Environmental Engineering -I

Lecture 8 – Introduction to Water Supply System

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Water Supply

- In the 17th–18th century, distribution systems utilizing cast-iron pipes, aqueducts, and pumps began to be installed.

- The link between polluted water and disease came to be understood in the 19th century, and treatment methods such as slow sand filtration and disinfection with chlorine were introduced.

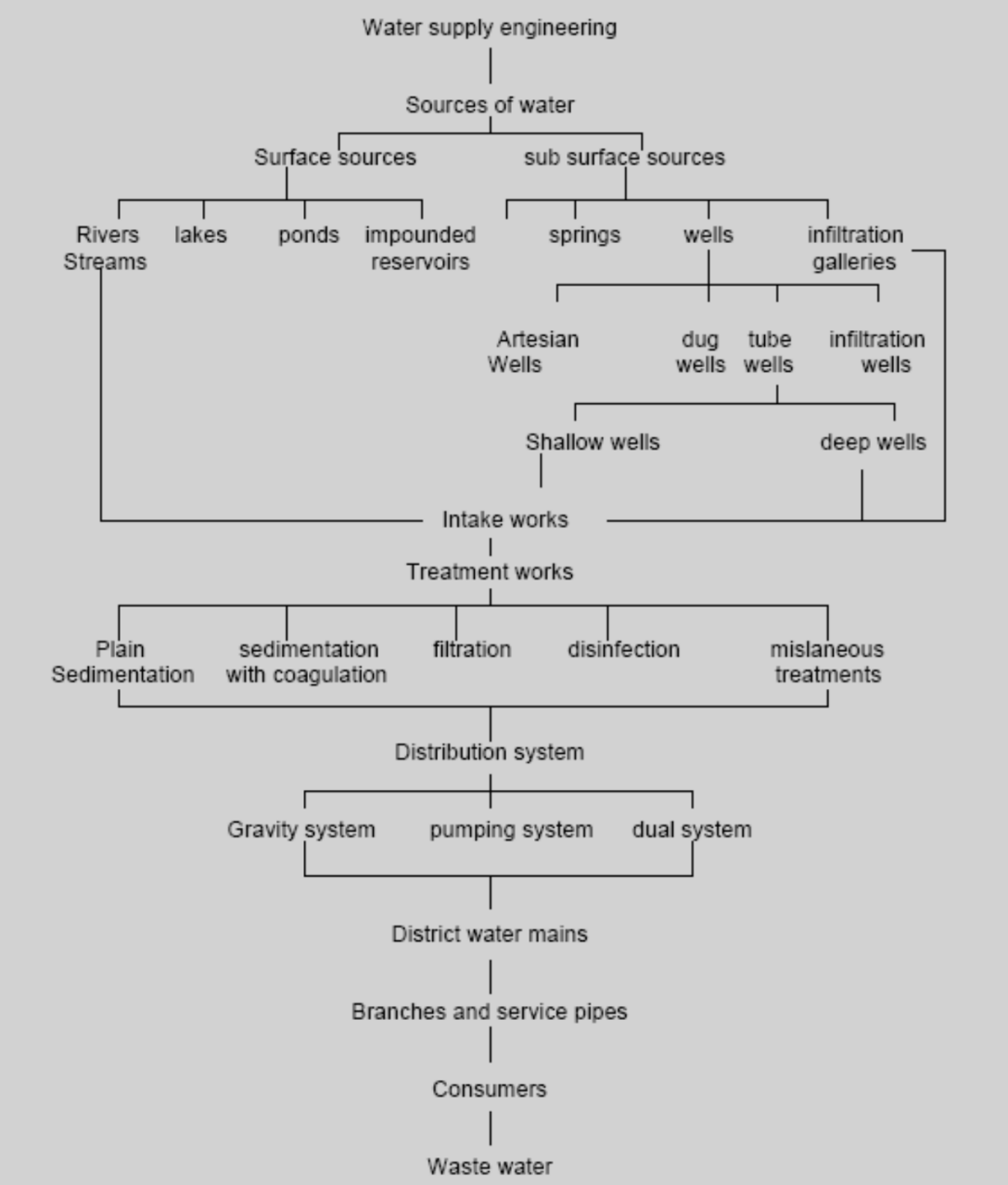
- Reservoirs are formed usually by constructing dams near the collection point of mountain-water runoff or across rivers.

Water Wholesome

- It should be free from bacteria
- It should be colorless and sparkling
- It should be tasty, odor free and cool
- It should be free from objectionable matter
- It should not corrode pipes
- It should have dissolved oxygen and free from carbonic acid so that it may remain fresh.

