UNIT-1

QUANTITY OF WATER AND TRANSMISSION OF WATER

UNIT-1 Fresh water, water demands, variation in demands, population forecasting by various methods, basic needs and factors affecting consumption, design period. Transmission of water: Various types of conduits, capacity and sizes including economical sizes of rising main, structural requirements; laying and testing of water supply pipelines; pipe materials, joints, appurtenances and valves; leakages and control.

UNIT OUTCOMES: After completion of this unit student will be able to assess water demand and optimal size of water mains.

Water:

- Water is a transparent, tasteless, odourless, and nearly colourless chemical substance
- Water is the main constituent of Earth's streams, lakes, and oceans, and the fluids of most living organisms.
- It is vital for all known forms of life, even though it is chemically simple and abundant in nature.
- Water molecules are made up of two hydrogen atoms and one oxygen atom (H_2O),
- It is the hydrogen bonds between water molecules that give water its unique physical and chemical properties, such as high surface tension and high heat capacity.
- Water is essential for many processes in the body, including digestion, metabolism, and the regulation of body temperature.
- It is also important for agriculture, industry, and energy production.
- However, access to clean and safe water is a major challenge in many parts of the world,
- Water scarcity and pollution are becoming increasingly pressing global problem.

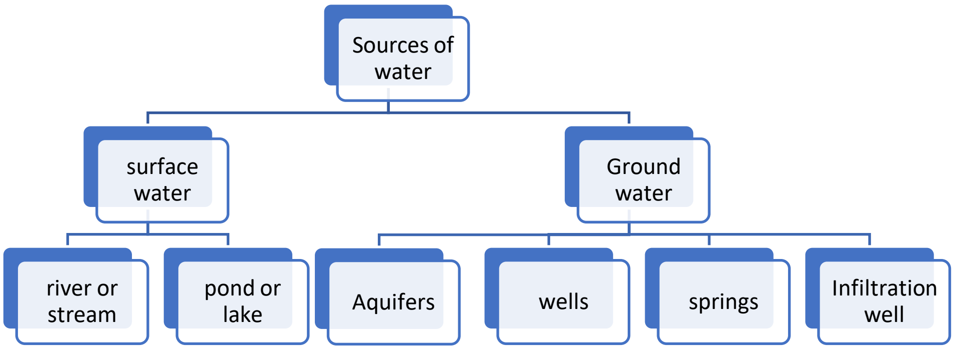
Fresh water:

- Approximately 71% of the Earth's surface is covered by water, but only a small fraction of this is fresh water.
- The majority of the fresh water on Earth is stored in glaciers and polar ice caps, with only a limited amount available for human use.
- The sources of fresh water on Earth include rivers, lakes, groundwater aquifers, and underground springs.
- It is estimated that about 2.5% of the total volume of water on Earth is freshwater, and much of this is not easily accessible or suitable for human use.
- Access to safe and clean drinking water remains a challenge for many communities around the world, particularly in developing countries.
- Climate change, increasing demand for water, and over-extraction of groundwater are putting increasing pressure on the world's freshwater resources.

Sources of Water:

- Source water refers to bodies of water (such as **rivers, streams, lakes, reservoirs, springs, and ground water**) that provide water to public drinking-water supplies and private wells.

- Water sources can include:
  1. Surface water (for example, a lake, river, or reservoir)
  2. Ground water (for example, an aquifer)



1. **Surface Water:**

- Surface water is a term used to describe all water that is on the Earth's surface and is accessible for use, including rivers, lakes, streams, and wetlands.
- It is an important source of drinking water, irrigation, and hydropower, and plays a critical role in supporting aquatic ecosystems.
- The availability of surface water resources can be affected by factors such as climate change, population growth, and human activities such as land use changes and pollution.

