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Lecture-21
Practice Problems on Reservoir Capacity Estimation

Hello friends and welcome back. So, we are in the last lecture of this week. This week we have discussed about water storage structure and we started with the necessity of the storage and then we did talk the raw water storage structure and the treated water storage structure. And in the last class we discuss how do we estimate the storage capacity of the reservoirs. So, this class we are going to see some practice problems on Reservoir Capacities Estimation.

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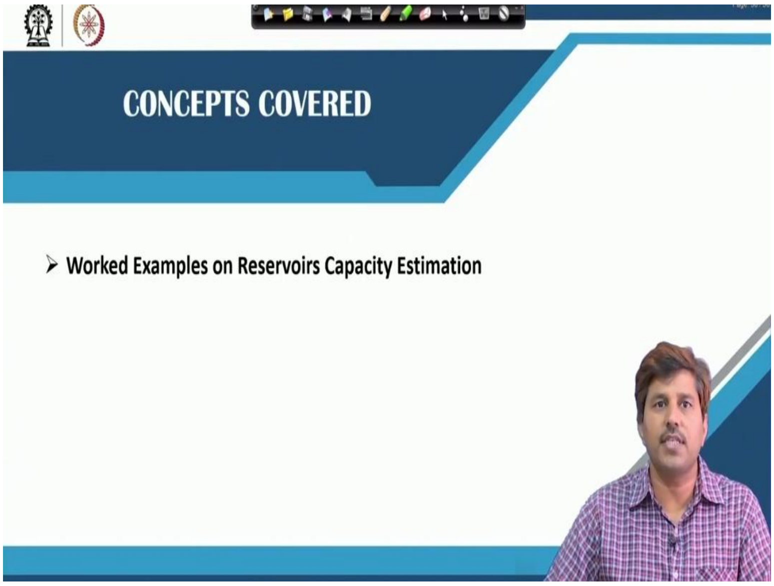

Eventually we will be taking some worked examples on Reservoir Capacities Estimation.

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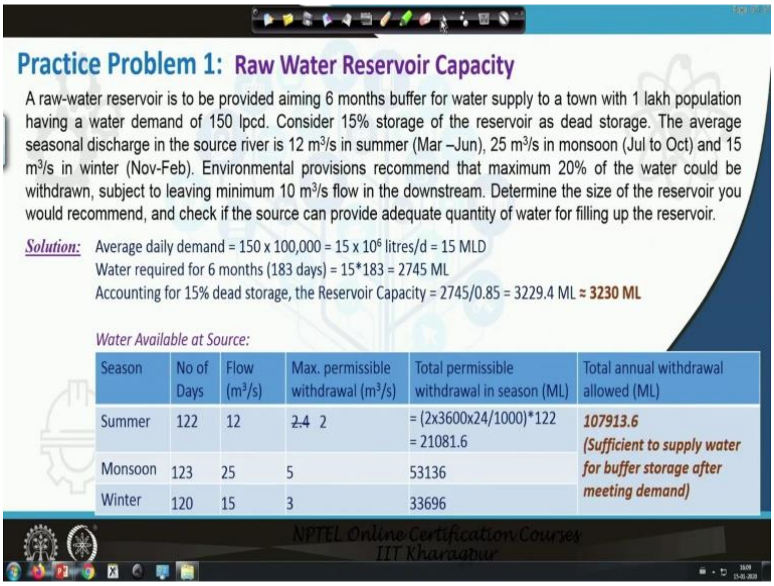

So, to begin with the first problem that we are going to discuss is on the raw water reservoir capacity. So, the question is a raw water reservoir which is aiming to provide 6 months water buffer for a water supply system for a town with 1 lakh population and average demand is given as 150 lpcd. So, the important information that we have is we need 6 months buffer we have 1 lakh population and we have a water demand of 150 litres per capita per day. Further we have to consider 15% storage of the reservoir as dead storage.