Design of Water Supply System

Introduction



Introduction

Requirements:

1. Selection of per capita water consumption(WC)
2. Future population forecast
3. Design period

Water Consumption

- It is amount of water consumed by a community in one day.
- Water consumption expressed as litre per capita per day i.e. Lpcd.

$$Water\ Consumption = \frac{Total\ amount\ of\ water\ consumed\ daily\ in\ litres}{Total\ number\ of\ persons\ served\ in\ the\ city}$$

- According to studies the per capita values varies from **150 to 600 lpcd** and depends from area to area
- For **Punjab** this values is typically around **270 liters per capita per day.**

Water Consumption

- There are multiple factors that are influencing the per capita water consumption values i.e. Climate , Living standards and culture .
- Water for domestic purpose is needed mainly for:

1. Drinking
2. Washing
3. Cooking
4. House Cleaning

Water Consumption

- Per capita water consumption data is useful for making estimates of a community's water demand.
- There are different level of service that are being provided to consume water.

1. Stand Posts
2. Yard Connection
3. Full Connection

- Public stand posts are preferred when we need to reduce the cost of supply system and also to minimize the wastewater generation.

Studied Facts about Water Consumption

- 12 mm diameter tap when fully **open *with residual head of 1.5m at tap*** can deliver water at rate of 15liters per minute.

- According WHO **one such tap can serve 9 people in one hour at the rate of 100 lpcd**. However the consumption pattern vary based on demands.

- For **public stand post a minimum two taps should be provided each for at least 150 persons**.

Water Consumption-Introduction

Classification of Water Consumed according to its Ultimate Use

Sr. #	Use	Source	Amount
1.	Domestic	Houses ,hotels (sanitary, drinking, washing. bathing, cooking, gardening, desert coolers etc.	30-40% of total water supplied
2.	Commercial	Markets, office buildings, dental clinics, private school, garages, workshops etc.	10-20%
3.	Industrial		20-30%
4.	Public use	Public buildings (town hall, jail, schools, street washing, public toilets, gardens)+fire fighting	10-20%
5.	Unaccounted for	Loss of water through leaks, unauthorized connections	10-15% For Lahore >50%

Typical Water requirements for non domestic purposes

Purposes	Water Requirement
Schools	15-30 liters per student per day
Hospitals	220-300 liters per bed
Hotels	80-120 liters per resident
Restaurants	65-90 liters per seat
Mosques	25-40 liters per visitor
Offices	25-40 liters per person
Cinemas	10-15 liters per seat
Livestock	10-25 liters per head

Per capita demand distribution for various part of Punjab

Use	Demand
Domestic	135 liters per capita per day
Industrial	40 liters per capita per day
Public	25 liters per capita per day
Fire Demand	15 liters per capita per day
Losses/Theft	55 liters per capita per day

Total = 270 Lpcd

Definitions

Average Daily Consumption:

- It is the average amount of water consumed by a community in one day divided by the number of people served.

$$Average\ Daily\ Water\ Consumption(lpcd) = \frac{Total\ amount\ of\ water\ used\ in\ one\ year}{365 \times Mid\ year\ population}$$

Introduction

Maximum Daily Consumption:

- It is the maximum water consumption during any one day in the year**. It is about 150 to 180% of average day consumption.**

Peak Hourly Consumption:

- The peak consumption during any hour of the year, excluding fire demand, is called peak hourly consumption. **It is around 150% of the maximum daily consumption & 225% of the average daily demand**.

Introduction

Ratio used in Lahore (WASA)

Max daily : Avg daily	1.5 : 1
Peak hourly : Max daily	1.5 : 1
Peak hour : Average daily	2.25 : 1

