The University of Zambia
School of Engineering
Dept. of Civil & Environmental Engineering

CEE 4412: Environmental Engineering I

Water Supply

JMT
August 2019

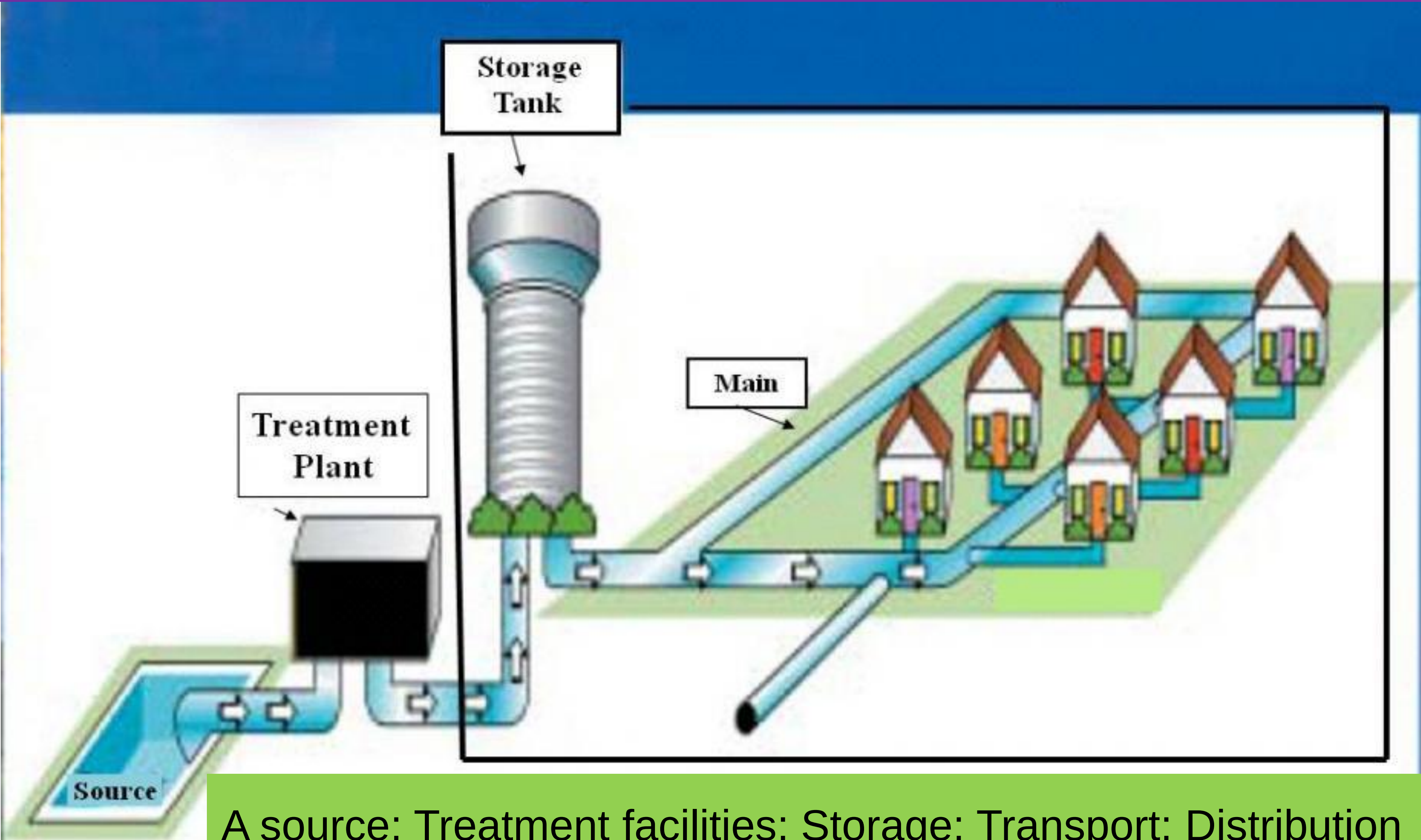
Water Supply – Objectives of course

- Introduce students to:
  - Water demand, water delivery for sizing of treatment plants and transport and distribution systems;
  - Water sources; what is a good source?
  - Distribution systems;
  - water treatment-unit operations; and
  - Low cost water supply systems

Water Supply – Historical developments

- ❖ Industrialization (Required transportation; treatment)

Water Supply - Components



A source; Treatment facilities; Storage; Transport; Distribution

Water Demand – What is it?

