



WATER SUPPLY **&** **URBAN DRAINAGE**

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Course Content

- QUANTITY OF WATER
- SOURCES OF WATER SUPPLY
- COLLECTION AND DISTRIBUTION OF WATER
- WATER SUPPLY AND SANITARY INSTALLATION FOR BUILDINGS
- WASTEWATER AND STROM WATER COLLECTION SYSTEM

Evaluation

- Exams
- Assignments (in a group of 4 students)
 - Mini-projects
 - Completeness
 - Genuine attempt 😊

A vertical strip on the left side of the slide shows water splashing or bubbling in a glass, with a dark background above and a lighter background below.

Required skills

- Word processing, spread sheet
- EPANET water distribution modeling
- AutoCAD



Materials

- Handout
- aaucivil.wordpress.com/water-supply
- Any book on water supply
- Search online



CHAPTER ONE

QUANTITY

OF WATER

Introduction

- Body composition
 - Body, 65% water; blood, 83%; bones, 25%
- Water loss: 1% thirst; 5% hallucinations; 15% death
- Basic requirements for safe water
 - Drinking: 2–3 liters/day
 - Minimum acceptable standard for living (WHO)
 - 20–50 liters/capita/day for cooking and basic hygiene



A vertical strip on the left side of the slide shows water splashing or bubbling, with white foam and clear water against a dark background.

Introduction

- The estimated water supply coverage for Ethiopia is 34% for rural and 97 % for urban and the country's water supply coverage 44%.
- Access to water-supply services is defined as **the availability of at least 20 litres per person per day from an "improved" source within 1 kilometre of the user's dwelling.**



“improved” source

- “improved” source is one that is likely to provide “safe” water, such as a household connection, a borehole, etc.
- An improved water supply is defined as:
 - Household connection
 - Public standpipe
 - Borehole
 - Protected dug well
 - Protected spring
 - Rainwater collection

A vertical graphic on the left side of the slide showing a splash of water with bubbles and droplets, extending from the top to the bottom of the frame.

Water Supply Engineering

- Planning, design, construction, operation and maintenance of water supply systems.
- Planning should be economical, socially acceptable, and environmentally friendly that meet the present as well as future requirement.

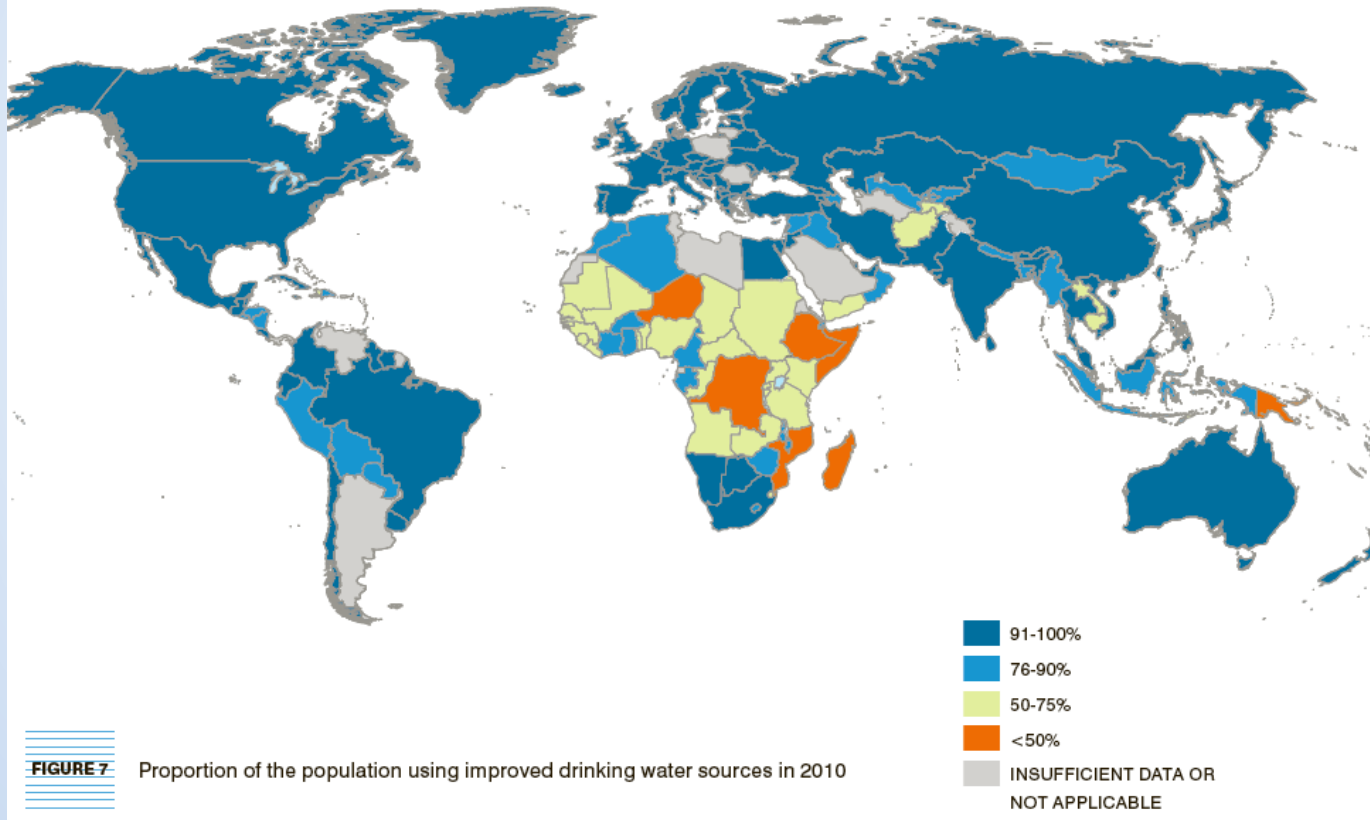
Water Supply System Objectives

A close-up photograph of a woman with dark hair drinking water from a tap. The water is splashing around her mouth. The background is a soft, out-of-focus green. The text 'Water Supply System Objectives' is written in white at the top. A list of three objectives is written in red in the lower-left quadrant.

