EWCE 331



WATER SUPPLY ENGINEERING

Course Contents

- Introduction to Water Supply Engineering; Water requirement in urban and rural communities; Sources of water supply; Ground water exploration, types of wells and pumps; design, drilling, construction and maintenance of wells.
- Rain water harvesting system and alternative water supplies for water stressed areas;
- **Surface water collection, transportation, treatment and distribution systems; analysis and design of distribution network; Fire hydrants;** Water meters; Water loss control.
- **Water quality requirements; Bangladesh and international standards; Water treatment methods**, climate resilient water safety plan (CRWSP).

Course References

- **Water Supply and Sanitation**

  M. Feroze Ahmed & Md. Mujibur Rahman

  (ITN-Bangladesh)
- **Water Supply Engineering**

  M. A. Aziz

What is Water Supply Engineering?

- A branch of civil engineering concerned with the development of sources of supply, transmission, distribution, and treatment of water.
- The term is used most frequently in regard to municipal water works, but applies also to water systems for industry, irrigation, and other purposes.

History and Development of Water Supply

- Structures of water supply, drainage , sewerage and swimming pools of Mohenjo-Daro civilianization in the Indus Valley.
- Also Egypt, Babylonia and Assyria-flat countries used open canals with large storage basins
- Wells were also used in many countries in ancient times to utilize underground water
- Italy, Greece , India and Egyptian used wells in 2100 BC.
- Artesian wells were sunk in China in early times.

History and Development of Water Supply

- Lake Mories in Egypt – built in 2000 BC –Supplied water for 2,00,00,000 people
- Numerous conduits – water supply in ancient Jerusalem –600 to 900 BC
- Water supply in Rome –Surrounding aqueducts and hills –616 km
- London –at end of 16^{th} century-first modern city to use lead pipe for conveyance of water
- European countries -Wood pipes bored out of logs

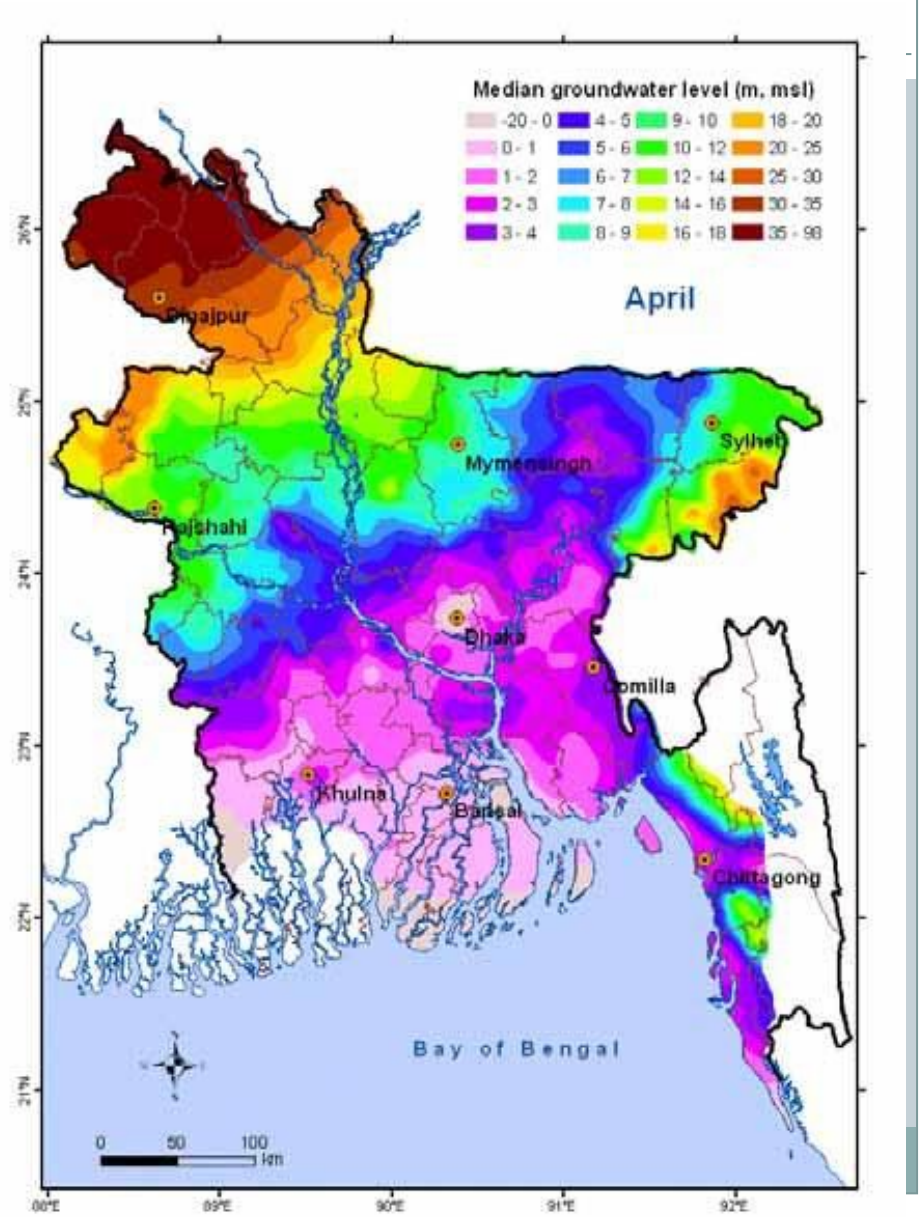
Purification attempts of the supplied water

