CHAPTER 01

Water Demand

INTRODUCTION

In this chapter, we are going to understand the duty of an engineer in designing a water supply scheme for a particular section of the community, which becomes imperative upon him.

- First of all, we will evaluate the amount of water available and the amount of water demanded by the public.
- In fact, the first study is to consider the demand and then the second requirement is to find sources to fulfill that demand. Many a times, a compromise is sought between the two.
- To design a water supply, we must first estimate the population for which the scheme should be designed. The scheme once installed, must cater for the demand of the projected population upto some predetermined future date.

1.1 Water Demand

Estimation of demand for water is the key parameter in planning a water supply scheme. The agriculture sector consumes more than 80 percent of total water potential created in our country. The remaining portion is utilized to meet domestic, industrial and other demands.

The improvement in life-style and associated industrial development of a nation push up the per capita demand for water.

1.2 Various Types of Water Demand

- The prediction of precise quantity of water demanded by the public is very difficult, because there are so many variable factors affecting water consumption.
- There are some certain thumb rules and empirical formulas, which are used to assess this quantity, which may give fairly accurate results.

There are different types of water demands:

1.2.1 Domestic Water Demand

Domestic water demand includes the water required in private building for drinking, cooking, bathing, gardening purposes etc. which may vary according to the living conditions of the consumers.

- The total domestic water consumption is near about 50 to 60% of the total water consumptions.
- The IS code caps a limit on domestic water consumption between 135 to 225 *l*pcd.
- As per IS code, the minimum domestic water demand under ordinary conditions for a town with full flushing system should be taken as 200 *l*pcd although it can be minimized upto 135 *l*pcd for economically weaker section and LIG colonies (low income group) depending upon prevailing conditions.

NOTE: In developed and an efficient country like USA, this figure usually goes as high as 340 *l*pcd. This is because more water is consumed in rich living, in air-conditioning, air-cooling, bathing in bath tubs, dish washing of utensils, car washing, home laundries, garbage grinders, etc.

1.2.2 Industrial Water Demand

The industrial water demand expresses the water required for industries which are either existing or are likely to be started in future, in the city for which water supply is being planned.

- This water requirement will thus vary with the types and number of industries present in the city.
- In industrial cities, the per capita requirement may finally be computed to be as high as 450 *l*/h/d as compared to the normal industrial requirement of 50 *l*/h/d.

Table: 1.1 Water Requirements for Commercial Buildings (as per IS code)

S.No.	Type of building	Average consumption in (*l*pcd)
1.	Factories	
	(a) Where bathrooms are required to be provided	45
	(b) Where no bathrooms are required	30
2.	Hospitals (including laundry, per bed)	
	(a) Number of beds less than 100	340
	(b) Number of beds exceeding 100	450
3.	Nurses homes and medical quarters	150
4.	Hostels	135
5.	Hotels (per bed)	180
6.	Restaurants (per seat)	70
7.	Offices	45
8.	Cinemas, auditoriums and theatres (per seat)	15
9.	Schools	
	(a) Day scholars	45
	(b) Residentials	135

Table: 1.2 Water Required by Certain Important Industries

Name of Industry	Unit of Production	Approximate Quantity of Water required per unit of production/raw material in kilo litres
1. Automobiles	Vehicle	40
2. Fertilizers	Tonne	80 - 200
3. Leather	Tonne (or 1000 kg)	40 (or 4)
4. Paper	Tonne	200 - 400
5. Petroleum Refinery	Tonne (Crude)	1 - 2
6. Sugar	Tonne (Crushed cane)	1 - 2
7. Textile	Tonne (goods)	80 - 140
8. Distillery (Alcohol)	kilo litre	122 - 170

1.2.3 Institutional and Commercial Water demand

On an average, a per capita demand of 20 *l*/h/d is usually considered to be enough to meet of such commercial and institutional water requirements although of course, this demand may be as high as 50 *l*/h/d for highly commercial cities.

The Individual requirements would be as follows:

1. Schools/Colleges : 45 to 135 *l*pcd
2. Offices : 45 *l*pcd
3. Restaurants : 70 *l*pcd
4. Cinema and theatres : 15 *l*pcd
5. Hotels : 180 *l*pcd
6. Hospitals : 340 *l*pcd (when beds is less than 100), and 450 *l*pcd (when beds exceed 100)
7. Airports : 70 *l*pcd
8. Railway : 70 *l*pcd (for junction with bathing facility)

1.2.4 Demand for Public Uses

This includes water requirement for parks, gardening, washing of roads etc. A nominal amount, not exceeding 5% of the total consumption may be provided to meet this demand.

A figure of 10 *l*pcd is usually added on this account while computing total water requirements.

1.2.5 Fire Demand

The quantity of water required for extinguishing fire is not very large. For a total amount of water consumption for a city of 50 lakhs population, it hardly amounts to 1 *l*pcd of fire demand, but this water should be easily available and kept always stored in storage reservoirs, as quantity of water required is in very less duration.

In thickly populated and industrial areas, fire generally breakout and may lead to serious damages, if not controlled effectively. Big cities, therefore, generally maintain full fire fighting squads. Fire fighting personnel require sufficient quantity of water, so as to throw it over the fire at high speed. A provision should, therefore be made in modern public water scheme for fighting fire breakouts.

Following requirements must be met for the fire demand:

- The minimum water pressure available at fire hydrants should be of the order of 100 to 150 kN/m^2 (10 to 15 m of water head) and should be maintained for 4 to 5 hours of constant use of fire hydrant.

- The jet streams are simultaneously thrown from each hydrants: one on the burning property and one each on the adjacent property on either side of the burning property. The discharge of each stream should be about 1100 l/min.
- The number of fire jets required depend on the size of population and given by $F = 2.8\sqrt{P}$, where P = Population in thousands.

Do you know? Generally, for a city of 50 Lakh population; the fire demand is 1 lpcd.

Calculation of Fire Demand

- For cities having population exceeding 50,000, the water required in kilo litre may be computed using the relation? Kilo litre of water required = $100\sqrt{P}$, where P = Population in thousand
- Kuchling's Formula : It states that

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

Q = Amount of water required in litre/minute
P = Population in thousands.

- Freeman's Formula : It states that $Q = 1136\left[\frac{P}{5} + 10\right]$
- National Board of Fire Underwriters Formula :

(a) For Central congested high valued city

(i) When population is less than or equal to 2 Lakhs $Q = 4637\sqrt{P}\left[1 - 0.01\sqrt{P}\right]$

(ii) When population is more than 2 Lakhs, a provision for 54,000 litres/minute may be made with an extra additional provision of 9,100 to 36,400 litres/minute for a second fire.

(b) For a residential city

The required draft for fire-fighting may be as follows: .

(i) Small or low building = 2200 litres/minute

(ii) Larger or Higher building = 4,500 litres/minute

(iii) High values residency, apartments, tenements = 7650 to 13500 litres/minute

(iv) Three storeyed buildings in densely built up section = upto 27000 litres/minute

- Buston's Formula : It states that, $Q = 5663\sqrt{P}$

NOTE: All the above formulas suffer from the drawback that they are not related to the type of district served and give equal results for industrial and non-industrial areas.