So, the dead storage is 15%. Now, the criteria given is that the average seasonal discharge in the source river is 12 meter cube per second in summer, which is from March to June, 25 meter cube per second in the monsoon period from July to October and 15 meter cube per second in winter period. There are environmental restrictions on the extraction of water and they recommend that maximum 20% of the water could be withdrawn from the river and this is also subject to living minimum 10 meter cube per second flow in the downstream.

So, we need to determine the size of the reservoir and check if the source has adequate quantity of water for filling up the reservoir. So, based on the information given we can estimate the average daily demand, we have the 150 litres per capita per day demand and population is 1 lakh. So, eventually if we multiply this will get 15 into 10 to the power 6 means 15 million litres per day of water is required for that particular town.

If we intend to provide 6 months buffer, which is the 183. So, we multiply 15 with 183 and the buffer quantity that we need for 6 months is 2,745 million litres. Now, for reservoir to stood this much of water or to ensure this much of water can be supplied, which has 15%

dead storage. So, if the total volume of reservoir is V, so, that means 0.15 V is the dead storage.

So, effective storage volume we have is 0.85 V, so, that 0.85 should be equal to 0.85 times of the volume should be equal to this number. And then we can get the reservoir capacity by dividing this by 0.85 which comes to 3229.4 approximately 3230 million litres of, 3230 million litres should be the capacity of the storage reservoir, okay, what we are going to plan. Now the second part is do the source have enough water to fill this?

Okay, so now let us check that.The water availability at source. So, we have different discharges in 3 different seasons in the Summer season, we have 12 meter cube per second discharge in the 3 months from March to June that accounts for 122 days, Monsoon 123 days the discharge is 25 meter cube per second and Winter of 120 days the discharge is 15 meter cube per second. The criteria is that we can withdraw maximum 20% of the flow in the river.

So, now if we go by that 20% criteria here 20% of 12 is 2.4, this is what maximum we can withdraw. 20% of 25 is 5 and 20% of 15 is 3 metercube per second. So, this much amount of water can be withdrawn from the source. However, there is another criteria that we should lead minimum 10 meters cube second flow in the downstream. So, here it is fine, here also it is fine, but here if you withdraw 2.4, we are going to leave here just 9.6, so, which is against that criteria.

So, maximum though by 20% it comes 2.4 but maximum we can withdraw here is 2, so, we can withdraw 2, 5 and 3. Now, total permissible withdrawal in that season if we estimate,so, 2 meter cube per second means if we multiply it with 3600 into 24, we get meter cube per day or we divide it with the 1000 we get million litres per day and we have 122 days in that season.

So, total in the summer season the amount we can withdraw further we multiplied with 122. So, this comes out to be 21,081.6 million litres; here it comes out to be 53,136. So, total what we get is 107,913.6 million litre water which is more than enough to kind of fill the reservoir which has a capacity of just 300,230 million litres. So, this should be the capacity and we have sufficient amount of water permissible withdrawal whichcan fill the reservoir completely.

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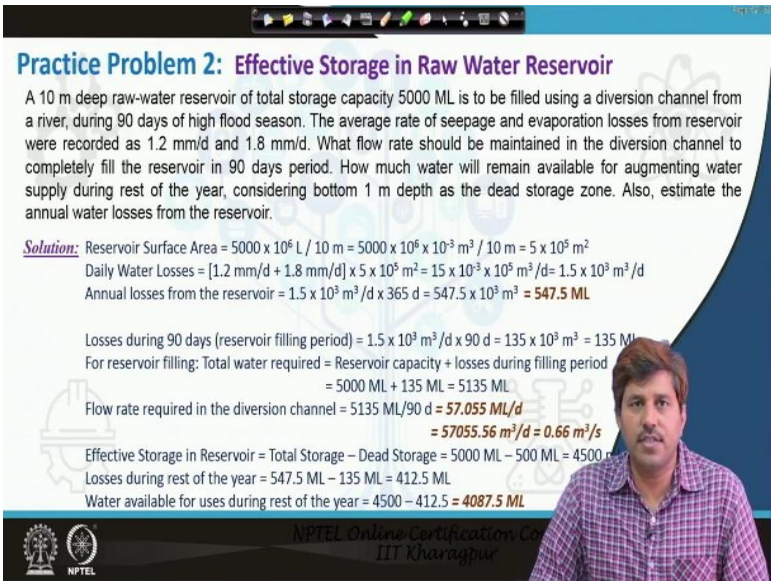

