Water and Waste Water Treatment
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Lecture - 31
Water Demand

Hello everyone, welcome back to the latest lecture session. Until now, , we covered a bit more than half of the content that we wanted to cover. So, the course is waste water, half of it - water, the other half of it. Waste water or needs and objectives are different. In the context of water, , the objectives are different. Let us look at what it is that we did in the context of waste water, a quick summary.

What do we have? We have particles like cloth rags and so forth, we have heavier particles like grid, inert particles, which will settle pretty fast. So, preliminary treatment and then we have suspended particles in the waste water, primary treatment, gravity are friends. And then we have mostly soluble COD or BOD and we use the bacteria or nature as our friend.

We supply oxygen, we degrade it, it meaning the BOD or the organic content and we form floc forming bacteria or microorganisms pardon me and they form flocs or heavier settled down and then we looked at nitrogen and phosphorus removal. Yes and then we looked at disinfection, relatively more, , encompass. In the context of water, what is it that we are concerned about?

So, depending on the source, , you can have what we said toxic compound present or first, then the kind of treatment mechanism that you would choose would be different. But we are going to look at the general cases while covering the different kinds of techniques that you can use or modify or employ according to the needs. Overview, where do we get the water from? Typically surface water, if surface water or good quality surface is available, in general, with respect to or constrain the water stress.

In India, good quality surface water or even surface water of any quality is not usually available. So, people end up what we say drilling, personal, municipal not municipal, groundwater pumps or pumps to pull out or pump up the groundwater and use it. But in quite a few municipalities, you still have piped drinking water being distributed; one hour in the morning, one hour in the night .

So, let us look at the principles and hopefully , in the coming decade, we will be in a much better off position. Let us see where we are.

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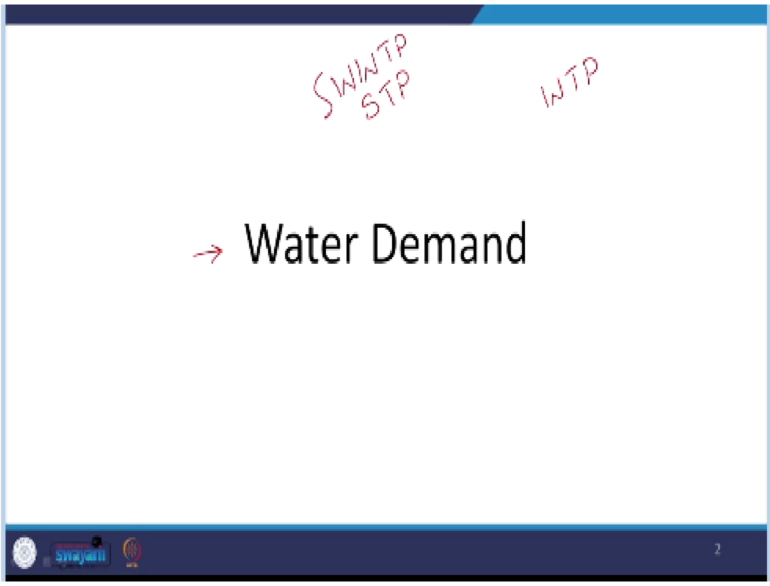

So, when I am going to design a plant, a water treatment plant, earlier, we used to call with respect to waste water, we used to refer to the plant as sewage treatment plant, sometimes as waste water treatment plant, , different people different ways. I am going to call this drinking water treatment plant as WTP. Fine.

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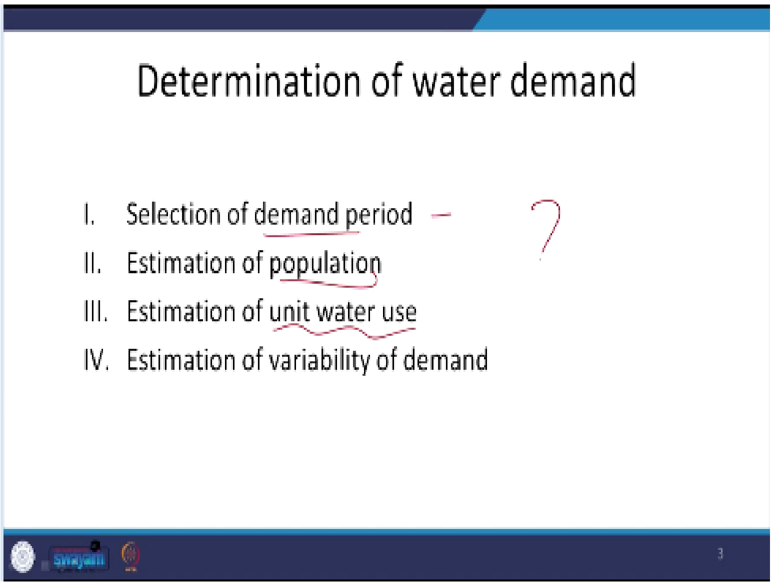

Water demand that is something that we need to be able to look at. So, why do I need to do that? , I need to know, what is it or for how much capacity should my plant be able to cater it? Or what should be the capacity of my plant? So, for that, , what do I need to do? Or what do I need to consider? For example, I can look at the need now and build a plant.

But the plant construction itself might take 2 years and then the population might increase, might decrease but rarely, at least stagnant or increase, and then I will be left with redundant plant pretty soon in 5 years. So, I am going to plan ahead, 30 years, typically or 25 years depending on the relevant availability of capital or the growth in that particular area.

So, how long, 20 period, 30 period, design period is something I need to consider. How far into the future? Once I do that, I then need to see what will be the population that is expected within this particular area that I am trying to cater to. So, then I need to be able to estimate the population and here comes the tricky part. People crunch numbers so on and so forth, but , human beings.

They typically do not follow or do not fit the patterns described by a set of formulae, depending on shore shell conditions, economic conditions, you are going to have growth, you can have , India, people leaving the community . But , these are aspects that we need to look into. In general, we look at the trends in the recent past and use that as an estimate.

, we also have what we say, some indication based on the kind of growth it has witnessed in the recent past that can be an indicator, we always are going to look at the census data. And then we have the 3 or 4 formula that we use. But , keep in mind that the formula only indicators, rarely will people depend only on these formula limits. So that is something to keep in mind.

So, what have I done? I am now looking at , 25 period, as years as my design period, I am able to estimate the population that will be present in this community or locality, 25 years down the line. What else I need to look at the expected, , a water demand per person or per capita? And then I will be able to calculate the relevant needs. And that is what we have here demand period, population and how much?

So, time, number of people, per person how much is it that they are going to consume. After this, I also need to consider, , contingencies, , fire that is one aspect for which people always have to design. And another aspect is, , you are going to have variation in flow or the need for water during the day. For example, we saw pretty good graphs in the context of waste water, how sewage was being generated.

And how you had higher, , water inflow into the sewage treatment plant around 11 or 12, because people wake up at 9, or , 8 o'clock and then morning ablutions and water is discharged. If water is being discharged, they will also need water. So , as we look at our day, we will use much more water in the morning, some during the afternoon and , some during the night.

So, , there will be variation in water demand every day. So, that is something we need to consider. So, these are the 4 aspects, we typically consider .

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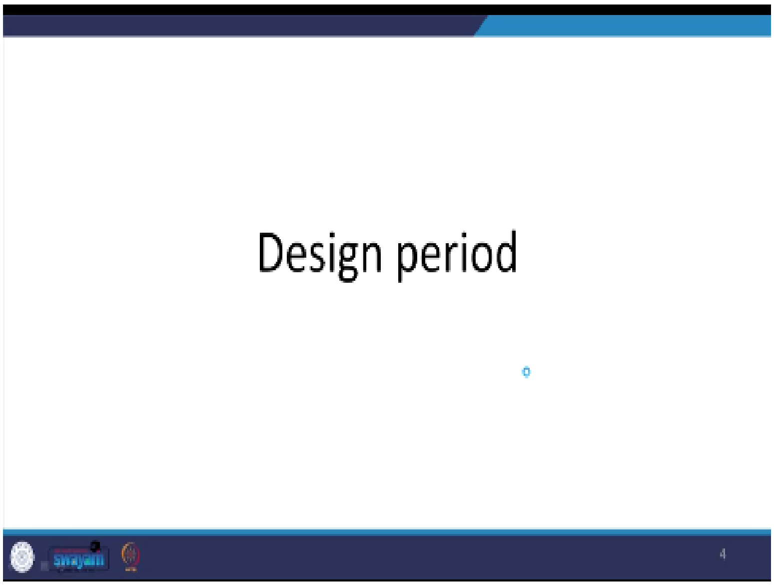

