going for the morning shifts.

So, we see that from 20 then it becomes 25, then 40, then 80 percent now it exceeds the average demand which is around 120 percent. So, that is around 7 to 8 in the morning when kid starts going to school, peoples start going to offices. So, people have to get ready so that is why we see higher consumption 120, 180, 220, 220 at around 10 to 11 when most of the house task of cleaning houses and such activities are being carried out.

Then it again falls down during the afternoon hours it becomes 80 percent around 1 o' clock to 2 o' clock and then it again increases during the evening we see again around 17 means 5 o' clock to 7 o' clock there is high consumption and then again, a little bit higher consumption around night around 20 to 21 and then again it falls down. So, this is how the typical consumption pattern varies in an urban area and that is what has been reflected in this particular table.

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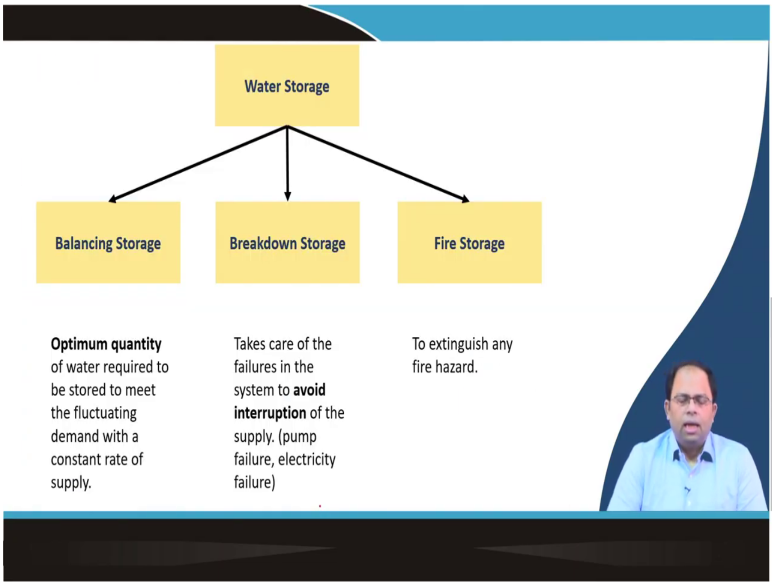


So, we have already learned that the water storage is not only the balancing storage, but we also store water for breakdowns and for fire. So, balancing storage is that optimum quantity of water required to be stored to meet the fluctuating demand with a constant rate of supply plus we add 25 percent of that as break down storage and we can add another 5 litres per capita to add as fire storage.

So, these are the three components that is usually added and so, first we need to determine the balancing storage.

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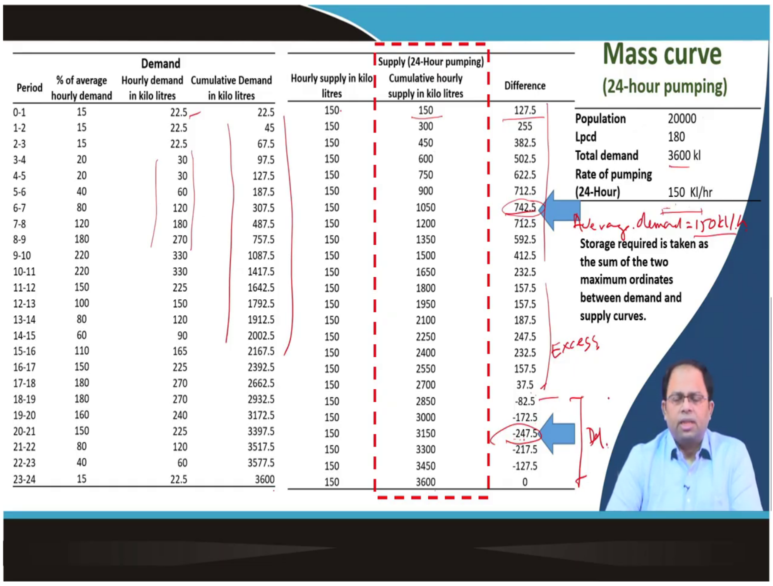


So, in this example, we first assume that there will be 24 hour pumping and we have population of 20000 liters per capita. The total consumption per days per capita is around 180 which is given. So, total demand is 180 into 20000 which comes to around 3600 kiloliters. So, this is the total amount of water that is required for this particular zone.