Example 1.1 Compute the 'fire demand' for a city of 2 lakh population by any two formulae (including that of the National Board of Fire Underwriters)

Solution:

(i) The rate of fire demand as per National Board of Fire Underwriters Formula for a central congested city whose population is less than or equal to 2 Lakh is given by

$$Q = 4637\sqrt{P}\left[1 - 0.01\sqrt{P}\right] = 4637\sqrt{200}\left[1 - 0.01\sqrt{200}\right]$$

$$= 56303.08 \text{ l/min} = \frac{56303.08 \times 60 \times 24}{10^6} \text{MLO} = 81.08 \text{ MLD}$$

(ii) Kuchling's formula, $Q = 3182\sqrt{P} = 3182\sqrt{200}$ l/min; R = 45000.27 l/m = 64.8 MLD

1.2.6 Water Required to Compensate Losses in Thefts and Wastes

This includes the water lost in leakage due to bad plumbing or damaged meters, stolen water due to unauthorised water connections, and other losses and wastes.

These losses should be taken into account while estimating the total requirements.

Even in the best managed water works, this amount may, be as high as 15% of the total consumption, which is nearly 55 lpcd.

Total Maximum Water Demand

It is the sum of above six demands and IS code permits for India, a total maximum demand of 335 lpcd.

The Per Capita Demand (q)

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

It may be, therefore expressed as Per Capita Demand(q) in litres per day per head

$$= \frac{\text{Total yearly water requirement of the city in litres (i.e V)}}{365 \times \text{Design Population}}$$

For an average Indian city, as per recommendation of I.S. code, the per capita demand(q) may be taken as (Table 1.3)

Table : 1.3 Break up for per capita demand (q) for an average Indian City

Use	Demand in l/h/d
(i) Domestic Use	200 (59.7% or 60%)
(ii) Industrial Use	50
(iii) Commercial Use	20
(iv) Civic or Public Use	10
(v) Waste and thefts, etc.	55
(vi) Fire demand	< 1
	Total = 335 = Per Capita Demand (q)

1.3 Factors Affecting Per Capita Demand

The annual average demand for water (i.e. per capita demand) considerably varies for different towns or cities. This figure generally ranges between 100 to 360 litres/capita/day for Indian conditions. The variations in total water consumption of different cities or towns depend upon various factors, which must be thoroughly studied and analysed before fixing the per capita demand for design purpose. These factors are discussed below:

1.3.1 Size of the City

The total water demand depends on size of population and for the design of water supply scheme for a given population size following guidelines may be adopted (Table 1.4).

Table: 1.4 Variation in Per Capita Demand (q) with population in India

S. No.	Population	Per Capita Demand in Liters/day/Person
1.	Less than 20000	110
2.	20000 - 50000	110 - 150
3.	50000 - 2 Lakhs	150 - 240
4.	2 Lakhs - 5 Lakhs	240 - 275
5.	5 Lakhs - 10 Lakhs	275 - 335
6.	Over 10 Lakhs	335 - 360

1.3.2 Climatic Conditions

At hotter and dry places, the consumption of water is generally more, because more of bathing, clearing, air-coolers, air-conditioning etc. are involved. Similarly, in extremely cold countries, more water may be consumed, because the people may keep their taps open to avoid freezing of pipes and there may be more leakage from pipe joints since metals contract with cold.

1.3.3 Types of Gentry and Habits of People

Rich and upper class communities generally consume more water due to their affluent living standards.

1.3.4 Industrial and Commercial Activities

The pressure of industrial and commercial activities at a particular place increase the water consumption by large amount.

1.3.5 Quality of Water Supplies

If the quality and taste of the supplied water is good, it will be consumed more, because in that case, people will not use other sources such as private wells, hand pumps, etc. Similarly, certain industries such as boiler feeds, etc., which require standard quality waters will not develop their own supplies and will use public supplies, provided the supplied water is upto their required standards.

1.3.6 Pressure in the Distribution Systems

If the pressure in the distribution pipes is high and sufficient to make the water reach at 3rd or even 4th storage, water consumption shall be definitely more.

This water consumption increases because of two reasons:

(i) People living in upper storage will use water freely as compared to the case when water is available scarcely to them.

(ii) The losses and waste due to leakage are considerably increased if their pressure is high. For example, if the pressure increase from 20 m head of water (i.e. 200 kN/m^2) to 30 m head of water (i.e. 300 kN/m^2), the losses may go up by 20 to 30 percent.

1.3.7 Development of Sewerage Facilities

The water consumption will be more, if the city is provided with 'flush system' and shall be less if the old 'conservation system' of latrines is adopted.

1.3.8 System of Supply

Water may be supplied either continuously for all 24 hours of the day, or may be supplied only for peak period during morning and evening. The second system, i.e. intermittent supplies, may lead to some saving in water consumption due to losses occurring for lesser time and a more vigilant use of water by the consumers.

1.3.9 Cost of Water

If the water rates are high, lesser quantity may be consumed by the people. This may not lead to large savings as the affluent and rich people are little affected by such policies.

1.3.10 Policy of Metering and Method of Charging

When the supplies are metered, people use only that much of water as much is required by them. Although metered supplies are preferred because of lesser wastage, they generally lead to lesser water consumption by poor and low income group, leading to unhygienic conditions.

Factors Affecting Losses and Wastes: The various factors on which losses depend and the measure to control them are below:

(i) Water Tight Joints
(ii) Pressure in the Distribution system
(iii) System of supply
(iv) Metering
(v) Unauthorized connections

Example 1.2 Consider the following statements:

Assertion (A): The leakage are less when the water supply is intermittent.

Reason (R): Pressure is less in intermittent water supply

Of these statements

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Ans. (c)

Variation in demand and effects on the design of various components of a water supply scheme

- The smaller the town, the more variable is the demand
- The shorter the period of draft, the greater is the departure from the mean

(i) **Maximum daily Consumption:** It is generally taken as 180 percent of the average

Therefore, Maximum daily demand = 1.8 (i.e. 180%) × Average daily demand = 1.8q

(ii) **Maximum hourly Consumption :** It is generally taken as 150 percent of its average.

Therefore, Maximum hourly consumption of the maximum day i.e. peak demand

$$= 1.5 \text{ (i.e. 150\%)} \times \text{Average hourly consumption of maximum daily demand}$$

$$= 1.5 \times \left(\frac{\text{Maximum daily demand}}{24}\right) = 1.5 \times \left(\frac{1.8 \times q}{24}\right) = 2.7\left(\frac{q}{24}\right)$$

$$= 2.7 \text{ (Annual average hourly demand)}$$

(iii) **Maximum Weekly Demand :** Maximum weekly Consumption = 1.48 × Average weekly

(iv) **Maximum Monthly Demand :** Maximum monthly consumption = 1.28 × Average monthly

NOTE

Goodrich formula is used to compute maximum or peak demand.

$$P = 1.8(t)^{-0.1} \qquad P = \frac{\text{Maximum demand}}{\text{Average demand}}$$

where, t = time in days, t = 1 for maximum daily, $t = \frac{1}{24}$ for maximum hourly

P = Annual average draft for time in t day

The GOI manual on water supply has recommended the following values of the peak factor, depending upon the population.

Table: 1.5 Peak Factor

S.No.	Population	Peak Factor
1.	Upto 50000 50001 - 200000 Above 2 Lakh	3.0 2.5 2
2.	For Rural water supply scheme, where supply is effected through stand post for only 6 hours	3

Evidently, the peak factor tends to reduce with increasing population.

