UNIT – I

OBJECTIVES OF PUBLIC WATER SUPPLY

- To supply safe and wholesome water to the consumers.
- To supply adequate quantity of water.
- To make water easily available to the consumers to encourage personal and household cleanliness.

REQUIREMENTS OF WATER SUPPLY

- The estimated probable population for a particular city or town.
- Rate of water supply per capita per day.
- The consumption of water for various uses.
- The demands that has to be met.

NEED FOR PROTECTED WATER SUPPLY

- The water available from the surface sources such as rivers, lakes, reservoirs, etc., may be polluted by the people residing near the sources. The industrial wastes also may pollute the water. It may carry suspended and/or dissolved impurities and bacteria which may cause water-borne diseases like typhoid, dysentery, cholera, etc.
- The underground water may be polluted by the percolating water which may carry harmful chemicals. Such pollution may be the cause of skin diseases and troubles of heart, lungs, kidney, etc.
- The source of water may be polluted by radioactive substances which may affect the human organs seriously. The discharges from nuclear power plant, nuclear research centre and nuclear explosion contain such radioactive substances.

REQUIREMENTS OF WATER FOR VARIOUS USES

- Drinking & Cooking
- Bathing
- Washing of clothes and utensils
- Gardening
- Swimming pools, Fountains, etc.
- Fire Fighting and
- Trades & Industries

WATER SUPPLY SYSTEMS

The Municipal water systems consist of the following units

- Collection works
- Conveyance works
- Treatment works and
- Distribution works

PLANNING FACTORS FOR PUBLIC WATER SUPPLY

- **Population Forecast**
  Every scheme should be such that it may run satisfactorily at least for three decades. So, the probable population of the town or city should be ascertained for the future decade.
- **Assessment of Water Demand**
  Depending upon the probable population, the total water requirement for the town or city should be estimated considering the domestic demand, public demand, industrial demand, fire demand, etc.
- **Record of Industry**

  The nature and number of industries in a town or city should be recorded because; the industries require much water for running and maintenance. This record should also be updated from time to time.

- **Record of Public Places**
  The nature and number of public places like markets, theatres, parks etc.

TYPES OF WATER DEMAND AND THEIR CONSUMPTION

The total quantity of water required for a town or city is based on satisfying the demand.

- **Domestic Demand**
  - ✓ Water required for drinking, bathing, cooking, washing etc.
  - ✓ Water demand depends on habits, social status, climate and custom of people.
  - ✓ In India, the average domestic consumption under normal condition is 135 litres/capita/day.
  - ✓ For developed countries, the average domestic consumption under normal condition is 350 litres/capita/day.

Use	Consumption in lpcd
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of Utensils	10
Cleaning of House	10
Flushing of latrines	30

- ✓ The total domestic water consumption is 50 to 60% of total water consumption.
- ✓ Total domestic water demand = Total Design Population x Per capita domestic consumption.

- **Commercial Demand**
  - ✓ The water demand for office, hotels, restaurants, theatres etc.
  - ✓ Commercial Demand is 25 litres/capita/day to 40 litres/capita/day.
- **Industrial Demand**
  - ✓ The water demand for various industries.
  - ✓ Industrial Demand is 20% to 25% of total water demand of the city.
- **Public Demand**
  - ✓ The water demands for various public uses like public toilets, swimming pool, parks are 5% of the total water consumption.
- **Fire Demand**
  - ✓ The water required during the outbreak of fire.

(a) National Board of Fire Underwriters Formula

$$Q = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

Where Q – litres/min

P- Population in Thousands

(b) Freeman Formula

$$Q = 1135.5\ ((P \div 10) + 10)$$

Both (a) and (b) are not suitable for Indian Conditions.