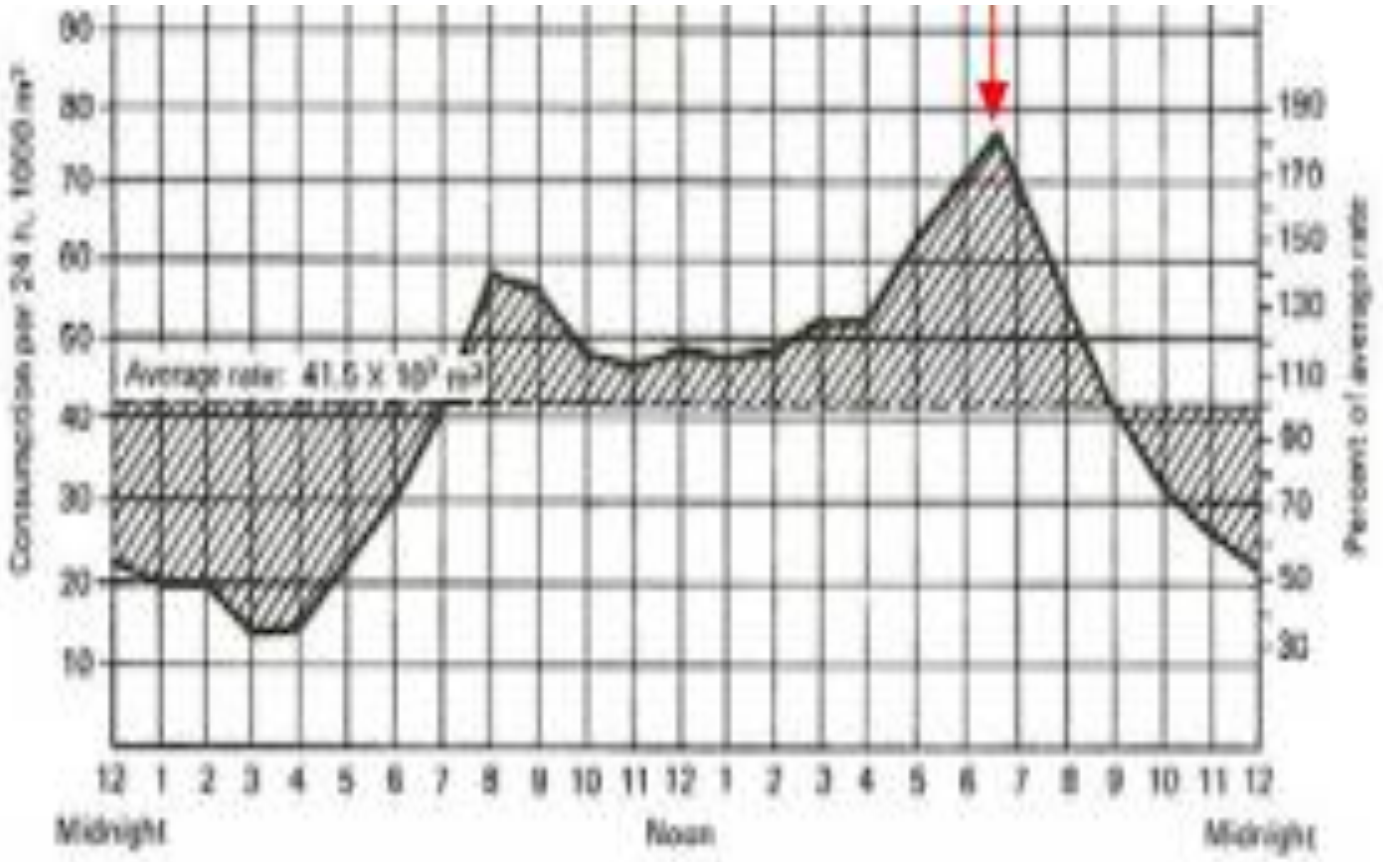
For design of water distribution system we usually consider **peak hourly flow and maximum daily flow + fire demand**

Variation in water demand

1. Monday : Highest
2. Sunday : Lowest
3. June/July : Highest
4. Dec/Jan : Lowest

Water Consumption-Introduction

- **Variation in Water Consumption**



Factors affecting Water Consumption

- **Climate**

If temperature is more, requirement of water will be more & vice versa.

- **Standard of living**

More standard of living ,consumption of water will be more.

- **Metering**

Metering reduces the use and wastage of water because consumer has to pay and also reduces load on pump etc.

- **Quality of Water**

If better the quality more will be the consumption of water.

Introduction

- **Size of City**

More size more will be the consumption of water.

- **Pressure of distribution system**

If pressure is high, wastage will be more. System should not be design for such a high pressure. If system pressure increases from 25-45 psi ,the consumption will increases by 30%.

- **Type of Water Supply**

If water supply is for 24 hrs, wastage will be more whereas in intermittent water supply wastage will be less.

- **Cost of Water**

C = 21 – log Q, where C is the cost in $ per 1000 ft3 of water and Q is rate of water in 1000 gallon/year

- **Level of service**

1. Stand post 2.Yard Post 3. Full connection

Fire Demand

Fire Demand

The actual amount of water used in a year for fire is very **small**, but the rate of flow is **large**.

Method of Estimation

$$F = 223.18\, C\sqrt{A}$$

Where,

F= Fire demand in L/min **(F should not exceed 45380 L/min and should not be less than 1890 L/min)**

A=Area of floors in m^2

C=A constant, with different values according to construction.

- ✓ C=1.5 for wood frame construction
- ✓ C=1.0 for ordinary construction
- ✓ C= 0.8 for non combustible construction

Fire Demand

Types :

1. Direct System
2. Mobile System

- Maximum flow required for an individual fire is **45 m^3/min**
- Fire hydrant serve an area of about **3750 m^2.**
- Minimum spacing between hydrant should be approx. **150 m.**

Storage Requirement for fire fighting

Water storage requirements for fire fighting vary with the size of city.