- Amount of water drawn from the system within a certain period of time. It is expressed as flow in m^3/h, l/s or l/c/d.

- Accurate determination is imperative for designs
  - Fixed area?
  - Expanding area?

Determination of Water Demand?

- Average demand computed by multiplying the per capita consumption by the total population
- Care to be taken where other water consumption categories exist (Domestic, Industrial, Public, Institutional, Commercial)
- Per capita consumption to be sourced from standards (ZS 361 in the case of Zambia) – composed of amounts for drinking, washing, bathing, laundry, gardening etc.

Determination of Water Demand?

TABLE 1: RESIDENTIAL WATER DEMAND

REQUIREMENTS	PERI-URBAN OR RURAL HOUSING (l/c/d)	LOW COST HOUSING (l/c/d)	MEDIUM COST HOUSING (l/c/d)	HIGH COST HOUSING (l/c/d)
Drinking	3	3	3	3
Bathing & Washing	15	25	50	90
W.C	-	30	30	40
Cooking & Cleaning	5	10	17	22
Laundry	5	10	20	30
Gardening	7	12	20	60
Other Uses	5	5	10	10
TOTAL	**40**	**95**	**150**	**255**

NOTES

1. The demand is expressed in litres per capita per day (l/c/d)
2. High and Medium Cost Housing based on main house occupants excluding servants quarters
3. For servants quarters, allow for Low Cost Housing demand figures
4. Water demand in Rural Areas is not explicitly covered, however the demand figures for Peri-urban Housing are recommended.
5. 'Other uses'inlude car washing, pet washing, etc

Determination of Water Demand?

TABLE 2: EDUCATION INSTITUTIONS

REQUIREMENTS	UNIVERSITY COLLEGE (l/c/d)	SECONDARY SCHOOL BOARDERS (l/c/d)	SECONDARY SCHOOL NON BOARDERS (l/c/d)	PRIMARY SCHOOL (with WC) (l/c/d)	PRIMARY SCHOOL (pit latrine) (l/c/d)
Drinking	3	3	1	1	1
Bathing & Washing	25	25	3	3	3
W.C	30	30	10	10	-
Cooking & Cleaning	15	10	-	-	-
Laundry	10	10	-	-	-
Gardening	10	10	10	5	5
Other Uses	32	12	6	6	6
TOTAL	**125**	**105**	**30**	**25**	**15**

NOTES

1. All Figures are in litres per capita per day (l/c/d).
2. Nursery schools are assumed to have same demand as primary schools.
3. Universities/ Colleges are assumed to have self catering facilities
4. 'other uses' may include water used by laboratories, teaching staff while directly on the school premises
5. Primary School boarders will utilize figures for Secondary School Boards

Water Demand (Consumption) categories

Classified according to intended use as follows:

- DOMESTIC: - Water supplied to a city/community for sanitary uses, drinking washing bathing etc.
- COMMERCIAL AND INDUSTRIAL:- Water supplied to commercial and industrial establishments
- PUBLIC:- Water that is supplied to public places like schools, hospitals, prisons and water for fire fighting.
- LOSS AND WASTE:- (Unaccounted For Water –UFW or Non Revenue Water NRW)
- Real Losses (leaks) Apparent losses (illegal connections in the system).

Demand determination – Per capita consumption approach

$$Q_a = dACq$$

Where

Q_a = Average water demand

d = Population density

A = Area of the distribution

C = Coverage of the area (i.e. 50%). Thus it is a factor that converts population to number of consumers.

q = Consumption per capita

Then add according to situation

Demand determination – Supply area consumption approach

$$Q_a = ACq_a$$

Where

Q_a = Average water demand

A = Area of the distribution

C = Coverage of the area (i.e. 50%). Thus it is a factor that converts population to number of consumers.