(a) River or Stream: A river or stream water source refers to the water that flows through a river or stream channel. It is a major source of surface water and is often used for drinking water, irrigation, and hydropower generation. Rivers and streams also play a crucial role in the water cycle by transporting water from the land to oceans, lakes, and other water bodies. The quality and quantity of water in rivers and streams can be influenced by various factors such as precipitation patterns, land use, and human activities such as pollution and dam construction.

(b) Pond or lake: A pond or lake as a surface water resource refers to a body of stagnant or slow-moving water that is usually formed by natural processes such as precipitation, melting ice, or river runoff. Ponds and lakes serve as important sources of drinking water, irrigation water, and recreation.

2. **Ground water :**

- Groundwater is water that is found underground in the spaces between rocks, gravel, and sand.
- It is a valuable resource because it is relatively pure and is not affected by surface pollution.
- Groundwater is often accessed using wells and is used for drinking water, irrigation, and industrial purposes.
- Groundwater is a finite resource so it is important to manage it sustainably to ensure its availability for future generations.
- Factors that can impact groundwater include over-pumping, contamination from human activities, and changes to the water cycle due to climate change.

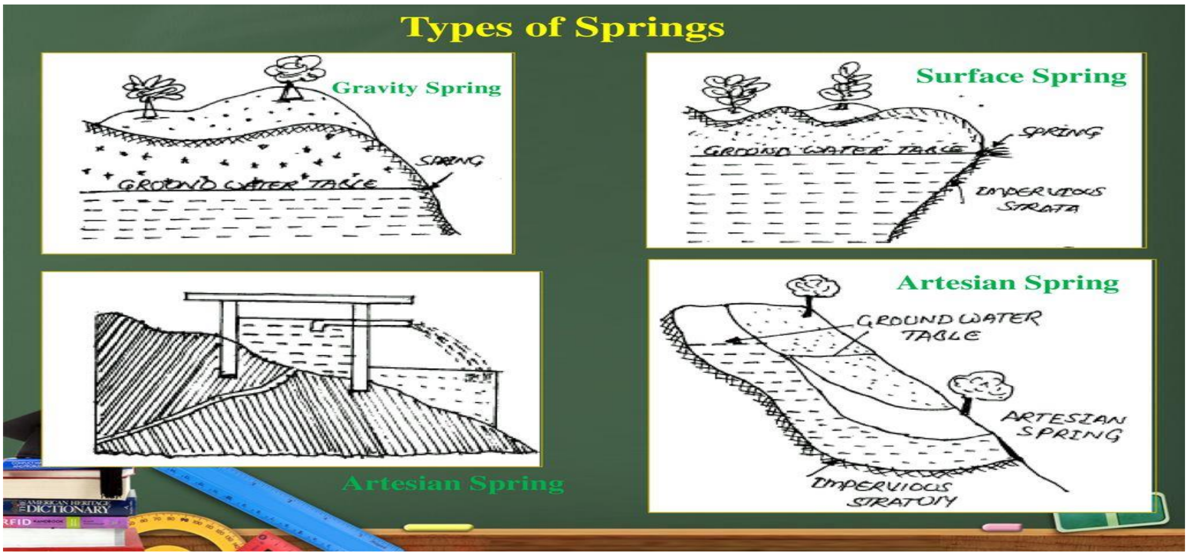
- Proper management and protection of groundwater resources is crucial for maintaining their quality and quantity over time.

  Following are the different types of ground water sources:

(a) Springs:

- Springs occur when water pressure causes a natural flow of groundwater onto the earth's surface. As rainwater enters or "recharges" the aquifer, pressure is placed on the water already present.
- Spring, in hydrology, opening at or near the surface of the Earth for the discharge of water from underground sources.
- The quality of water discharged by a spring depends on the type of aquifer and rock strata through which the water has passed.