- **Safe and wholesome water**
- **Adequate quantity**
- **Readily available to encourage personal and household hygiene**

Access to safe water

Sub-Saharan Africa has the lowest drinking water coverage of any region



Access to safe water

Ten countries are home to two thirds of the global population without an improved drinking water source

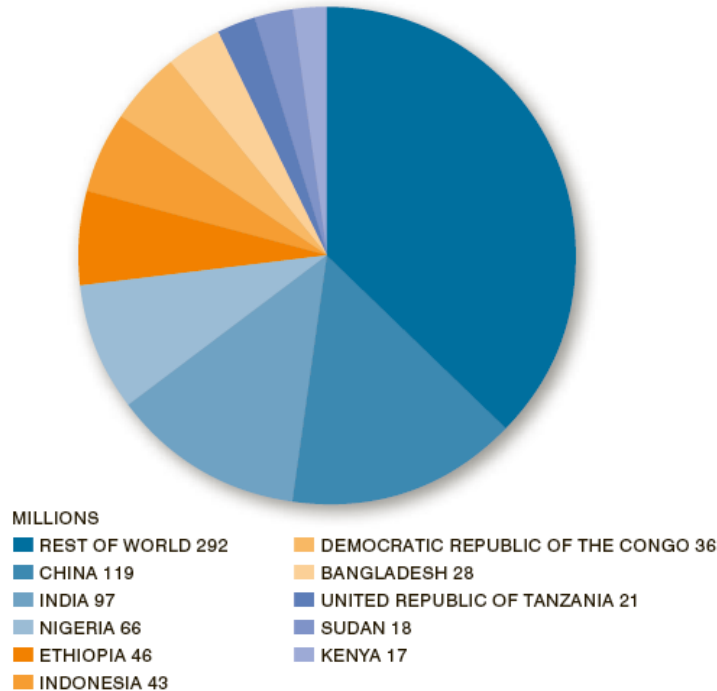
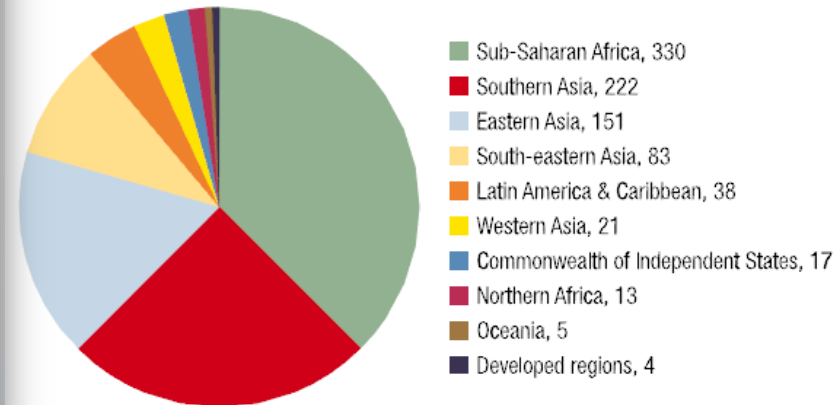


FIGURE 8

Ten countries with the largest population without access to an improved drinking water source in 2010, population without access (millions)

884 million people – 37% of whom live in Sub-Saharan Africa – still use unimproved sources for drinking-water



884 Million People lack
access to safe water



ETHIOPIA

URBAN 97%

RURAL 34%

NATIONAL 44%

3.575 MILLION PEOPLE

DIE EACH YEAR FROM WATER-RELATED DISEASE

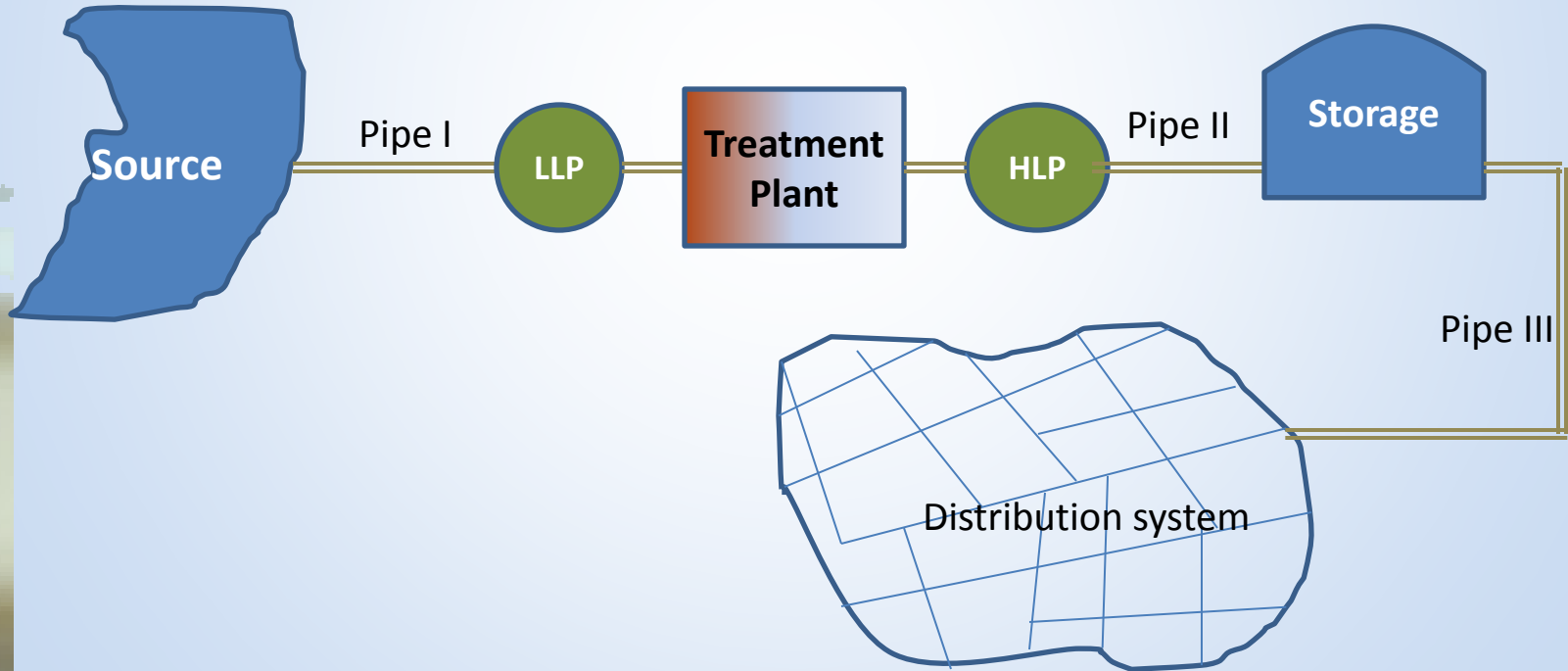


Water Supply Components

The system comprises the following major elements:

- Source (groundwater or surface water)
- Raw water collection structures (intake structure, transmission line)
- Treatment plant
- Distribution systems (pipes, pumps, reservoir, different appurtenances)

Water Supply Components



A vertical strip on the left side of the slide shows water splashing or bubbling, with white foam and clear water against a dark background.