q_a = average consumption per unit area

Demand determination – Per capita consumption approach – Heterogeneous situation

$$Q_a = A\sum_{i=1}^{n} d_i q_i p_i C_i$$

Where

Q_a = Average consumption of the town

A = Area of the town

n = Consumption categories in the district

q_i = Unit consumption per category i

p_i = percentage of district territory occupied by category i

C_i = Coverage within district territory occupied by category i

d_i = population density within the district i

Demand determination – Supply area consumption approach – Heterogeneous situation

$$Q_a = A\sum_{i=1}^{n} q_a p_i C_i$$

Where

Q_a = Average consumption of the town

A = Area of the town

q_a = Average consumption per unit area

n = Consumption categories in the district

p_i = percentage of district territory occupied by category i

C_i = Coverage within district territory occupied by category i

Other important considerations

- In computation of demand, it is important to take note of other users like fire fighting and NRW (Real/physical losses + Apparent losses) …. very important!!!

Demand forecasting

- When designing - establish the length of time the improvement will serve the community before it is abandoned or enlarged – project life span.

- Important to get city demographical data (i.e. is it expanding industrially? Population? And if so, at what rate. And how?

Demand Forecasting-Assessments to be undertaken

- Projections based on per capita consumption and population growth trends for domestic category

- Forecast based on assessment of growth trends of other main consumer categories (Industry, Commercial)

- Forecast based on developmental plans and programs.

Demand Forecasting – Models based on population growth – Linear Model

$$Q_{i+n} = Q_i * (1 + n * \frac{a}{100})$$

Where

Q_i = Water demand at year "i"

Q_{i+n} = forecasted water demand after n years

n = design period

a = average annual growth rate during the design period

Demand Forecasting – Models based on population growth – Exponential Model

$$Q_{i+n} = Q_i * (1 + \frac{a}{100})^n$$

Where

Q_i = Water demand at year "i"

Q_{i+n} = forecasted water demand after n years

n = design period

a = average annual growth rate during the design period

Selection of a and n

- ‘a’ is obtained from statistical data.
- Factors to consider in selecting n include:
    - Useful life-span of component structures and equipment
    - Easy or difficulty of extensions
    - Anticipated population growth
    - Economy at time of designing (interest rates)
    - Anticipated industrial potential of the area etc

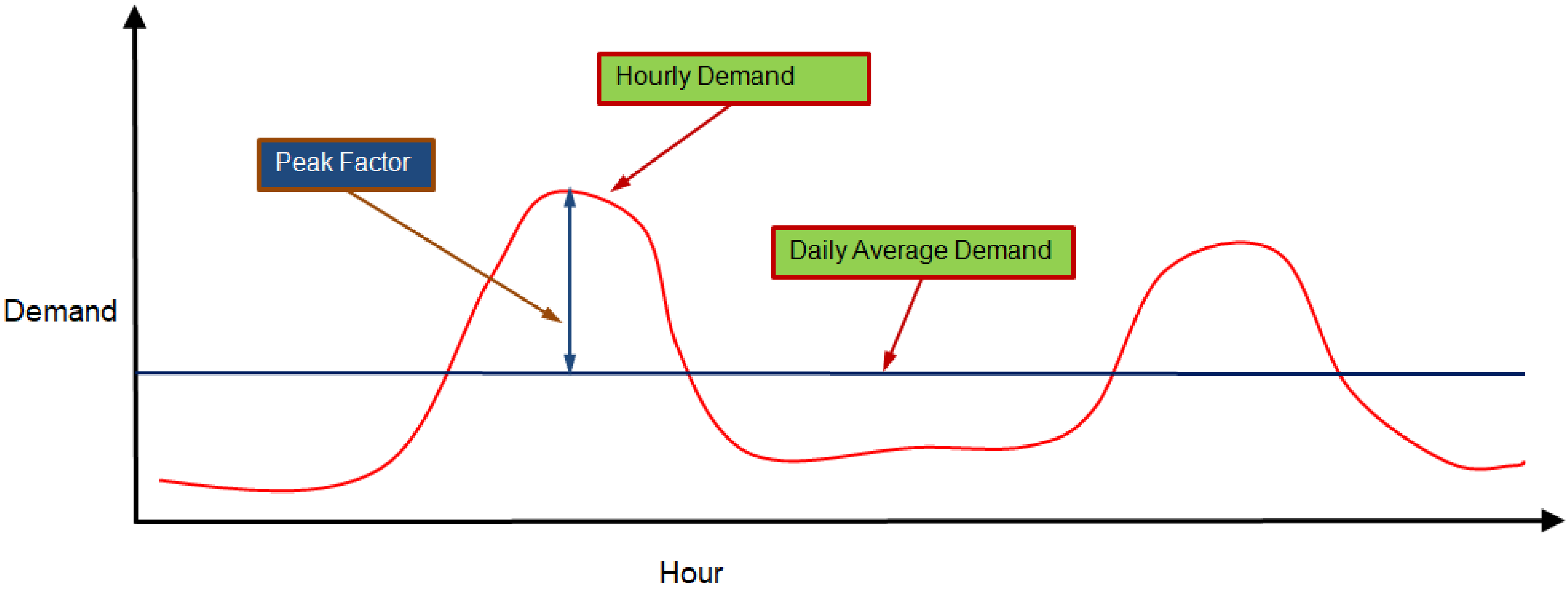
Other Design Aspects – Water Demand pattern