  The different types of ground water sources:



i) Gravity springs:

- Gravity springs occur in unconfined aquifers**.**
- Gravity springs is also known as Depression springs.
- Gravity springs result where the land surface intersects the water table by some cracks or fractures and flows horizontally out of the ground.
- These are usually found along the hillside and cliffs.

ii) Artesian springs:

- Artesian springs come from pressure in confined aquifers forcing the water to the surface.
- The pressure inside the confined aquifer (between impermeable layers) is less than the pressure outside the aquifer, so the water moves in that direction.
- Any cracks or holes in the land will easily let the water escape.

ii) Seepage spring:

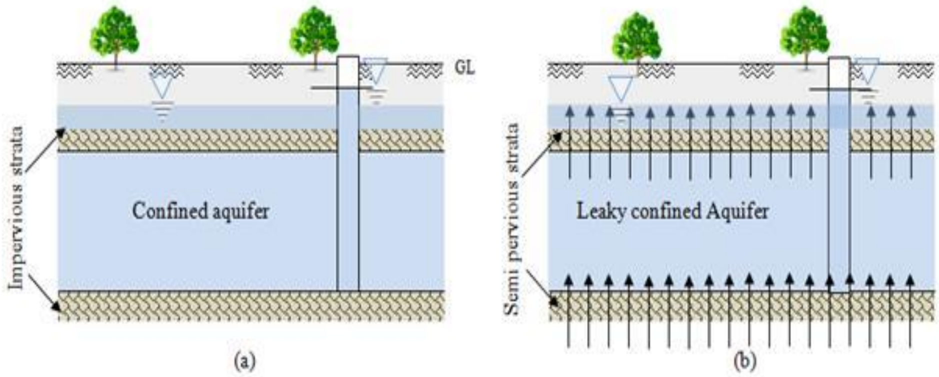
- It is groundwater seeping out at the surface.
- Seepage springs slowly let water out through loose soil or rock
- These are often found in land depressions or low in valleys.

(b)Aquifers:

- An aquifer is a body of rock and/or sediment that holds groundwater.
- Groundwater is the word used to describe precipitation that has infiltrated the soil beyond the surface and collected in empty spaces underground.
- An aquifer is an underground geological formation which contains water and sufficient amount of water can be extracted economically using water wells.
- Aquifers comprise generally layers of sand and gravel and fracture bedrock.
- There are two general types of aquifers:
  i) Confined aquifer
  ii) Unconfined aquifer

i) Confined aquifer:

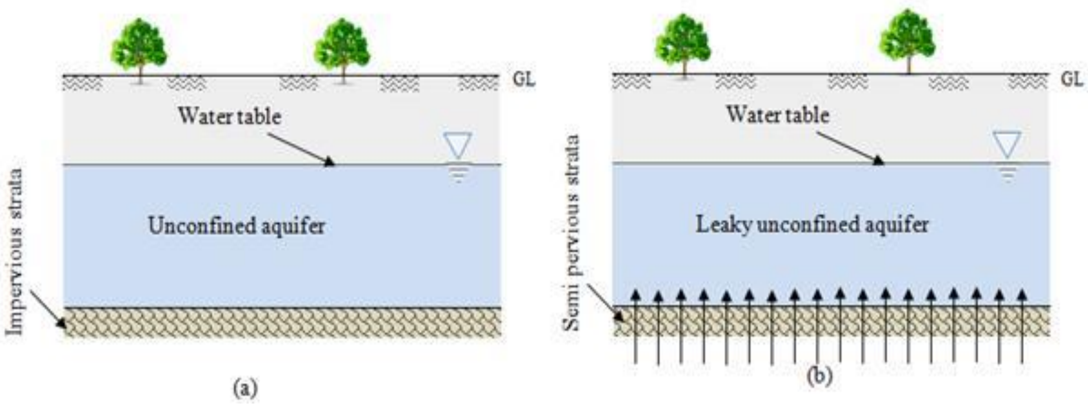
- Confined aquifers are where thick deposits overly the aquifer and confine it from the Earth's surface or other rocks.