Water supply system planning

- Water supply system planning involves
 - identification of service needs
 - evaluation of options
 - determination of optimal strategy to meet services
 - development of implementation strategies
- The planning exercise involves
 - collection of pertinent data
 - consideration of relevant factors, and
 - preparation of project documents and cost estimates



Factors to be considered

- ***Population.*** Factors affecting the future increase in the population
- ***Per capita Requirement.*** the various factors and living standard and the number and type of industries, number and type of the commercial establishments in the town etc.
- ***Public places, parks, institutions etc.***
- ***Industries.*** existing industries as well as future
- ***Sources of water.*** Detailed survey
- ***Conveyance of water.*** from source to water treatment units depend on the relative levels



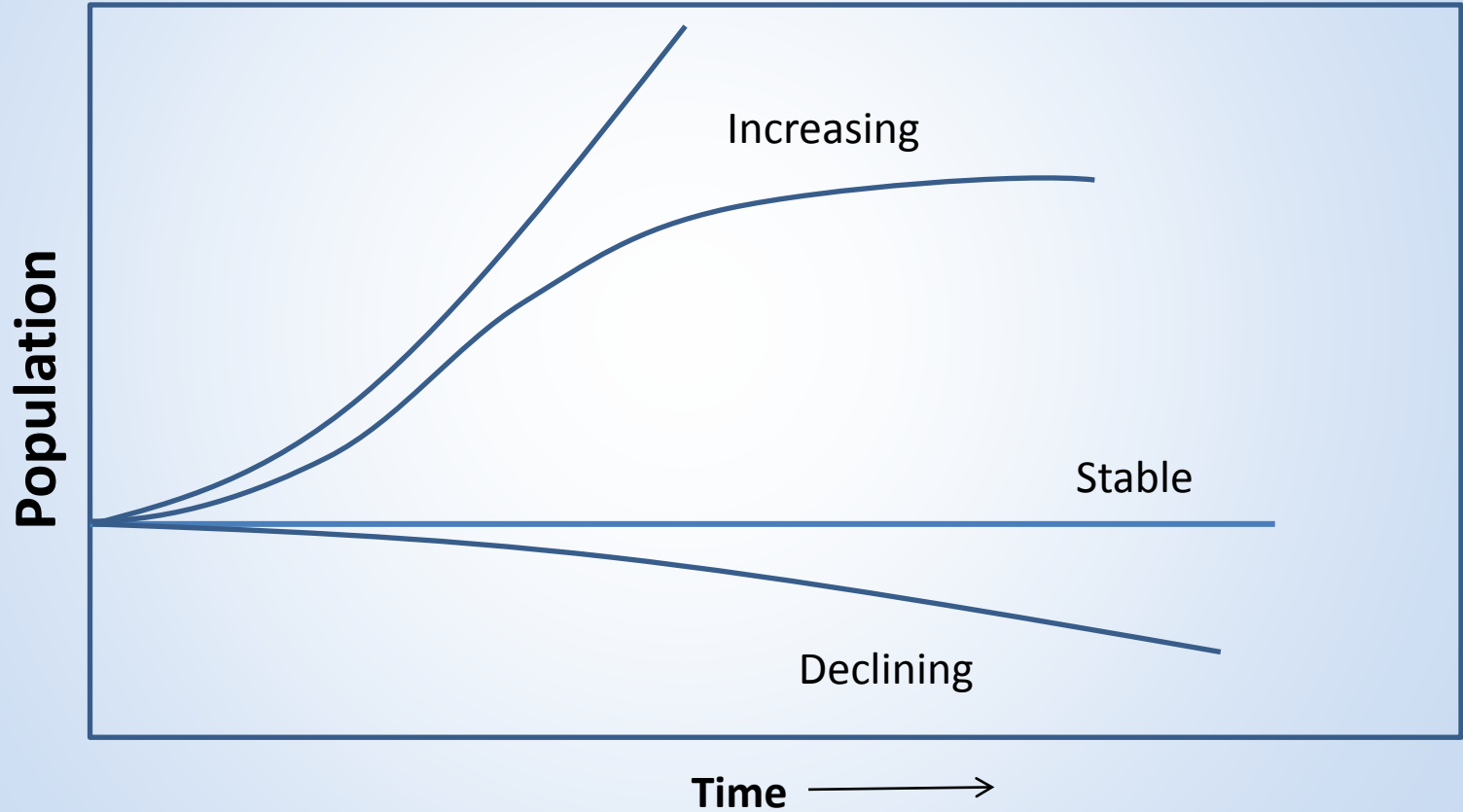
Factors to be considered

- ***Quality of water.*** The analysis of the raw water quality should be made to know the various impurities present in it, and to decide on the required treatment processes.
- ***Treatment works.*** sizes and number of treatment units
- ***Pumping units for treated water.***
- ***Storage.*** The entire city or town should be divided into several pressure zones and storage facility should be provided in each zone.
- ***Distribution system.*** The distribution system should be designed according to the master plan of the town, keeping in mind the future development.
- ***Economy and reliability.*** should be economical and reliable