Now, rate of pumping is for 24 hours; that means, if we divide 3600 by 24, we get around 150 kilolitres per hour. This is the rate of pumping and the rate of pumping is uniform throughout the day or the average demand throughout the day is 150 kilolitres per hour. So, both the rate of pumping as well as the average demand is equal to 150 kl per hour.

We have made this table to create the hydrographs of inflow and outflow for the mass curve method. So, this is the cumulative amount of water that is either coming into the reservoir or going out.

We have 24 hours and we also know that the supply is around 150 kilolitres per hour or the average demand is also 150 kilolitres per hour. We take 15 percent of that that comes to around 22.5 kilolitres per hour.

So, that is the demand during the period 0 to 1 and over here we can see the demand per hour for different time periods and when we add this all up and we get the cumulative demand in kilolitres. So, we see that the first hour it is 22.5 then 45 then gradually we keep on adding and at the end we get 3600 kiloliters.

So, this is the demand which is the amount of water that has to be supplied. So, the amount of water that has to be supplied is the cumulative value. We have already determined that and based on that to supply that in 24 hour period we will divide it by 24 and we get 150.

So, hourly supply is 150 continuously for every hour but we have to determine the hydrographs of both inflow and outflow.

Next, we have to determine the hydrograph of inflow. So, this is the hydrograph of inflow where we keep on just adding the cumulative supply which is 150 then 150 plus 150, 300, and so on. The total value is 3600; that means, whatever amount is being supplied is being consumed.

Now we have to determine the maximum ordinate of deficit period and excess period. So, how do we do that? So, how do we determine if it is a deficit period or an excess period? We have to find the difference between the total cumulative supply and the cumulative demand for every hour to determine if it is in the deficit period or in or in an excess period.

So, if it is positive then it is an excess period, if it is a negative it is a deficit period; that means, if supply is more, then it is a positive period or excess period. So, we see that initially the difference is 127.5 it increases to 255, then 382, then 502.5, 622.5, 712, 742.5 which is the maximum value and then again it comes down 712, 592 this is the difference between cumulative demand and cumulative supply at this particular point of time and gradually it comes down and then finally, it reaches a negative value. This is the time when it is deficit period. The highest value in the excess period is 742.5. and in the deficit period the highest value is minus 247.5. We take a summation of these two values and this amount of water has to be stored.

So, that is the total balancing storage capacity of of this particular reservoir.

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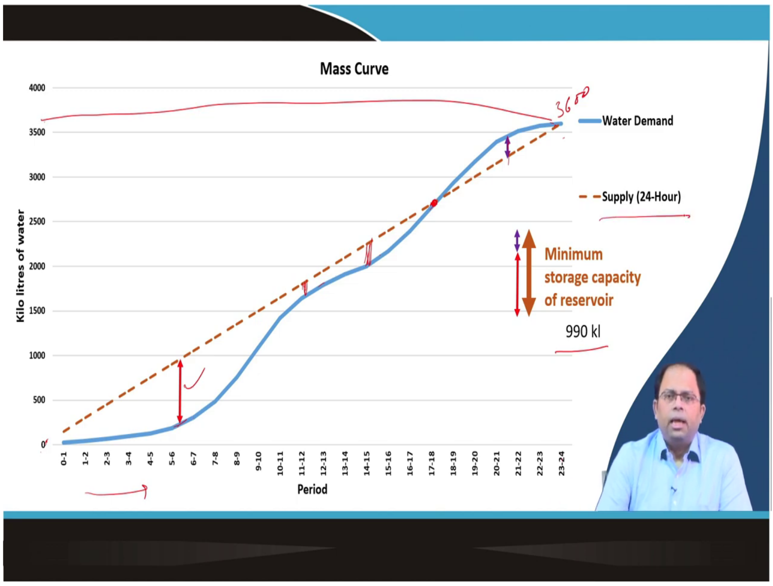