- An aquifer which is bounded by two impervious layers at top and bottom of the aquifer is called confined aquifer.
- The confined aquifer is also known as pressure aquifer.
- Top and bottom layer of a confined aquifer is generally impervious.
- When these layers may be semipervious in nature. In such a situation, the water may gain or lose through these semipervious layers. The aquifer is then called **leaky confined aquifer**.

ii) Unconfined aquifer:

- Unconfined aquifers are where the rock is directly open at the surface of the ground and groundwater is directly recharged, for example by rainfall or snow melt.



- The unconfined aquifer is also known as water table aquifer and phreatic aquifer.

- An impervious layer is generally served as the bottom boundary of an unconfined aquifer.
- When the bottom of an unconfined aquifer may be semipervious and water may gain and lose through the semipervious bottom layer. The aquifer is then known as **leaky unconfined aquifer.**

iii) Perched Aquifer:

- Located on impermeable lenses or discontinuous layers.
- A perched aquifer occurs above the regional water table and is generally a relatively small body of water with an impermeable base under which lies an unsaturated zone.

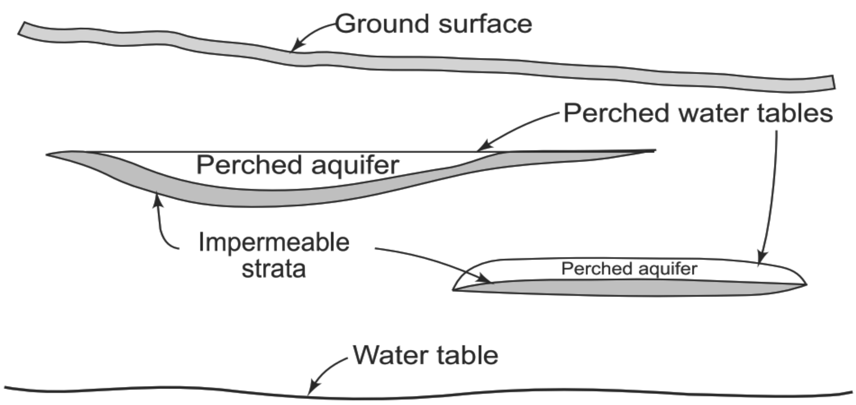


Fig. 13.5 *Perched (unconfined) aquifer*

- These are unique water bodies not widely distributed and are not targeted for water supply.

(c) **Aquitard**:

- An aquitard is an underground geological formation which contains water but significant amount of water cannot be extracted using water wells.
- Aquitard comprises of generally layers of clay soil with low hydraulic conductivity.
- saturated, permeable geologic unit which cannot transmit significant quantities of water (but can transmit small quantities)
- Also called a semi-pervious formation or leaky formation.

(d) **Aquifuge**:

- Geologic formation which neither contains nor transmits any water.
- It is incapable to absorb or transmit water through it.
- Thus it is an impermeable formation.

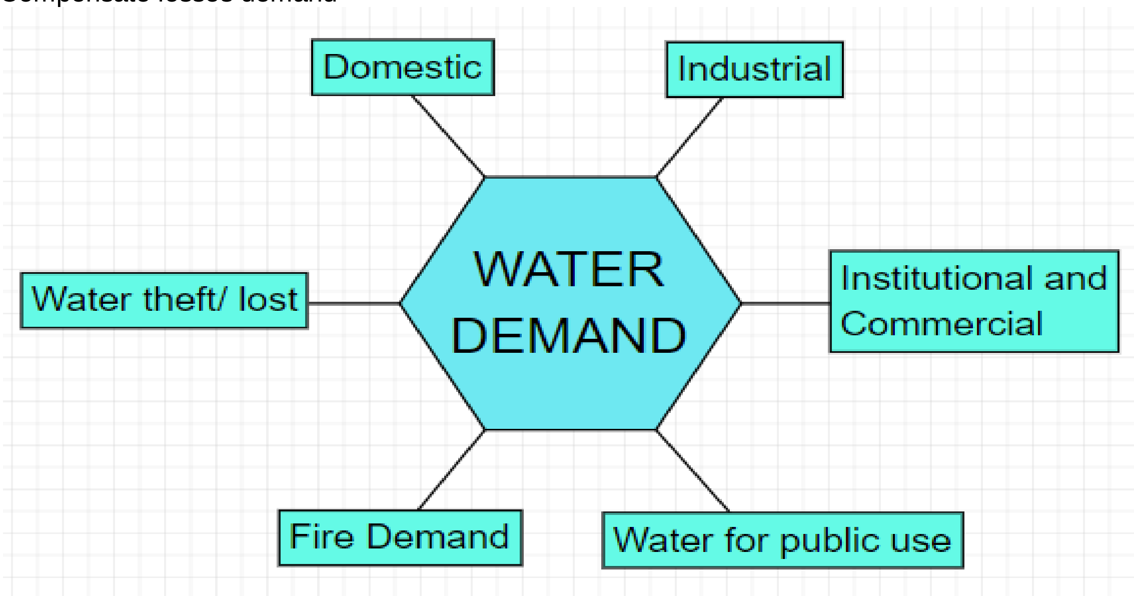
(e) Aquiclude:

- Geologic formation which may contain water,
- It is incapable of transmitting water.

Water demand:

- The quantity of water required by a community, society or industry is called water demand.
- It is normally expressed as litres per person per day or LPCD.
- While designing the water supply scheme for a region,
- It is necessary to determine the total quantity of water required for different purposes.
- The various types of water demands are:

1. Domestic water demand
2. Industrial or commercial water demand
3. Fire demand
4. Demand for public uses
5. Compensate losses demand



1. **Domestic water demand**:
    - Refers to the water required by houses for drinking, cooking, washing, bathing etc.
    - It depends upon habits, social status, climatic conditions and customs of people.
    - In India, on an average, the domestic consumption of water under normal circumstances is **135 litres/day/capita** according to **IS1172:1171**.
    - This figure may be as high as 350 litres/day/capita in developed countries.
2. **Commercial water demand:**
    - Refers to requirements of water to commercial buildings or centres like office buildings, warehouses, stores, hotels shopping centres, health centres, schools, temples, cinema houses, and railway and bus stations.
    - The water demand in such cases is **30 to 40 litres/day/capita**.
3. **Industrial water demand:**
    - The industrial water demand represent the water demand of industries.
    - The industries demand of water depends on the type of industry in the area.
    - The ordinary per capita demand consumption on account of industrial needs of a city is generally taken as 50liters/person/day.
    - The industrial water demand is generally as 20% and 25% of the total water demand of the city or town.
4. **Public demand:**
    - It included the water requirement for public utility purposes such as watering of public parks, gardening, public sanitary block, washing and sprinkling on road, use in public fountains etc.

5. **Fire demand:**
    - Fire demand is the amount of water required to extinguish fire. The water required for fire fighting in a given area,
    - the quantity of water required for fire fighting should always be kept stored in underground reservoirs in specific places and fire hydrant should be establish in main pipe lines at an interval of about 100m to 150m.,
    - It is the amount of water required for fire fighting purposes if in case a fire breaks out in an area. This water is required to be available at a pressure of about 100 to 150 kN/m^2 or 10 to 15m head of water,

- fire demand is calculated using various empirical formulas which are discussed further**;**

i. KUICHLING'S FORMULA

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

Where,
Q - Water required in litres/minute
P - population in 1000s (i.e., if population is 1,00,000 then P = 100)

ii. BUSTON'S FORMULA

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

Where,
Q - Water required in litres/minute
P - Population in 1000s.

iii. FREEMAN'S FPRMULA

$$Q = 1136 * [(P/10)+10],$$

Where,
Q - Water required in litres/minute
P - Population in 1000s,

iv. THE NATIONAL BOARD OF FIRE UNDER WRITERS FORMULAS:

$$Q = 4637 * \sqrt{P} * [1 - (0.01*\sqrt{P})],$$

Where,
Q - Water required in litres/minute
P - Population in 1000s (valid for population of less than 2, 00,000)
NOTE- When population is more than 2 lakhs, a provision for 57,600 Liters/minutes may be made an extra addition provision of 9100 to 36400 liters/minute for a second fire.

