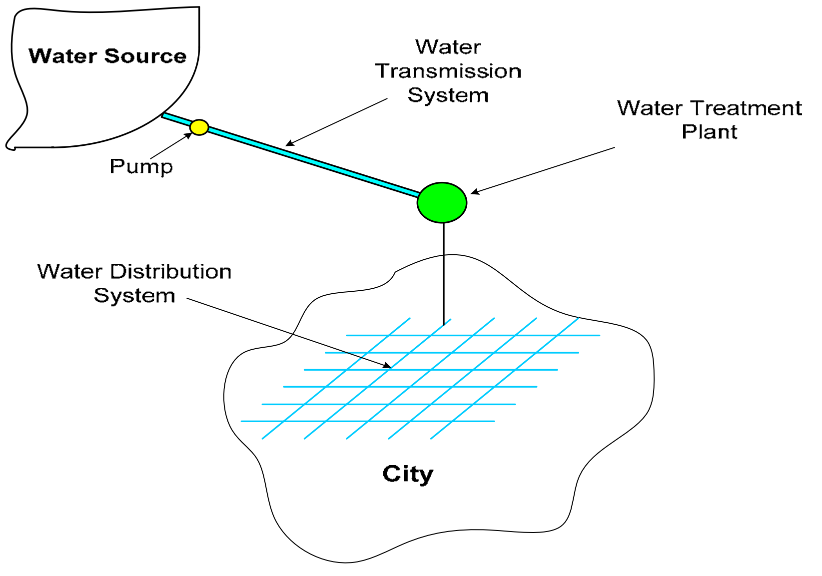
Water Demand and Supply

CE 370 - Lecture 2

Components of a water supply system

- The components of a water supply system may include:
  - The water source (Dam, Well, River, etc…)
  - Transmission system
  - Treatment plant
  - Distribution network

Components of Water Supply System



The design capacities of a water supply system

- The design capacities are governed by:
  - Design period
    - The number of years for which the system is to be adequate
  - Design population
    - The number of persons to be served
  - Design flows
    - The rates of consumption

Design Period

- The choice design periods is governed by:
  - useful life based on wear and tear
  - expected population growth and developments
  - feasibility for addition or expansion
  - Financial constraints and interest rates
- The design periods usually adopted are as follows:
  - dams: 25 - 100 years
  - wells: 5 years
  - transmission pipes: 25 years
  - treatment plants: 10-15 years
  - pumps: 10 years
  - distribution system: 35-45 years

Design Population

- Before a water treatment plant can be designed, it is necessary to determine the design population (present and future population).
- The Census Bureau is the main source of past population figures. It publishes its figures every 10 years (decennial count).
- To find the present population, engineers depend on the ratios of the last census population to the number of :
  - School enrolment
  - Utility connections
  - Telephone connections

Example (1)

The last census population of a city was 67250 in the year 2000. What is the present population in the year 2007 given the following statistics:

	2000	2007
Utility connections (U)	19214	23057
School enrolment (S)	12933	15778
Telephone connections (T)	17698	21415

Solution (1)

- Determine the utility connections, school enrolment, and telephone connections rations for the year 2000:
  - U = 67250/19214 = 3.5 : 1
  - S = 67250/12933 = 5.2 : 1
  - T = 67250/17698 = 3.8 : 1
- Determine population for 2007 from above ratios:
  - Population from U = 3.5 × 23057 = 80700
  - Population from U = 5.2 × 15778 = 82045
  - Population from U = 3.8 × 21415 = 81377
  - Population 2007 = 1/3 (80700+ 82045+ 81377) = 81374

Design Population

- The population expected at the end of the chosen design period is influenced by:
  - births
  - deaths
  - migration
- Methods of Estimating Future Population:
  - Arithmetic Progression Method
  - Geometric Progression method
  - Decreasing Rate of Increase Method
  - Graphical Comparison Method
  - Logistic Method
  - Ratio Method
  - ... and many other methods