- Minimum Storage required is for 4 hours.

- Maximum Storage required is for 10 hours.

Population Forecasting

Population Forecasting

- A community water supply should have available surplus capacity to account for future population growth and improved level of service.
- It is self-evident that a large population will use more water than a small population.
- Water consumption estimates have been historically based on population projections.
- An analysis of the future demand of a particular community should always done by considering their present use.

Population Forecasting

- Consumption should be broken down by classes users (domestic ,commercial, industrial, public), area of city, economic level of the users, season of the year etc.
- Population forecasting is an important factor for designing water supply, sewerage and other infrastructural facilities for a city.
- Graphical and Mathematical methods are used for estimating future population by using past data records that can be obtained from local census office.
- None of the method is accurate, Engineer has to use his own judgement for the most applicable method
- Factors such as discovery of oil field, gold mines, industrial development , migration, epidemics, earth quake may upset all calculations of future growth

Population Forecasting

- Water demand is being calculated based on

1. Design Period
2. Present water demand plus 50%
3. Demand based on computed population growth models or estimates.

Population Growth Factor (table)

Design period (Years)	Growth Rate (2%)	Growth Rate (3%)	Growth Rate (4%)	Growth Rate (5%)
10	1.22	1.34	1.48	1.63
15	1.35	1.56	1.80	2.08
20	1.49	1.81	2.19	2.65

1.Graphical Method

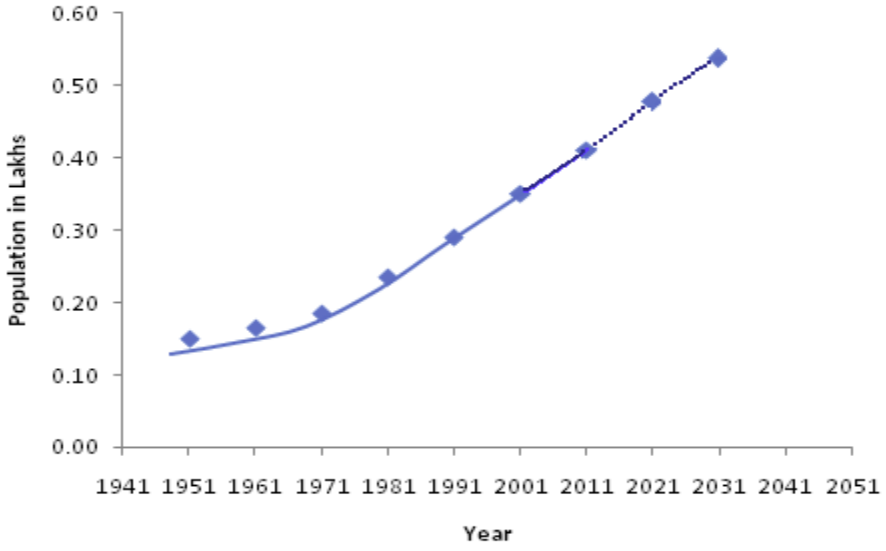
- Simplest method to estimate the future population
- Can be used in two cases;

1. first one is the graphical method based on single city and
2. second one is the graphical method based on cities having similar growth conditions.