(c) **Kuichling's Formula**

$$Q = 3182\ \sqrt{P}$$

(d) Buston's Formula

$$Q = 5663\sqrt{P}$$

Where Q – litres/min, P- Population in Thousands

- **Compensate Losses**
  - ✓ Defective pipe joints, crack in pipe, Fault in valve fittings, Public taps damaged, Wasting water keeping the taps in open condition, Unauthorized connection.
  - ✓ 15% of total water requirement.

PER CAPITA DEMAND

- ✓ The average daily water required per person per day based on the annual average demand.
- ✓ If Q is the total quantity of water required by a town per year in litres and the population of the town is P, then

Per capita Demand = Q / (Px365) litres/capita/day

- ✓ The per capita demand of the town depends on various factors and will be according to the living standard of the public and the type of the commercial places in the town etc.
- ✓ For an average Indian town, the requirement of water in various uses is given below

Domestic Use	–	135 litres/capita/day or lpcd
Industrial Use	-	40 lpcd
Commercial Use	-	25 lpcd
Public Use	-	15 lpcd
Loss & Waste	-	55 lpcd
Total	-	270 lpcd

- ✓ Total quantity of water required by the town/day – 270 lpcd x population

RATE OF CONSUMPTION (OR) PER CAPITA DEMAND

It is the annual average amount of daily water required by one person and includes the domestic use, industrial and commercial use, public use, wastes etc.

Rate of consumption = Total yearly water requirement of the city / (365 x Design population)

FACTORS AFFECTING PER CAPITA DEMAND

- **Climatic Conditions**
  The requirement of water is more in summer than in winter. In extreme cold conditions, the taps are kept open to avoid freezing of pipes which results in increased rate of consumption.
- **Cost of Water**
  Higher the cost of water results in less quantity of water consumption.
- **Distribution Pressure**
  Increase in distribution pressure will increase the water consumption. Increase of 2-3 kg/cm^2 lead to increase in water consumption to an extent of about 25 to 30 %.
- **Habits of Population**
  The rate of consumption will be more due to the better standard of living of persons. The higher status will have more consumption when compared to the middle and lower class people.
- **Industrial & Commercial Activities**
  The water consumption will be more when more industries are located and more commercial activities are taking place in the city. Also there is no direct connection with the population or the size of the city.
- **Policy of metering and method of charging**
  Installing water meter and charging water will lead to lesser water consumption.
- **Quality of water**
  Improved water quality will lead to more water consumption. Unpleasant taste and odour will lead to reduced water consumption.
- **Existing Sewerage Facilities**
  More quantity of water is consumed for flushing system for properly designed sewerage system. Less quantity of water will be required for old conservancy system.
- **Size of the city**
  If the city is small, the water consumption is less and if the city is big the water consumption will be more.

- **System of supply**
  If the water supply is continuous there is an increase in the rate of water demand and if the supply is intermittent, the will be reduction in the rate of water demand.

POPULATION DATA

- The Population data is determined by the Census Department.
- Official surveys are carried out by the government at intervals of about 10 years to estimate the future population.

POPULATION DENSITY

- It indicates the number of persons per unit area.
- The distribution of population is studied by determining the population densities of various parts of the city.

POPULATION FORECAST

Estimating the future population is known as population forecast. The population change can occur in following three ways.

- By birth (gain in population)
- By death (loss in population)
- By migrations (loss or gain in population)

USES OF POPULATION FORECAST

- To assist the government agencies for the preparation of economic, employment and social programmes.
- To collect information for location of an industry, its future expansion, availability of labored marketing and distribution of the product etc.
- To design water supply system and sewerage system.
- To provide data to transportation industry.
- To workout requirements for other public utilities such as telephones, electric power etc.