We can estimate it using the mass curve as well. In the x axis we have got the time periods and on this side we have kilolitres of water. This is the cumulative amount of water that is coming in. So, we see we start from 0; that means, the supply is 0 and at the end that is the 24th hour the supply is 3600. Both supply and the demand is same. Similarly, we can plot the cumulative demand. We get two lines; this dotted line is the cumulative supply and this solid blue line is the cumulative demand. The demand is maximum around 6$^{th}$ to 7$^{th}$ time period. We can estimate the difference between the two curves at this point.

So, this is how we actually determine the ordinates using the mass curve method, but; obviously, you can understand that whenever we have this kind of curves we need to actually measure at the different points where we feel like there is a chance that the ordinate is highest for each period. We can confirm this using the analytical method as well.

Analytical method may not be appropriate in case of variation in demand or in case data is not there for all the data points for every hour. The mass curve can be used, but the concept is more or less same in both the cases.

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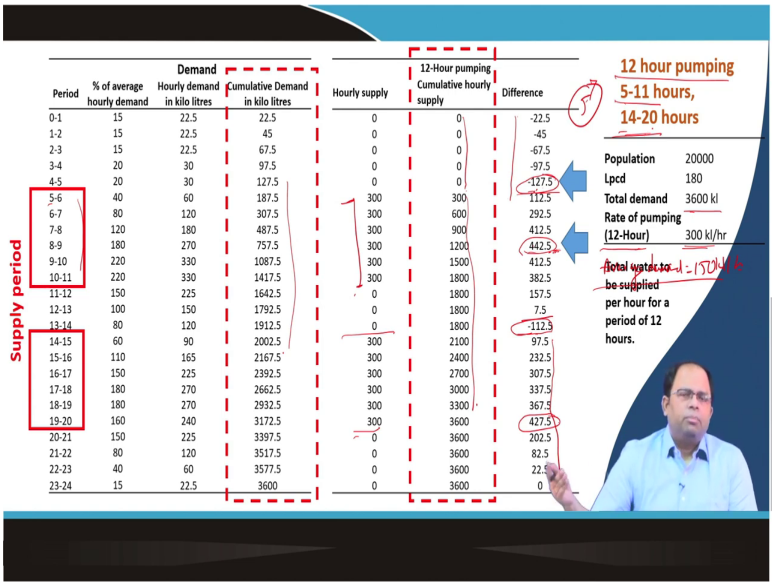


| Period | Demand: % of average hourly demand | Demand: Hourly demand in kilo litres | Cumulative Demand in kilo litres | Hourly supply | 12-Hour pumping Cumulative hourly supply | Difference |
|---|---|---|---|---|---|---|
| 0-1 | 15 | 22.5 | 22.5 | 0 | 0 | -22.5 |
| 1-2 | 15 | 22.5 | 45 | 0 | 0 | -45 |
| 2-3 | 15 | 22.5 | 67.5 | 0 | 0 | -67.5 |
| 3-4 | 20 | 30 | 97.5 | 0 | 0 | -97.5 |
| 4-5 | 20 | 30 | 127.5 | 0 | 0 | -127.5 |
| 5-6 | 40 | 60 | 187.5 | 300 | 300 | 112.5 |
| 6-7 | 80 | 120 | 307.5 | 300 | 600 | 292.5 |
| 7-8 | 120 | 180 | 487.5 | 300 | 900 | 412.5 |
| 8-9 | 180 | 270 | 757.5 | 300 | 1200 | 442.5 |
| 9-10 | 220 | 330 | 1087.5 | 300 | 1500 | 412.5 |
| 10-11 | 220 | 330 | 1417.5 | 300 | 1800 | 382.5 |
| 11-12 | 150 | 225 | 1642.5 | 0 | 1800 | 157.5 |
| 12-13 | 100 | 150 | 1792.5 | 0 | 1800 | 7.5 |
| 13-14 | 80 | 120 | 1912.5 | 0 | 1800 | -112.5 |
| 14-15 | 60 | 90 | 2002.5 | 300 | 2100 | 97.5 |
| 15-16 | 110 | 165 | 2167.5 | 300 | 2400 | 232.5 |
| 16-17 | 150 | 225 | 2392.5 | 300 | 2700 | 307.5 |
| 17-18 | 180 | 270 | 2662.5 | 300 | 3000 | 337.5 |
| 18-19 | 180 | 270 | 2932.5 | 300 | 3300 | 367.5 |
| 19-20 | 160 | 240 | 3172.5 | 300 | 3600 | 427.5 |
| 20-21 | 150 | 225 | 3397.5 | 0 | 3600 | 202.5 |
| 21-22 | 80 | 120 | 3517.5 | 0 | 3600 | 82.5 |
| 22-23 | 40 | 60 | 3577.5 | 0 | 3600 | 22.5 |
| 23-24 | 15 | 22.5 | 3600 | 0 | 3600 | 0 |