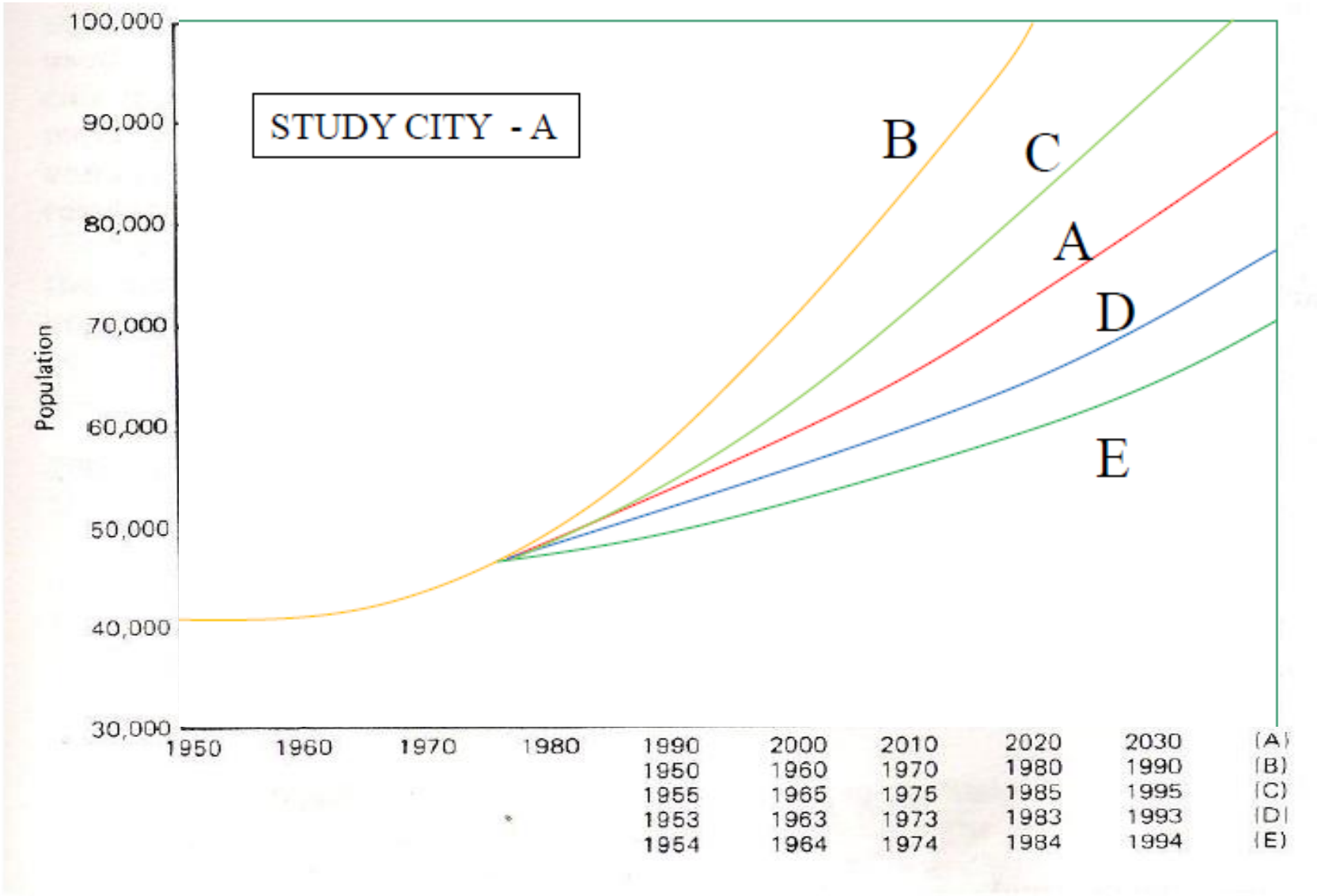
- Plot the population of the city for the pervious year and by eye judgement extent the line to get the future population

Graphical method based on a single city:

- In this method, the population of last few decades of existing city is plotted with respect to time to a suitable scale on graph as shown in a figure below.
- The population curve is smoothly extended for getting future population. This extension should be done very carefully by considering all factors which effect population growth in that area and it also requires proper experience and judgment.
- This method is very simple but may not be accurate method for estimating future population.