- John Gibb -first water filter at Paisley in Scotland, **UK in 1804**.
- James P. Kirkwood - also designed the first sizeable water filter (New York, in **1871**).
- In **1849 Dr. John Snow**, a medical researcher in England demonstrated the role of fecal pollution of drinking water in the epidermicity of cholera.
- From **1857onward** Dr. William Budd investigated the water-borne diseases.

Bangladesh Scenario

Around 700 rivers in Bangladesh

- Annual Average Rainfall approx. 2500 mm
- Groundwater available within a depth of 1.0 m–60.0 m



Bangladesh Scenario

- In late 1960s and early 1970s about 3 to 4 million hand tube wells in Bangladesh have been sunk to provide drinking water to 97% of the rural population.
- In the context of very high prevalence of diarrheal diseases in Bangladesh, groundwater being usually free from disease producing micro-organisms, received priority as a source of water supply.

Water Supply system of Dhaka City

- Piped water supply in Dhaka in 1876
- 1963 demand was 150 million liters per day.
- Today demand 2000 mld considering per capital consumption rate 160lit/person/day
- DWASA supply 1500 million litre per day
- DWASA has pipeline of 2358.86 km

Water Supply system of Dhaka City

- from surface water 310 mld (225 mld from Saidabad, 39 from Chandni Ghat, and 46 from Narayangonj),rest from ground water.

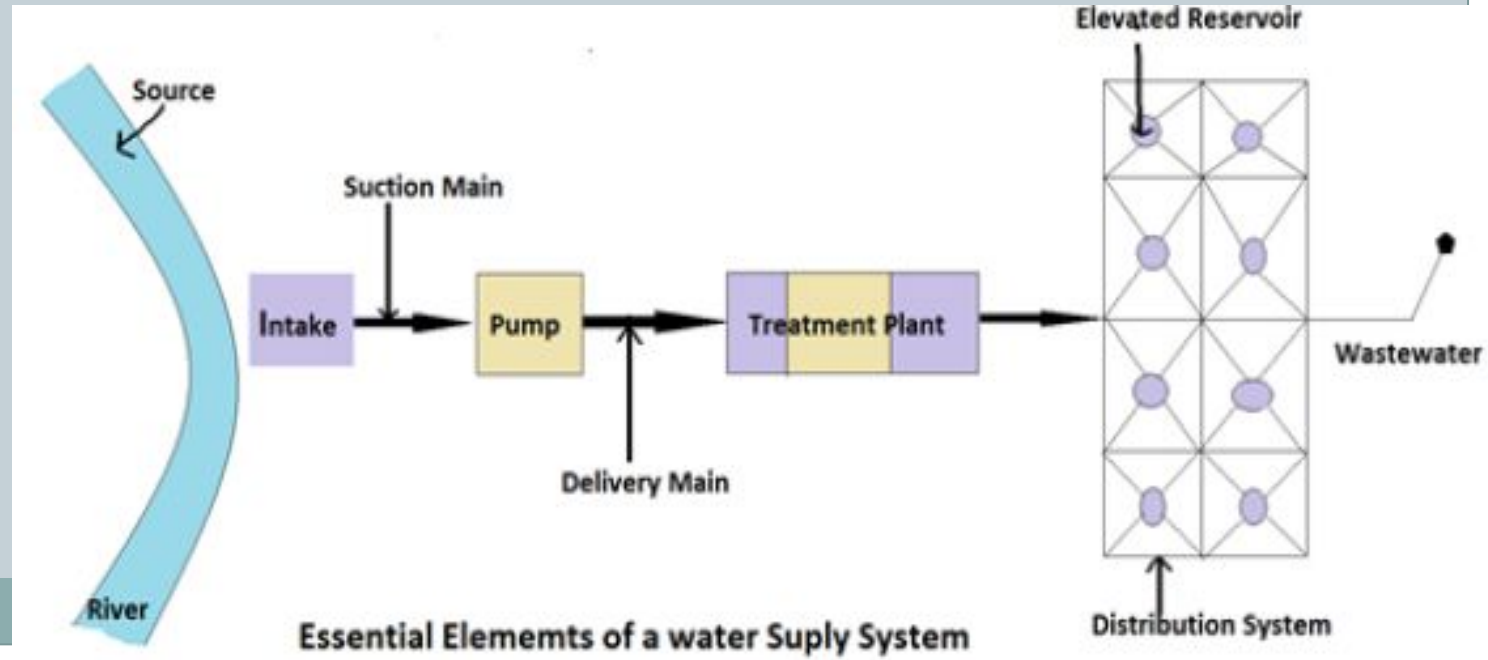
- There are 406 deep tube well of which 332 are functioning and produced 1330 mld.