Remember: As far as the design of distribution system is concerned, it is hourly variation in computation that matters.

1.4 Coincident Draft

For general community purpose, the total draft is not taken as the sum of maximum hourly demand and fire demand, but is taken as the sum of maximum daily demand and fire demand, or the maximum hourly demand, whichever is more. i.e. maximum of

(i) Maximum daily demand + Fire demand (ii) Maximum hourly demand

Example 1.3 Coincident draft in relation to water demand, is based on

(a) Peak hourly demand (b) Maximum daily demand

(c) Maximum daily + fire demand (d) greater of (a) and (c)

Ans. (c)

Example 1.4 A water supply scheme has to be designed for a city having a population of 1,00,000. Estimate the important kinds of drafts which may be required to be recorded for an average water consumption of 250 lpcd. Also record the required capacities of the major components of the proposed water works system for the city using a river as the source of supply. Assume suitable data.

Solution:

(i) Average daily draft = (per capita average consumption in litre/person/day) × population

$= 250 \times 1{,}00{,}000$ litres/day $= 250 \times 10^5$ litres/day = 25 MLD

(ii) Maximum daily draft may be assumed as 180% of annual average daily draft

$\therefore$ Maximum daily draft $= \frac{180}{100}[25 \text{ MLd}] = 45$ MLD

(iii) Maximum hourly draft of the maximum day: It may be assumed as 270 percent of annual average hourly draft

$\therefore$ Maximum hourly draft of maximum day $= \frac{270}{100}[25 \text{ MLd}] = 67.5$ MLD

(iv) Fire flow may be worked out from

$$Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right] = 4637\sqrt{100}\left[1-0.01\sqrt{100}\right] = 41733 \text{ litre/min}$$

where P = in thousand population

$$= \frac{41733 \times 60 \times 24}{10^6} \text{ million litres/day} = 61 \text{ MLD}$$

Coincident draft = maximum daily draft + fire draft

= 45 + 61 = 106 MLD

which is greater than the maximum hourly draft of 67.5 MLD

NOTE It shows that the distribution system has to be designed for 106 MLD instead of 67.5 MLD, which proves that the fire allowance considerably affects the design of distribution system.

1.5 Design Period of Water Supply Unit

- A water supply scheme includes huge and costly structures (such as dams, reservoirs, treatment works, penstock pipes, etc.) which can not be replaced or increased in their capacities, easily and conveniently. For example, the water mains including the distributing pipes are laid underground, and cannot be replaced or added easily, without digging the roads or disrupting the traffic.
- In order to avoid these future complications of expansion, the various components of a water supply scheme are purposely made larger, so as to satisfy the community needs for a reasonable number of years to come.
- This future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as design period.
- The design period should neither be too long nor should it be too short. The design period cannot exceed the useful life of the component structure, and is guided by the following considerations.

Factors Governing the Design Period

- Useful life of component structures and the chances of their becoming old and obsolete. Design period should not exceed there respective values.
- Ease and difficulty that is likely to be faced in expansions, if undertaken at future dates.
- Amount and availability of additional investment likely to be incurred for additional provision.
- The rate of interest on the borrowings and the additional money invested.
- Anticipated rate of population growth, including possible shifts in communities, industries and commercial establishment.

Design Period Values

Water supply projects, under normal circumstances, may be designed for a design period of 30 years excluding completion time of 2 years. The design period recommended by the GOI manual on water supply for designing the various components of a water supply projects are given below: (Table 1.6)

Table 1.6 : Design Period of Various Components of Water Supply Project

S.No.	Units	Design (Parameters) Discharge	Design Period
1.	Water Treatment Unit	Maximum daily demand	15 Years
2.	Main supply pipes (Water mains)	Maximum daily demand	30 Years
3.	Wells and Tube wells	Maximum daily demand	30-50 Years
4.	Demand Reservoir (Overhead or ground level)	Average annual demand	50 Years
5.	Distribution system	Maximum hourly demand/ Coincident draft	30 Years

1.6 Population Forecasting

Population census/enumerations and growth in population etc. are not only used in demographic sphere but also by Engineer and people concerned with economic growth, national planning and policy decision making in the sector of agriculture, growth in industries and infrastructure, drinking water supply schemes and other social welfare activities etc

Population Growth

Growth of population is of great concern to people engaged in policy planning and decision making at the national level. Population growth means the change (increase) of population size between two dates.

However, a population increasing in size is said to have a positive growth rate and the one declining is to have a negative growth rate.

The number of inhabitants of a country depends on (i) The rate of growth in population and (ii) Migrations

The second factor is of importance only in new countries and the old countries are the sources of migrants.

In order to predict the future population as correctly as possible, it is necessary to know the factors affecting population growth. These are three main factors responsible for changes in population.

They are: (i) Births (ii) Deaths (iii) Migrations

All these factors are influenced by social and economic factors and conditions prevailing communities.

- The Birth rates may decrease due to excessive family planning practices and legalized abortions. Spread of education and development of extra recreational facilities for the people, also tend to reduce the birth rates.
- The death rates may decrease with the development and advancement of medical facilities, thereby controlling infant mortality rates and adult death rates due to control of infections and other diseases.
- The migrations are dependent upon the industrialization and commercialization of the particular cities or towns. People generally migrate from villages to cities where livelihood are available.
- Besides these three main factors, some other factors like war, natural havocs and disasters may also bring about sharp reduction in the population.
- Considering all these factors, arithmetic balancing is done to arrive at the future population. It can be expressed as $\boxed{P_t = P_0 + (B - D) - (I - E)}$

where, P_0 and P_t refer to the size of population at the beginning and end of a time period, and B, D, I and E refers to the number of births, deaths, immigration and emigration respectively during period under consideration.

Growth Rate Curve

When all the unpredictable factors such as war, or natural disasters do not produce sudden changes, the population would probably follow the growth curve as discussed in the theory of demographic transition. This curve is S-shaped as shown in figure and is known as "the logistic curve". According to this curve, rate of growth of population varies from time to time.

The curve represents early growth AB at an increasing rate

$\left(\text{i.e. geometric or log growth, } \frac{dP}{dt} \propto P\right)$ and late growth DE at a decreasing rate

$\left[\text{i.e. first order } \frac{dP}{dt} \propto (P_S - P)\right]$ as the saturation

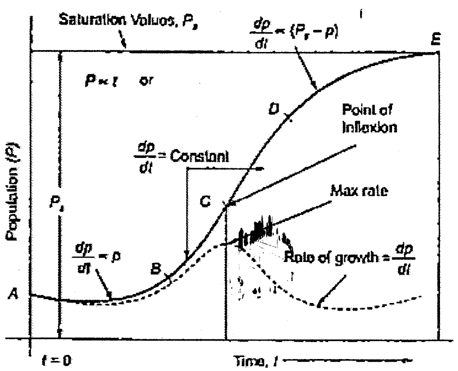

Fig. 1.1 Growth Rate Curve

value (P_S) is approached. The transitional $\left[\text{i.e. } \frac{dP}{dt} = \text{constant}\right]$. What the future holds for a given population, depends upon, as to where the point lie on the growth curve at a given time.

i.e.

$$\text{in } AB \rightarrow \frac{dP}{dt} \propto P \rightarrow \text{increasing growth rate}$$

$$\text{in } BCD \rightarrow \frac{dP}{dt} = \text{Constant} \rightarrow \text{High growth rate}$$

$$\text{in } DE \rightarrow \frac{dP}{dt} \propto (P_s - P) \rightarrow \text{Decreasing growth rate}, \; P_s = \text{Saturation value}$$

1.7 Population Forecasting Methods

The various methods which are generally adopted for estimating future populations by engineers are described below. Some of these methods are used when design period is small, and some are used when the design period is large. The particular method to be adopted for a particular case or for a particular city depends largely upon the factor discussed in these methods and the selection is left to the discretion and intelligence of the designer.