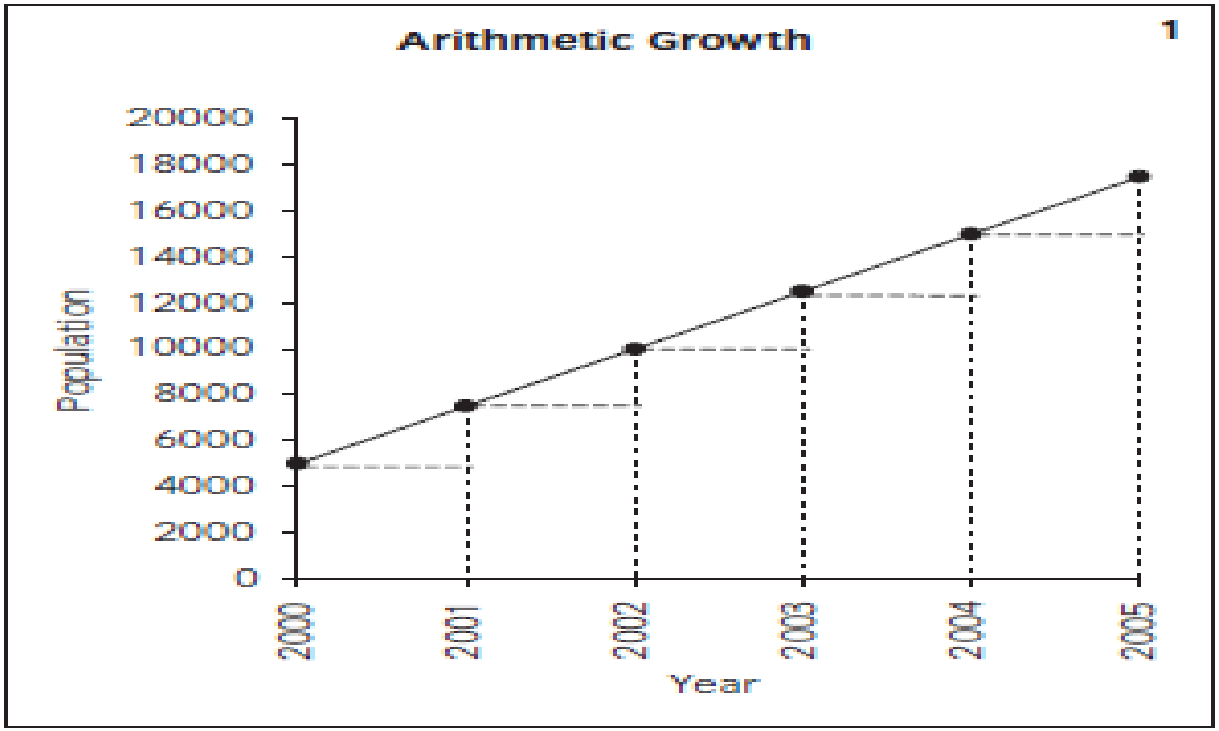


- **Graphical method based on similar cities with similar Growth Pattern**
- This technique involves the census populations of cities already developed under similar conditions are plotted.
- A commonly used variant of this technique includes comparison of the projected growth of other cities of larger size.
- The cities chosen for comparison should be as similar as possible in terms of activities ,life styles and culture to some extent with the city being studied.
- This method gives the best estimate of population growth since there is “real-time analysis” involved.


STUDY CITY - A
Population
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
B
C
A
D
E
1950
1960
1970
1980
1990
2000
2010
2020
2030
(A)
1950
1960
1970
1980
1990
(B)
1955
1965
1975
1985
1995
(C)
1953
1963
1973
1983
1993
(D)
1954
1964
1974
1984
1994
(E)

2.Arithmatic Method

- Based on hypothesis that **"the rate of growth is constant"**.
- A constant increment of growth is added periodically to the city population.



2.Arithmatic Method(Contd..)

- Mathematically,

$$\frac{dP}{dt} = K$$

$$dP = K\,dt$$

$$\int_{P_o}^{P_f} dP = K \int_{t_o}^{t_f} dt$$

Integrating:

$$P_f - P_o = K(t_f - t_o)$$

$$P_f = P_o + K(t_f - t_o)$$

Where,

P_f= Future population in year t_f

P_o = Present Population

t_o =Present Population

t_f =Future Population

$$K = \frac{P2 - P1}{t2 - t1}$$

P2, P1, t2 & t1 are points on projected population vs time line.

3.Uniform %age Method or Geometric Growth Method

- Based on hypothesis that "**the rate of increase in population is proportional to the population**".
- Mathematically,

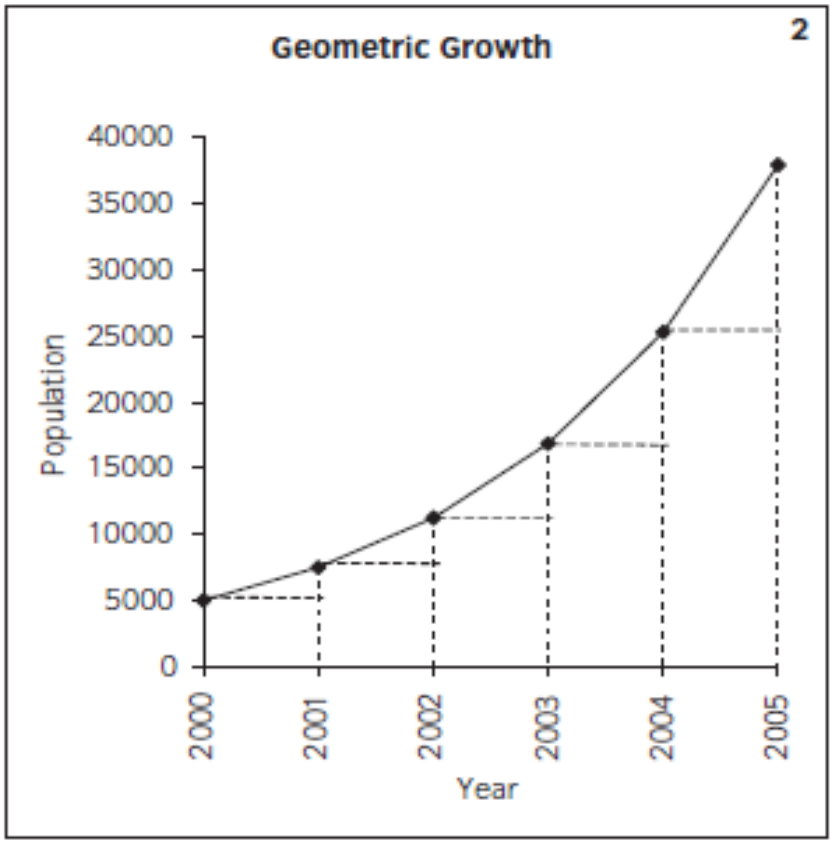
$$\frac{dP}{dt} = K'P$$

$$\int_{P_o}^{P_f} \frac{dP}{P} = K' \int_{t_o}^{t_f} dt$$

$$\ln P_f - \ln P_o = K'(t_f - t_o)$$

$$\ln P_f = \ln P_o + K'(t_f - t_o)$$

$$P_f = P_o e^{K'(t_f - t_o)}$$



Numericals
(Water Demand)