METHODS OF POPULATION FORECAST

- Arithmetical Increase Method
- Geometrical Increase Method
- Incremental Increase Method
- Decreasing rate of growth method
- Graphical method (a) Simple (b) Comparative
- Master Plan Method (or) Zoning Method
- Logistic Curve Method
- Ratio Method (or) Apportionment Method

Arithmetical Increase Method

This method is based on the assumption that the population increases at a constant rate or the rate of change of population with time is constant.

$$dP/dt = C$$

$$P_n = P + nC$$

Where,

P_n = Forecasted Population after n decades

P = Population at present

n = Number of decades between present and future

C = Average arithmetic increase of population

Geometrical Increase Method

In this method, it is assumed that the percentage increase in population from decade to decade remains constant. This method is also known as uniform increase method. The increase is compounded over the existing population in every decade.

$$P_n = P + (1 + (I_G/100))^n$$

Where,

P_n = Forecasted Population after n decades

P = Population at present

n = Number of decades between present and future

I_G = Average percentage growth at the end of the decade

Incremental Increase Method

This method is an improved method of other two methods. The average increase in the population is determined by the arithmetic method and to this is added the average of the net incremental increase once for each future decade.

$$P_n = P + n\,(Ia + Ic)$$

Where,

P_n = Forecasted Population after n decades

P = Population at present

n = Number of decades between present and future

Ia = Average Arithmetical Increase

Ic = Average Incremental Increase

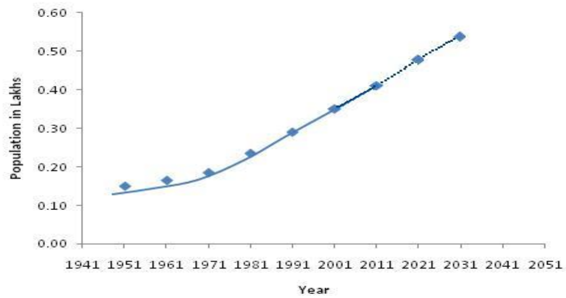
Decreasing Rate Method

In this method, the average decrease in the percentage increase is worked out and is then subtracted from the latest percentage increase for each successive decade.

Graphical Method

(i) Simple method

In this method, the populations of last few decades are correctly plotted to a suitable scale on graph. The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment.



(ii) Comparative method

In this method the census populations of cities already developed under similar conditions are plotted. The curve of past population of the city under consideration is plotted on the same graph. The curve is extended carefully by comparing with the population curve of some similar cities having the similar condition of growth. The advantage of this method is that the future population can be predicted from the present population even in the absence of some of the past census report.

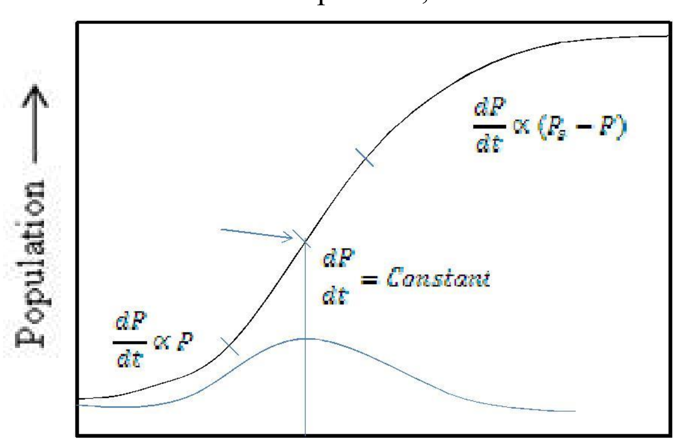
Master Plan Method / Zoning Method

The big and metropolitan cities are generally not developed in haphazard manner, but are planned and regulated by local bodies according to master plan. The master plan is prepared for next 25 to 30 years for the city. According to the master plan the city is divided into various zones such as residence, commerce and industry. The population densities are fixed for various zones in the master plan. From this population density total water demand and wastewater generation for that zone can be worked out. By this method it is very easy to access precisely the design population.

Logistic Curve Method

This method is used when the growth rate of population due to births, deaths and migrations takes place under normal situation and it is not subjected to any extraordinary changes like epidemic, war, earth quake or any natural disaster, etc., and the population follows the growth curve characteristics of living things within limited space and economic opportunity. If the population of a city is plotted with respect to time, the curve so obtained under normal condition looks like S-shaped curve and is known as logistic curve.