Variation of water demand

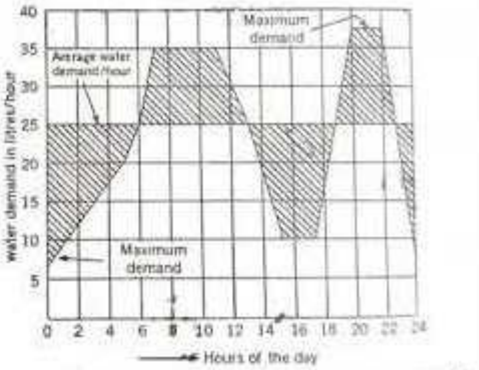
The rate of demand for water varies considerably from season to season. In the summer season, the average rate of demand for water is usually 30 to 40 percent above the annual average rate of demand for water, because more water is required for drinking, bathing, washing clothes, air coolers, etc. The demand varies from seasons to seasons, month to month, day to day, and even from hour to hour. This fluctuation of demand is also known as variation of demand.

These variations in the rate of demand for water are termed as:
1. **Seasonal Variations:** The rate of demand for water varies considerably from season to season. In the summer season, the average rate of demand for water is usually 30 to 40 percent above the annual average rate of demand for water, because more water is required for drinking, bathing, washing clothes, air coolers, etc.

2. **Daily Variations:**

The rate of demand for water also varies from day to day.This is due to changes in the day-to-day climatic conditions, or due to the day being a holiday or some festival day. Thus on a rainy day, the requirement for water will be much less than on the other day which may be dry and hot.

3. **Hourly Variations:** The demand for water also varies from hour to hour of the day.A typical graph use to show the hourly variation in the rate of demand for water (expressed in million litters per head per hour). It may be seen from the graph that the peak or maximum demand for water usually occurs in the morning from about 7 a.m. to 9 a.m. and in the evening from about 7 p.m. to 9 p.m.



Hourly variation of the rate of consumption

Population forecasting by various methods

A water supply project is planned to meet the present requirements as well as the requirement for a reasonable future period termed as the design period. Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended; similarly overestimated value will make it costly. Change in the population of the city over the years occurs, and the system should be designed taking into account of the population at the end of the design period. it is necessary to know the factors affecting the population growth which are as discussed below.

Factors affecting changes in population are:

- **i.** **Economic factors:** such as development of new industries, discovery of oil or other minerals in the vicinity of the city.
- **ii.** **Development programmes:** projects of national importance such as river valley projects etc.
- **iii.** **Social facilities:** educational, medical, recreational and other social facilities.
- **iv.** **Communication links:** connection of the town with other social facilities.
- **v.** **Tourism:** tourist facilities, religious places on historical buildings.
- **vi.** **Community life:** living habits, social customs and general education in the community.
- **vii.** **Unforeseen factors:** earthquakes, flood, epidemics, frequent famines

Population forecasting methods:

The present and past population record for the city can be obtained from the census population records. After collecting these population figures, the population at the end of design period is predicted using various methods as suitable for that city considering the growth pattern followed by the city.

1. **ARITHMETICAL INCREASE METHOD** :
   - This method is suitable for large and old city with considerable development.
   - If it is used for small, average or comparatively new cities, it will give low result than actual value.
   - In this method the average increase in population per decade is calculated from the past census reports.

- This increase is added to the present population to find out the population of the next decade.
- Thus, it is assumed that the population is increasing at constant rate.

Hence, dP/dt = Constant

i.e. rate of change of population with respect to time is constant.