The way water is being consumed over a specified period. The most common types of patterns are:

- ❖ instantaneous
- ❖ daily
- ❖ Weekly
- ❖ monthly and
- ❖ Yearly

Water Demand pattern

Water demand patterns bring in issues of peak factors in design

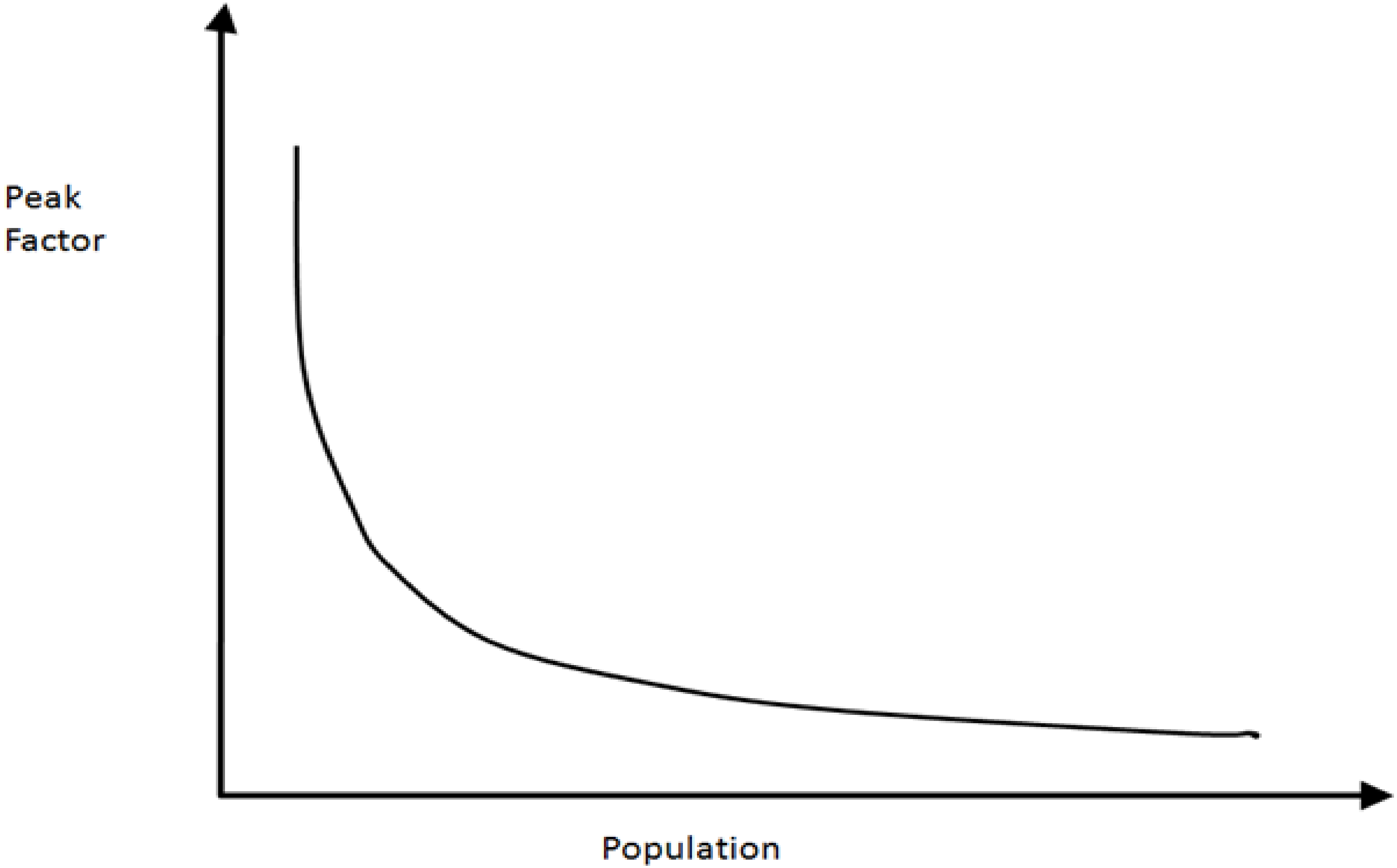


- ❖ Peak Factor: The ratio between the flow during some specified time to the average flow over the supply period
- ❖ As population increases, the Peak Factor reduces

Daily Water Demand pattern

- Maximum Peak Factor: The ratio between the maximum flow during some specified time to the average flow over the supply period
- Generally ranges from 1.2 for very large **water supply** systems to 3.0 or even higher for smaller systems
- As population increases, the Peak Factor reduces

Relationship between population and peak factors



Water delivery

- Water delivery is the amount of water required to be put in a system to satisfy demand
- Therefore, Water Delivery: Qd = Qa + UFW

$$Q_d = Q_a/(1-L/100)$$

- Where Q_d = Water delivery

  Q_a = Water demand

  L = Losses and wastage (%)

Determination of design volume

- Due to varying water demand, design is based on maximum hourly demand for maximum daily demand for maximum weekly demand for maximum monthly demand. Thus

- $Q_d = (Q_a * pf_o) / (1 - L/100)$

- Where pf_o is the overall peak factor given as

$$pf_o = pf_1 * pf_2 * pf_3 * \ldots . pf_n$$

Factors affecting Demand (Consumption)