Arithmetic method

- This method assumes that the rate of growth will be constant

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

P=Population

t = time

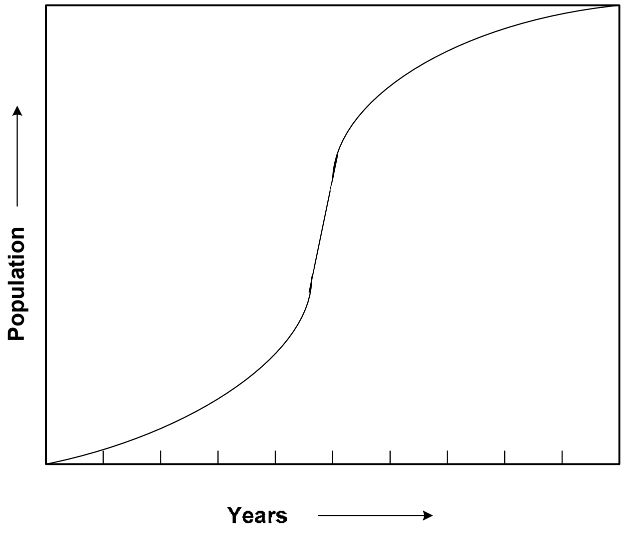
K = arithmetic growth constant $\quad K = \frac{(P_2 - P_1)}{(t_2 - t_1)}$

$P = P_o + K\Delta t$

Logistic Method

- This method assumes that the growth, as a function of time, follows some logical mathematical relationship. The population tends to grow according to logistic or S-shaped curve, starting with a low rate, followed by a high rate and the progressively low rate to a saturation population. This saturation population is the final limit to growth which is limited by economic opportunities and other conditions.

Plot of logistic method



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- The equation for the logistic model is:

$$P = \frac{P_{sat}}{1 + e^{(a + b\,\Delta t)}}$$

P = population for future year
P_{sat} = saturation population
a, b = data constants
Δt = future time period, years

- Three successive years, represented by t_o, t_1, and t_2 are chosen that are equidistance from each other
- The number of years from t_o to t_1 is denoted by n.
- The population figures corresponding to t_o, t_1, and t_2 are P_o, P_1 and P_2 through which the logistic curve is to pass.

Continue

		Year	City A Population	
	$t_o \rightarrow$	1900	10400	$\leftarrow P_o$
		1910	12080	
$n = 40$		1920	17113	
		1930	28256	
	$t_1 \rightarrow$	1940	38968	$\leftarrow P_1$
		1950	51230	
$n = 40$		1960	57770	
		1970	70507	
	$t_2 \rightarrow$	1980	84628	$\leftarrow P_2$
		1990	101750	
		2000	185626	

Continue

- The constants are obtained by the following equations:

$$P_{sat} = \frac{2P_oP_1P_2 - P_1^2(P_o + P_2)}{P_oP_1 - P_1^2}$$

$$a = \ln\frac{P_{sat} - P_o}{P_o}$$

$$b = \frac{1}{n}\ln\frac{P_o(P_{sat} - P_1)}{P_1(P_{sat} - P_o)}$$

Constant percentage method

- This method assumes that the rate of growth is proportional to the population (first order):