Objectives of Water Supply

- supply water in adequate quantity
- supply safe and wholesome water to the consumers
- make water easily available to consumers

Elements of Water Supply

- Source of supply
- Collection system
- Treatment and
- Distribution system



Essential Elememts of a water Suply System

Source of Supply

- Surface water
- Ground water
- Rainwater

Selection of source depends on –

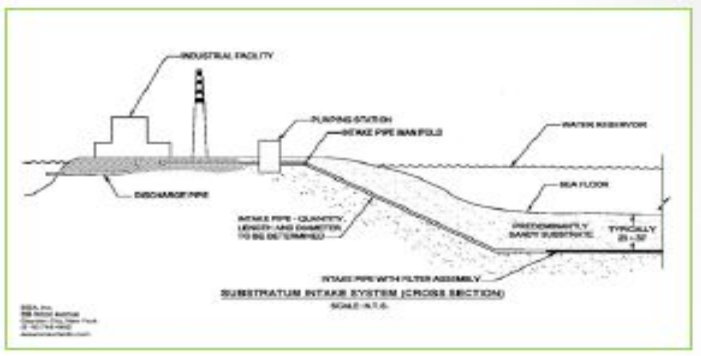
- Quantity
- Quality
- Cost

Choice of Source for Water Supply

- **Quantity:** The quantity of water available at all time s of the year should meet all the requirements of the community.
- **Quality:** the quality of water at the source should be such that the requirement for treatment is minimum.
- **Cost:** The cost involved in development, operation and maintenance of the water supply system should be reasonably affordable to the consumers.

Collection System

- Surface water – Intake with pumping facility required



- Ground water – Dugwells or tube wells are common devices



- Rainwater – A permanent roof or uncontaminated ground surface



Treatment

- Surface water
  - Turbidity
  - Color
  - Taste
  - Odour
  - Pathogens
- Ground water
  - Mineral substances
  - Iron
  - Arsenic
  - Fluoride
  - hardness

Methods:

- **Screening**
- **Sedimentation**
- **Aeration**
- **Chemical treatment**
- **filtration**
- **demineralization**
- **Disinfection**

Distribution System

- Urban -Piped Water supply
  - Storage reservoirs
  - Pumping devices
  - Standposts
  - Valves
  - Other appurtenances
- Rural -Unpiped Water supply –manually operated tubewells
  - Location
  - Accessibility
  - Serving distance and extent

Planning and Design Considerations

- Quality of water should not deteriorate below WHO standard
- Water in adequate quantity in convenient location
- Traditional sources should be selected for water supply development
- Construction, operation, maintenance and repair should be within reach of the available skills
- The equipment should be robust, reliable and locally available
- Construction and operation cost should be minimum
- Use of pumping and chemicals should be minimum
- System should be planned together with the community
- Women should be involved and consulted to address their needs
- In built system for monitoring of performance
- Provision for preventing deterioration of water quality
- Sustainability should be preferred in planning, designing and pricing the water supply

Water Requirement

Per Capita Water Consumption

- The per capita consumption of water is the total consumption divided by the population and the number of days in the year. It is generally expressed as liter per capita per day (lpcd).

Water Requirement

Factors affecting per capita demand:

- **Size of the city**: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.
- **Presence of industries**: industry uses large volumes of water in its manufacturing and supporting operations.
- **Climatic conditions**: water consumption on a summer day is 30 to 50% higher than the average daily demand.
- **Habits of people and their economic status**: per capita use of water is much less in slum areas than that in the high class residential areas due to gardening, car washing, air conditioning etc.