Okay, let us move to the 2nd problem. So, which is on the effective storage in the raw water reservoir. So, the question we have is 10 meter deep raw water reservoir of total storage capacity 5000 million litres is to be filled using diversion channel from a river during 90 days of high flood season. So, the important information given us is the capacity total storage capacity of the reservoir is 5,000 million litres, the depth is 10 meter and it has to be filled in 90 days period.

Again, there are seepage and evaporation losses from reservoir is also given which is 1.2 millimetre per day and 1.8 millimetre per day,millimetre per day essentially means it is per unit area okay like we measure rainfall we measure evaporation all in terms of all generally represent in terms in the units of millimetre per day. That means from unit area, the total thickness or depth of water which evaporates is say in this case 1.8 millimetre, the total water that seeps through unit area is 1.2 millimetre in a daytime Okay.

Now, we need to determine the flow rate which would be maintained in the diversion channel to completely fill the reservoir in 90 days period. And we also need to see how much water will remain available for augmenting water supply during rest of the year, where we consider 1 meter depth as the dead storage zone.

So, total depth is 10 meters, if total reservoir depth is 10 meter and out of 1 meter is dead storage zone that means, it is basically 10% of the 5000 million litres. So, that means our dead storage zone is actually equal to 500 million litres okay. Also we need to estimate the annual water losses from the reservoir. So, we have been given the capacity means the volume of reservoir and the depth.

So, we can get the plan area or surface area of the reservoir, Okay so 5000 million litres mean 5000into the power 6 litres and depth is 10 meters. So, 5000 into the power 6 in litres and we further multiply it with 10 to the power -3 to get it into the meter cube and divided with the depth, so, we get 5 into 10 to the power 5 meters square as the area and as we said that the losses will be estimated are actually given us per unit area.

So, we have to multiply it with the area in order to get the total losses. So, daily water loss is 1.2 millimetre per day to seepage and 1.8 millimetre per day through evaporation that means total 3millimetre per day is the last and this is our plan area. So, 3 millimetres into 5 in that means 15 and it is a millimetre, so, we multiply with 10 to the power -3 to get into the meter and 10 to the power 5 is already there of area.

So, this much this also millimetre is also converted to meter and then we already had meter square as area so, we get in meter cube per day which comes out to be 1.5 into 10 to the power 3meter cube per day as the daily water losses. So, and well water losses which we need to determine we have to multiply the daily water losses with number of days in a year. So, 365 and what we get is 547.5 into 10 to the power -3 meter cube or 547.5 million litres water getting lost from the reservoir annually. So, that is one thing which we need to determine.

The losses during the 90 days period when we are filling the reason, it is important because, if you see, let us say this is our reservoir, this is our reservoir and we have a divergent channel filling it and it is taking 90 days period. So, in this 90 day when we are filling the reservoir, during this 90 day also there is a seepage and there is evaporation taking place.

So, if we estimate the capacity only for like based on the reservoir volume, how much water needs to be like if we send just 500 million litres of water there, but in this 90 days we will see that 135 million litre water seep so, we are actually reservoir will never reach the 500 million litres water. So, we have to send 5000 million litres water for reservoir filling plus 135 million litres water for compensating these losses.

So, we have to basically for filling the reservoir we have to send that 5000 plus 135 million litres water. So, the total water that would be needed is 5000 million litres plus 135 million litres. So, that is 5135 million litres water would actually be needed. This 135 million litres water is coming from the 90 days our water loss. So, flow rate required would be because we total need 5135 million litres water and this is to be supplied in 90 days.