Therefore, Population after nth decade will be

$$P_n = P + n.\bar{x}$$

Where,

P_n = the population after n decade and

n = number of decade between last census and future

$\bar{x}$ = average (arithmetic mean) of population increase in the known decades

P = present population

Example:1

Predict the population for the year 2021, 2031, and 2041 from the following population data.

Year	1961	1971	1981	1991	2001	2011
Population	8,58,545	10,15,672	12,01,553	16,91,538,	20,77,820,	25,85,862

Solution:

Year	Population	Increment
1961	858545	-
1971	1015672	157127
1981	1201553	185881
1991	1691538	489985
2001	2077820	386282
2011	2585862	508042

Population in year 2021 is, P_{2021} = 2585862 + 345463 x 1 = 2931325

Similarly, P_{2031} = 2585862 + 345463 x 2 = 3276788

P_{2041} = 2585862 + 345463 x 3 = 3622251

2. GEOMETRICAL INCREASE METHOD

(OR GEOMETRICAL PROGRESSION METHOD)

In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population. Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of n^{th} decade 'P_n' can be estimated as:

$$P_n = P\,(1+ I_G/100)^n$$

Where, I_G = geometric mean (%)= $\sqrt[t]{i_1 . i_2 . i_3 \ldots \ldots i_t}$

P = Present population

N = no. of decades.

Example : 2

Considering data given in example 1 predict the population for the year 2021, 2031, and 2041 using geometrical progression method.

Solution

Year	Population	Increment	Geometrical increase Rate of growth
1961	858545	-	
1971	1015672	157127	(157127/858545) = 0.18
1981	1201553	185881	(185881/1015672) = 0.18
1991	1691538	489985	(489985/1201553) = 0.40
2001	2077820	386282	(386282/1691538) = 0.23
2011	2585862	508042	(508042/2077820) = 0.24

Geometric mean $I_G = (0.18 \times 0.18 \times 0.40 \times 0.23 \times 0.24)^{1/5}$

$= 0.235$ i.e., 23.5%

Population in year 2021 is, $P_{2021} = 2585862 \times (1+ 0.235)^1 = 3193540$

Similarly for year 2031 and 2041 can be calculated by,

$$P_{2031} = 2585862 \times (1+ 0.235)^2 = 3944021$$

$$P_{2041} = 2585862 \times (1+ 0.235)^3 = 4870866$$

3. INCREMENTAL INCREASE METHOD

This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

Hence, population after n^{th} decade is

$$P_n = P + n.\bar{x} + \{n\,(n+1)/2\}.\bar{x}$$

Where, P_n = Population after n[th] decade

$\bar{x}$ = Average increase

$\bar{y}$ = Incremental increase

Example : 3

Considering data given in example 1 predict the population for the year 2021, 2031, and 2041 using incremental increase method.

Year	Population	Increase (X)	Incremental increase (Y)
1961	858545	-	-
1971	1015672	157127	-
1981	1201553	185881	+28754
1991	1691538	489985	+304104
2001	2077820	386282	-103703
2011	2585862	508042	+121760
	Total	1727317	350915
	Average	$\bar{x}$ =345463	$\bar{y}$= 87729