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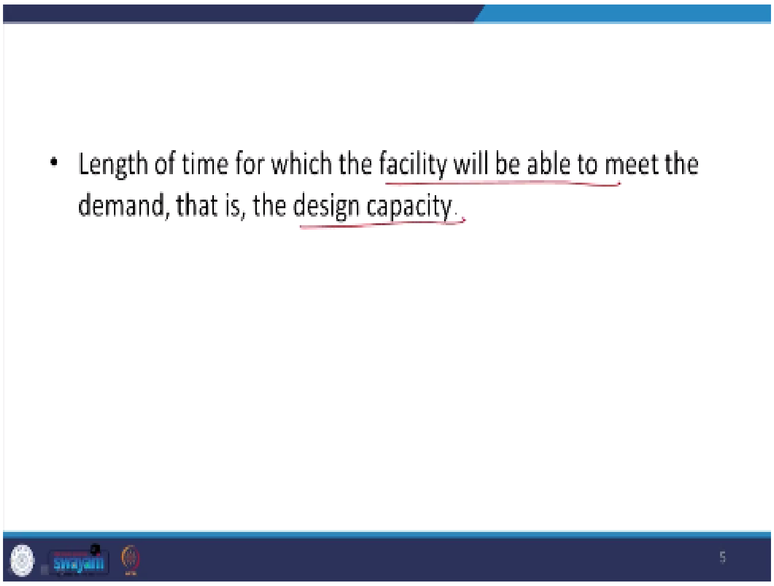

Let us move on design period. So, the time period for which the facility will be able to meet the demand or the design capacity. So, I am concerned about what will be the design capacity? So, how is it that I come up with the, what is this, design period?

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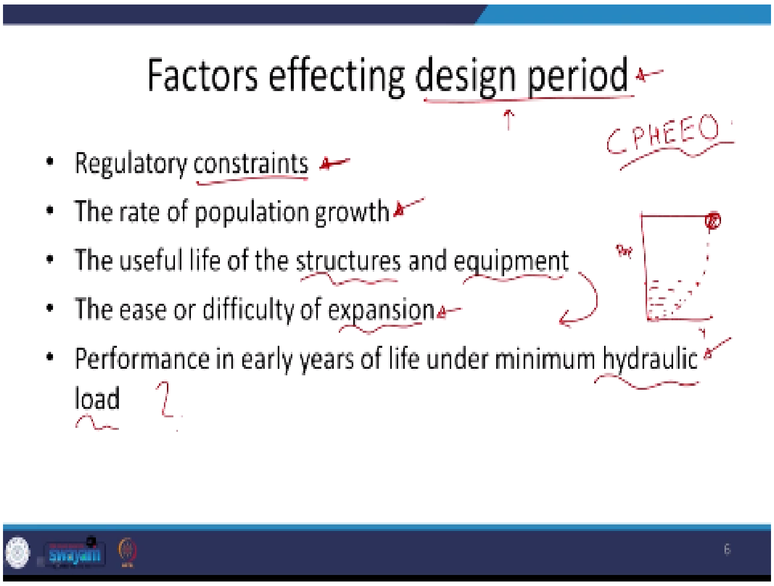

So, there are some thumb rules , you can always or should always look at this CPHEEO manual for India for different countries, they have their own, , guidelines or such, for example, in the US, I think the different states have different guidelines. So, that is one model there. So, regulatory aspects, as in government guidelines, typically how to be considered if there are any constraints, binding constraints, that is one aspect.

When I am talking about design period, , population growth comes into the picture. As if it is being explosive growth, I cannot and if it is difficult to predict, , that is another aspect. So, rate of population growth is something that we are also going to look at when I am looking at the design period. And it is not as if I can say that I am going to design it for 100 years. Why is that?

The structures that I built this with the cement or the concrete structures or the equipment that I use, , mechanical and electrical equipment that I use, how their own lifetimes. So, the cost of replacing them, maintenance and certainly their lifetimes also come into picture when we are considering the design period. Why that is tied up with how easy or difficult is it to expand?

In general, India difficult to expand earlier or even now, we still try to have the water treatment plants outside the city but with the rapid growth near the, what we say, cities or in around the cities. Now, we have the water treatment plants and even sewage treatment plants within the cities. So, , these are aspects that we need to consider why expansion due to lack of land or relevant aspects is going to be an issue.

And more importantly or equally importantly, , so, for example, my population growth is something like this. And my design, so, this is the year and this is the population. So, , this is for the design, I am designing it for this population but as you see for most of the time or quite a significant fraction of the time, the population is pretty less. So, during that particular period when there is relatively less or minimum hydraulic load, how will the plant performance?

So, that is also one aspect to keep in mind. I might not plan to capture this entire, , population growth in with only one plant, maybe multiple plants later or such. Yes. Or , standby areas or units, which can be used or set up later, . So, different aspects come into picture when we look at the design period.

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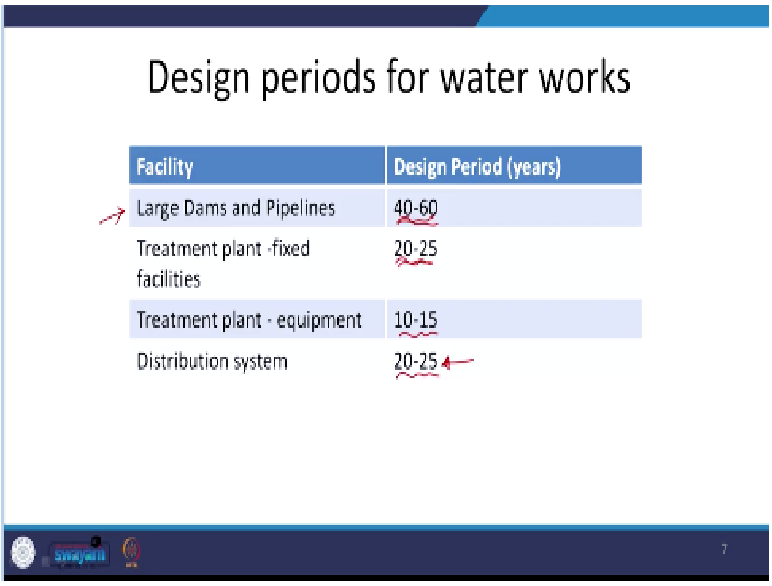

So, typical periods, , we have, , some information here, which will give us an idea. So, large dams, , people think that these are what we say, going to be there forever but , as you see, it is 1 or 2 generations, treatment plants with fixed facilities, , the facilities, concrete 2025 years, the equipment 10 to 15 years and distribution network, which is much critical aspect, at least in my point of view, at least in India.

So, 2025 years, as you see, , they have their own lifetime. So, your design periods , need to consider these aspects . So, population forecast.

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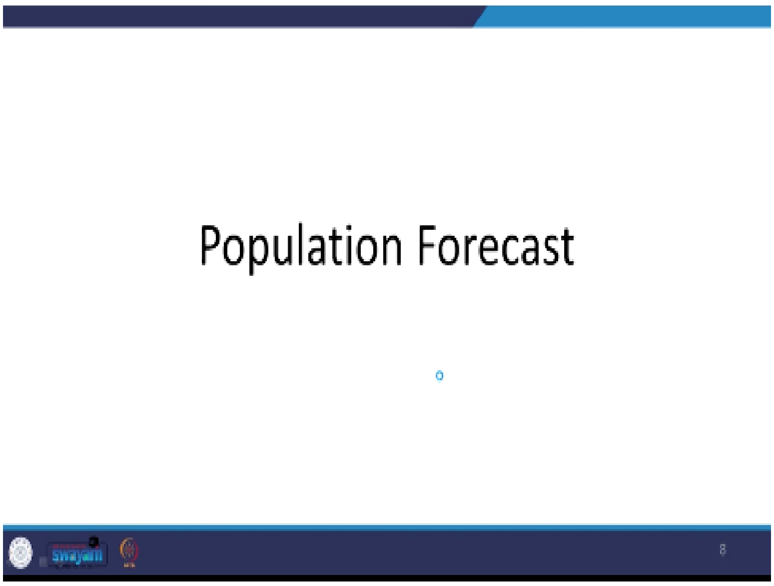

So, once I know, , which year or until which year will I try to capture or cater to the needs of the relevant population in that community, I will now need to calculate the population. So, I am going to estimate or forecast the population. So, in general, the best way is to look at data. But I will give you the example , Gaziabad not Gaziabad, pardon me, Greater Noida.