So we divided this with 90 days. We get 57.055 million litres per day or in millimetrecube per day or approximately 0.66 meters per second water should be there in the diversion channel, okay. The effective storage of the reservoir if we need to determine, so, we have the total storage of the reservoir which is 5000 million litres per day minus there is a dead storage of 1 meter depth.

So, 1 meter into this cross-sectional area, so, if you multiply that with 1 meter, what we get is 500 million litres okay, or as we said that we can take 10% because of out of 10 total depth one meter is the dead storage so, 10% of the total capacity is dead storage. So, that becomes 500 million litres. So, the 500 million litresis dead storage, 5000 million litres is the total storage. So effective storage we get is the 4500 million litres.

Now losses in 1 year is 547 but 90 days is during the filling period 135 which we have already compensated for. So, during the rest of the year when it is actually being used the losses will be this is the from year and this is from the 90 days. So, the rest of the year losses is going to be 412.5 million litres. So, we subtract this losses from the effective volume what we had 4500. So, what we get is 4,087.5 million litres water as the water which can be used okay. So, that way we get the effective volume of water which can be used.
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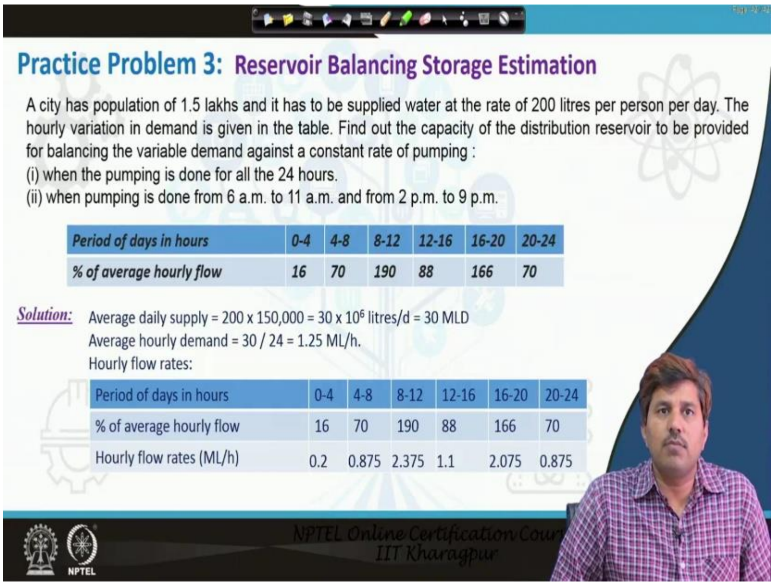

Now, we move to the next problem, which is the reservoir balancing storage estimation. And this is onto the distribution side. So, basically treated waters. A city has a population of 1.5 lakhs and it has to supply water at a rate of 200 litres per person per day. The hourly variation in the demand is given in this table. So, we have given the hourly variation in the demand as this and we need to find out the capacity of the distribution reservoir for providing the balancing is storage.

We have been given two conditions when pumping is done for 24 hours and the second condition is when pumping is done from 6 am to 11 am and from 2 pm to 9 pm. So, in any case we have population as 1.5 lakhs and per capita demand as 200 lpcd. So, total if we multiply we get 30 million litres per day as the water requirement and the in first case when we are actually considering 24 hours supply.

So, average hourly demand, because total demand is 30 million litres per day and average hourly demand is going to be 1.25 million litres per day. Now, hourly flow rate if you see 1.25 million litres per day will also be the flow rate when we are pumping around the clock, otherwise, this is the average demand over the entire day.

The hourly flow rate is given to us so, 0 to 4, our percentage of hourly flow is 16; from 4 to 8, it is 8 to 12,190; 12 to 16, 88; 16 to 21, 166, that way we have been given. So, mean 16% of 1.25 is 0.2. again 70% of 1.25 is 0.875 and 90% of this is this, so, we can get the hourly flow rate also further demand. So, what is the flow rate of the demand now? As discussed earlier.