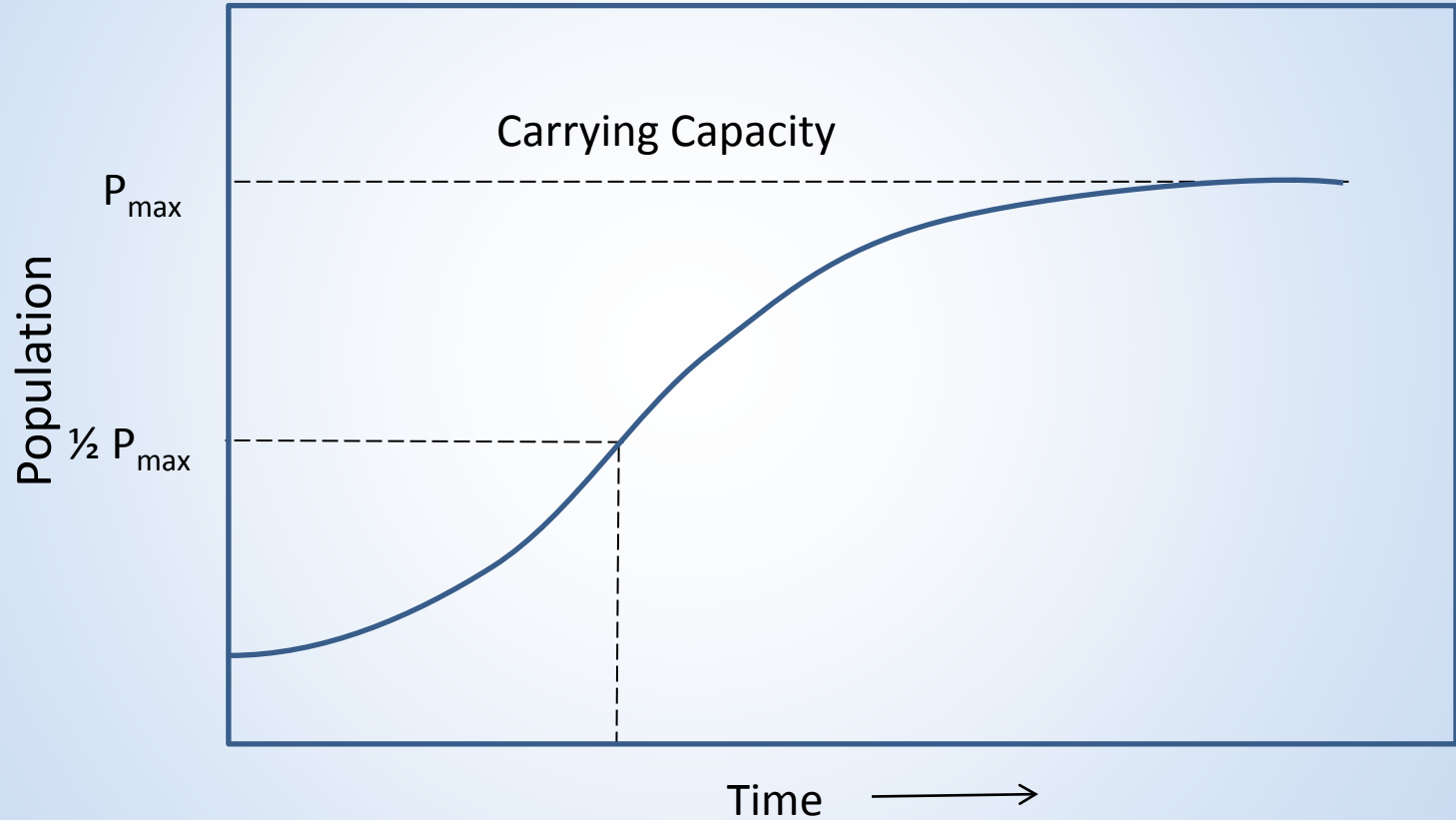


POPULATION FORECASTING

Population growth models



Logistic growth model



Population forecasting

- **Arithmetic method:** the rate of population growth is constant. Mathematically the hypothesis may be expressed as

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

- k is determined graphically or from successive population figures.
- And the future population is given by $\rightarrow P_t = P_o + kt$

Where, P_t = population at some time in the future

P_o = present population

t = period of projection

Population forecasting

- **Geometric or uniform percentage method:** rate of increase which is proportional to the population.

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

- Integrating yields
 - $\ln P = \ln P_0 + k\Delta t$
- This hypothesis could be verified by plotting recorded population growth on semi-log paper. If a straight line can be fitted to the data, the value of k can be estimated from the slope.

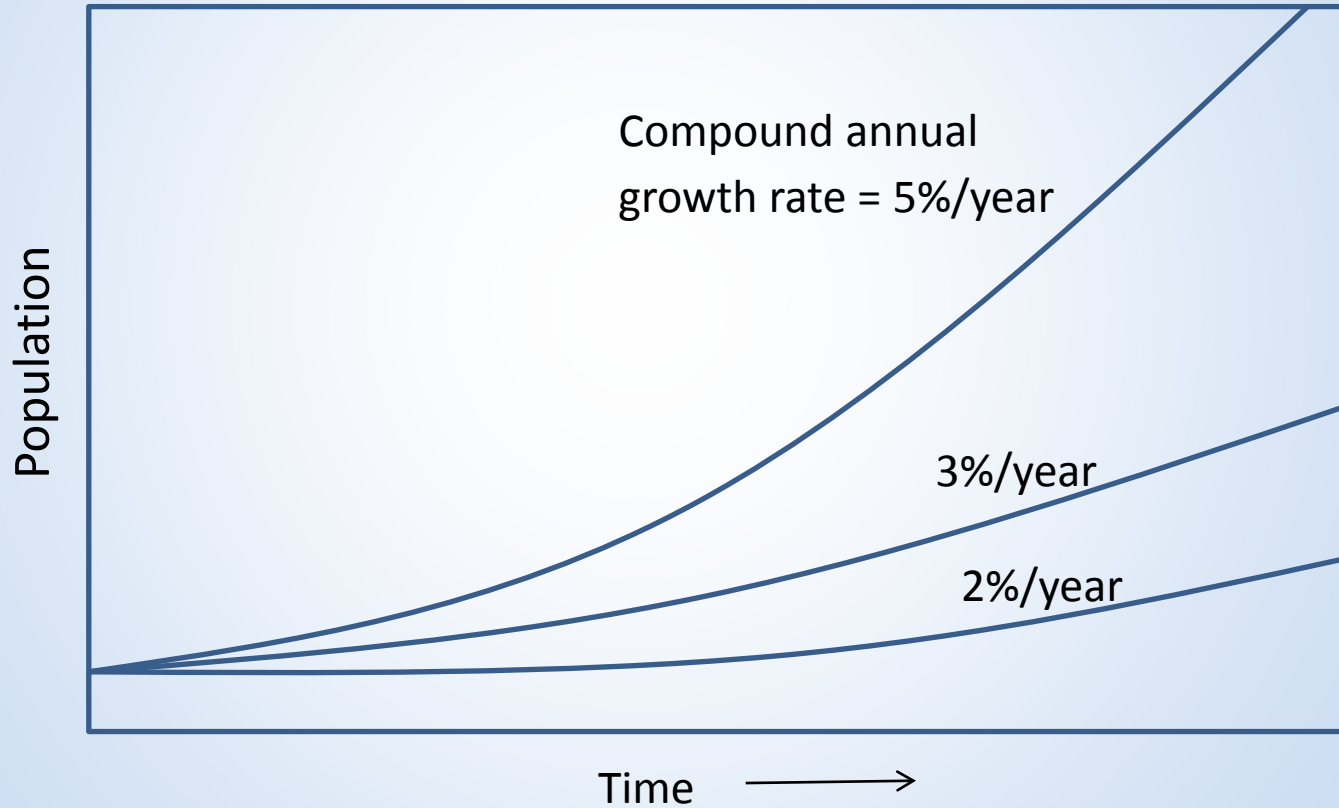
Population forecasting

- **Geometric increase method:** the average percentage of the last few decades/years is determined, and the forecasting is done on the basis that percentage increase per decade/year will be same. Thus, the population at the end of n years or decades is given as

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

- Where, AGR = annual growth rate of the population
- P_n = population at time n in the future
- P_o = present population
- n = periods of projection

Geometric increase models



Example 1.1.

- The census figure of a city shows population as follows
 - Present population 50000
 - Before one decade 47100
 - Before two decades 43500
 - Before three decades 41000
- Work out the probable population after one, two and three decades using arithmetic increase and geometric increase method.