Problems-Water Demand & Fire Flow

- Problem 1: Determine the average daily demand of water in cubic meter per day for a community having a population of 30,000 persons with average water consumption of 350 lpcd.
- Problem 2: A housing scheme has 50 plots with 5 persons per plot. Per Capita consumption is assumed to be 550 liter per capita per day. Calculate total average and maximum demand of scheme?
- Problem 3 :Estimate the peak hourly demand for the population of 68,000 persons, use a total amount of water 7,546,600 m^3 during 52 weeks.
- Problem 4: Estimate the average daily rate ,maximum daily rate, and peak hourly rate for the population of 58,000 persons , use a total amount of water 9,526,500 m^3 during 12 months.
- Problem 5: Calculate maximum daily flow and peak flow of a water use for a community having 1000 houses , 7 persons per house with an average water consumption of 350 l/c/d.
- Problem 6: Calculate minimum demand of water for a society having a population of 29,146 persons with a average water consumption of 400 l/c/d.

Problems-Water Demand & Fire Flow

- Problem 7 : City with present population 58000 persons used a total flow 9526600 m3 during last 12 months. On the day of maximum consumption 42000 m3 of water was used .Estimate Qavg, Q max , to be excepted in 10 years when the population is estimated to be 72500 persons.
- Problem 8 : Calculate average daily demand and peak hourly demand for a city having a 3000 houses, 5 persons per house, 3 schools , 1000 students per school , 2 commercial building with a floor area of 0.1 hector. The water consumption is assumed to be 300 L/person/d, 30 L/student/d, and 75 $L/m^2/d$.
- Problem 9: Determine the fire flow required for a three storey building with a planned area of 700 m2 and wood frame construction. If this building dictates a fire flow for the community of 78000 persons with the average water consumption of 350 Lpcd. What will be the maximum daily demand including fire flow.
- Problem 10 :Determine the fire flow required for the community of 22000 person has an average consumption of 600 lpcd. The fire flow is dictated by a building of ordinary construction with a floor area of 1000 m2 and height of 6 stories. Find total flow required during the day of fire.

Problems-Water Demand & Fire Flow

Problem 11: Determine the Peak hourly requirement of water and total flow for a community of population 30,000 persons and average consumption of 350 lpcd, during a peak hour flow , the fire demand flow is maintained for 3 hrs per day for the building of ordinary construction with floor area of 1000m^2 and the height is 3 stories.

Problem 12: A three storey wooden frame building has each floor area : a) 900 m2 b) 700 m2 c) 400 m2 .Determine fire flow and total daily amount of flow for maximum duration of fire flow.

Problem13: Community with a population of 50000 persons has an average consumption of 550 lpcd. Fire flow is dedicated by 2 storey building of wooden structure with a floor area of 1000m2 and 500m2 .Find the total flow required for this day.

Problem14: Estimate the water requirement for the following communities a) 20000 persons with 150 lpcd b) 55000 persons with 170 lcpd c) 120000 persons with 610 lpcd, having 7 storey building with a)Ordinary construction b)wood construction for each community (Each floor area=1000 m2.)

Problems-Water Demand & Fire Flow

Problem 15: Determine the required fire flow for a 3-storey wood frame building covering 700 m2 which connects with a 5- storey building of fire resistive construction covering 900 m2.

Problem 16: Calculate the required maximum daily demand , fire flow and total flow for a society having 5000 single storey houses covering 1000 m2 of area with 500 m2 of basement. Each house contains 10 persons wit average water consumption of 450 lpcd. (C=1)

Problem-Population Forecasting

- Problem 17: Predict the population for the years 1981, 1991, 1994, and 2001 from the following census figures of a town by different methods

Year	Population: (thousands)	Arithmetic Increment per year(K)	Geometric Increment per year(K)
1901	60	-	-
1911	65		
1921	63		
1931	72		
1941	79		
1951	89		
1961	97		
1971	120		
Averages	-		

Problem-Population Forecasting

Problem 18: A city had a population of 210000 in 1991 and 240000 in 2001.If the city is assumed to follow arithmetic rate of growth find the population of the city in 2018

Problem 19: Present (2015) population of city is 1350000 and it is expected to grow at a uniform rate of 3% per annum. Find its population in 2033.