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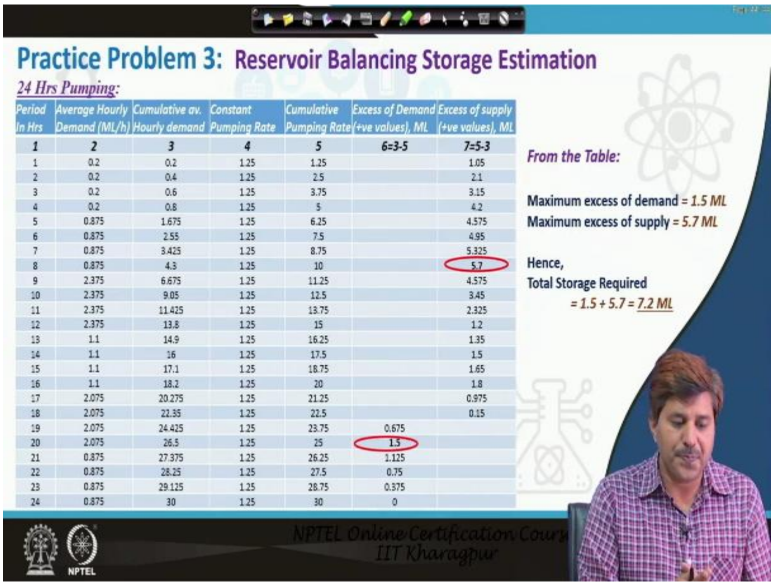

Period In Hrs	Average Hourly Demand (ML/h)	Cumulative av. Hourly demand	Constant Pumping Rate	Cumulative Pumping Rate	Excess of Demand (+ve values), ML	Excess of supply (+ve values), ML
1	2	3	4	5	6=3-5	7=5-3
1	0.2	0.2	1.25	1.25		1.05
2	0.2	0.4	1.25	2.5		2.1
3	0.2	0.6	1.25	3.75		3.15
4	0.2	0.8	1.25	5		4.2
5	0.875	1.675	1.25	6.25		4.575
6	0.875	2.55	1.25	7.5		4.95
7	0.875	3.425	1.25	8.75		5.325
8	0.875	4.3	1.25	10		5.7
9	2.375	6.675	1.25	11.25		4.575
10	2.375	9.05	1.25	12.5		3.45
11	2.375	11.425	1.25	13.75		2.325
12	2.375	13.8	1.25	15		1.2
13	1.1	14.9	1.25	16.25		1.35
14	1.1	16	1.25	17.5		1.5
15	1.1	17.1	1.25	18.75		1.65
16	1.1	18.2	1.25	20		1.8
17	2.075	20.275	1.25	21.25		0.975
18	2.075	22.35	1.25	22.5		0.15
19	2.075	24.425	1.25	23.75	0.675	
20	2.075	26.5	1.25	25	1.5	
21	0.875	27.375	1.25	26.25	1.125	
22	0.875	28.25	1.25	27.5	0.75	
23	0.875	29.125	1.25	28.75	0.375	
24	0.875	30	1.25	30	0	

We need to basically see the cumulative demand versus cumulative pumping rate okay. So, this is the same table that we discussed in the previous lecture. Here we have entered those numbers. So, now there is a 24 hours time that we have and average hourly demand for the demand curve. So, as we said from hour 1 to 4 it is the 0.2, then 4 to 8 it is 0.875, 9 to 12 it is 2.375 then 1.1 then 2.075 and then in the end 0.875. So, this is the average demand during that particular hours.

For cumulative demand, for 1st hour it will remain the same for 2nd hour2+0.2, 0.4+0.2, 0.6+0.2. 0.8 and 0.8+0.875 then 1.675+0.875. So, this way we like keep on adding this in order to get the demand here. So, that way we can estimate the cumulative demand when the pumping is done for 24 hours, so, we have a constant pumping rate which is 1.25 and cumulative pumping rate again 1.254 first then you add 1.25 it becomes 2.5, 3.755 so, that we will get the cumulative pumping rate.