Solution

- **Arithmetic Increase**

- Increase in present and first decade

- $50000 - 47100 = 2900$

- Increase in first and second decade

- $47100 - 43500 = 3600$

- Increase in second and third decade

- $43500 - 41000 = 2500$

- Average increase = $(2900 + 3600 + 2500) / 3 = 3000$

- Population after 1st decade = $50000 + 3000 = 53000$

- Population after 2nd decade = $50000 + 6000 = 56000$

- Population after 3rd decade = $50000 + 9000 = 59000$

Solution

- **Geometric Increase**
- Percent increase in present and first decade
 - $(2900/47100)*100 = 6.16\%$
- Percent increase in first and second decade
 - $(3600/43500)*100 = 8.26\%$
- Percent increase in second and third decade
 - $(2500/41000)*100 = 6.09\%$
- Average increase = $(6.16 + 8.26 + 6.09)/3 = 6.84\%$
- P after 1st decade = $50000 (1 + 6.84/100)^1 = 50342$
- P after 2nd decade = $50000 (1 + 6.84/100)^2 = 53786$
- P after 3rd decade = $50000 (1 + 6.84/100)^3 = 57465$

Example 1.2.

- The Annual Growth Rate of a town in Ethiopia is 3.5%. Assuming the present population of the town (in 2010) is 4500, what would be the population in 2025?

$$\text{AGR} = 3.5\%; P_0 = 4500$$

$$n = 2025 - 2010 = 15$$

$$P_n = P_0(1 + \text{AGR}/100)^n$$

$$P_{15} = 4500(1 + 3.5/100)^{15} = \mathbf{7540}$$

Example 1.3.

- The following data shows the variation in population of a town from 1944 to 2004. Estimate the population of the city in the year 2014 and 2019 by arithmetic and geometric increase methods.

Year	1944	1954	1964	1974	1984	1994	2004
Population	40185	44522	60395	75614	98886	124230	158800

Solution 1.3

Year	1944	1954	1964	1974	1984	1994	2004
Population	40185	44522	60395	75614	98886	124230	158800
Change		4337	15873	15219	23272	25344	34570
% Change		10.79	35.65	25.20	30.78	25.63	27.83

Average change = $(4337+15873+15219+23272+25344+34570)/6 = 19770$ per decade

Average % change = $(10.79+35.65+25.20+30.78+25.63+27.83)/6 = 25.98$ % per decade

Using Arithmetic Method

$$P_{2014} = P_{04} + 1 \times 19770 = 158800 + 19770 = 178570$$

$$P_{2019} = P_{04} + 1.5 \times 19770 = 158800 + 1.5 \times 19770 = 188455$$

Using Geometric Method

$$P_{2014} = P_{04}(1 + \text{AGR}/100)^1 = 158800 (1 + 25.98/100) = 200057$$

$$P_{2019} = P_{04} (1 + \text{AGR}/100)^{1.5} = 158800 (1 + 25.98/100)^{1.5} = 224545$$



Population Density

- It is information regarding the physical distribution of the population
- It is important to know in order to estimate the flows and to design the distribution network.
- Population density varies widely within a city, depending on the land use.
- May be estimated from zoning master plan

Components of water demands

- Water demand is defined as the volume of water required by users to satisfy their needs.
- Demand is the theoretical while consumption is actual
- Design of a water supply scheme requires knowledge of water demand and its timely variations.
- Various components of a water demand are residential, commercial, industrial, public water uses, fire demand and unaccounted for system losses.



Water Demand Components

Domestics

Non domestic

Public uses

Losses and leakage

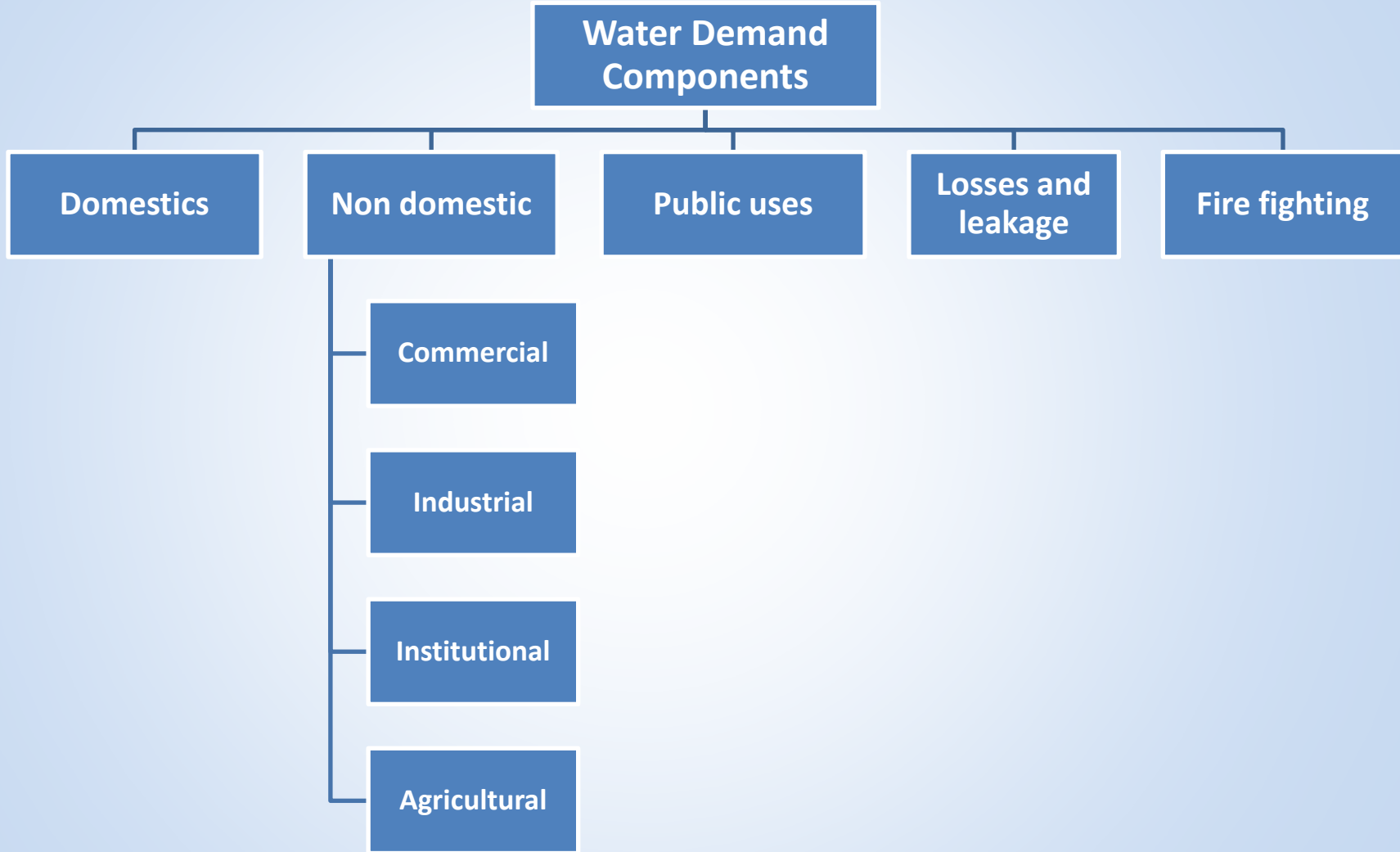
Fire fighting

Commercial

Industrial

Institutional

Agricultural





Residential Water Demand

- This includes the water required in residential buildings for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purposes, etc.
- The amount of domestic water consumption per person varies according to the **living standards** of the consumers.
- In most countries the residential demand constitutes 50 to 60% of the total demand.