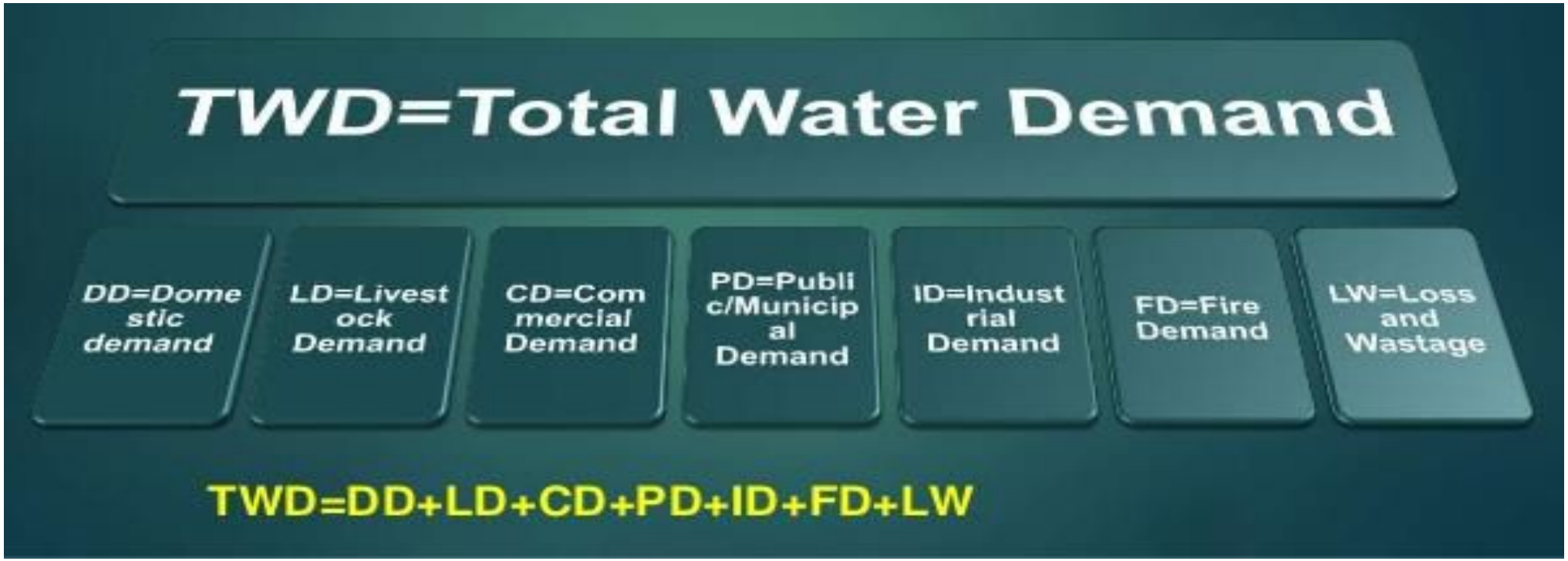
Water Requirement

- **Quality of water**: If water is aesthetically and medically safe, the consumption will increase.
- **Pressure in the distribution system**: incase of piped system the rate of water use increases with pressure.
- **Efficiency of waterworks administration**: Leaks in water mains and services; and unauthorized use of water can be kept to a minimum by surveys.
- **Cost of water**: if the cost is high people become more conservative in water use.
- **Policy of metering and charging method**: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.

Water Consumption

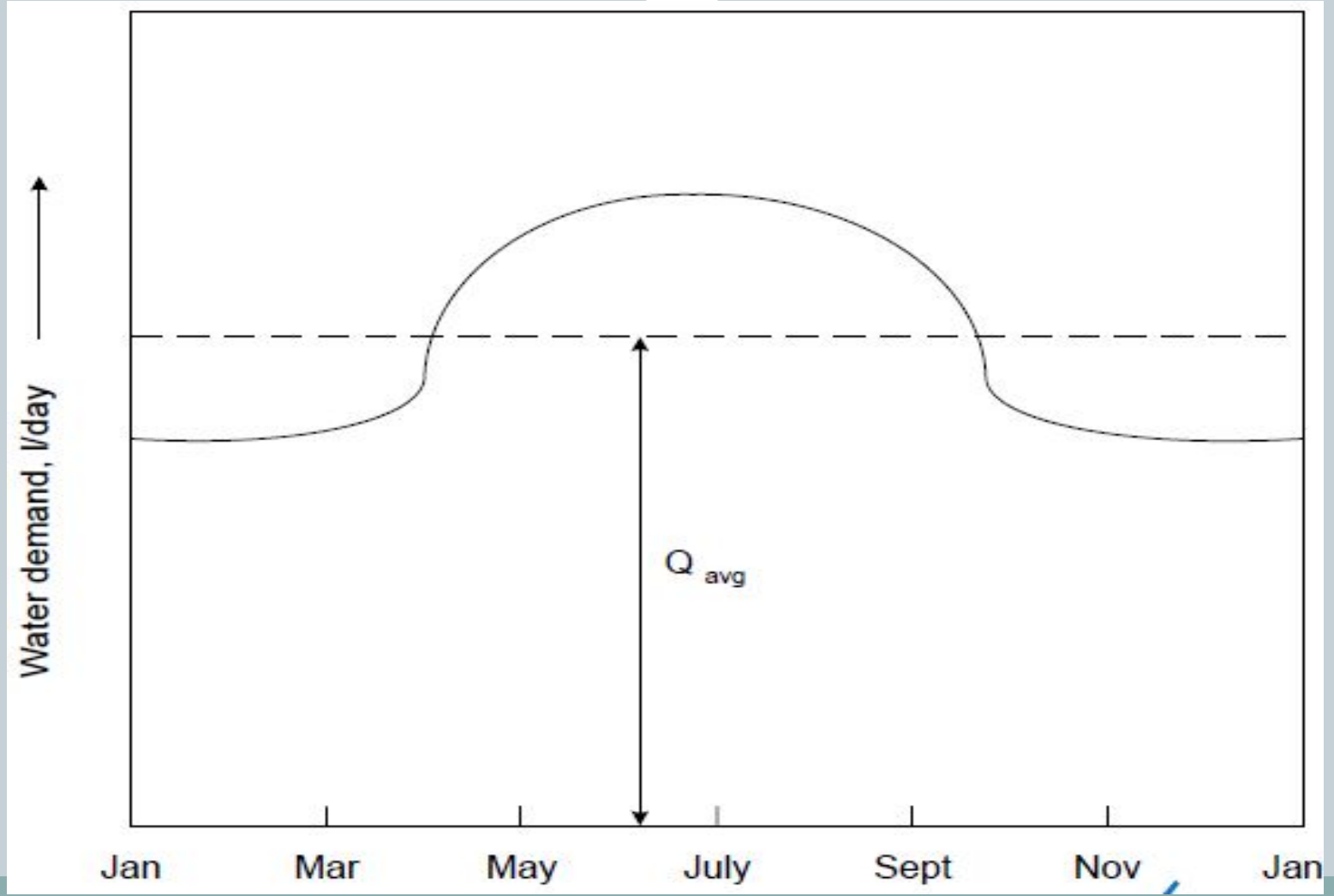
Water Consumption for Various Purposes:

Types of Consumption	Normal Range (lit/capita/day)	Average	%
Domestic Consumption	65-300	160	35
Industrial and Commercial Demand	45-450	135	30
Public Uses including Fire Demand	20-90	45	10
Losses and Waste	45-150	62	25

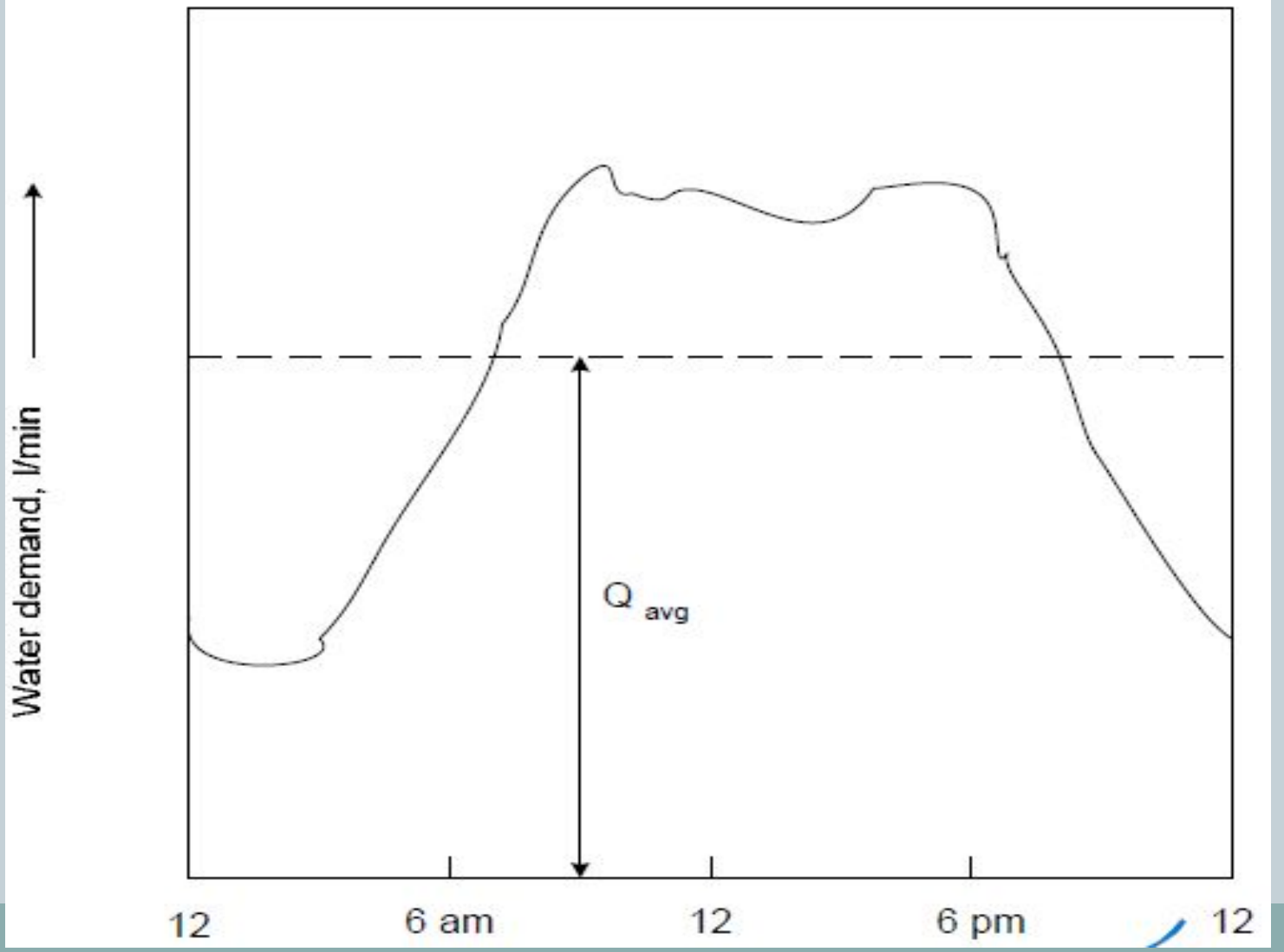

TWD=Total Water Demand
DD=Domestic demand
LD=Livestock Demand
CD=Commercial Demand
PD=Public/Municipal Demand
ID=Industrial Demand
FD=Fire Demand
LW=Loss and Wastage
TWD=DD+LD+CD+PD+ID+FD+LW


Variation in Demands of Water
Seasonal Variation
Variation in Demands of Water
Hourly Variation
Daily Variation

Seasonal Variations



Hourly Variations



Water Demand

Estimation of water requirement is important for designing a water supply system, which is designed for a future population. Total quantity of water required:

$$Q_f = P_f \times q$$

Where,

Q_f : water requirement per day

P_f : Projected population estimated at the end of the design period

q : rate of water consumption per capita per day.

Population Prediction

Methods for population projection