1.7.1 Arithmetic Increase Method

In this method, a constant increment of growth in population is observed periodically. This method is of limited application, mostly used in large and established towns where future growth has been controlled.

This method is based upon the assumption that the population increase at a constant rate, i.e. the rate of change of population with time $\left(\text{i.e. } \frac{dP}{dt}\right)$ is constant.

Thus, $\frac{dP}{dt} = \text{Constant} = k$ or, $dP = k \cdot dt$

or, $\int_{P_1}^{P_2} dP = k \int_{t_1}^{t_2} dt$ $\quad P_{t_2} = P_{t_1} + k(t_2 - t_1)$

Here P_{t_2} and P_{t_1} represent the population at time t_2 and t_1 respectively. This time period is usually reckoned in decades. k is the rate of increase of population per unit time (decade). thus $(t_2 - t_1)$ = Number of decades.

The equation can be rewritten as, $\boxed{P_n = P_0 + n \cdot \bar{x}}$

where P_n = perspective or forecasted population after n decades from the present (i.e. last known census)

P_0 = Population at present (i.e. last known census)

n = Number of decades between now and future

$\bar{x}$ = Average (arithmetic mean) of population increase in the known decades.

Example 1.5 The population of 5 decades from 1930 to 1970 are given below in table 1.7. Find out the population after one, two and three decades beyond the last known decade, by using arithmetic increase method.

Table: 1.7

Year	Population
1930	25,000
1940	28,000
1950	34,000
1960	42,000
1970	47,000

Solution: The given data in table 1.7 is extended in table 1.8, so as to compute the increase in population (x) for each decade (col. 3), the total increase, and average increase per decade ($\bar{x}$), as shown.

The future populations are now computed by using equation as $P_n = P_0 + n \cdot \bar{x}$

∴ (a) Population after 1 decade beyond 1970

$= P_{1980} = P_1 = P_{1970} + 1 \cdot \bar{x}$

$= 47{,}000 + 1 \times 5500 = 52{,}500$

(b) Population after 2 decades beyond 1970

$= P_{1990} = P_2 = P_{1970} + 2 \cdot \bar{x}$

$= 47{,}000 + 2 \times 5500 = 58{,}000$

(c) Population after 3 decades beyond 1970

$= P_{2000} = P_3 = P_{1970} + 3 \cdot \bar{x}$

$= 47{,}000 + 3 \times 5500 = 63{,}500$

Table: 1.8

Year (1)	Population (2)	Increase in population (x) (3)
1930	25,000	
1940	28,000	3000
1950	34,000	6000
1960	42,000	8000
1970	47,000	5000
Total		22,000
Average increase per decade ($\bar{x}$)		$\bar{x} = \frac{22000}{4} = 5{,}500$

1.7.2 Geometric Increase Method

The method of Geometric progression is applicable to the cities with unlimited scope for future expansion and where a constant rate of growth is anticipated.

The basic difference between arithmetic and geometric progression or increase method of population forecasting is that, in Arithmetic method no compounding is done whereas, in Geometric method compounding is done every decade. This method is, therefore, also known as uniform increase method.

In Geometric increase method, a constant value of percentage growth rate per decade (k) analogues to the rate of compounding interest per annual.

Thus, population after one decade can be given by, $P_1 = P_0 + kP_0 = P_0(1 + k)$

Similarly, population after n decades $\boxed{P_n = P_0(1+k)^n = P_0\left(1+\frac{k}{100}\right)^n}$

Where, P_0 refers to initial population i.e. at the end of last known census.

Average percentage growth rate per decade k to be used in the above equation is computed from the percentage growth rate of each decade. The value of k can be calculated as $\boxed{k = \sqrt[n]{k_1 \cdot k_2 \cdot k_3 \cdots k_m}}$

In geometric increase method the growth rate per decade, $k = \sqrt[t]{\frac{P_2}{P_1}} - 1$

Example 1.6 Determine the future population of a satellite town by the Geometric Increase method for the year 2011, given the following data (Table-1.9)

Table: 1.9

Year	Population in Thousand
1951	93
1961	111
1971	132
1981	161
......	......
2011	?

Solution: The given data is analysed in table to determine growth rates for each decade.

Table: 1.10

Year	Population in thousand	Increase in Population in thousand	%age increase in population = growth rate = $\frac{col(3)}{col(2)} \times 100$
1951	93		
1961	111	18	19.35
1971	132	21	18.92
1981	161	29	21.97

Constant growth rate, assumed for future

r = geometric mean of past growth rates = $\sqrt[3]{19.35 \times 18.92 \times 21.97}$ = 20.03 % per decade

The population after n decades in now given by equation

$$P_n = P_0\left(1+\frac{r}{100}\right)^n$$

P_{2011} = Population after 3 decades from 1981

$$= P_{1981}\left(1+\frac{20.03}{100}\right)^3 = 1{,}61{,}000(1.2003)^3 = 2{,}78{,}417$$

1.7.3 Incremental Increase Method

This method is another case of arithmetic increase with some modifications. Incremental increase method is adopted for cities which are likely to grow progressively of increasing or decreasing rate rather than a constant rate.

According to this method, population after n decades can be given by

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \cdot \bar{y}$$

where, $\bar{x}$ and $\bar{y}$ are the average increase of population per decade and average incremental increase respectively. The other notations carry their usual meaning and $\bar{x}$ and $\bar{y}$ are given by

$\bar{x}$ = Average increase of population per decade = $\frac{x_1 + x_2 + \ldots + x_p}{p}$ and

$\bar{y}$ = Average of incremental increase = $\frac{y_1 + y_2 + \ldots + y_p}{p}$

where, $x_1, x_2, x_3 \ldots x_m$ are increase in each decade, $y_1, y_2, y_3 \ldots y_p$ are incremental increase in each decade

NOTE

- The "GOI manual on water and water treatment" recommends the use of geometric mean here; and hence, we can safely use that value.
- Geometric increase method gives high results which is suitable for cities growing with fast rate such as new cities whereas arithmetic increase method gives low results which is suitable for cities growing with slow rate such as old cities.

Example 1.7 As per the census records for the years 1911 to 1971, the population of a town is given below in the table. Assuming that the scheme of water supply was to commence in 1996, it is required to estimate the population of 10 years hence i.e. in 2006 and also the intermediate population after 15 year since commencement.