A vertical strip on the left side of the slide shows water splashing or bubbling, with a dark background above and a lighter, yellowish background below.

Typical Average Domestic Water Demand

Town	Unit	2007	2017	2027
House Connection	lpcd	90	100	110.0
Own Yard Connection	lpcd	25.4	31.7	38.0
Shared Yard Connection	lpcd	16.9	18.9	21.0
Public Tap	lpcd	11.3	12.6	14.0

A vertical strip on the left side of the slide shows water splashing or bubbling, with white foam and clear water against a dark background.

Commercial and industrial water demand

- **Commercial water demand:** as hotels, shopping centres, service stations, movie houses, airports, etc.
- The commercial water demand may vary greatly depending on the **type** and **number** of establishments.
- **Industrial water demand:** tanning, brewery, dairy, etc.
- The quantity of water required for commercial and industrial purposes can be related to such factors as **number of employees**, **floor area** of the establishment, or **units produced**.



Public water use

- The quantity of water required for public utility purposes
- Includes water for public institutions like schools, watering of public parks, washing and sprinkling of roads, use of public fountains, clearing wastewater conveyance, etc.
- Usually the demand may range from 2-5% of the total demand.

Typical public water demands

Category	Typical rate of water use per day	
Day schools	5	l/pupil
Boarding schools	50	l/pupil
Hospitals	100	l/bed
Hostels	80	l/bed
Mosques	5	l/visitor
Cinema houses	5	l/visitor
Offices	5	l/person
Public baths	100	l/visitor
Hotels	100	l/bed
Restaurant/Bar	10	l/seat
Camp	60	l/person
Prison	30	l/person

A vertical strip on the left side of the slide shows water splashing or bubbling, with white foam and droplets against a dark background.

Unaccounted system losses and leakage

- Water lost or unaccounted for because of leaks in main and appurtenances, faulty meters, and unauthorized water connections.
- Should be taken in to account while estimating the total requirements.
- Losses and leakage may reach as high as 35% of the total consumption.

Fire Fighting systems

A photograph of a fire hydrant on a concrete sidewalk. The hydrant is dark red and black, with a silver nozzle attached to its side outlet. Water is spraying out of the nozzle in several streams. The hydrant has a black cap on top and a chain hanging from the side. The background shows a concrete sidewalk and a dark, possibly wet, surface.

- Hydrant systems
- Sprinkler systems
- Hose-reel systems
- Portable fire extinguishers

Fire Fighting Water Demand

A photograph of a fire hydrant on a sidewalk. A fire hose is connected to the hydrant, and water is being sprayed out of the nozzle. The hydrant is a standard cast-iron design with a top cap and a side outlet. The background is a concrete sidewalk.

- Fire hydrants are usually fitted to the water mains and fire-fighting pumps are connected to these mains by the fire brigade personnel when a fire breaks out
- Small amount but high rate of use
- Pressure at the outlet of the hose ~ 190 Kpa
- Flow rate ~ 4.0 l/s
- Minimum reserve ~ 2 hrs

A vertical strip on the left side of the slide shows a close-up of water being sprayed, with many small droplets and a misty texture.

FIRE FLOW REQUIREMENTS

Required fire flow : the rate of water flow, at a residual pressure of 140 kPa and for a specified duration, that is necessary to control a major fire in a specific structure.

$$\text{quantity} = \text{rate} \times \text{duration}$$

Fire fighting demand

From Insurance services office (For a particular building)

$$Q_F = 227C\sqrt{A}$$

Where, Q_F = is fire demand (l/min); A = floor area excluding basements, m^2 ; C = coefficient for construction material

$C = 1.5$ for wood frame

$C = 1.0$ for ordinary construction

$C = 0.8$ for non-combustible construction

$C = 0.6$ for fire-resistant construction

For this equation, flow should be:

- Greater than 1900 lpm, but
- Less than 22,700 lpm (single-story structure); 30,270 lpm (single building); 45,400 lpm (single fire)

Fire fighting demand

- ***National Board of Fire Underwriters (NBFU) (For communities less than 200, 000)***

$$Q_F = 231.6\sqrt{P}(1 - 0.01\sqrt{P})$$

Where, Q_F = is fire demand (m^3/hr); P = Population in 1000's.

Note: This formula is used for sizing reservoir taking the community as whole.
Should not be Used for distribution system pipes!

Fire fighting demand

- *For group of building (ISO Method)*

$$NFF_i = C_i O_i (X + P)_i$$

- C is the construction factor based on the size of the building and its construction,
- O is the occupancy factor reflecting the kinds of materials stored in the building (ranging from 0.75 to 1.25), and
- (X+P) is the sum of the exposure factor and the communication factor that reflect the proximity and exposure of the other buildings.

Fire fighting demand

- **C construction factor**

$$C_i = 220 F \sqrt{A_i}$$

- C (L/min),
- A (m²) is the effective floor area, typically equal to the area of the largest floor plus 50% of all other floors,
- F is a coefficient based on the class of construction

Fire fighting demand

Construction coefficient, F

Class of construction	Description	F
1	frame	1.5
2	joisted masonry	1.0
3	noncombustible	0.8
4	masonry, noncombustible	0.8
5	modified fire resistive	0.6
6	fire resistive	0.6

Source: AWWA (1992).

Fire fighting demand

Occupancy factors, O_i

Combustibility class	Examples	O_i
C-1 Noncombustible	steel or concrete products storage	0.75
C-2 Limited combustible	apartments, churches, offices	0.85
C-3 Combustible	department stores, supermarkets	1.00
C-4 Free burning	auditoriums, warehouses	1.15
C-5 Rapid burning	paint shops, upholstering shops	1.25

Fire fighting demand

Needed fire flow for one- and two-family dwellings

Distance between Buildings		Needed Fire Flow	
<i>ft</i>	<i>(m)</i>	<i>gpm</i>	<i>(L/s)</i>
More than 100	(more than 30.5)	500	(31.5)
31–100	(9.5–30.5)	750	(47.3)
11–30	(3.4–9.2)	1,000	(63.1)
Less than 11	(Less than 3.4)	1,500	(94.6)

*Dwellings not to exceed two stories in height.