- Uniform growth rate method
- Uniform percentage growth rate method
- Decreasing growth rate method
- Graphical extension or curvilinear method
- Graphical comparison method
- **Geometric progression method**
- **Least square parabola method**

Population Prediction

1. Uniform growth rate method:

A constant increment of growth is added for a period based on the population growth of the same period in the recent past.

Example:

If population increased from 10,000 to 11,000 during last 5 years, the population will increase from 11,000 to 12,000 during next 5 years.

2. Uniform percentage growth rate method:

A constant percentage of growth is added for an equal period of time.

Example:

If population increased from 10,000 to 11,000 (10% increase) during 5 years, the population will increase to 12,100 during next 5 years.

Population Prediction

3. Decreasing growth rate method:

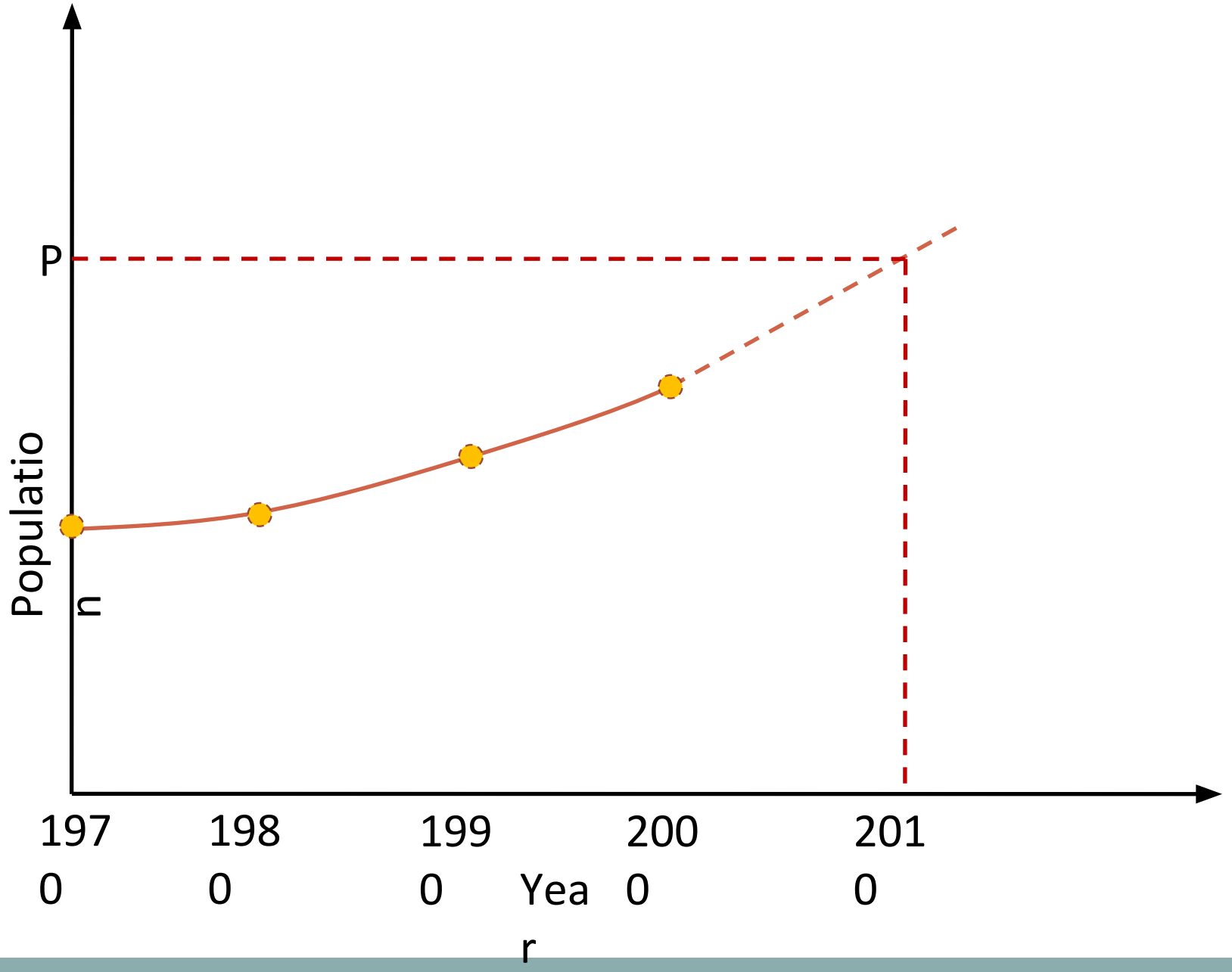
Similar to uniform growth rate method but the growth rate is decreasing.