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

$$\ln P = \ln P_o + K\Delta t$$

P=Population

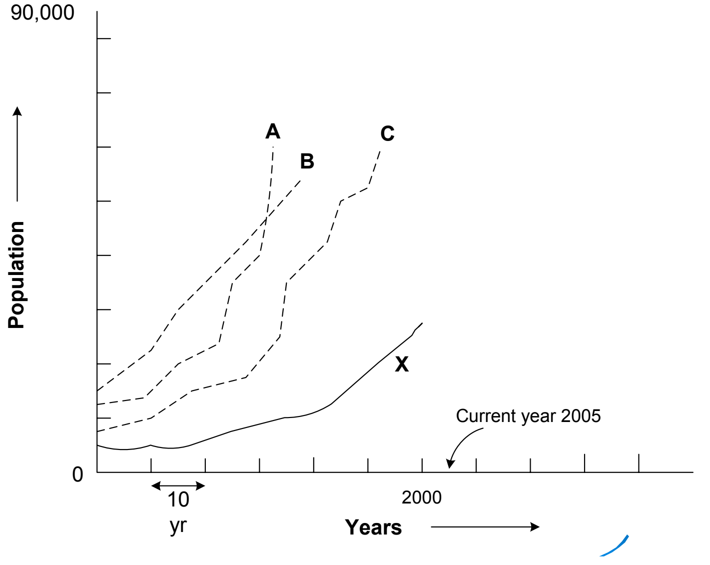
t = time

K = rate constant $\qquad K = \frac{\ln P - \ln P_o}{\Delta t}$

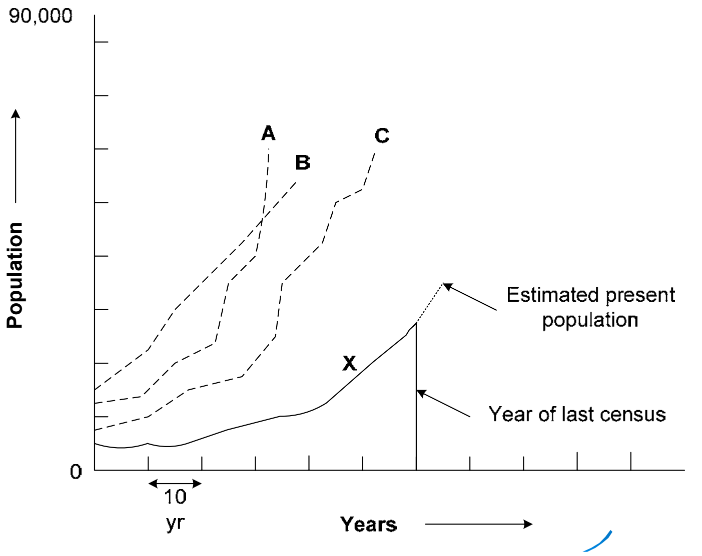
Curvilinear method

- This method is based on a graphical projection of the past population of similar but larger cities.
- The cities selected for comparison should be similar in as many characteristics as possible (economics, geographical, etc…).
- This is the most commonly used method for population projection.