Now, let us look at a case when there is intermittent supply. For example, we can have 12 hours of pumping and; that means, we have two intermittent supply periods one is from 5 to 11 hours and then from 14 to 20 hours. In case of normal overhead tank inside our house we run our pumps just for 20 minutes or 30 minutes so, this does not have much impact on determining reservoir capacity since consumption during these 20 minutes will make little difference. Thus for overhead tanks inside our house we go for standards based on the total consumption.

In case of overhead tanks in urban areas, pumping takes a lot of time which has an impact on reservoir capacity. During this time say 5-7 hours there may be a lot of consumption. So, balancing could actually reduce the capacity of the reservoir. In this example we have used the same demand as earlier i.e., 3600 kilo litres of cumulative demand which has to be supplied within a 12 hour period. This comes to around 300 kiloliters per hour and that you can see the red boxes where the service periods are. The cumulative demand also remains the same. So, the hydrograph remains same. Now we have pumping during 5 to 11 and then again from 14 to 20. So, these are the two time periods of pumping and cumulative supply is computed. Thus, the hydrograph of inflow and hydrograph of outflow is prepared.

We see there is a deficit period at the beginning because there is consumption, but there is no supply. So, within this deficit period we see the maximum value is 127 then there is an excess period and within this the maximum value is 442.5.

Then we have got another deficit period and here we have one maximum ordinate and then again, a positive period where we have a maximum value of 427. So, out of these two positive periods or excess periods we see that the maximum ordinate is 442.5 during the excess period and minus 127 is the maximum ordinate during the deficit period. So, their summation is the storage capacity. Then we have to add fire storage and break down storage.

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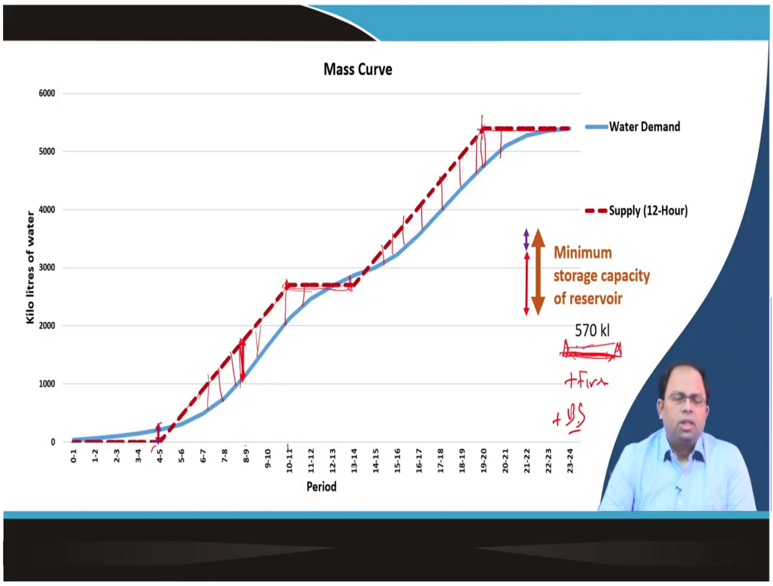