So, one of the more developed and relatively planned, , cities if I may say so, mostly just what we say, agricultural land earlier, but with the shift towards industrialization, , some people looked far ahead and Greater Noida at least they did. This was with respect to or when they were planning for the NCR that was way long ago. So, what do we have now or what did they have?

They, , divided into zones, different areas, , different land, what we say, population density per area and group housing projects and they estimated the water demand . But initially, the growth was very less and the distribution network too was patchy or water distribution network or sewage capture or sewage network too was pretty patchy. And later, there was explosive growth.

And also, this growth was not something that was constant as in when the economy was doing good, there was a floating population of almost 10 lakhs and the water network, sewage network used to be under remarkable stress. And then when the economy was not doing good, , people used to move out, , , you had issues or such issues so, considerable, , issues or , or aspects or at play.

So, , it is not as straightforward as we look at. So, population forecast, , it is not as , easy as we expect it to be from the formulas such, you have this at least in India, considerable floating population in the centres of economic activity. Let us move on.

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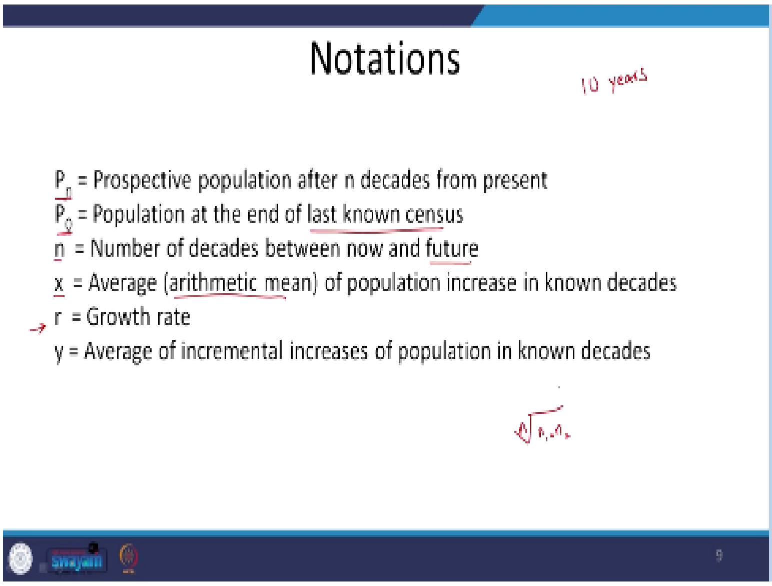

So, some variables we will come at, look at. So, this is P after n decades, population after n decades, decade is equal to 10 years, one decade equal to 10 years. P_0 or n equal to zeo now, or at the end of the last known census years, n is equal to the number of decades between now or this particular end of the last known census and the future point or time at which you want to calculate the population.

x, , different numbers or variables, you understand, but these will be clear once we look at the simple example later. So, average, which is arithmetic mean of the population increase in known decades, . So, , I look at over, look at it over a 10 year period, or not 10 year, 30 year period. So, per year, per decade, pardon me, you are going to have some increase.

And the average increase over these three decades that is what we have that is the average arithmetic mean. So, growth rate, this is dependent upon the geometric mean. Geometric mean, yes, so on and so forth. And average of incremental increase of population in known decades. We will see why or how this comes into play.

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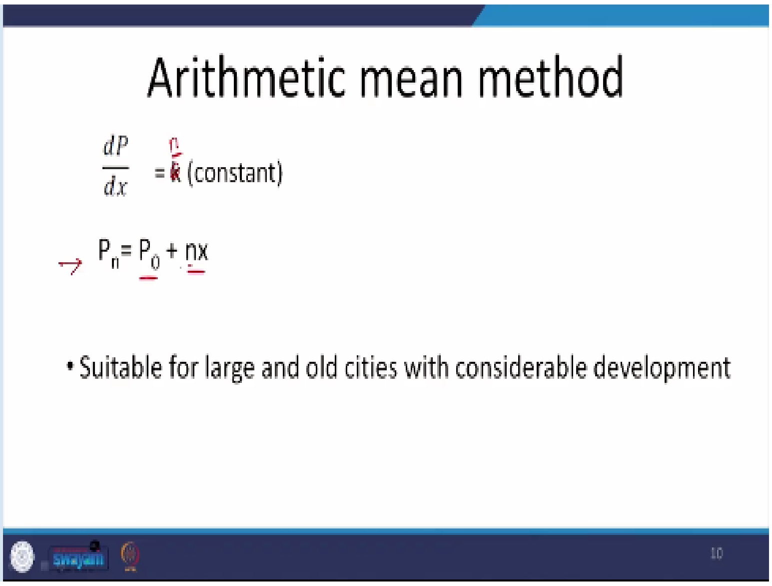

Let us look at some of the usual population forecasting methods. So, here, what do we see? This should have been n. So, this is arithmetic mean method. So, what are those? We have a base population and it is growing at a constant rate. It does the population is increasing at constant rate. If I take the derivative with respect to x, it is not with respect to x, I would say, it is with respect to x, pardon me.

So, we see that it is a constant. It is just we assume it to be constant. So, there is going to be linear increase, . So, this is the case when I know the city has been developed and occupied to the maximum extent possible and is more or less constant, , growth or sometimes even, I would not say decay, decrease, but that is rarely the case or even stagnation. So, that is what you will see that is when you will employ this arithmetic mean method.

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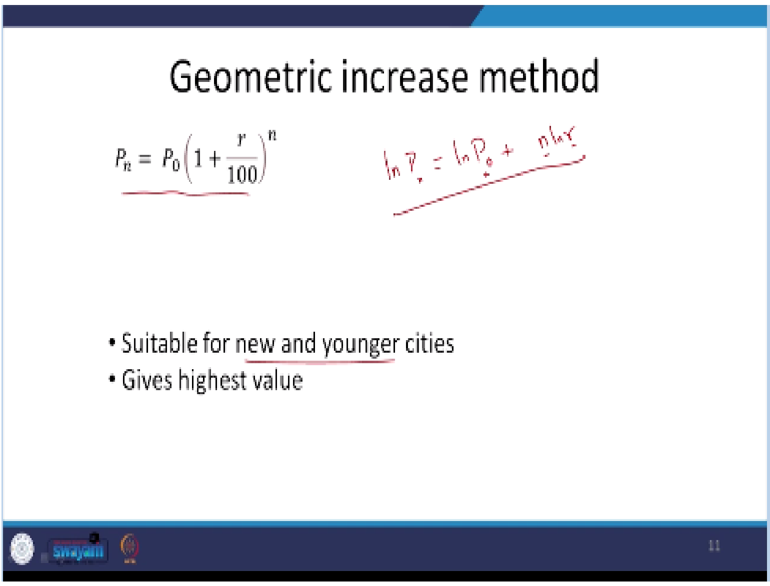

But, what about the case of Greater Noida, which we mentioned earlier, when we had explosive growth. So, then we will look at this particular geometric increase method as mentioned or , as we have or we do have here, it is for younger cities, where or especially those where people can see considerable, , sources of income and thus, quite a few people coming in , but rarely do we see this level of increase?

If we take the natural logarithm and you look at that, you will see that it is more or less similar to the exponential growth here. Let me take a short at that. So, , as you can see, it is exponential growth out here. r was the geometric mean that is something that we saw earlier; n is the number of decades; P is the population of the at the last known census; P n is the population after n decades, .

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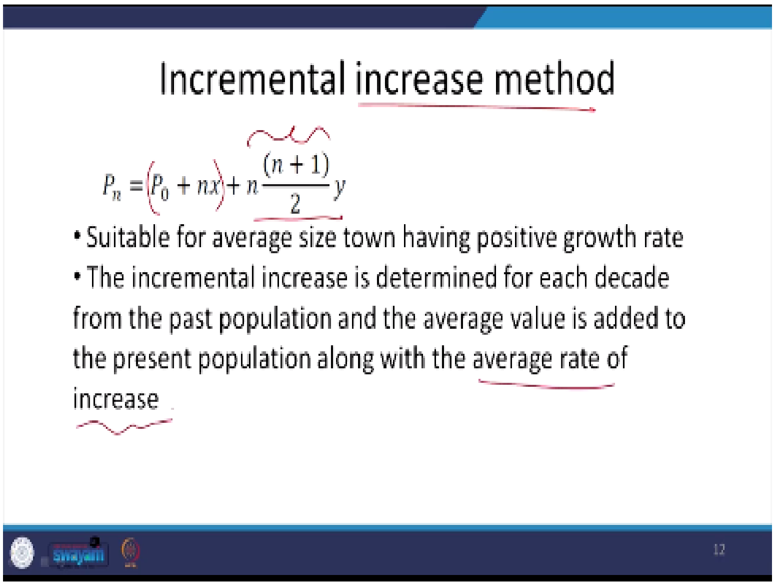

And that one is incremental increase as it is an increase, but it is going to not increase at a constant rate but incrementally. So, I will say 4, 5, 6, 7. , I just use random terms, but you understand what I am trying to get it. If you see the formula here, so, this is for that the arithmetic mean method. But here, we also have this incremental increase terms, .