Example:

If population increased from 10,000 to 11,000 during 2005 to 2009, the population will increase from 11,000 to 11,900 during 2009 to 2013.

4. Graphical extension or curvilinear method:

In this method the population time curve is extended by eye estimation to obtain the future population.


P
Populatio
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Population Prediction

5. Graphical comparison method:

This method involves the extension of the population-time curve of the community under study into the future based on a comparison of population-time curves of similar communities instead of projection by estimation. This method is also known as **modified curvilinear method.**

6. Geometric Progression Method:

Future population can be estimated using the following equation:

$$P_f = P_p (1 + r)^n$$

The rate of population growth can be estimated from population data of two years of n year interval in the recent past using the expression:

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1$$

Population Prediction

6. Geometric Progression Method:

Example - 1

The population of a town was 180,000 in 1980 and 220,000 in 1990. What will the population be in 2000?

Solution: $P_{1980} = 180.000$; $P_{1990} = 220,000$; $n = 10$

$$r = (P_{1990} / P_{1980})^{1/10} - 1 = (220.000/180,000)^{0.1} - 1 = 0.0203$$

$$P_{2000} = P_{1990} (1 + 0.0203)^{10} = 220,000 (1 + 0.0203)^{10} = 268,969$$

Population Prediction

7. Least Square Parabola method:

In this method the ***equation*** of the ***population-time curve*** is determined by the least square method using the available ***statistical data***.

Let the variables:

- X denote the years
- Y denote population of each year (X)

The equation of the least square parabola fitting the time population data is given by:

$$Y = a + bX + cX^2 \text{ ------- (1)}$$

Population Prediction

7. Least Square Parabola method:

$$Y = a + bX + cX^2 \text{ ------- (1)}$$

Where a, b, c are constants to be found from ***normal equations*** by applying the actual population data:

$$\sum Y = aN + b\sum X + c\sum X^2 \quad \text{--------- (2)}$$

$$\sum XY = a\sum X + b\sum X^2 + c\sum X^3 \quad \text{--------- (3)}$$

$$\sum X^2Y = a\sum X^2 + b\sum X^3 + c\sum X^4 \text{ ------- (4)}$$

Where ***N* = number of observations** or sets of data.

Example 2

The population of a community in 1950, 1960, 1970, 1980 and 1990 was 200, 230, 280, 350 and 450 respectively. Estimate the population of the community in the year 2000 and 2010.

Solution:

Year	X	Y	X^2	X^3	X^4	XY	X^2Y
1950	-2	200	4	-8	16	-400	800
1960	-1	230	1	-1	1	-230	230
1970	0	280	0	0	0	00	0
1980	1	350	1	1	1	350	350
1990	2	450	4	8	16	900	1800
Sum	ΣX=0	ΣY=1510	ΣX2=10	ΣX3=0	ΣX4=34	ΣXY=620	ΣX2Y=3180

In the above table 1970 has been taken as base year and a decade has been taken as 1 unit in X–Ordinate to eliminate some of the terms and make the computation simpler.