Fire fighting demand

Needed fire flow for residences two stories and less

Distance Between Buildings (ft)	Fire Flow (gpm)
More than 100	500
31-100	750
11-30	1000
Less than 11	1500

Fire flow rate and duration

Required fire flow durations

Required fire flow (L/min)	Duration (h)
< 9000	2
11,000–13,000	3
15,000–17,000	4
19,000–21,000	5
23,000–26,000	6
26,000–30,000	7
30,000–34,000	8
34,000–38,000	9
38,000–45,000	10

Example 1.4

For a town having population of 60,000 estimate average daily demand of water. Assume industrial use 10%, institutional & commercial use 15 %, public use 5% and live stock 10% of domestic demand. Take per capita consumption of 50 l/day and leakage to be 5%.

Solution 1.4

- $P = 60,000$
- Domestic = $50 \times 60,000 = 3,000,000 \text{ l/day} = 3,000 \text{ m}^3/\text{day}$
- Industrial = $0.10 \times 3,000 \text{ m}^3/\text{day} = 300 \text{ m}^3/\text{day}$,
- Inst & com. = $0.15 \times 3,000 \text{ m}^3/\text{day} = 450 \text{ m}^3/\text{day}$
- public = $0.05 \times 3,000 \text{ m}^3/\text{day} = 150 \text{ m}^3/\text{day}$
- live stock = $0.10 \times 3,000 \text{ m}^3/\text{day} = 300 \text{ m}^3/\text{day}$
- leakage = $0.05 \times 3,000 \text{ m}^3/\text{day} = 150 \text{ m}^3/\text{day}$
- Total average daily demand = $4,350 \text{ m}^3/\text{day}$



Example 1.5

Estimate the flowrate and volume required to provide adequate protection to a 10-story noncombustible building with an effective floor area of 8,000 m².

Solution 1.5

$$NFF_i = C_i O_i (X + P)_i \quad C_i = 220F \sqrt{A_i}$$

The construction factor is calculated as ($F=0.8$ for class 3 noncombustible construction and the floor area is $8,000 \text{ m}^2$):

$$C_i = 220(0.8)\sqrt{8000\text{m}^2} = 16,000\text{L}/\text{min}$$

The occupancy factor C is 0.75 (C-1 noncombustible) and the $(X+P)$ is estimated using the median value of 1.4 . Therefore, the required fire flow is:

$$NFF_i = (16,000\text{L}/\text{min})(0.75)(1.4) = 17,000\text{L}/\text{min}$$

The flow must be maintained for a duration of 4 hours, and the required volume is therefore:

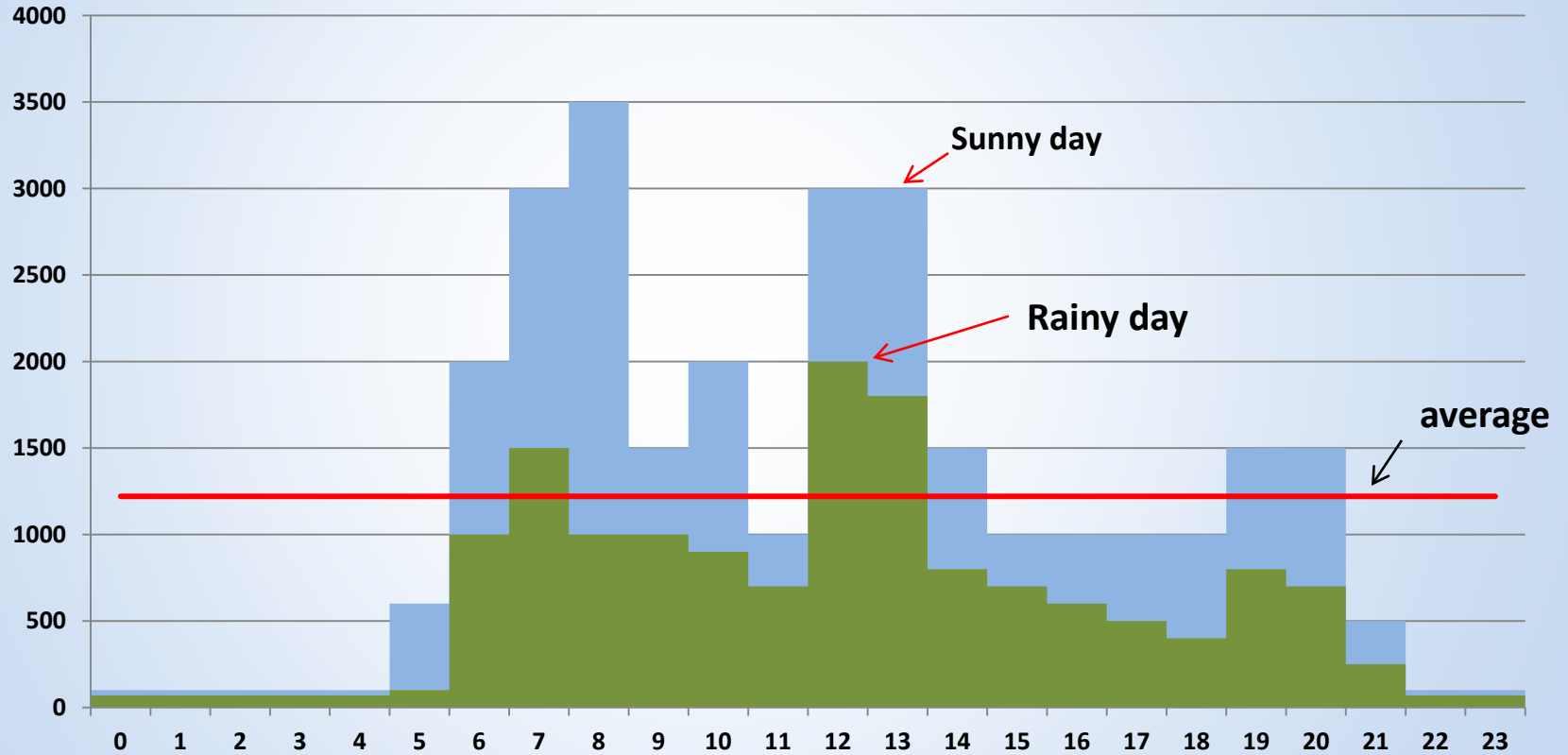
$$V = 17,000\text{L}/\text{min}(4\text{hours})(60\text{min}/\text{hr}) = 4.08 \times 10^6\text{L} = 4,080\text{m}^3$$



Factor Affecting Water Use

- Climatic conditions
- Cost of water
- Living Standards
- Industries
- Metering water lines
- Quality of water supply
- Size of city