Table: 1.11

Year	1911	1921	1931	1941	1951	1961	1971
Population	40185	44522	60395	75614	98886	124230	158800

Solution: Let us try to get the solutions using all the three methods to which you have been introduced by now. The incremental population and increase in incremental population are summed up in table below:

Table: 1.12

Year	Population	Increment	Incremental Increase(y)
1911	40185	–	–
1921	44522	4337	–
1931	60395	15873	+ 11536
1941	75614	15219	– 654
1951	98886	23272	+ 8053
1961	124230	25344	+ 2072
1971	158800	37570	+ 9226

From the above table, the following parameters can be worked out as

Total increase in population = 118,615

Total of incremental/decrease = 30,233

Average incremental value decade $(\bar{x}) = \frac{1}{6} \times 118615 = 19769$

Average incremental increase per decade $(\bar{y}) = \frac{1}{5} \times 30233 = 6047$

1. **By Arithmetic Progression Method:**
   Increase in population from 1911 to 1971, i.e. in 6 decades = 158,800 – 40,185 = 118,615

$$K = \frac{1}{6} \times 118,615 = 19,769$$

Now, using equation $P_n = P_0 + k.n$

∴ Population in 2006 = 158,800 + 19,769 × 3.5 = 227,992

and population in 2011 = 158,800 + 19,769 × 4 = 237,876

2. **By Geometrical progression method**
   Rate of growth per decade

$$\text{between 1911 and 1921, } k_1 = \frac{4,337}{40,187} = 0.108$$

$$\text{between 1921 and 1931, } k_2 = \frac{15,873}{44,522} = 0.356$$

$$\text{between 1931 and 1941, } k_3 = \frac{15,219}{60,395} = 0.252$$

$$\text{between 1941 to 1951, } k_4 = \frac{23,272}{75,614} = 0.308$$

$$\text{between 1951 to 1961, } k_5 = \frac{25,344}{98,886} = 0.256$$

$$\text{between 1961 to 1971, } k_6 = \frac{34,570}{124,230} = 0.278$$

$$\text{Geometric mean} = \sqrt[6]{0.108 \times 0.356 \times 0.252 \times 0.308 \times 0.256 \times 0.278}$$

or, $k = 0.24426$

Assuming that the future population will grow in geometric progression as in the post during 1911 to 1971.

Now using Equation, $P_n = P_0(1 + k)^n$

∴ Population in 2006 = $158,800(1 + 0.24426)^{3.5} = 341,224$

Population in 2011 = $158,800(1 + 0.24426)^{4} = 380,623$

3. **By Incremental Increase Method**
   Now applying equation $P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \cdot \bar{y}$

$$P_{2006} = 158,800 + 3.5 \times 19769 + \frac{3.5 \times 4.5}{2} \times 6047 = 275,612$$

$$P_{2011} = 158,800 + 4 \times 19769 + \frac{4 \times 5}{2} \times 6047 = 298,346$$

1.7.4 Decreasing Growth Rate Method

If population is reaching towards saturation and growth rate is decreasing, then this method is suitable.

- In this method average decrease in the % increase is calculated and then subtracted from the last % increase computation made for each increased year.
- Calculate the % increase in population for each decade and work out the decrease in percentage increase in each decade and find average percentage decrease say 'r''. The population of upcoming decade from the previous known decade is given as

$$P_1 = P_0 + \left(\frac{r_0 - r'}{100}\right) \times P_0$$

where, P_0 = Population of last known decade
r_0 = Growth rate of last decade
r' = Average decrease in growth rate

Population after next two decades from the last known decade is given as

$$P_2 = P_1 + \left(\frac{r_0 - 2r'}{100}\right) \times P_1$$

NOTE: The validation of decreasing growth rate method is only in those cases, where the rate of growth shows a downward trend.

Example 1.8 The census record of a particular town is shown in table. Estimate the population for the year 2020 by decreasing growth rate method

Table: 1.13

S.No.	Year	Population	% Increase in Growth rate	% Decrease in Growth rate
1.	1960	55500		
2.	1970	63700	14.77%	
3.	1980	71300	11.93%	+ 2.84%
4.	1990	79500	11.50%	+ 0.43%

Solution:

We know that, $P_1 = P_0 + \left(\frac{r_0 + r'}{100}\right) \times P_0$

r_0 = growth rate of last known census = 11.80%

r' = Average decrease in growth rate = $\frac{2.84 + 0.43}{2} = 1.635\%$

$$P_{2020} = P_{2010} + \left(\frac{r_0 - 3r'}{100}\right) \times P_{2010}$$

$$P_1 = P_{2000} = 79500 + \left(\frac{11.5 - 1.635}{100}\right) \times 79500$$

$$P_{2000} = 87343$$

$$P_2 = P_{2010} = 87343 + \left(\frac{11.5 - 2 \times 1.635}{100}\right) \times 87343$$

$$P_{2010} = 94531$$

$$P_3 = P_{2020} = 94531 + \left(\frac{11.5 - 3 \times 1.635}{100}\right) \times 94531$$

$$P_{2020} = 100,765$$

1.7.5 Graphical Projection or Extension Method

In this method from the available data, a graph is plotted between time and population, either on arithmetic paper or on a semi-log paper.

- This time-population curve is then smoothly extended upto the desired year for projecting the future population. The line of best fit may also be by the method of least square.
- If the graph is plotted on semi-log paper with time on arithmetic scale and population on log-scale, the time population curve form a straight line.
- Plotting on simple graph paper give approximate results as the expansion of curve is done by the judgement and skill of designer.

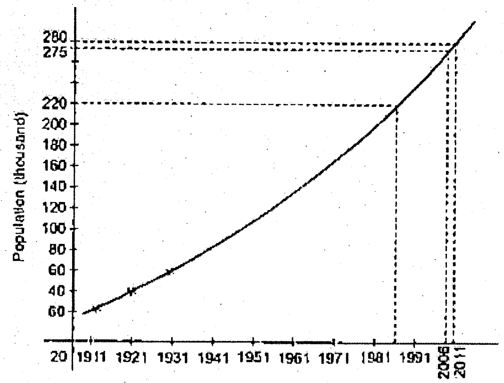

Fig. 1.2 Graphical Projection Method

The data given in example 1.7 are plotted in figure 1.2 and the projected population in the years 2006 and 2011 from given figure 1.2 can be approximately read as

$$P_{2006} = 275000$$

$$P_{2011} = 280000$$

- If plotting is done on a semi-log graph as shown in figure 1.3, the graph is straight line. The projected populations for the desired years from the figure 1.3 can be read as

$P_{2006} = 370000$, $P_{2011} = 400000$

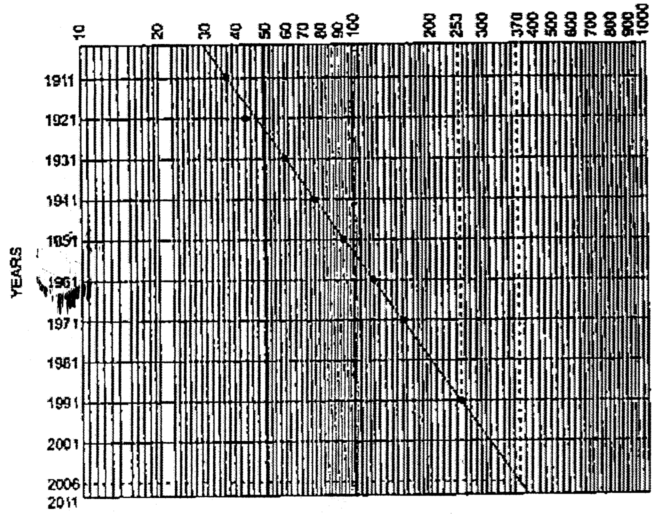

Fig. 1.3 Semi log Plot for Estimation of Future Population

NOTE

- This method is suitable when past record is available for long duration and extension is required for small duration.
- All the above five methods described upto now are based on the assumption that factors and conditions which were responsible for population increase in the past will continue even in future also, with same intensity. That is a vague assumption and may or may not be satisfied. Due to such reasons, the results obtained from these methods may or may not be precise. Inspite all, they are less time consuming and are used by engineers.