Saturation Population, Ps



$$P = Ps / 1 + m\log_e^{-1}(nt)$$

$$m = (Ps - Po) / Po$$

$$n = (2.3/t_1) \log_{10}((Po\ (Ps-P_1)) / (P_1\ (Ps-Po)))$$

$$Ps = \frac{2P_oP_1P_2 - P_1^2\ (P_o+P_2)}{P_o P_2 - P_1^2}$$

Where, Ps = Saturated Population

P = Population at any time t

m & n = constants

The Apportionment Method

Also known as ratio method. In this method the census population record is expressed as the percentage of the whole country. The population of the city under consideration and the country's population for the last five decades are collected from the census department. The ratio of the town under consideration to the national population is calculated for these decades. Now a graph is plotted between these ratios and the time. The extension of this graph will give the ratio corresponding to the future years for which the forecasting of population is to be done. The ratio so obtained is multiplied by the expected national population of the town under reference.

Numerical Problem

1. Predict the population for the year 2021, 2031, and 2041 from the following population data. Using Arithmetical Increase Method.

Year	1961	1971	1981	1991	2001	2011
Population	8,58,545	10,15,672	12,01,553	16,91,538	20,77,820	25,85,862

Solution: -

Year	**Population**	**Increment**

1961	858545	-
1971	1015672	157127
1981	1201553	185881
1991	1691538	489985
2001	2077820	386282
2011	2585862	508042

Average Increment = 345463

Population forecast for year 2021 is, P_{2021} = 2585862 + 345463 x 1 = 2931325

Similarly, P_{2031} = 2585862 + 345463 x 2 = 3276788

P_{2041} = 2585862 + 345463 x 3 = 3622251

2. Considering data given in problem 1 predict the population for the year 2021, 2031, and 2041 using geometrical progression method.

Solution: -

Year	Population	Increment	Geometrical increase Rate of growth
1961	858545	-	
1971	1015672	157127	(157127/858545) = 0.18
1981	1201553	185881	(185881/1015672) = 0.18
1991	1691538	489985	(489985/1201553) = 0.40
2001	2077820	386282	(386282/1691538) = 0.23
2011	2585862	508042	(508042/2077820) = 0.24

Geometric mean $I_G = (0.18 \times 0.18 \times 0.40 \times 0.23 \times 0.24)^{1/5}$

= 0.235 i.e., 23.5%

Population in year 2021 is, $P_{2021} = 2585862 \times (1+ 0.235)^1 = 3193540$

Similarly for year 2031 and 2041 can be calculated by,

$P_{2031} = 2585862 \times (1+ 0.235)^2 = 3944021$

$P_{2041} = 2585862 \times (1+ 0.235)^3 = 4870866$

3. Considering data given in problem 1 predict the population for the year 2021, 2031, and 2041 using incremental increase method.

Solution :-

Year	Population	Increase (X)	Incremental increase (Y)
1961	858545	-	-
1971	1015672	157127	-
1981	1201553	185881	+28754
1991	1691538	489985	+304104
2001	2077820	386282	-103703
2011	2585862	508042	+121760
	Total	1727317	350915
	Average	345463	87729

Population in year 2021 is, P_{2021} = 2585862 + (345463 x 1) + {(1 (1+1))/2} x 87729

= 3019054

For year 2031 P_{2031} = 2585862 + (345463 x 2) + {(2 (2+1)/2)} x 87729

= 3539975

P_{2041} = 2585862 + (345463 x 3) + {(3 (3+1)/2)} x 87729

= 4148625

4. The following data have been noted from the census department

Year	1940	1950	1960	1970
Population	8000	12000	17000	22500

Find the forcasted population using decrease rate of growth method.

