POSTAL BOOK PACKAGE 2025

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CIVIL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

ENVIRONMENTAL ENGINEERING

1 CHAPTER Water Demand

Q.1 **The present population of a community is 28000 with an average water consumption of 4200 m^3/d. The existing water treatment plant has a design capacity of 6000 m^3/d. It is expected that the population will increase to 44000 during the next 20 years. Find the number of years from now when the plant will reach its design capacity, assuming an arithmetic rate of population growth**

Solution:

Given dat: Present population, P_0 = 28000; Population after 20 years, P_n = 44000

$\therefore$ Increase in population per year, $\bar{x}$

$$\boxed{P_n = P_0 + n\bar{x}}$$

$$\bar{x} = \frac{P_n - P_0}{n} \qquad (n = 20)$$

$$= \frac{44000 - 28000}{20} = 800$$

Now, for population for 28000, water consumption = 4200 m^3/d

Hence, population for water consumption of 6000 m^3/d

$$= \frac{28000}{4200} \times 6000 = 40000 \text{ persons} = \text{Population at design capacity}$$

$\therefore$ No. of years from now when plant will reach at design capacity

$$P_n = P_0 + n\bar{x}$$

$$n = \frac{40000 - 28000}{800} = 15 \text{ years}$$

Q.2 **What is meant by 'design period' and 'population forecast'? Describe the 'incremental increase' method of future population forecast of a city, stating its advantages.**

Solution:

Design Period : The number of years for which the system is to be adequate is called design period.

Population forecasting: Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended, similarly overestimated value will make it costly.

The present and past population record for the city can be obtained for the census population record. After collecting these population figures, the population at the end of design period is predicted using various methods as suitable for that city considering the growth pattern followed by the city.

Incremental Increase method: This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method, the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

Hence, population after n^{th} decade is $P_n = P + nX + \left\{\frac{(n+1)n}{2}\right\} Y$

Where, P_n = Population after n^{th} decade
X = Average increase
Y = Incremental increase

- Advantages of incremental increase method:
  1. This method gives/predict more accurate value of population.
  2. This method embodies the advantage of arithmetic average method and geometrical average method.

Q.3 **The population of a city at previous consecutive census year was 4,00,000, 5,58,500, 7,76,000 and 10,98,500. Calculate the anticipated population at the next census nearest to 5,000**

Solution:

Since the method is not mentioned in the question, hence the question is solved by *incremental increase method*. This is done because

- This method gives results between the results given by the arithmetic increase method and the geometric increase method.
- The method is considered to be the best for any city, whether old or new.

Census year	Population	Population Increment	Incremented Increase
1	4,00,000		
		1,58,500	
2	5,58,500		59000
		2,17,500	
3	7,76,000		10,5000
		3,22,500	
4	10,98,500		
		$\overline{X} = \frac{\Sigma X}{3}$ = 232833.33	$\overline{Y} = \frac{\Sigma Y}{2}$ = 82000

$$\boxed{P_n = P_0 + n\cdot\overline{X} + \frac{n(n+1)}{2}\overline{Y}}$$

For $n = 1$

$$P_5 = P_0 + 1\cdot\overline{X} + \frac{1(1+1)}{2}\overline{Y}$$

$$= 10{,}98{,}500 + 232833.33 + 82000 = 1413333.33$$

∴ The anticipated population at the next census to the nearest 5000 would be 1415000.

Q.4 **Compute the 'fire demand' for a city of 2 lac 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

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

where Q is amount of water required in litres per minute and P is population in thousands

$$Q = 4637\sqrt{200}\left[1 - 0.01\sqrt{200}\right] = 56303.08 \text{ litres per minute}$$

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

(ii) Kuichling's formula,

$$Q = 3182\sqrt{P} = 3182\sqrt{200}$$

$$= 45000.28 \text{ litres per minute} = 64.8 \text{ MLD}$$

(iii) Freeman Formula,

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

$$= 1136\left[\frac{200}{10} + 10\right] = 34080 \text{ litres per minute} = 49.0752 \text{ MLD}$$

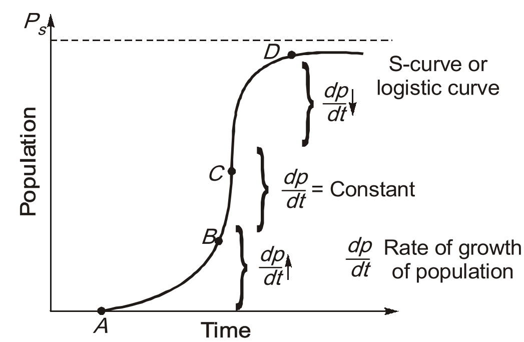
(iv) Buston's formula,

$$Q = 5663\sqrt{P} = 5663\sqrt{200}$$
$$= 80086.91 \text{ litres per minute} = 115.33 \text{ MLD}$$

Q.5 Explain any three methods of estimating the future population of a city. What are their relative merits?