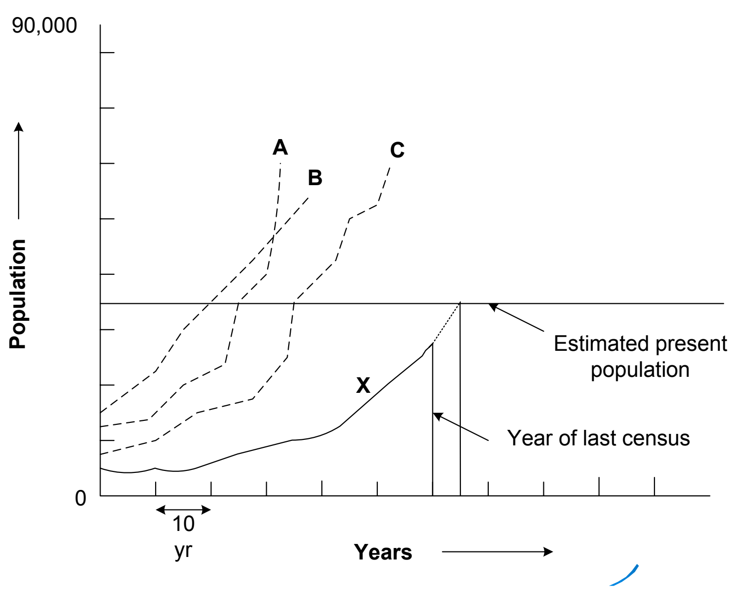
Curvilinear method



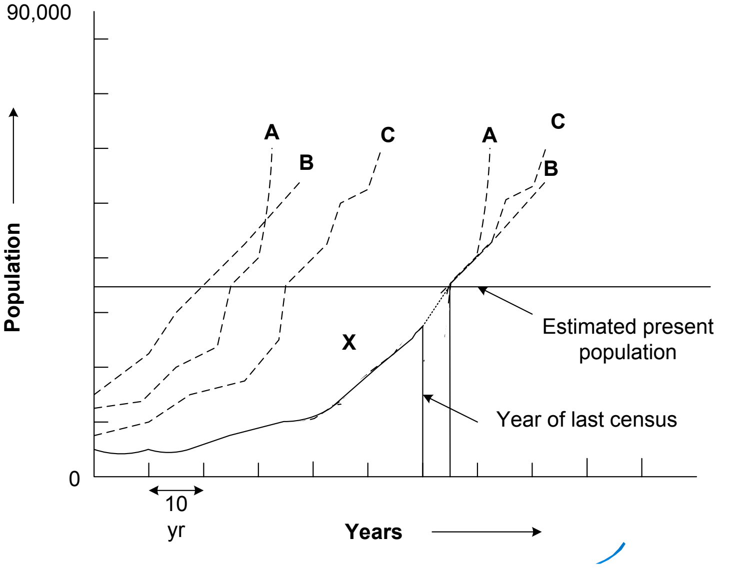
Curvilinear method



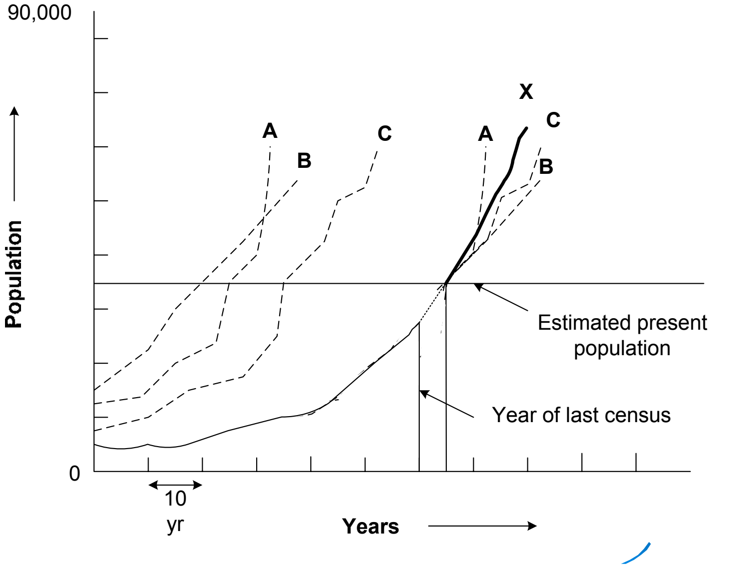
Curvilinear method



Curvilinear method



Curvilinear method



Water Usage

- Available water to a city can be classified based on its ultimate use. Water is used for:
  - **Domestic:**
    - Includes houses, apartments, and other dwellings.
    - It ranges from 60-265 l/cap-day.
    - About 33% of the average city consumption.
  - **Commercial:**
    - Businesses, laundries, hospitals, etc….
    - About 20% of total use.

Water Usage continue

- **Industrial:**
  - Includes paper mills, chemical plants, textile, food processing, etc…...
  - Industries may develop their own water supply.
  - Water quantities depend on type of industry.
- **Public:**
  - Public buildings (courts, police, jails, schools, etc…)
  - About 20-75 l/cap-day.
- **Leakage and wastage:**
  - Due to meter problems, leakage from pipes, unauthorized connections.
  - About 40-150 l/cap-day.

Variations In Water Consumption Rates

➢ **Seasonal Variations**

In summer, daily water consumption rate may reach 120 to 160% of average daily consumption rate throughout the year. In winter, daily water consumption may reach only 70% of average daily use throughout the year.

➢ **Daily Variations**

Water consumption varies from one day to another. Daily variation could reach maximum of 130 to 170% of average daily consumption during the year or may reach a minimum value of 60% of average daily water consumption during the same year.

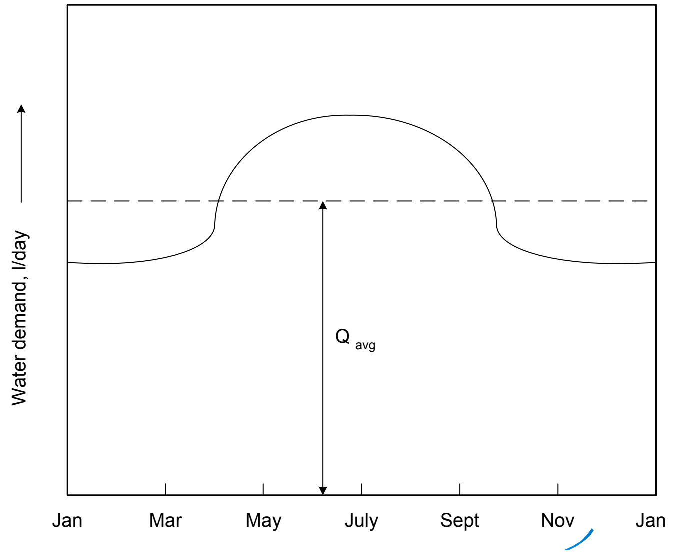
➢ **Hourly Variations**

Maximum rate may reach up to 150% of average daily rate, of the same day, at the peak, or may reach 225% of average daily consumption during one year.

Factors influencing water use

- Size of city (small vs large)
- Climate and location (warm vs cool)
- Industrial development
- Habits and living standards
- Parks and gardens
- Water quality
- Water pressure
- Cost of water
- Administration of water supply system

Seasonal Variations



Hourly Variations