And this is for cities that are not too big, not too small and has decent growth. And what is this term going to give you an idea about? The average value is added to the present population along with the average rate of increase, . , I think once we look at the relevant data, it will be clearer, . So, this is that average increase. And then the average rate of increase also is being considered here in the second term.

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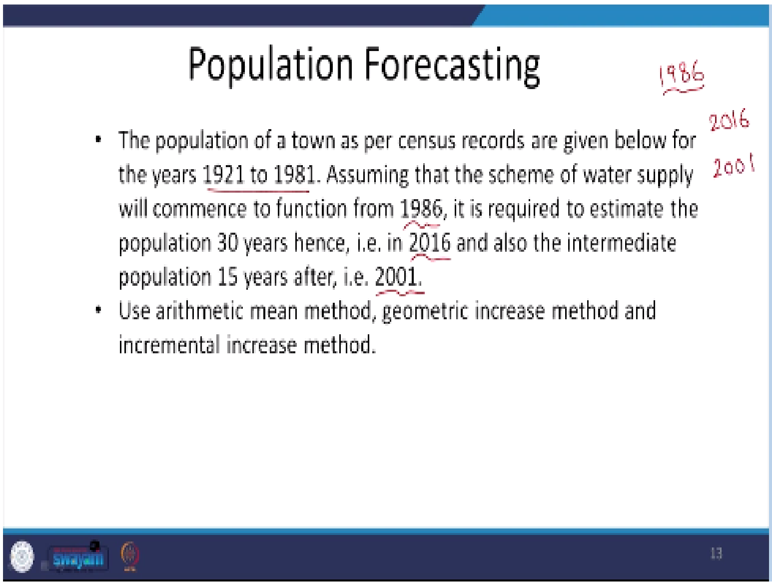

So, looks like we have one particular set of data, the population of a town as per census records is available. And assuming that the scheme of water supply will start from 1986. So, this is back to the future, it is required to estimate the population 30 years from them 2016 still back to the future and also the intermediate population after 15 years. So, we are now in the past 1986.

And they want to use the data from 1921 to 1981. To get the data or forecasts population in 2016 and 2001. So, we are going to look at all the 3 methods.

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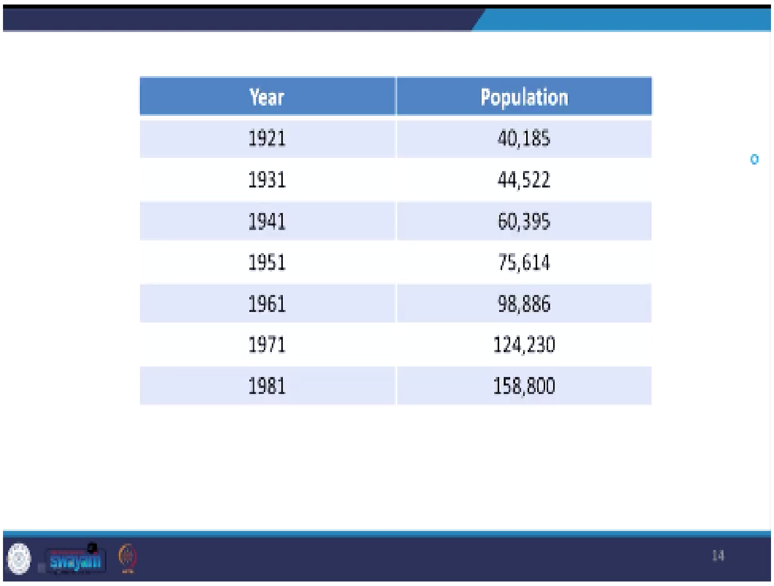

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So, first, this is the data 1921, 40, 44, so on and so forth. And if I plotted, this is what it looks like. You see that it is almost linear. If I may say so, yes, other than during the initial periods, it is more or less linear. But , we will not, what we say, look at this for now. But in general, if I was, if I had considerable information about the reasons for it or reasons for this linear growth and also looking at the economic conditions and the forecast, that is how we will be able to come up with more educated guess. Yes.

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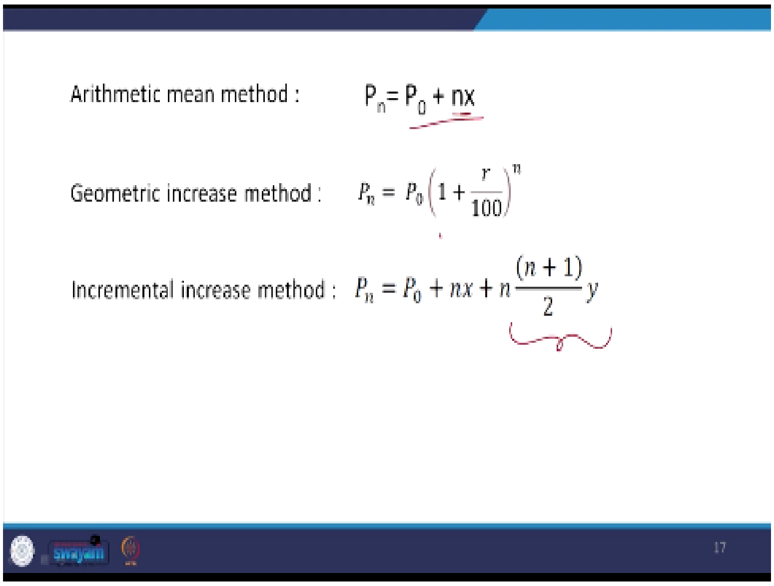

So, what do we have here? We have the 3 formula for the 3 methods, yes, constant increase, incremental increase and more or less like compound interest. This is like simple interest, like, , compound interest.

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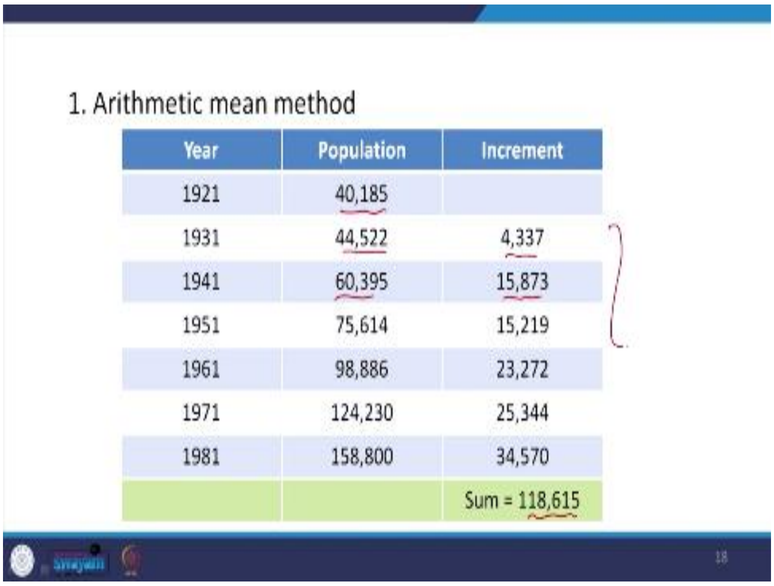

So, arithmetic mean method, this is the population. So, 44,000 minus 40,000 change, so, 4300, same case, 60 minus 4416, , 15,000 change, so on and so forth. The sum will be this, but I want to take the average of this. So, 1, 2, 3, 4, 5, 6, 1 lakhs 18,000 by 6. So, that is what is going to be my constant, .