Water Use Variation



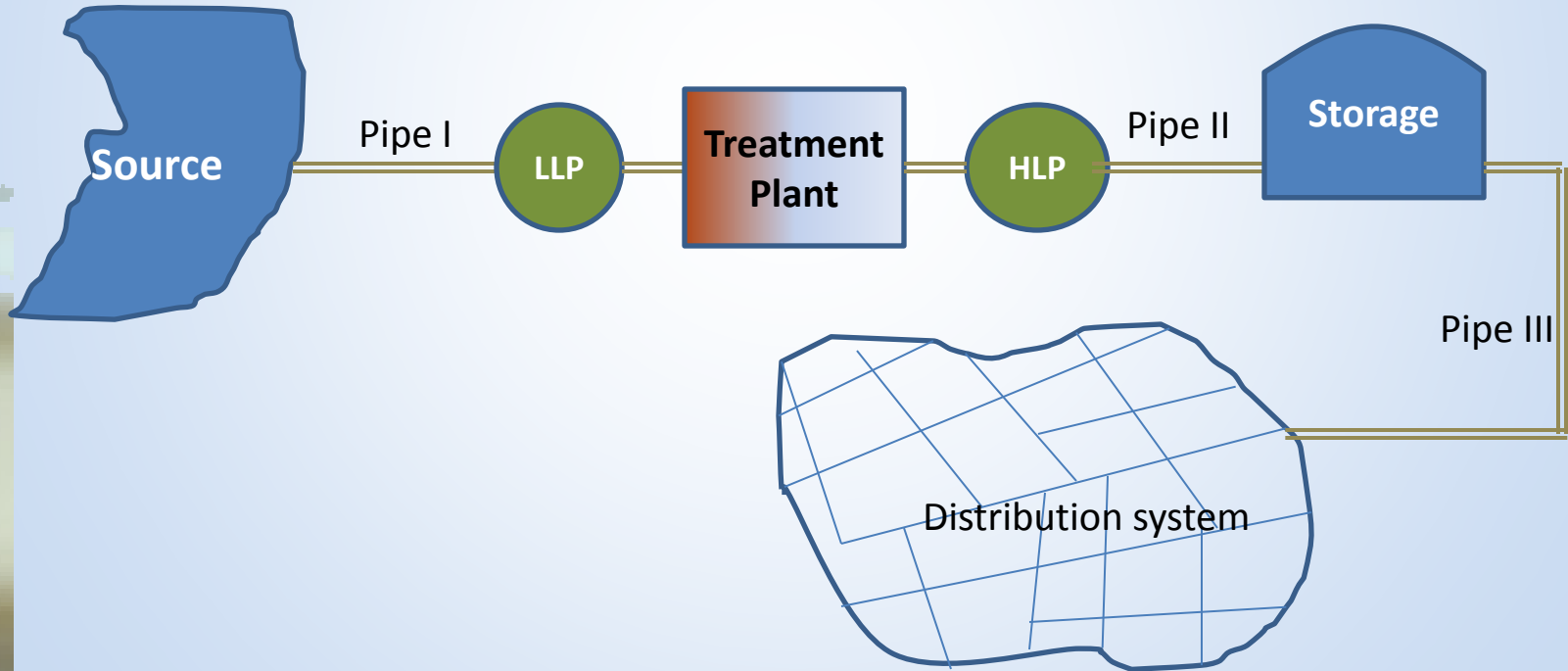
Variations in water demand

- **Annual average day demand** ($Q_{day-avg}$) the average daily demand over a period of one year. For economical calculations and fire fighting.
- **Maximum day demand** ($Q_{day-max}$) the amount of water required during the day of maximum consumption in a year. Important for water treatment plants and water storages.
- **Peak hour demand** (Q_{hr-max}) the amount of water required during the maximum hour in a given day. Important for design of distribution systems.
- **Coincident draft** (Q_{cd}). the sum of maximum daily demand, $Q_{day-max}$, and the fire demand (Q_F).

Typical Peak Factors

Population	Maximum Day Factor	Peak Hour Factor
0 to 20,000	1.30	2.00
20,001 to 50,000	1.25	1.90
50,001 and above	1.20	1.70

Water supply components



Design period and capacity

Component	Special characteristics	Design period	Design capacity
Source: Groundwater Surface sources	✓ Easy to expand ✓ Uneasy to expand	5-10 20-50	$Q_{\text{day-max}}$
Pipe mains (Type I and Type II)	✓ Long life ✓ Cost of material is only a small portion of the cost of construction	>25	✓ $Q_{\text{day-max}}$ ✓ Suitable velocities under all anticipated flow conditions
Treatment plant	✓ Expansion is simple	10-15	$Q_{\text{day-max}}$

Design period and capacity

Component	Special characteristics	Design period	Design capacity
Pumping units	<ul style="list-style-type: none"> ✓ Easy to modify and expand 	10	LLP: $2Q_{\text{day-avg}}$ or $4/3Q_{\text{day-max}}$ whichever is greater HLP: $3Q_{\text{day-avg}}$ or $4/3Q_{\text{day-max}}$ whichever is greater
Service reservoir	<ul style="list-style-type: none"> ✓ Long life ✓ Easy to construct ✓ Relatively inexpensive 	Very long	Design should consider: <ul style="list-style-type: none"> ✓ Hourly fluctuations of flow ✓ The emergency reserve ✓ The provision required when pumps satisfy the entire days demand in less than 24 hrs. ✓ The fire demand.
Type III pipe and distribution pipes	<ul style="list-style-type: none"> ✓ Long life ✓ Replacement is very expensive 	Indefinite	$Q_{\text{hr-max}}$ or $Q_{\text{day-max}} + Q_F$, whichever is greater (calculated for anticipated maximum growth)

Example 1.5

Calculate the water requirements for a community that will reach a population of 120,000 at the design year. The estimated municipal water demand for the community is 300 l/c/d. Calculate the **fire flow**, design capacity of the **water treatment plant**, and design capacity of the **water distribution system**. Use NBFU formula for fire flow.

Solution 1.5

- $P = 120,000$
- $Q_{\text{day-avg}} = 300 \times 120,000 = 36,000,000 \text{ L/d} = 36,000 \text{ m}^3/\text{d}$
- Take PF for $Q_{\text{day-max}} = 1.6$ and 2.0 for $Q_{\text{peak-hr}}$
- $Q_{\text{day-max}} = 1.6 \times 36,000 = 57,600 \text{ m}^3$
- $Q_{\text{peak-hr}} = 2.0 \times 36,000 = 72,000 \text{ m}^3$
- Fire flow rate = $Q_F = 231.6\sqrt{P}(1 - 0.01\sqrt{P})$
 $Q_F = 231.6\sqrt{120}(1 - 0.01\sqrt{120}) = 2259.13 \text{ m}^3/\text{hr} = 54,219 \text{ m}^3/\text{day}$

Design capacity of treatment plant = $57,600 \text{ m}^3/\text{day}$

Distribution system Design capacity = $\max(72,000 \text{ or } 57,600 + 54,219) = 111,819 \text{ m}^3/\text{day}$