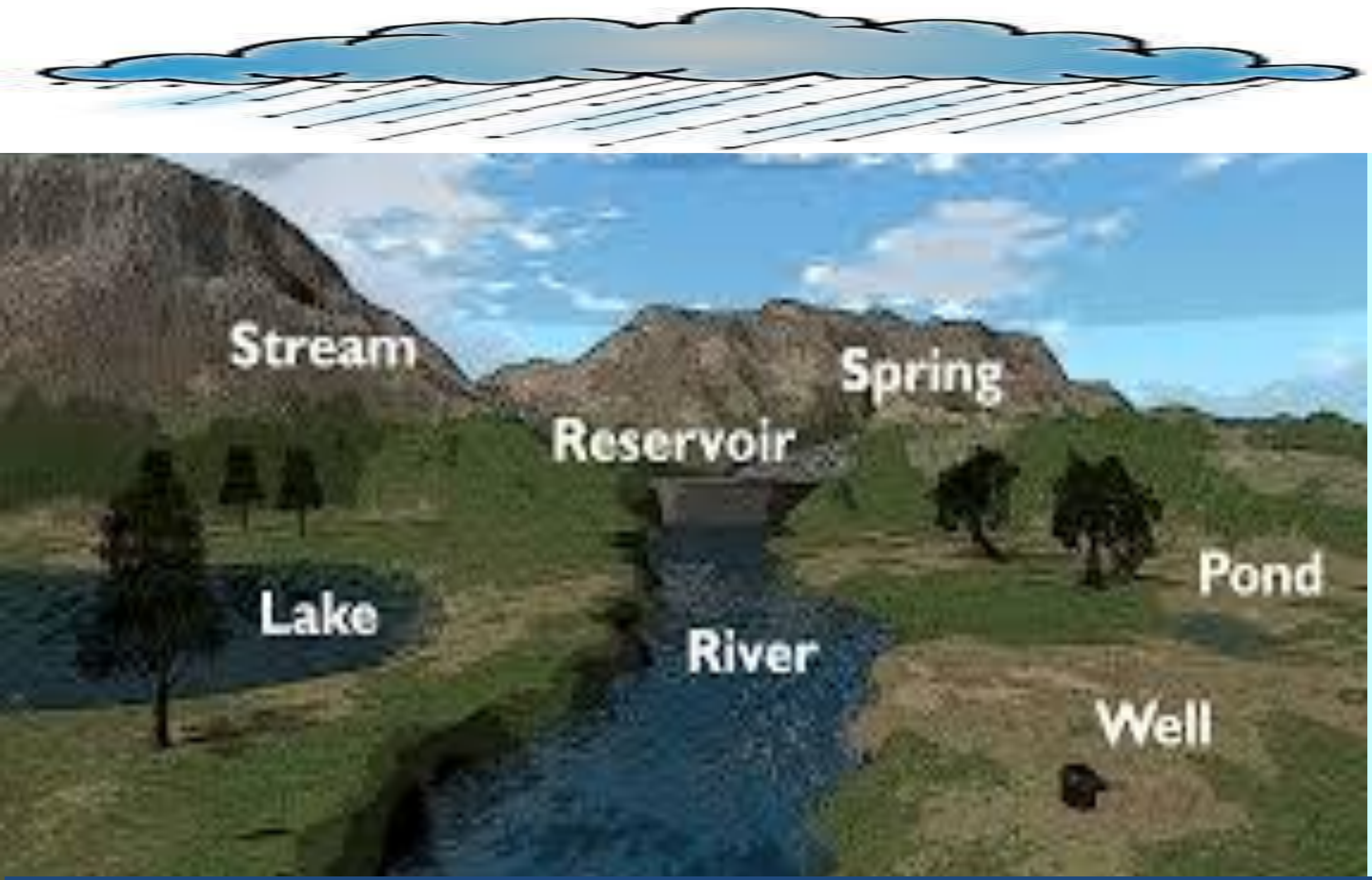
- Size of the city (e.g. Small = unsewered = low)
- Characteristic of the population (rich/poor)
- Presence of industries (Yes = high)
- Quality of the water (poor = low)
- Cost (high = low)
- Pressure in the system (low =low)
- Climate (hot = high)
- Cultural background of the community
- Whether supplies are metered (Not = high)

Factors affecting Demand (Consumption)

❖ Level of Service

- ❖ Public standpipe (In peri-urban areas)
- ❖ Yard connection (Low cost areas)
- ❖ House or in-house connections (medium and high cost areas)


WATER SOURCES



Source: Google images

Water Sources: Comparisons

- Groundwater is usually of a better quality
- Can be supplied directly without treatment

Water Sources: Characteristics

- Good water source is always wrt the purpose for which it is to be used. For domestic purposes it should:
  - be free from pathogenic bacteria;
  - have low concentrations of compounds that are acutely toxic or that have serious long term effects such as lead (guidelines to be observed);
  - Aesthetically acceptable (clear and free from compounds that cause offensive odour and taste;
  - Not saline; and
  - Neither corrosive nor scale forming in piping or staining of clothes.

Water quality considerations in Design – Source Characterisation

Parameter characterisation	Excellent source	Good source	Poor source	Rejectable source
Average BOD_5 (mg/l)	0.75- 1.5	1.5 - 2.5	2.5 - 4.0	>4
Average coliforms (MPN)/100ml	50 - 100	100 – 5000	5000 - 20000	>20000
pH	6 - 8.5	5 - 6, 8.5 – 9	3.8-5, 9-10.3	<3.8, >10.3
Chlorides (mg/l)	<50	50 – 250	250 - 600	>600
Flourides (mg/l)	<1.5	1.5 – 3	>3	-

- Why do we use the above parameters in characterising source? Why not suspended solids?

Choice of a Water Source

Some Factors to Consider

- ❖ Adequacy
- ❖ Reliability
- ❖ Quality
- ❖ Location (defines energy requirements which can affect recurrent operational costs)

- ❖ In most cases, water quality will not meet guideline values.
- ❖ As it is not practical to abandon all polluted sources, water is subjected to treatment!!

END OF PART 1

THANK YOU