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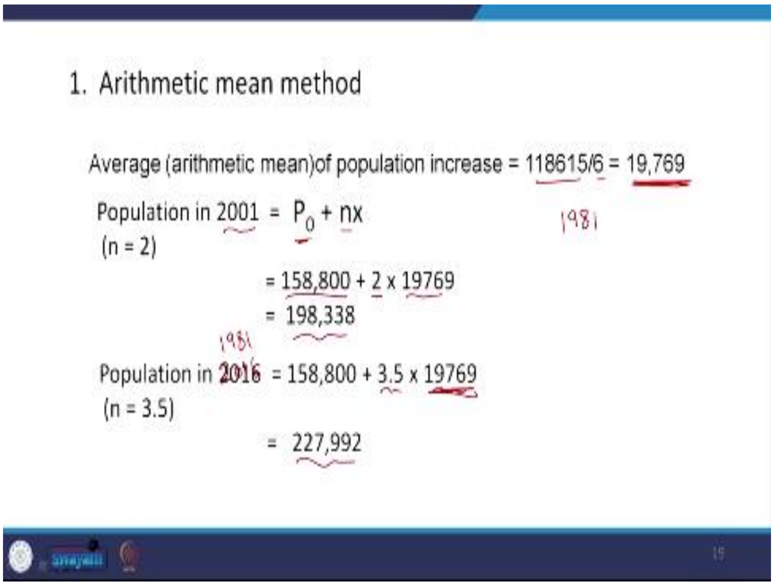

So, that is what we see here. We are assuming that the population will increase each decade by almost 19,000 or almost 20,000 that is what we have here. So, in 2001, because we were looking at 1981 data, so, 2001 so, 2 decades or 20 years, so, what do we have here? So, n is equal to 2. P 0 at the end of 1981 was this 2 decades. We are assuming that it grows at the rate of 19,769 per decade. So, 2 times and this is what I get in 2001.

And I think next one was 2016 and 1981 so, 35 years, yes, so, 3.5 decades, , constant growth, assuming that it growths at this, , 20,000 people come into the city every decade and thus, we get it pretty simple.

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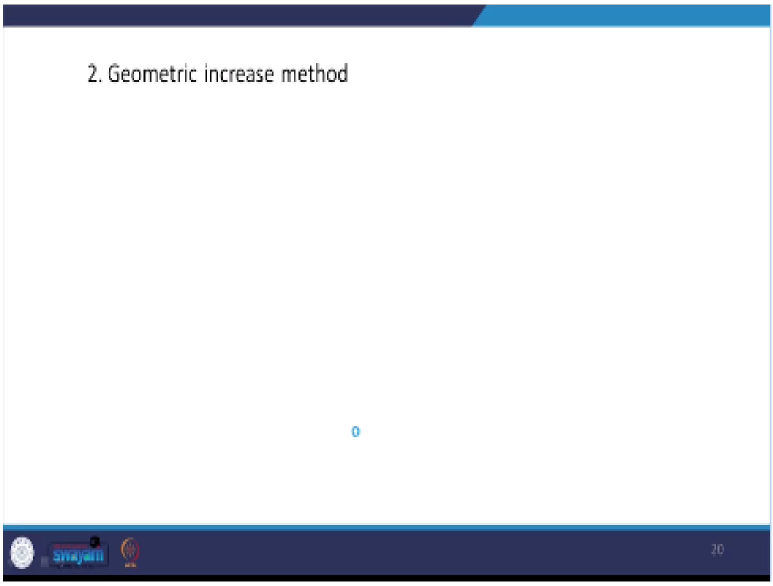

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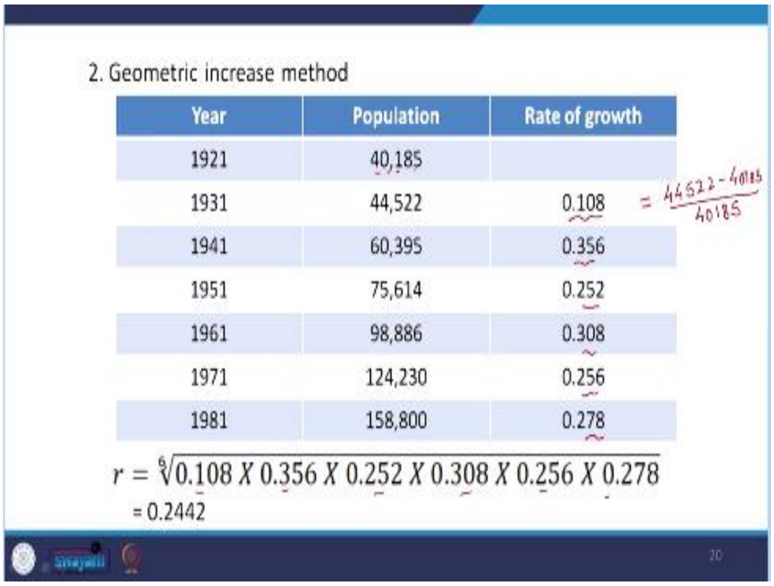

Let us move on to the geometric increase method and look at how to calculate that or such. So, here, we have the population and rate of growth. Earlier, we just looked at the actual , difference here, the difference divided by the base. So, 44,522 minus 40,185 by 40,185 that should come to this. Similarly, we have the rate of growth for that particular decade for each decade and then you will calculate are the geometric mean.

So, geometric mean 1, 2, 3, 4, 5, 6 years, yes, so, what do we get? The geometric mean is 0.244.

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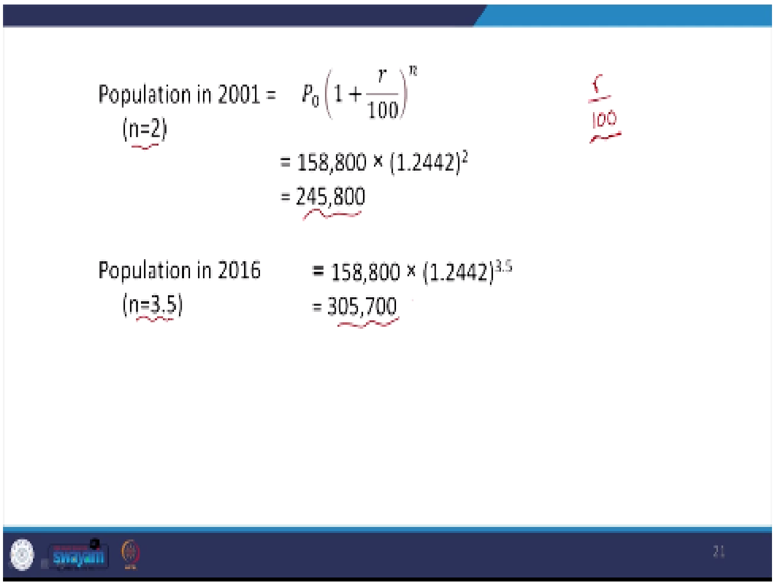

So, in the previous calculation, we already looked at r by 100. Yes, if it was percentage growth, then we would have had to divide by 100 here. But we already calculated r by 100. Earlier, yes, that is what we have. For example, if we multiplied this by 100 to get percent, then , it would have been 10.8% here and 24% growth per decade and then we would have had to divide that by 100. But , we calculate r by 100 earlier.

, different ways to go about it. it is just algebra. So, using that we can calculate the population in 2001, when n is equal to 2. Similarly, when n is equal to 3.5, we will plug it in and get this particular population.

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3. Incremental increase method

Year	Population	Increase	Incremental increase
1921	40,185		
1931	44,522	4,337	
1941	60,395	15,873	+11,536
1951	75,614	15,219	-654
1961	98,886	23,272	+8,053
1971	124,230	25,344	+2,072
1981	158,800	34,570	+9,226
		Sum = 118,615	Sum = +30,233

Then what about the incremental increase method? So, this is all this part is similar to the arithmetic increase where we had the constant increase, , yes. So, as you see, here, we are talking about incremental increase. As we are assuming that each decade, it will increase a bit more incremental increase. So, what is the increase in increase? So, 15,000 minus 4000, so, 11,000. 15,200 minus 15,800, so, decrease 23 minus 15 825 minus 3 232, so on and so forth.

And then the average increase in increase average, not average, total incremental increase is 30,000 over this period.