So, let us see the mass curves. In the mass curve this red line represents the hydrograph of inflow or the supply line. It is flat at the beginning and then it rises up steeply to 1800 then it remains stable at 1800s for 3 hours and then it again starts increasing. So, this is 1800 and this is at 11th hour. So, we draw a straight line connecting this two which get the slope of supply and then again it becomes flat because no more water is supplied it remains stable at this particular level and then it again it increases right. And increases in the sense then again it is supplied it is supplied till this period again it becomes flat.

Next ordinates are measured at expected highest points and at certain intervals considering the feedback from the cumulative inflow outflow table. So, when we add the maximum ordinate at the excess and deficit period we get a storage capacity of 570 kilolitres. So, for the same consumption but different pumping hours and pumping strategy we can reduce the overhead reservoir size to 570 kiloliters from 990 kiloliters. So, whenever we design the hydraulic network or we do the hydraulic design for the entire distribution network we optimize the overall cost of the system by changing reservoir capacity by changing pump capacity and so on right.

So, you can see if we have used the different rating pumps which would be able to pump for 300 litres per hour instead of 150 kilolitres per hour. So, in that case we will spend more on cost on pumps, but the services our cost would be down will be lower. So, we need to find the optimum combination which would be most suitable for us and then accordingly we design the size of overhead reservoir or what kind of pumps that we are going to utilize.

So, this is how we can determine the storage capacity and; obviously, we can add fire demand plus breakdown storage within this particular capacity and then we can determine the overall reservoir capacity. So, this is how we solve the reservoir capacity problem using the mass curve method or we can follow an analytical approach as we have done over here and using both ways we can actually solve this problem.

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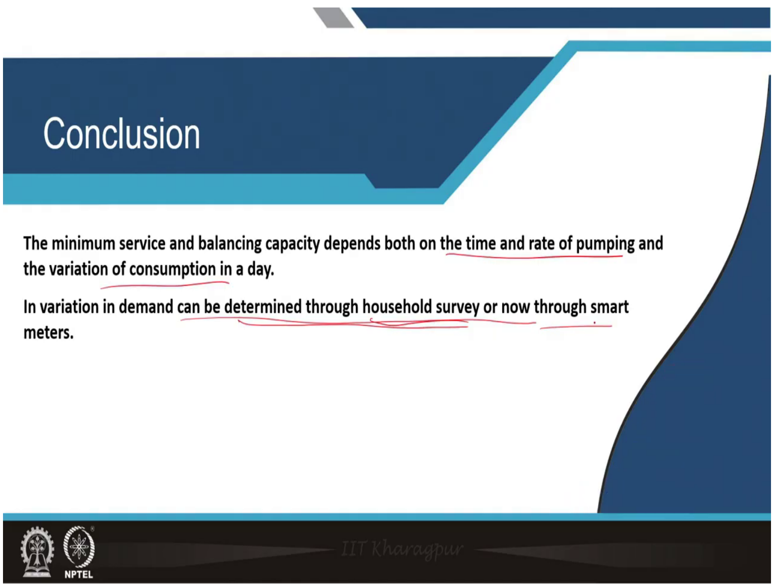

So, to conclude the minimum service and balancing capacity depends both on the time and the rate of pumping and the variation of consumption in a particular day. So, you see that both the time and rate of pumping is important and that actually determines the balancing capacity; obviously, the consumption pattern is more or less fixed for a particular area or a particular country.

So, based on both these we can determine the balancing capacity and variation in demand can be determined through household survey or now through smart meters. Smart meters can send a feedback how much is being consumed by each household during different time periods of the day. In case smart meters are not present we can conduct household survey and ask people about when they go to school what kind of school or offices and what kind of water is being used throughout the day.

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So, these are some of the references that you can follow.

Thank you.