1.7.6 Comparative Graphical Method

In this method, the cities of similar condition and characteristics (migration, development activities etc.) are selected, which have grown in similar fashion in the past and their graph are plotted.

- Therefore, to estimate the population of a relatively new city, population-time curve of cities having conditions and characteristics similar to the city whose future population is to be estimated, are obtained. Based on a comparison of population time curve for comparable cities, the population-time curve of the city under consideration is extended from the point of last available data upto the desirable future data. The method is explained with the help of an example in the figure 1.4.

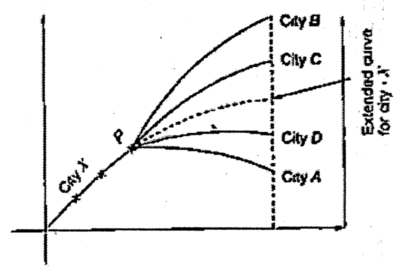

Fig. 1.4 Compartive Graphical Method

For example, let the population data of a relatively new city X is given for four decades 1940, 1950, 1960 and 1970; and its present population has reached say 50000 in the last census of the year

1970. It is required its population after 50 years from the last census i.e. at the end of the year 2020. First of all, the population-time curve of the city X is plotted upto the latest census year i.e. 1970. Then from the available population data of cities which had the same population as that of the city under consideration; their respective population-time curve is plotted. Now the population-time curve of city X is extended smoothly as shown in the figure.

1.7.7 Master Plan or Zoning Method

In general, big and metropolitan cities are not allowed to develop in haphazard and natural ways, but are allowed to develop only in planned ways. The expansions of such cities are regulated by various by-laws of corporations and other local bodies. Only those expansions are allowed, which are permitted or proposed in the master plan of that city.

- However, sometime, the density and distribution of such population within constituent areas or zones of the city are to be made with a discerning judgement on the relative probabilities of expansion within zone.
- This has to be based upon the existing and contemplated town planning regulations, master plans and also according to the nature of development of whole region.
- The master plan prepared for a city is generally such as to divide the city in various zone and thus to separate the residence, commerce and industry from each other. The population density are also fixed.
- For example, there may be 10 persons living in a residential plot and there may be 10000 plots in a zone. Then, the total population of this size, when fully developed, can be easily worked out as 10 × 10000 = 100000. Hence, when the development regulated by such a scheme, it is very easy to access precisely the design population.

NOTE: The Master plan or Zoning method can give us as when and where the given number of houses, industries and commercial establishments would be developed.

1.7.8 Ratio Method or Apportionment Method

In this method, population of any town is expressed as a percentage of population of whole country and by taking the average growth rate of country population may be projected.

In this method, a graph is plotted between time and ratio of local population to national population.

NOTE: This method is valid for those whose growths are parallel to the national growth.

1.7.9 The Logistic Curve Method

The logistic method is suitable for regions where the rate of increase or decrease of population with time and also the population growth is likely to reach an ultimate saturation limit because of special local factors.

- The growth of a city which follows a logistic curve, will plot as a straight line on the arithmetic paper with time intervals plotted against population in percentage of saturation
- P.F. Verhulst has put forward a mathematical solution for the logistic curve. According to him, the entire curve can be represented by an autocatalytic first order equation, given by

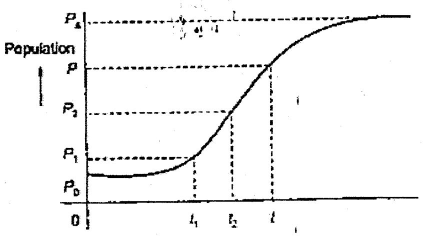

Fig.1.5 The Logistic Curve Method

Let P_0 = Population at the beginning of census record. P_1 = Population after time t_1 years

P_2 = Population after time t_2 years, P_s = Saturation population

Then population after any time from the start is given as,

$$\boxed{P = \frac{P_s}{1 + m\log_e^{-1}(nt)}} \quad \text{where,} \quad \frac{P_s - P_0}{P_0} = m \text{ (a constant)}$$

The saturation population (P_s)

$$\boxed{P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}}$$

$$n = \frac{1}{t}\cdot\log_e\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right] = \frac{2.3}{t_1}\log_{10}\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

Knowing P_0, P_1 and P_2 from census data and using then in these equations, the equation of the logistic curve is thus known.

Example 1.9 In two periods of each 20 years, a city has grown from 30,000 to 1,70,000 and then to 3,00,000. Determine (a) The saturation population, (b) The equation of logistic curve, (c) The expected population after the 60 years from the start.

Solution: (1) In this equation, we have

P_0 = 30,000, P_1 = 1,70,000, P_2 = 3,00,000

$t = 0$, $t = 20$ years, $t = 40$ years

Using equation, $$P_s = \text{Saturation Population} = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2} = 3{,}26{,}000$$

(2) $$m = \frac{P_s - P_0}{P_0} = \frac{3{,}26{,}000 - 30{,}000}{30{,}000} = 9.87$$

$$n = \frac{1}{30}\log_e\left[\frac{30{,}000(3{,}26{,}000 - 1{,}70{,}000)}{1{,}70{,}000(3{,}26{,}000 - 30{,}000)}\right] = -0.1119$$

∴ Equation of logistic curve is

$$P = \frac{P_s}{1 + m\log_e^{-1}(nt)} = \frac{3{,}26{,}000}{1 + 9.87\log_e^{-1}(-0.119t)}$$

(3) If t = 60 years

then, $$P = \frac{3{,}26{,}000}{1 + 9.87\log_e^{-1}(-0.119 \times 60)} = 3{,}23{,}470$$

Illustrative Examples

Example 1.10 Compute the population of the year 2000 and 2006 for a city whose population in the year 1930 was 25,000 and in the year 1970 was 47,000. Make use of geometric increase method.

Solution: In this example, the intermediate census data between 1930 to 1970 is not given, and hence geometric mean method of all known decades is not possible. The growth rate per decade (r) can, however, be computed by using equation as

$$r = \sqrt[t]{\frac{P_2}{P_1}} - 1 = \sqrt[4]{\frac{47000}{25000}} - 1 = 0.17095 = 17.095\% \text{ per decade.}$$

Now using equation as, $P_n = P_0\left(1+\frac{r}{100}\right)^n$, we have

Hence, $P_{2000} = P_3$ (after 3 decades from 1970 onward)

$$= P_{1970}\left(1+\frac{r}{100}\right)^3 = 47{,}000(1+0.17095)^3 = 47{,}000(1.17095)^3 = 75{,}459$$

Population for the year 2006, means that it is after 36 year (3.6 decades) from 1970 onward

$$\therefore \quad P_{2006} = P_{3.6} = P_{1970}(1+0.17095)^{3.6} = 47000(1.17095)^{3.6} = 82{,}954$$

Example 1.11 In a town, it has been decided to provide 200 *l* per head per day in the 21st century. Estimate the domestic water requirements of this town in the year 2000 AD by projecting the population for the town by incremental increase method.