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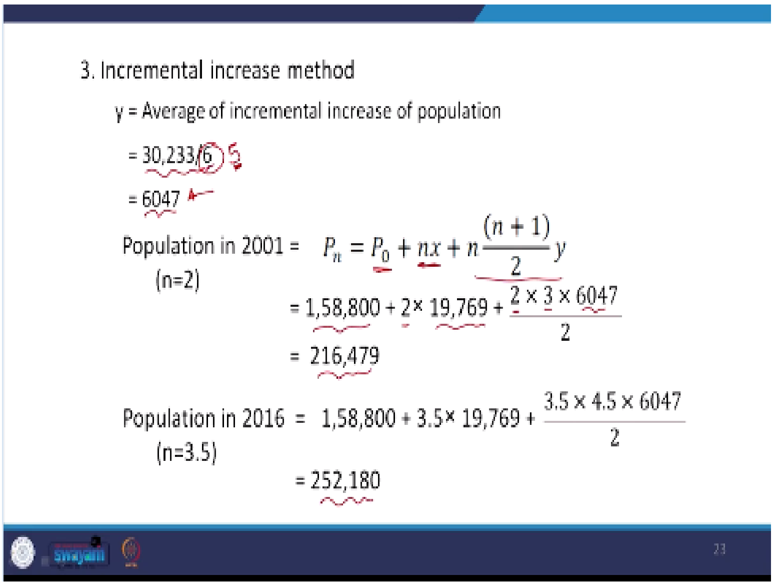

So, average of incremental increase of population so, that is what we have out here and 6047. So, that is how you calculate the y. So, let us move on. So, population in 2001 is equal to P 0 1981 and two decades, x, we have that average increase per decade. This, we calculated when we were looking at arithmetic mean method. So, n is 2, n + 1 is 3. 6047 is what we calculated earlier. And now we end up with this.

So, similarly, , just plugging it in and getting the relevant value. So, just to summarise, we have the population at the base year. Now, each decade, it is increasing at this constant rate. And from the decade after, after this first one, you see that its incremental increase is this. So, that is why we have to look at this particular aspect.. I think one aspect that should have been looked at was 1, 2, 3, 4, 5, 6 and 1, 2, 3, 4, 5.

This is for the period after so, this should be by 5. So, maybe a minor change in calculation, but you understand what needs to be done. So, that is changing aspects is the average here, it should have been 5, not 6. So, the 6 decades, average is this or it is going to increase at this rate. And after the first decade, it is going to increase by 30 by 5. Yes. So, that is the rate at which is going to the increase is going to increase every after every decade. So, that is something to keep in mind. Let us move on.

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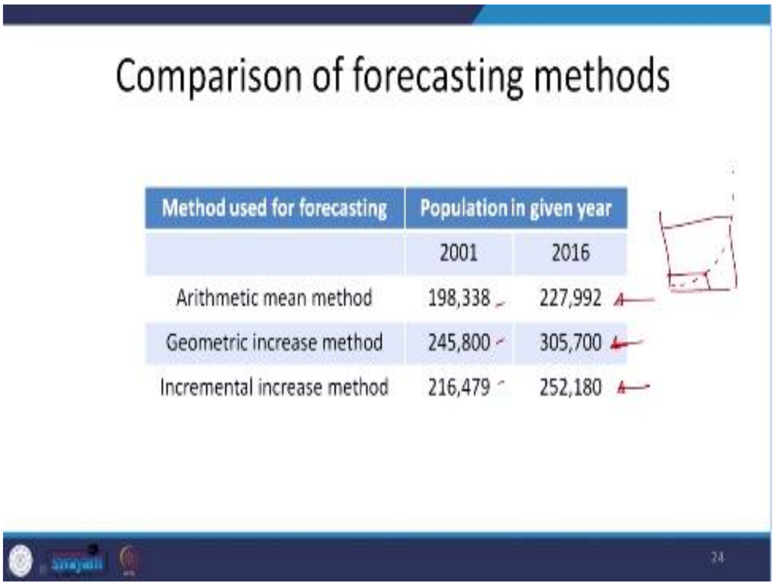

Method used for forecasting	Population in given year	
	2001	2016
Arithmetic mean method	198,338	227,992
Geometric increase method	245,800	305,700
Incremental increase method	216,479	252,180

So, what do we have here? Comparison of the, what we say, values we obtained from each of these methods, let us just look at 2016. So, arithmetic mean, geometric mean and incremental. So, constant rate, to the lesser value, incremental increase higher value, assuming that it is exponential increase, exponential, it will look like something like this. So, that is what we have out here.

Let us move on , here, we will see that relatively lesser disparity between the values but as the time period increases, geometric mean is going to raise ahead (25:34) head that is what you would see. It is exponential growth out. So, let us move on.

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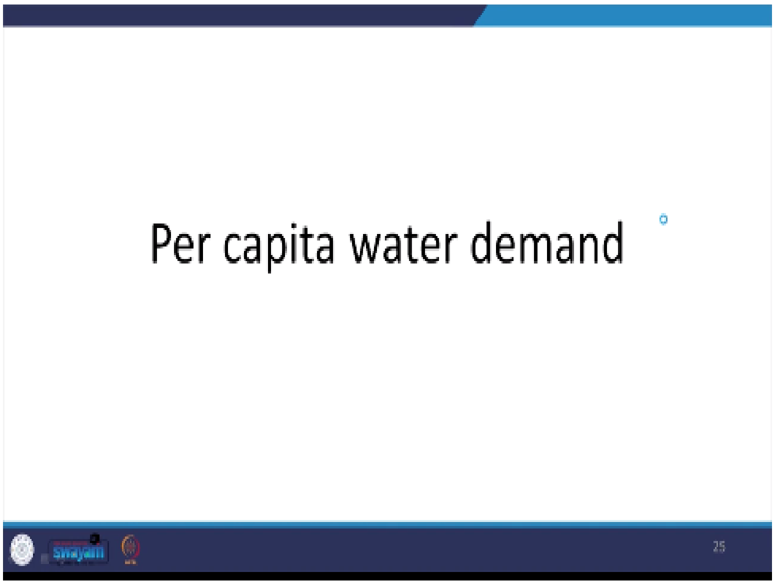

So, per capita water demand. So, we now know what period or until what period and from that we know what population to cater to, now that I know the population. I need to know per person I know per day what is it or what are the water requirements? So, depending upon where they are, it varies depending upon the kind of water usage but typically if it is in cities, more or less the functions that water is used for and you can come up with an average value.

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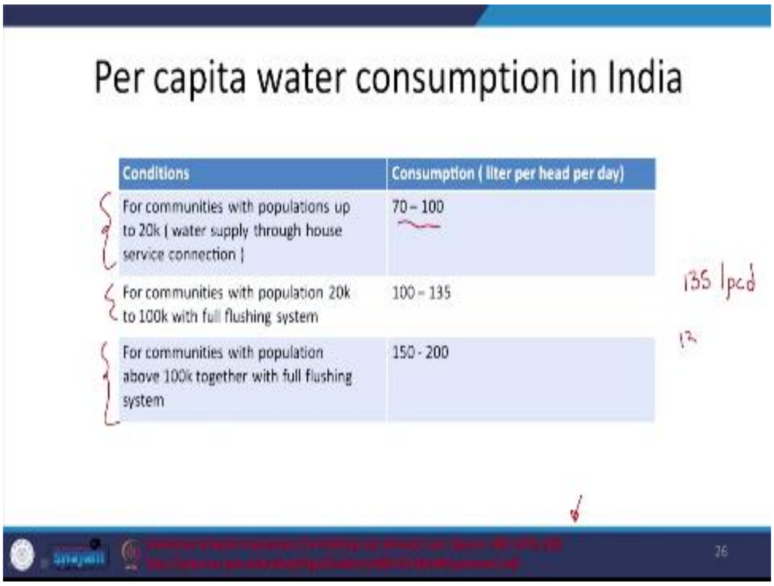

Conditions	Consumption (liter per head per day)
For communities with populations up to 20k (water supply through house service connection)	70 – 100
For communities with population 20k to 100k with full flushing system	100 – 135
For communities with population above 100k together with full flushing system	150 - 200

So, per capita water demand in India, it is around 135 litres per person per day. So, for communities up to, based on this reference, we know that for different, , types of communities based on the population, the consumption is relatively different, . But in general, I believe 135 litres per capita per day, 135 litres per person or per capita per day that is the average in India, but , you see that depending on the population it changes.