Solution:

Population forecasting: General population growth curve with respect to time is given by following method:



1. Arithmetic increase method: In this method rate of growth of population is assumed to be constant i.e. for region BC. for which $\frac{dp}{dt}$ = Constant, i.e., population increases by same amount in a given time duration.
2. Geometric increase method (compound/uniform increase method): In this method rate of growth of population is assumed constant but population is compounded for this given rate to compute population in future.
3. Incremental increase method: In this method, rate of growth of population is not assumed to be constant. Rate of growth of population may increase or decrease. In this method average incremental increase in increase of population is also considered.
4. Merits of different forecasting methods:
   (a) Population forecasted by geometric increase method is maximum in comparison to that computed by arithmetic or increment increase method.
   (b) Population forecasted with arithmetic increase method is minimum in comparison to geometric increase method and incremental increase method.
   (c) Geometric increase method is generally recommended for young cities and arithmetic increase method for old ones.

Q.6 Compute the population of the year 2000 and 2006 for a city whose population in the year 1930 was 25000 and in year 1970 was 47000. Make use of geometric increase method.

Solution:

The growth rate can be computed by,

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

Now, using
$$P_n = P_o\left(1 + \frac{r}{100}\right)^n, \text{ we have}$$
$$P_{2000} = P_3 \text{ (i.e., after 3 decades from 1970 onwards)}$$
$$= P_{1970}\left(1 + \frac{r}{100}\right)^3 = 47000(1 + 0.17095)^3 = 75459$$

and
$$P_{2006} = P_{3.6}$$
$$= P_{1970}(1 + 0.17095)^{3.6} = 47000(1 + 0.17095)^{3.6} = 82954$$

Q.7 A city has following recorded population :

1951	50000
1971	110000
1991	160000

Estimate: (i) the saturation population, and (ii) expected population in 2011.
(Use Logistic Curve Method)

Solution:

Given data: $n = 20$ years, $P_0 = 50000$, $P_1 = 110000$, $P_2 = 160000$

$$\text{Saturation population, } P_S = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$\Rightarrow \quad P_S = \frac{2\times 50000\times 110000\times 160000 - (110000)^2(50000+160000)}{50000\times 160000 - (110000)^2}$$

$$\simeq 190488$$

$$P_t = \frac{P_s}{1+\left(\frac{P_s - P_o}{P_o}\right)e^{(-kP_st)}} = \frac{P_s}{1+\left(\frac{P_s - P_o}{P_o}\right)e^{nt}}$$

(where $n = -kP_s$)

$$n = \frac{1}{t_1}\ln\left[\frac{P_o(P_s - P_1)}{P_1(P_s - P_o)}\right] = \frac{1}{20}\ln\left[\frac{50000(190488-110000)}{11000(190488-50000)}\right] = -0.0673$$

$$\therefore \quad P = \frac{190488}{1+2.80976\times e^{-0.0673\times 60}} = 181496$$

Q.8 In a town, it has been decided to provide 200 litres per head per day in the 21st century. Estimate the domestic water requirements of this town in the year AD 2000 by projecting the population of the town by incremental increase method:

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:

Thy given population data is analysed, as shown in table below:

Year (1)	Population (2)	Increase in population (3)	Increment over the increase, i.e. incremental increase (4)
1940	2,3798,624		
1950	4,69,78,325	2,31,79,701	(–) 1,53,71,589
1960	5.4786,437	78,08,112	(+) 8,73,274
1970	6,34,67,823	86,81386	(–) 30,71,788
1980	6,90,77,421	5609,598	
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)

$$= P_2 = P_0 + 2.\bar{x} + \frac{2 \times 3}{2}.\bar{y}$$

$$= 6{,}90{,}77{,}421 + 2(1, 13{,}19{,}699) - 3(58{,}56{,}701) = 7{,}41{,}46{,}716$$

∴ Water requirement in AD 2,000 @ 200 l/head/d

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

Q.9 What do you mean by the term per Capita Demand? How is it estimated? The population of a locality as obtained from census record is as follows:

Year	1970	1980	1990	2000	2010
Population	15000	20000	24500	29500	32500

Estimate the population of the locality in 2040 by Arithmetic increase, geometric increase, incremental increase and rate of decrease of methods.

Solution:

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

It is estimated as,

$$\text{Per capital demand (in } l\text{/c/d)} = \frac{\text{Total yearly water requirement of city}}{365 \times \text{Design population}}$$

Arithmetic increase method: $P_n = P_0 + n \cdot \bar{x}$

$$\bar{x} = 4.375 = \frac{P_{1970} + P_{1980} + P_{1990} + P_{2000} + P_{2010}}{5}$$

$$P_{2040} = P_{2010} + 3 \cdot \bar{x}$$

∴ $P_{2040} = [32.5 + 3 \times 4.375] \times 10^3 = 45625$

Year	Population (in 10^3)	Increase in Pop. (in 10^3)	Growth rate	Incremental Increase	% Decrease in growth rate
1970	15			–	–
1980	20	5	$\frac{5}{15} \times 100 = 33.3\%$	–	–
1990	24.5	4.5	22.5%	–0.5	10.8%
2000	29.5	5	20.41%	0.5	2.09%
2010	32.5	3	10.17%	–2	10.24%
		$\bar{x} = 4.375$	$r = \sqrt[4]{33.3 \times 22.5 \times 20.41 \times 10.17}$	$\bar{y} = -0.6667$	$r' = 7.71\%$

Geometric increase method: $r = (33.3 \times 22.5 \times 20.41 \times 10.17)^{1/4} = 19.86\%$

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