Table: 1.14

Year	1940	1950	1960	1970	1980
Population	2,37,98,624	4,69,78,325	5,47,86,437	6,34,67,823	6,90,77,421

Solution: The given population data is analysed, as shown in Table 1.15

Table: 1.15

Year	Population	Increase in Population	Increment over the increase, i.e. Incremental increase
1940	2,37,98,624		
		2,31,79,701	
1950	4,69,78,325		(–) 1,53,71,589
		78,08,112	
1960	5,47,86,437		(+) 8,73,274
		86,81,386	
1970	6,34,67,823		(–) 30,71,788
		56,09,598	
1980	6,90,77,421		
Total		4,52,78,797	(–) 1,75,70,103
Average per decade		$\bar{x}$ = 1,13,19,699	$\bar{y} = (-)\frac{1{,}75{,}70{,}103}{3} = (-)\ 58{,}56{,}701$

Expected population at the end of year 2000 (i.e. after 2 decades from 1980)

$$= P_2 = P_0 + 2\cdot\bar{x} + \frac{2\times3}{2}\cdot\bar{y} = 6{,}90{,}77{,}421 + 2(1{,}13{,}19{,}699) - 3(58{,}56{,}701) = 7{,}41{,}46{,}716$$

$\therefore$ Water requirement in 2,000 AD @ 200 l/head/d

$$= \frac{200\times 7{,}41{,}46{,}716}{10^6} = 14{,}829 \text{ MLD}$$

Example 1.12 Given the following data, calculate the population at the end of next three decades by decreasing rate method (Table :1.16).

Table: 1.16

Year	1940	1950	1960	1970
Population	80,000	1,20,000	1,68,000	2,28,580

Solution: The given table is extended to table, as shown below:
The table is otherwise self-explanatory.

Table: 1.17

Year	Population	Increase in population	Percentage increase in population	Decrease in the percentage increase
1940	80,000			
		40,000	$\frac{40{,}000}{80{,}000}\times100 = 50\%$	
1950	1,20,000			10%
		48,000	$\frac{48{,}000}{1{,}20{,}000}\times100 = 40\%$	
1960	1,68,000			4%
		60,580	$\frac{60{,}580}{1{,}68{,}000}\times100 = 36\%$	
1970	2,28,580			
Total				14%
Average per decade				$\frac{14}{2} = 7\%$

(a) The expected population at the end of year 1980

$$= 2{,}28{,}580 + \left(\frac{36-7}{100}\right)2{,}28{,}580 = 2{,}28{,}580\,(1.29) = 2{,}94{,}870$$

(b) The expected population at the end of year 1990

$$= 2{,}94{,}870 + \frac{29-7}{100}\times 2{,}94{,}870 = 2{,}94{,}870(1.22) = 3{,}59{,}740$$

(c) The expected population at the end of year 2000

$$= 3{,}59{,}740 + \frac{22-7}{100}\times 3{,}59{,}740 = 3{,}59{,}740(1.15) = 4{,}13{,}700$$

Summary

- The IS code lays down a limit on domestic water consumption between 135 to 225 *l*pcd, and maximum water demand for ad developing city is 335 *l*pcd.
- The fire demand for a city of 50 lakh population is hardly 1 *l*pcd.
- 15% of total consumption, which is nearly 55 *l*pcd water required to compensate losses in thefts and wastes.
- Maximum daily demand is 1.8 times of average daily demand and maximum hourly or peak demand is 2.7 times the annual average hourly demand.
- Peak factor is inversely proportional to population of city.

Important Expressions

1. Kuchling's formula, $Q = 3182\sqrt{P}$ where, P = population in thousands
2. Freeman's formula, $Q = 1136\left[\frac{P}{5}+10\right]$
3. National Board of Fire Underwriters formula, $Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right]$

4. Buston's formula, $Q = 5663\sqrt{P}$

5. Arithmetic increase method, $P_n = P_0 + n \cdot \bar{x}$

here, n = number of decades; $\bar{x}$ = average arithmetic mean of population increase

P_0 = population at present; P_n = population after n decades

6. Geometric increase method $P_n = P_0\left(1+\frac{k}{100}\right)^n$

where, k = growth rate and $k = m\sqrt{k_1 k_2 k_3 \ldots k_m}$; $r = \sqrt{\frac{P_2}{P_1}} - 1$

7. Incremental increase method, $P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \cdot \bar{y}$

8. Decreasing growth rate method

$P = P_0 + \left(\frac{r_0 - r'}{100}\right) \times P_0$

Where, P_0 = Population of last known decade

r_0 = growth rate of last decade

r' = average decrease is growth rate

9. Logistic Curve method, $P = \frac{P_s}{1+m\log_e^{-1}(nt)}$, $P_s = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2}$

and $n = \frac{2.3}{t_1}\log_{10}\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$, $m = \frac{P_s - P_0}{P_0}$

Objective Brain Teasers

Q.1 The distribution mains are designed for
(a) Maximum daily demand
(b) Maximum hourly demand
(c) Average daily demand
(d) Maximum hourly demand of maximum day

Q.2 As compared to geometrical increase method of forecasting population, arithmetical increase method gives
(a) Lesser value (b) Higher value
(c) Same value (d) Accurate value

Q.3 The total domestic consumption in a city water supply, is assumed
(a) 20% (b) 30%
(c) 40% (d) 60%

Q.4 The fire demand for ascertaining the empirical formula

$$Q = 1136\left[\frac{P}{5} + 10\right]$$

(a) Kuchling's formula
(b) Buston's formula
(c) Freeman's formula
(d) Underwriter's formula

Q.5 According to Goodrich, the ratio of peak demand rate to mean demand is
(a) $\frac{\text{Maximum daily demand}}{\text{Average daily demand}} = 180\%$
(b) $\frac{\text{Maximum weekly demand}}{\text{Average weekly demand}} = 148\%$
(c) $\frac{\text{Maximum monthly demand}}{\text{Average monthly demand}} = 128\%$
(d) All of the above

Q.6 In the equation $P = \frac{P_s}{1+m\log_e^{-1}(nt)}$ of a logistic curve of population growth, the constant m is
(a) $P_s \times P$ (b) P_s / P
(c) $\frac{P_s - P_0}{P_0}$ (d) KP_s

Q.7 P_0, P_1, P_2 be the population of a city at times to t_0, t_1 and t_2 and $t_2 = 2t_1$, the saturation value of the population P_s of the city is
(a) $P_s = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2}$
(b) $P_s = \frac{2P_0P_1P_2 - P_2^2(P_0+P_1)}{P_0P_2 - P_1^2}$
(c) $P_s = \frac{P_0P_1P_2 - P_2^2(P_0+P_1)}{P_0P_2 - P_1^2}$
(d) $P_s = \frac{P_0P_1P_2 + P_2^2(P_0+P_1)}{P_0P_2 - P_1^2}$

Q.8 If P_0 is population on the start of a logistic curve, P_s is saturation population and K is a constant of equality, population of the city is given by
(a) $\log\left(\frac{P_s - P}{P}\right) + \log\left(\frac{P_s - P_0}{P_0}\right) + KP_s t = 0$
(b) $\log\left(\frac{P_s - P}{P}\right) - \log\left(\frac{P_s - P_0}{P_0}\right) + KP_s t = 0$
(c) $\log\left(\frac{P_s - P}{P}\right) \times \log\left(\frac{P_s - P_0}{P_0}\right) + KP_s t = 0$
(d) $\log\left(\frac{P_s - P}{P}\right) + \log\left(\frac{P_s - P_0}{P_0}\right) + KP_s t = 0$

Q.9 Consider the following statements:
1. Maximum hourly consumptions of the maximum day is called peak demand.
2. The hourly variation factor is generally taken as 1.5.
3. Peak factor tends to reduce with the increasing population.