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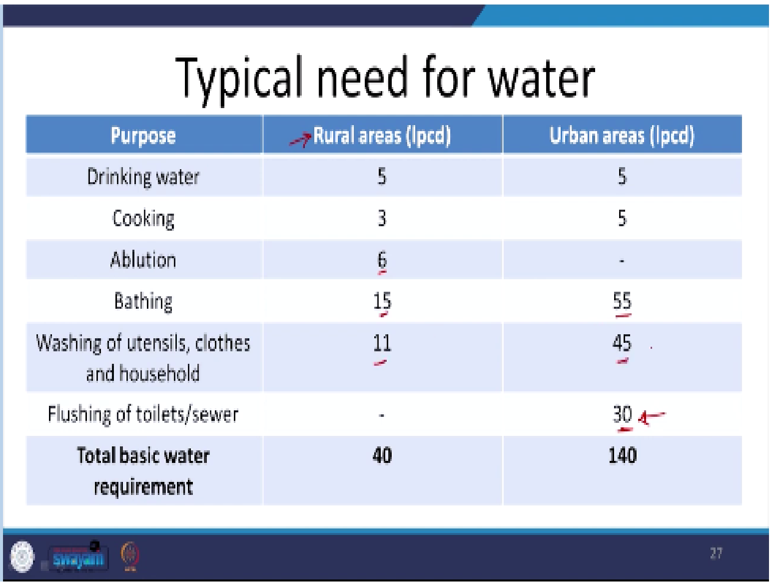

Typical need for water

Purpose	Rural areas (lpcd)	Urban areas (lpcd)
Drinking water	5	5
Cooking	3	5
Ablution	6	-
Bathing	15	55
Washing of utensils, clothes and household	11	45
Flushing of toilets/sewer	-	30
Total basic water requirement	**40**	**140**

And what is it typically used for? , urban and rural areas, rural areas, typically, water requirements are less. We are talking about what requirement for personal use or such or household use; not for agriculture or such purposes. So, drinking water cooking fine, ablution, , they did not consider that here. But flushing of toilet here, it comes into play here.

It depends on the kind of toilets and kind of flushing systems that you have here. And bathing depending upon bucket shower or such and washing too you will see that there is relatively supposedly greater requirement for water. So, rural areas will relatively less; urban areas relatively high.

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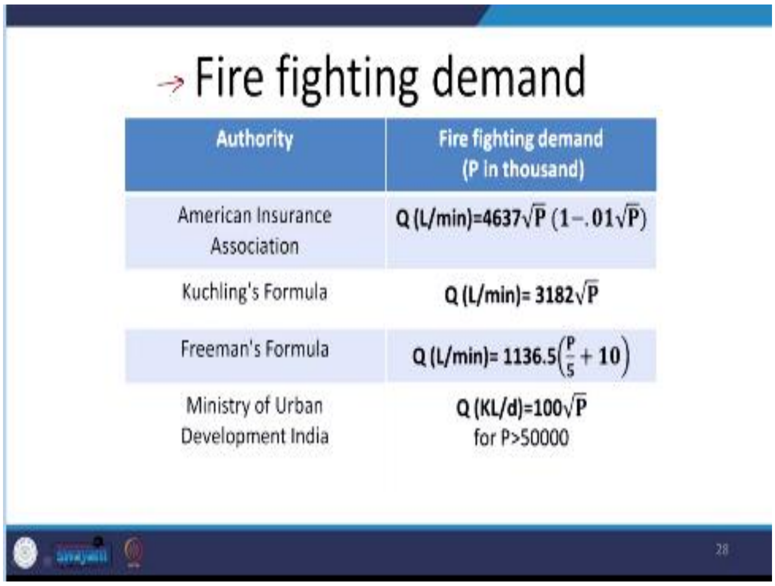

And other aspect is that , you always need to be prepared for the contingency, not just the daily variation in water or need for water. So, here, you are going to look at fire fighting demand. Demand that is required for fire fighting. In India though, even if you provide the water access out to , accessibility know for the fire engines to the relevant areas is an issue. So, that is why we hear such catastrophe and catastrophic loss of life in India.

But , that is a different aspect . At least fire fighting demand, we need to be able to need the, meet the need for fire fighting, at least from the engineer’s point of view. And , you have different empirical formulae. And , P is in population, P is for population in 1000. So, you can calculate this, I think they use this or this formulae in different exams, but it is not worth going into detail in this class. But please be aware that there are different formulas and different, , limits .

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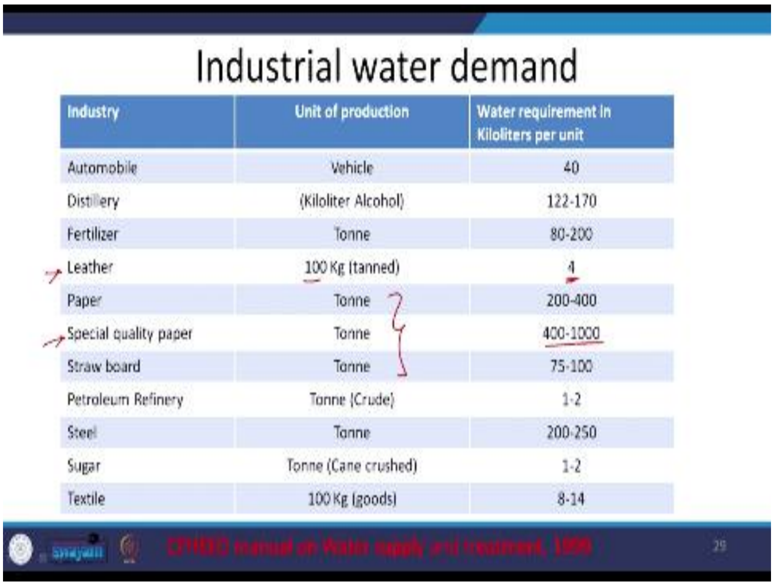

Industry	Unit of production	Water requirement in Kiloliters per unit
Automobile	Vehicle	40
Distillery	(Kiloliter Alcohol)	122-170
Fertilizer	Tonne	80-200
Leather	100 Kg (tanned)	4
Paper	Tonne	200-400
Special quality paper	Tonne	400-1000
Straw board	Tonne	75-100
Petroleum Refinery	Tonne (Crude)	1-2
Steel	Tonne	200-250
Sugar	Tonne (Cane crushed)	1-2
Textile	100 Kg (goods)	8-14

So, with respect to industries, depending upon the industrial zone, , Greater Noida, some areas where you are marketed as industrial zones and , for those zones, you have to have some idea about what industries they are and then you need to be able to provide the relevant, what we say, water supply infrastructure, . So, , that is why we see this year leather 100 kgs 4 but , , typical consumption is pretty high quality of paper or paper relatively high consumption, but , note that the unit is different.

You cannot compare a tonne here and 100 kgs here. So, but these are the different units. So, per 100 kgs for kilolitres is required. Per tonne of paper 200 to 400 kilolitres and now, the government is pushing for, what we say, what recycle such that net water requirement from the ground or such is relatively low or negligible for some, what we say, kinds of industries. Let we move on.

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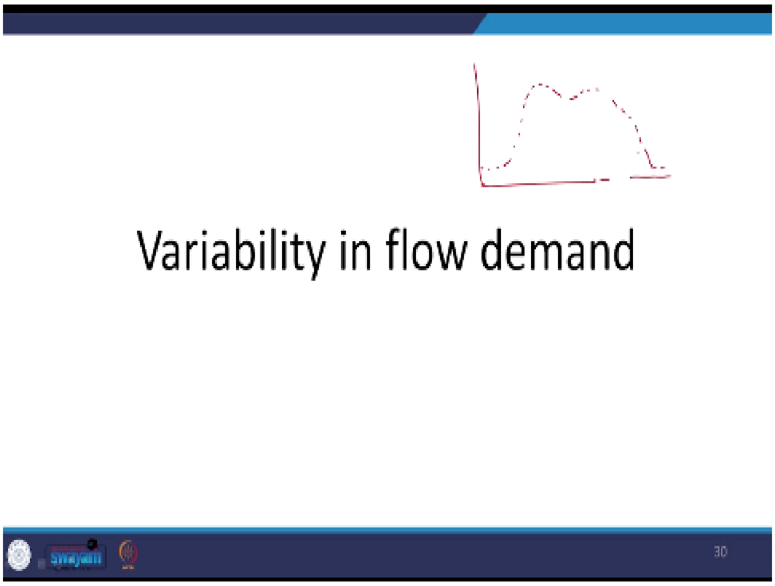

So, variability in flow demand. What do we have out here? So, as we solve for the waste water, what do we see, I think in the nights, this is the picture; morning, it increases; afternoon, it comes down. There is a peak in the evening . And this is the cycle . But if this is the sewage cycle or we know the flow into the STP, , it is based on the water that is being used. So, the water consumption pattern 2 will be similar to this. So, there is always going to be variability in demand, .