Problem 20:A community has experienced the growth in population and water use as shown in table. Estimate the population ,per-capita water use and average daily water demand in the year 2030

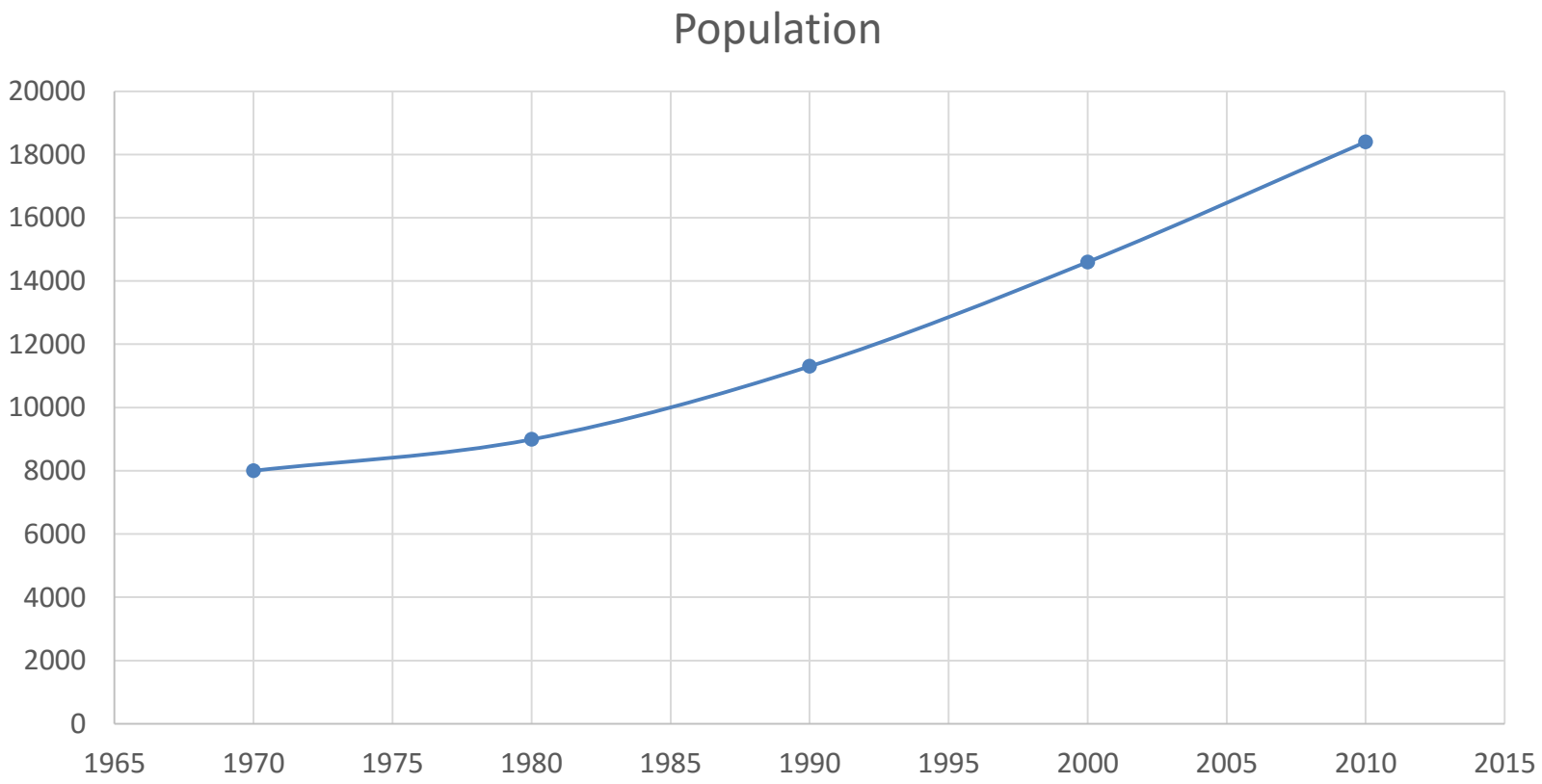
year	1979	1980	1990	2000	2010	2030
population	8000	8990	11300	14600	18400	?
WC(m3/d)	2270	2720	3630	4970	6600	?

Problem 21: A community is expected to reach a population of 35000 in 20 yrs. It has present population of 28000 with average water consumption of 16×10^6 lit/day. The existing water treatment plant has a design capacity of 19000 m^3/day.

Assume an arithmetic rate of population growth. Determine in which year the existing plant will reach its design capacity.

Assume the plant to be designed on max. daily consumption.

Population Vs time(Prob – 20)



Water consumption Vs time(prob-20)