Now, we can estimate the excess of demand and excess of supply. So, as discussed in the previous class for axis of demand we have to multiply, we have to subtract the supply from the demand. Okay, so supply is the pumping rate so, we subtract 5 from the 3 in order to get the excess of demand and we note down only positive value, so all this is turning negative only positive numbers we have here. Similarly, the axis of supply again we note down the positive numbers when we subtract thedemand from the supply.

So, column 5- column 3 again note down the positive numbers. So, we get this. So, from this table we need to note down the maximum axis of demand and maximum axis of supply, so maximum axis of demand we can see is 1.5 is the highest number here and 5.7 is the highest number here. So, we note down these two we add and 7.2 becomes the capacity of the reservoir. Now, for the same problem.

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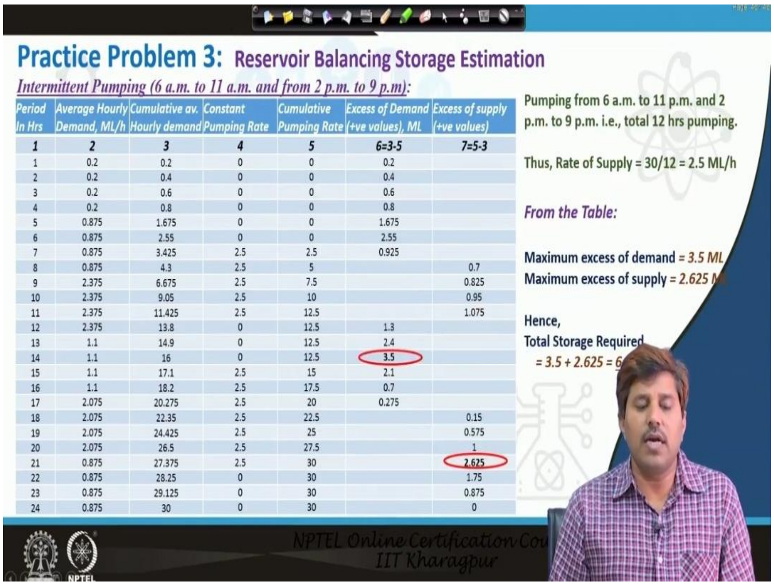

If we are doing pumping intermittently, so, like 6 am to 11am and 2 pm to 9 pm. So basically 6 am to 11 am pumping and 2 pm to 9 pm pumping that means total 12 hours pumping we are talking about Okay. Now, total water that needs to be pump is 30 million litres and in if we are pumping that in 12 hours, so the rate of pumping has to be 30 by 12. So, 2.5 million litres per hour, when we are pumping it for 24 hours the rate was 1.25 when we are pumping for 12 hours, the rate would be of course, be doubled because the pumping hour is half.

So, instead of 1.25 our pumping rate is 2.5 million litres per hour. Again, we do the similar exercise, these remain same the demand portion still remain the same. For supply portion now, we donot have any pumping till the first 6 hours from 6 hour onwards like6 to 11 we have pumping 2.5 and then again from 11 to 2 we have no pumping and from 2 to 9 pm again we have pumping at a rate of 2.5. So, cumulative 0 up till 6 and then from here building it will start building.

So, first like on the 7th hour it will be 2.5 on the 8th hour 5 then 7.5, 10, 12.5 and then again pumping stops which will remain as 12.5 till the pump starts again. So, then it becomes 15 17.5 and at the end it will be 30. So, we do the similar exercise we subtract pumping from the demand okay in order to get the axis of demand and no down the positive number. So, earlier we are just getting 1 slot a positive number now, we are getting 2 slots a positive number here and excess of supply again we subtract demand from the supply in order to get the axis of the supply and note, when we note down the positive numbers.

So, we can see that from these data the maximum value here which is the maximum access of demand is 3.5 million litres and the maximum access of supply is 2.6 to 5 million litres. So, total it is 6.1 to 5 million litres. So, that way we can estimate the capacity of the reservoir in this case when the pumping is intermittent.