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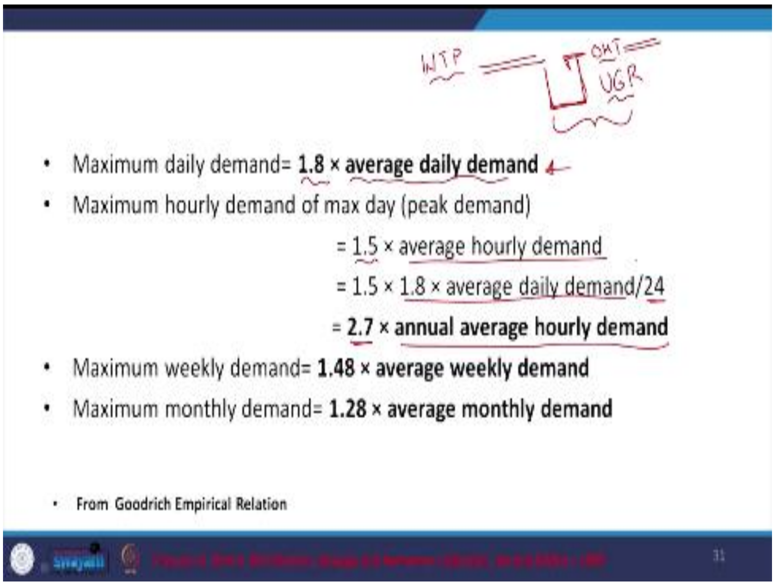

So, maximum daily demand, I think these are the ones or empirical relations that are used typically in India. So, different countries, they use different relations. I think this is the one that is used in India, . So, how do we get the maximum daily demand? It is 1.8 times the average daily demand, . And one aspect that I need to mention before I go further is that in India, how is it that water supply takes place? Or how does it end up at the homes?

So, you have your water treatment plant here under pressure, sewerage flows under gravity, water, you are pumping it up, you need more energy , because typically from low or lower head to higher head. It goes to your tanks and from that, , it comes to your particular pipe. So, I need to supply the energy required, . So, under pressure, it is going to flow.

So, that is one thing or depending upon the type of system before it goes directly from the water treatment plant to the homes, you will have underground reservoirs, , UGR underground reservoirs and from here, you will have at that place, what is called overhead tanks, overhead tanks and from these overhead tanks, the pumping will go or we know, the water will be pumped to your particular home.

So, that the typical (31:46) and because of this particular buffer capacity in either the underground reservoirs or the OHTs. Typically, even though maximum flow is expected or you need to look at that that is typically taken care of when we look at the UGR or OHTs and also the pump capacity. So, that is where it comes into play that is something I wanted to mention.

So, maximum daily demand, maximum hourly demand of maximum day, so, big demand. So, it seems it is considered as 1.5 times the average hourly demand and we are getting this average hourly demand from this particular case. Maximum daily demand, it is 1.8 into average daily demand by 24 hours per day. And from that we get this 2.7 into annual average hourly demand, let us see or this , yes, you can look at the variables and see which one is equal to which one.

So, what do we have? , maximum weekly demand and maximum monthly demand , these are all pretty simple, , empirical, , formula, it is not worth going into detail here.

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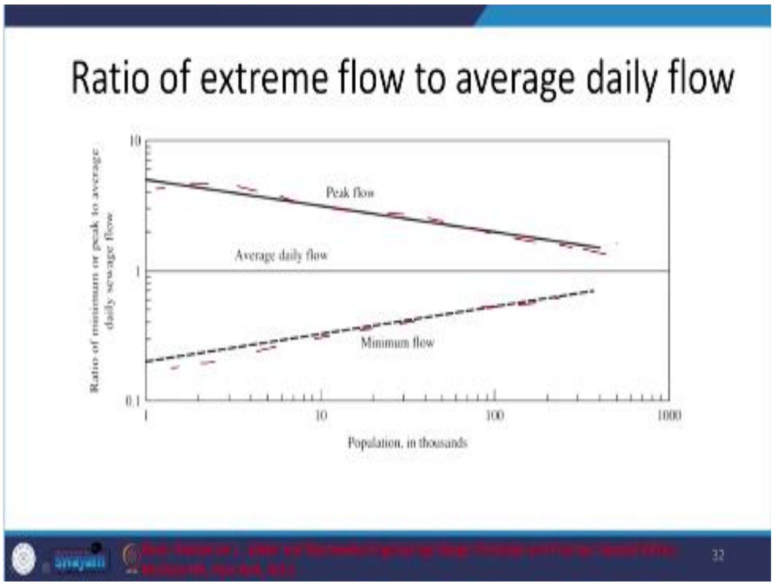

One aspect as we also looked at earlier, in the case of the CPHEEO or other reference data, we see that as the population increases, the variability will decrease as you can see, variability evens out, the variability decreases. So, that is something to keep in mind.

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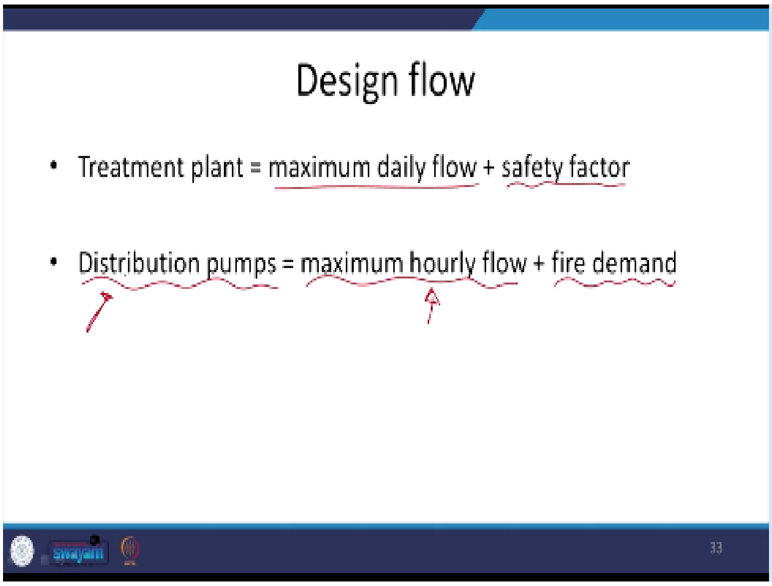

And design flow at the treatment plan, what treatment plan, what is it that we look for maximum daily flow and some safety factor, but with respect to the pumps, what do they need to be able to calculate or look at maximum hourly flow. This is with respect to hourly flow and more importantly to need the fire demands. So, this is something that we need to consider especially when we are looking at the distribution pumps or OHT, . Let we move on.

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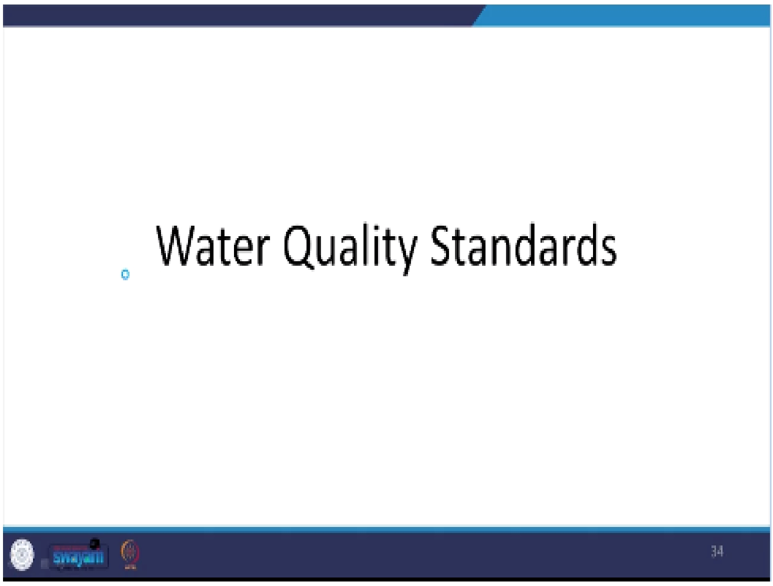

So, what water quality standards? But looks like, I spent considerable time in this session and the next session, we will see what is the kind of water we need to supply until now we have looked at how much water we need to supply and the next session, we will see what is the kind of water we have to supply as usual. Thanking you for your patience.