Year	**Population**	**Increase**	**Percentage Increase in population**	**Decrease in the percentage increase**
1940	8000	-	-	-
1950	12000	4000	(4000/8000)*100 = 50.0	-
1960	17000	5000	(5000/12000)*100 = 41.7	+8.3
1970	22500	5500	(5500/17000)*100 = 32.4	+9.3
			Total =	17.6

Average = 8.8

Population for future decades

Year	Net Percentage Increase in population	Population
1980	32.4 - 8.8 = 23.6	22500+(.236*22500) = 27810
1990	23.6 - 8.8 = 14.8	27810+(.148*27810) = 31926
2000	14.8 – 8.8 = 6	31926+(.060*31926) = 33842

FLUCTUATION IN DEMAND OF WATER

The demand does not remain uniform throughout the year but it varies from season to season, even from hour to hour.

- **Seasonal Fluctuation**
  Water demand varies from season to season. Summer water demand is maximum. This demand goes on reducing and in winter it becomes minimum. The variation may be upto 15% to the average demand of the year.
- **Daily and Hourly Fluctuation**
  Variation depends on the general habits of people, climatic conditions and character of city. More water demand will be on Sundays and hoildays.Peak hour flow will be from 6 A.M to 10 A.M and 4P.M to 8P.M. Minimum flow may be between 12P.M to 4P.M.
  - ✓ Maximum Hourly Consumption is 150% of the average consumption
  - ✓ Maximum Daily Consumption is 180% of the average consumption

FACTORS AFFECTING THE VARIATION OF WATER DEMAND

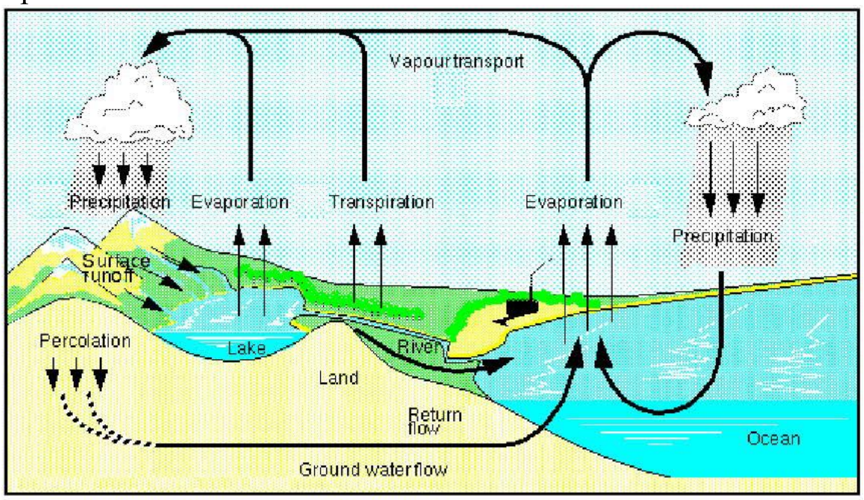
- ✓ Climatic Conditions
- ✓ Size of the community
- ✓ Living standards of the people
- ✓ Industrial and Commercial Activities
- ✓ Pressure in the distribution system
- ✓ System of Sanitation
- ✓ Cost of water

SOURCE AND CONVEYANCE OF WATER

Sources of water:

i) Surface water
- Ponds and lakes
- Streams and rivers
- Storage reservoirs
- oceans

ii) Sub- surface water (or) underground sources
- Springs
- Infiltration galleries
- Infiltration wells and
- Open Wells and tube-wells.



Surface water:

Water that gets collected on the surface of the ground or top layer of a body of water is called surface water.

Ponds and Lakes:

- ❖ A natural large sized depression formed within the surface of the earth, when gets filled with water is known as pond or lake.
- ❖ The difference between the pond and lake is only size.
- ❖ If size is small, its termed as pond, large size lake
- ❖ Flow of water in lake is like flow in stream channel
- ❖ Quality of water in lake is good
- ❖ Quality of water available in lake is small
- ❖ Quality depends upon the catchment area of the lake basin, annual rainfall and geological formation
- ❖ Due to smaller quantity of water available for them, lakes are not considered as principal sources of water supplies.