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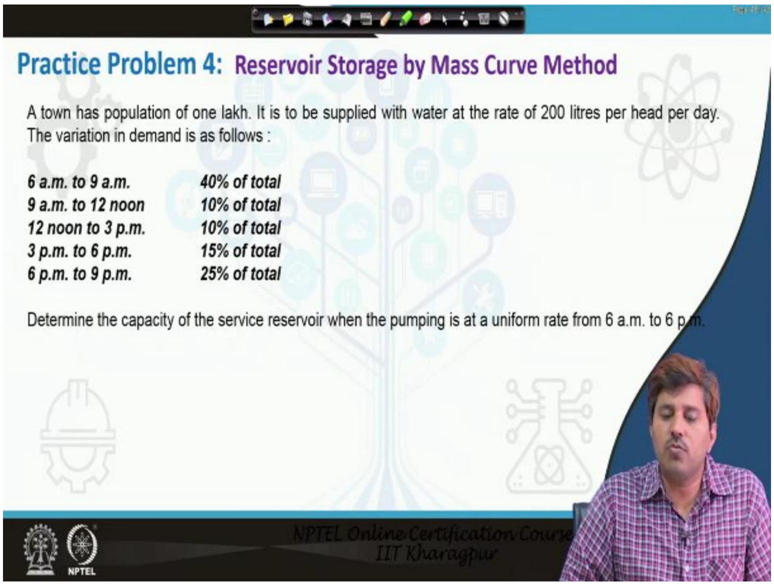

We move to the next problem which is about a town which has population of 1 lakh it has to be supplied water at a rate of 200 litres per head per day. The variations are given to us 6 to 9, 40% of the total; 9 to 12, 10% of the total; 12 to 3, 10% of the total;3 to 6, 15% of the total; and 6 to 925% of the total. So, here even the demand is not round the clock okay demand is also distributed between just 6am to the demand is also distributed between 6 am to 9 pm.

So, demand is also distributed in these 15 hours and beyond these 15 hours there is no demand or negligible demand okay. And the pumping is done at a uniform rate from 6 am to 6 pm. So, pumping is done for 12 hours whereas demand we have is for 15 hours and total demand we can estimate okay the population is 1 lakh. So, 1 lakh and the per capital supply is 200 litres. So, 1 lakh into 200 litres will.

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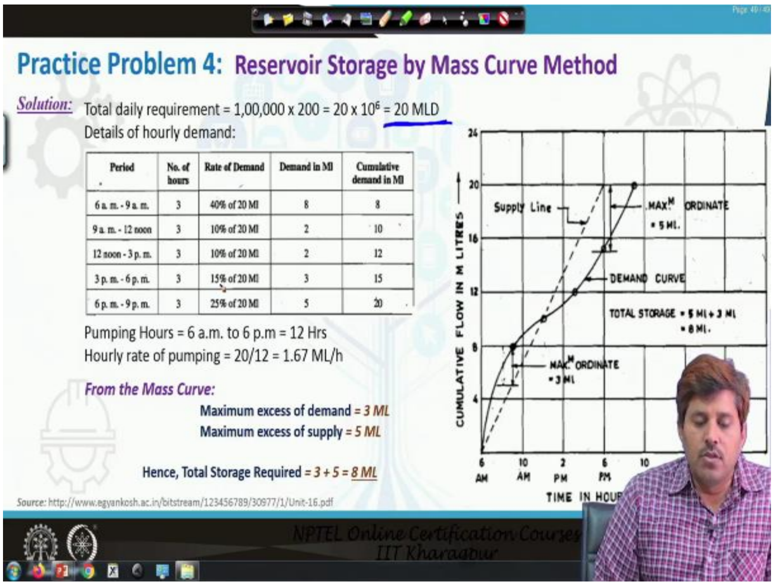

Eventually give us 20 million litres per day okay. So, what we have is 20 million litres per day water requirement and which is distributed in 3 hours 5 slots as 40% 10% 10% 15% and 25%. So, means 6 to 9 requires the 40% of the total water So, 40% of 20 million litres becomes 8 million litres 9 to 12 requires 10% of the 20 million litres that is 2, again 12 to 3 requires another 10% means another 2 million litre, 3 to 6 pm requires 15% that means 3 million litres and 6 to 9 pm requires 25% of the 20 million litres that means 5 million litres.