Using the data in the table the equations (17.2), (17.3), and (17.4) become

$$1510 = 5a + 0 + 10c \quad (17.7)$$
$$620 = 0 + 10b + 0 \quad (17.8)$$
$$3180 = 10a + 0 + 34c \quad (17.9)$$

Solving the equations (17.7), (17.8) and (17.9), the following values of a, b, and c are obtained:

$$a = 279.14; \quad b = 62; \quad c = 11.43$$

Thus the equation fitting the population data is given by :

$$Y = 279.14 + 62X + 11.43X^2$$

Population of the year 2000. $Y_{2000} = 279.14 + 62 \times 3 + 11.43 \times 3^2 = 568$

Population of the year 2010. $Y_{2010} = 279.14 + 62 \times 4 + 11.43 \times 4^2 = 710$

Population Prediction

Least square method of population projection

It is common to fit a straight line to the past observations.

y= a+bx

$$\Sigma Y = Na + b.\ \Sigma X$$
$$\Sigma XY = a.\ \Sigma X + b.\ \Sigma X^2$$

Example

Given Data

Year	population (in million)
1997	51.99
1998	52.49
1999	55.12
2000	54.07
2001	57.56

Population Prediction

Year	Population (in million) (Y)	S. No. of Col. 1 (X)	Square of 'X'	X.Y
1997	51.99	1	1	51.99
1998	52.46	2	4	104.92
1999	55.12	3	9	165.36
2000	54.07	4	16	216.23
2001	57.56	5	25	287.80
Total	(ΣY) 271.20	(ΣX) 15	(ΣX^2) 55	ΣXY) 826.35

$\Sigma Y = Na + b\Sigma X = 271.20 = 5a + 15b$ 1

$\Sigma XY = a \Sigma X + b \Sigma X^2 = 826.33 = 15a + 55b$ 2

$Y = 50.43 + 1.27 X$ (with 1997 as X=1)

population in 2002 (Y) = 50.43 + 1.27 x 6 = 58.05, X = 6

FIRE FIGHTING

- Fire fighting requires sufficient quantity of water, so as to throw it over the fire at high speeds .
- The quantity of water required extinguishing fires should be easily available and kept always stored in storage reservoirs.
- High rate of water consumption during a fire considerably affects the design of distribution system ,hence while designing public water supply schemes, the rate of fire demand is sometimes treated as function of population .

Fire Water Demand

- At least four streams should be available at all points within the area protected.
- Each stream should be capable of delivering at least 175 gpm of water in low risk areas and 250 gpm in high risk areas for 5 hours.
- Water pressure should be around 80 psi.

Fire Water Demand

- The number of fire streams based on Kuchling's formula will be:
- F= 2.8 $\sqrt{P}$; F= number of simultaneous fire streams and P= population in thousands.

Calculate the total stream flow in gpm for a town having a population of 10,000. Assume that each stream will spray 250 gpm on the fire simultaneously.

Answer: number of stream, F = 2.8 $\sqrt{10}$ = 9

Total stream flow = 250 × 9 = 2250 gpm. However, according to National board of Fire Underwriters, for population of 10,000, the stream flow will be 3000 gpm

Fire Hydrant





- Fire hydrants are usually fitted in the water mains at about 100 to 150m apart and firefighting pumps are immediately connected into them by fire brigade personnel.

Fire Hydrant





Fire Demand

1) **Kuichling"s formula**

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

2) **Freeman formula**

$$Q = 1136 [P/5+10]$$

3) **National board of fire under writers formula**

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

4) **Buston formula**

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

P – population in thousands

Q – Water Required in litres/ minute

Example 5.5. *Compute the 'fire demand' for a city having population of 1,40,000 using various formulae.*

Solution. P = population in thousands = 140.

1. ***Kuichling's formula***

$$Q = 3182\sqrt{P} = 3182\sqrt{140} = 37650 \text{ litres/min.}$$
$$= 0.627 \text{ cumecs.}$$

2. ***Buston's formula***

$$Q = 5663\sqrt{P} = 5663\sqrt{140} = 67000 \text{ litres/min.}$$
$$= 1.117 \text{ cumecs.}$$

3. ***Freeman's formula***

$$Q = 1136\left(\frac{P}{5} + 10\right) = 1136\left(\frac{140}{5} + 10\right)$$
$$= 43168 \text{ litres/min} = 0.719 \text{ cumecs}$$

4. ***National Board of Fire Underwriter's formula***

$$Q = 4637\sqrt{140}\,(1 - 0.01\sqrt{140})$$
$$= 48,374 \text{ litres/min.} = 0.806 \text{ cumecs.}$$