Streams and Rivers:

- ❖ Small stream channels feed their waters to the lake or rivers which is not used for water supply
- ❖ Larger and perennial streams are used a sources of water by providing storage reservoirs, barrages etc.
- ❖ Rivers are most important sources of water for public supply
- ❖ Quality of water obtained from rivers is generally not reliable

Storage Reservoirs:

- Barrier in the form of dam, may be constructed across the river so as to form a pool of water o the upstream side of the barrier
- This pool or artificial lake formed on the upstream side of the dam is known a storage reservoir.
- Water can stored in reservoir can be used not only for water supply but also for other purposes.
- Various kinds of dams are
    - Earth dams + made of soil
    - Rock fill dams + made of loose rocks
    - Solid masonry gravity dams – made of stone masonry

Oceans:

- Not used as water supply source normally.

Sub- surface water (or) underground sources:

Springs:

- Natural outflow of ground water at the earth's surface forms a spring
- A pervious layer sandwiched between two impervious layers form a spring.
- Capable of supplying very small amount of water, not recommended for water supplies.
- Good developed springs can sometimes used for water supply source for small towns, especially in hilly areas.
- The two types of springs are

  a) Gravity springs – when the ground water raises high and water overflows through the sides of a natural; valley or depression.

  b) Surface springs – sometimes an impervious obstruction (or) stratum supporting the underground storages becomes inclined causing water table to go up and get exposed to the ground surface.

  c) Artesian springs – when water comes out of pressure it's called artesian springs. Since water comes out of pressure, they are able to provide higher yields and may be considered as source of water supply.

Infiltration Galleries:

- Horizontal tunnels constructed at shallow depth (3-5m) along the banks of rivers through the water bearing strata.
- Also called as horizontal wells.
- Constructed of masonry walls with roof slabs and extract water from the aquifer by various porous lateral drain pipes located at suitable intervals in the gallery.
- Discharge from gallery can be computed using Darcy's law, Q=KiA

Infiltration Wells:

- Shallow wells constructed in series along the banks of a river in order to collect the river water seeping through their bottoms
- Constructed of brick masonry with open joints.
- Various infiltration wells are connected by porous pipes to a sum well, called jack well.

Open wells:

- Open masonry wells having bigger diameter and suitable for low discharge (18 cumecs/hr)
- Discharge is limited to 3 to 6 l/s.
- Diameters vary from 2 to 9m and less than 20m in depth.
- Yield is limited
- Can put 8 to 10 cm diameter bore hole in the center of the well, to extract additional water.
- Types: a) shallow wells – rests in pervious strata and draws supplies from surrounding matter.
  b) Deep wells – rests on impervious layer
- Yield of open well, $Q = nv_aA_s$
  Q – discharge
  V_a – actual flow velocity
  N – porosity
  A_s – surface area of the aquifer

Tubewells:

- Deep as 70 to 300m and tap more than one aquifer
- Yield as high as 200 to 220 l/s.
  Types: a) deep tubewell
  b) shallow tubewell
  c) cavity type tubewell – draws water from the bottom of well
  d) screen type tubewell – drawn from the sides
    1. Strainer tubewell
    2. Slotted pipe gravel pack tubewell

Qualitative and Quantitative Studies of Water:

Water that may be considered absolutely pure is not to be found in nature. Even rainwater which is in fact, distilled water, collect impurities such as dust, gases, bacteria, etc. during its passage through the atmosphere. The portion of rainwater which flows over the surface and called run-off picks up organic and suspended matter, whereas the portion percolating through the ground has got mineralogical, organic and inorganic matter which it gathers while traversing through the underground strata before reaching the water table.