So, this is the demand. And if you see the cumulative demand now, so, at 9 am cumulative demand is 8 at 12 am cumulative demand is 8+2 means 10, at 3 pm cumulative demand is 10+2 is 12, at 6 pm 12+3 is 15 and then 15+3 as 20. So, by the night we get the total demand 20 cumulative demand. Pumping hours are 6 am to 6 pm that means, 12 hours pumping, hourly pumping rate is 12 by 20 is total requirement 20 by 12.

So, that is 1.67 million litres per hour. Okay. This is our constant pumping rate. Now, let us use the concept of Mass Curve which we discussed in the previous class. So, for Mass Curve again we can make a graph in where time is on the X axis and cumulative flow is on the Y axis. Now, time we have 6am 10 2 610 22 that way means, let us say for our slot is taken here, we can have a little bifurcation also. So now at 6 am, the demand is 0 and supply is also 0.

So, we may consider 1 point here. At 9 am, the cumulative demand is 8. So 9 am would be here and at 9 am will have cumulative demand as 8 so we get one point here. At 12 noon, again in between this 12 noon, we have another point here, okay, which is 10. Okay because at 12 noon our total cumulative demand is 10 At 3pm our cumulative demand is 12. So, at 3 pm our cumulative demand is 12.

So, we have another point here then at 6 pm we have cumulative demand as 15. So, at 6 pm we have cumulative demand as 15 and at 9 pm we have cumulative demand as 20. So, at 9 pm this becomes our cumulative demand 20. So, we got these points now, if we join these points through curve, so, we get our demand curve. Okay, so, let us say this becomes our demand curve just joining these points with a smooth line Okay.

Then, the supply line is constant, we know that we have to pump 20 million litres water in 12 hours and the average pumping rate is 1.67 million litres per hour. So, we can take a draw line with that slope or straight forward, we have 1 point at 6 and another point at 6 pm. And we need these to be the straight line because it us a constant rate of pumping. So, this becomes our supply line.

So, we have the demand line, we have the supply line, we need to kind of see the maximum ordinate. So, we can find here graphically and then that will give us the maximum ordinate which is 5 million litres in this case and the maximum ordinate here is 3 million litres in this case, so this essentially is the axis of supply and this essentially is the axis of demand. So here what we can see is demand is higher than the supply.

So, this is axis of demand is 3 million litres and this is axis of supply or this ordinate is actually 5 million litres. So, from graph from Mass Curve graph also we can see that this is how we get the two values or maximum axis of demand 3 million litres maximum axis of supply 5 million litres. Total storage required would be summation of these 2. So, 3 million litres+ 5 million litres we some we get 8 million litres as the total storage required. So, this way we can estimate the capacity ofthe reservoirs.

So, these were a fewexamples generally, these are the concepts which are followed and this remember is going to give us the balancing storage only Okay, for the overall storage capacity of the reservoir we have to have another provisions like we can estimate the fire storage based on the fire demand requirements which we discuss during the water demand in the 2nd week of this course.

So, as we discuss the fire demand, so fire demand may be estimated and we may have a provision for fire storage in the reservoir, we may have a provision for dead storage in the reservoir or we may have provision for some buffer or some free board in the reservoir. So, overall capacity can be estimated that way but the major component the balancing is storage, which serves the most purpose of the reservoir can be estimated through this means okay so, either analytical means are through Mask Curve methods, as we discussed.

So, with this we conclude discussions for this week and next week we are going to start discussing about the quality aspects and water treatment. So, thank you for joining and see you next week.