Which of these statements is/are correct?
(a) Only 2 (b) Both 1 and 2
(c) Both 1 and 3 (d) 1, 2 and 3

Q.10 The population of a town in three consecutive year are 5000, 7000 and 8400 respectively. The population of the town in the fourth consecutive year according to geometrical increase method is
(a) 9500 (b) 9800
(c) 10100 (d) 10920

Q.11 The population figure in a growing town are as follows:

Year	Population
1970	40,000
1980	46,000
1990	53,000
2000	58,000

Predicted population in 2010 by Arithmetic Regression method is
(a) 62,000 (b) 63,000
(c) 64,000 (d) 65,000

Q.12 The present population of a community is 28000 with an average water consumption of 150 lpcd. The existing water treatment plant has a design capacity of 6000 m^3/d. It is expected that the population will increase to 48000 during the next 20 years. The number of years from now when the plant will reach its design capacity, assuming an arithmetic rate of population growth, will be
(a) 5.5 years (b) 8.6 years
(c) 12 years (d) 16.5 years

Q.13 Which of the following factors has the maximum effect on figure of per capita demand of water supply of a given town?
(a) Method of charging of the consumption
(b) Quality of water
(c) System of supply intermittent or continuous
(d) Industrial demand

Q.14 Which one of the following methods given the best estimate of population growth of a community with limited land area for future expansion?
(a) Arithmetical increase method
(b) Geometrical increase method
(c) Incremental increase method
(d) Logistic method

Direction: Each of the next consists of two statements, one labelled as the 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.15 Assertion (A): In estimating population for assessing water supply demand, the geometric progression (GP) method gives correct estimate for a developing city.
Reason (R): In the GP method, a constant rate of increase in population is assumed.

Q.16 Assertion (A): The future population is predicted on the basis of knowledge of the city and its environment
Reason (R) : The future population depends on the trade and expansion of the city, discovery of mineral deposits, power generation etc.

Q.17 Which one of the following Acts/Rules has provision for "No right to appeal"?
(a) Environment (Protection) Act, 1986
(b) The hazardous waste (management and handling) rules, 1989
(c) Manufacture, storage and import of Hazardous chemical rules, 1989
(d) Environment (Protection) Rules, 1992

Q.18 When was the water (prevention and control of pollution) Act enacted by the Indian Parliament?
(a) 1970 (b) 1974
(c) 1980 (d) 1985

Q.19 Per Capita water demand is defined as the litre of water consumed daily by each person. Naturally it has to be some average value, over a period of time. Over how much period, the averaging is done here:
(a) 24 hours (b) 1 year
(c) 10 years (d) 35 year

Q.20 The water treatment units may be designed, including 100% reserves, for water demand equal to
(a) Average daily (b) Twice of (a)
(c) Maximum daily (d) Twice of (c)

Q.21 The population of a town in three consecutive decades are 1 Lakh, 1.4 Lakh, 1.60 Lakh, respectively. The population of this town in the fourth consecutive decade, according to geometric methods would be
(a) 1.9 Lakh (b) 2.024 Lakh
(c) 2.2 Lakh (d) 2.5 Lakh

Q.22 The suitable method for forecasting population for a young and a rapidly developing city is
(a) arithmetic mean method
(b) geometric mean method
(c) comparative graphical method
(d) none of these

Q.23 Which among the following brings about the Hazardous waste management and handling rules in India?
(a) Central Pollution Control Board
(b) Ministry of Environment and Forests
(c) Ministry of Urban Development
(d) Ministry of Rural Development

Q.24 Water losses in water supply system, are assumed as
(a) 5% (b) 7.5%
(c) 15% (d) 25%

Q.25 The pipe mains carrying water from the source to the reservoir are designed for the
(a) maximum daily draft
(b) average daily draft
(c) maximum hourly draft of the maximum day
(d) maximum weekly draft

Q.26 The distribution system in water supplies is designed on the basis of
(a) average daily demand
(b) peak hourly demand
(c) coincident draft
(d) greater of (b) and (c)

Q.27 The multiplying factor, as applied to obtain the peak hourly demand, in relation to the average daily demand (per hour of course), is
(a) 1.5 (b) 1.8
(c) 2.0 (d) 2.7

Q.28 Which of the following statements about Design period are true?
1. It is concerned with economy of investments
2. It takes into account of aspects like life and durability and ease or difficulty of use of installations.
3. It considers the frequency of occurrence of extremes of river flow
4. It is concerned with estimating future requirements.

Codes:
(a) 1, 2, 3 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 3 and 4

Q.29 Consider the following statements:
The daily per capita consumption of water apparently increase with
1. higher standard of living of people
2. availability of sewerage in the city
3. metered water supply
4. wholesome and potable public supply of water

Which of the above statements are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4

Answers

1. (d)	2. (a)	3. (d)	4. (c)	5. (d)
6. (c)	7. (a)	8. (b)	9. (d)	10. (d)
11. (c)	12. (c)	13. (d)	14. (d)	15. (c)
16. (a)	17. (a)	18. (b)	19. (b)	20. (d)
21. (b)	22. (b)	23. (b)	24. (c)	25. (a)
26. (d)	27. (d)	28. (c)	29. (d)	

Hints and Explanations:

Ans.3 (d)
Total domestic consumption in a city water supply is assumed to 55 to 60%

Ans.4 (c)
The freeman's formula $Q = 1136.5\left[\frac{P}{5} + 10\right]$

Ans.6 (c)
The constant m in logistic curve $m = \frac{P_s - P_0}{P_0}$

Ans.11 (c)

Year	Population	Decadal Increasa
1970	40,000	6000
1980	46,000	7000
1990	53,000	5000
	2000	58,000

$$\therefore \text{ Design growth rate} = \frac{6000 + 7000 + 5000}{3}$$
$$= 6000 \text{ per decade}$$

In 2010 population will be
$P = 58000 + 6000 = 64000$

Ans.12 (c)
Population after n years
$$P_n = P_0 + n\bar{x}$$
$\bar{x}$ is arithmetic design growth rate
Given $P_0 = 28000$
For $n = 20$, $P_{20} = 48000$
$$\therefore \bar{x} = \frac{48000 - 28000}{20} = 1000 \text{ per year}$$
The population when design capacity will be required,
$$P_n = \frac{6000 \times 1000}{150} = 40000$$
$\therefore$ Number of years to reach the plant at design capacity,
$$\eta = \frac{P_n - P_0}{\bar{x}} = \frac{40000 - 28000}{1000} = 12.0 \text{ years}$$