Population in year 2021 is,

P_{2021} = 2585862 + (345463 x 1) + {(1 (1+1))/2} x 87729= 3019054

For year 2031,

P_{2031} = 2585862 + (345463 x 2) + {((2 (2+1)/2)}x 87729= 3539975

For year 2031,

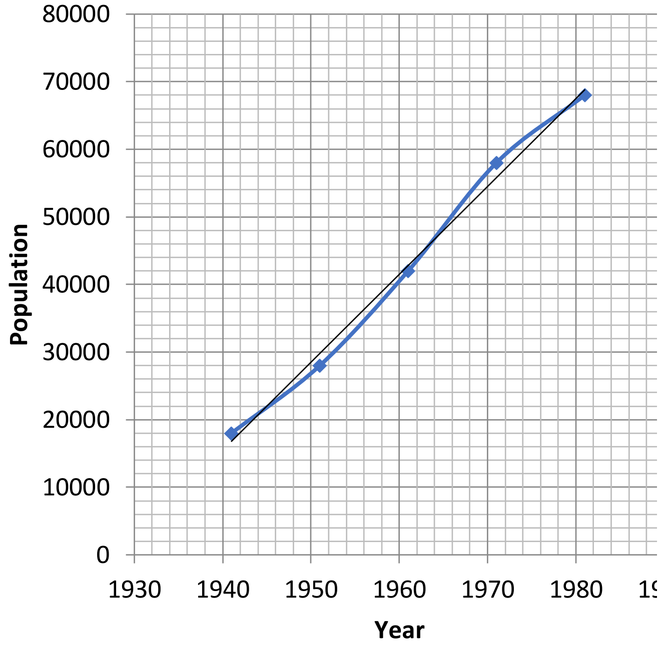
P_{2041} = 2585862 + (345463 x 3) + {((3 (3+1)/2)}x 87729= 4148625

4.GRAPHICAL METHOD

In this method, the populations of last few decades are correctly plotted to a suitable scale on Graph. The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment. The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

year	population
1941	18000
1951	28000

1961	42000
1971	58000
1981	68000
1991	75000



5.COMPARATIVE GRAPHICAL METHOD:

In these method cities having similar characteristics and condition to that city whose population is to be forecasted are selected. It is assumed that the city under consideration will develop similarly as selected cities have been developed in the past.

From the census records, the population growth curve of different cities is plotted in the graph. By comparing the nature of the curves, the curve of the city under consideration is drawn by a dotted line(Y). This dotted line shows the shows the expected population of the city under consideration.

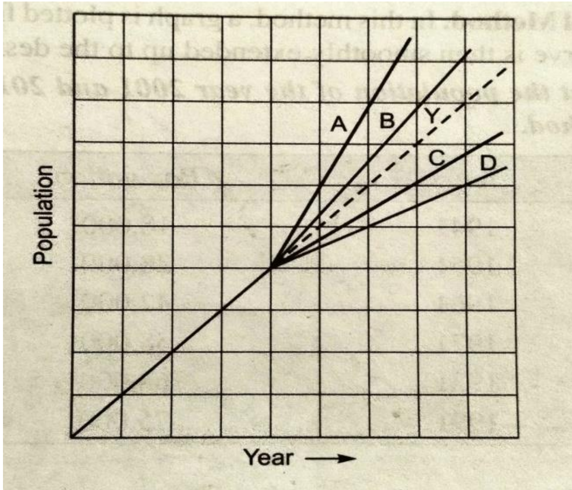


Fig. 1.4 Comparative growth curve.

6. **Master plan method or zoning method:**

In this method, a master plan of the city should be prepared by dividing the city into various zones such as residential, industrial and commercial zone etc. Each zone is allowed to develop as per master plan only which is regulated by various by laws of corporations. This method is more advantageous because of the fact that the total water requirement of the city depends not only for domestic purpose but also for commercial, industrial, social health and other purposes.

The common figures for population densities which may be taken in master plan preparation are shown in table below

Common population densities

Area type	Persons per hectare
Residential- single family unit	15-80
Residential multiple family unit	80-250
Apartments	250-2500
Commercial areas	40-75
Industrial areas	15-40

7. The Logistic curve method:

The three factors responsible for changes in population are:

i. Birth
ii. Deaths
iii. Migrations

When all these varying influences do not produce extraordinary change the population would probably follow the growth curve characteristics of living thing with in limited space or with limited economic opportunity. The curve is S-shape and is known as logistic curve.

$$\log_e\left(\frac{P_s-P}{P}\right)-\log_e\left(\frac{P_s-P_0}{P}\right) = -KP_s t$$

Where,

P_0= the population at any time t from the origin A

P_s= saturation population

P= population at any time t from the origin A

K= constant

$$P_s=\frac{2P_0P_1P_2-P_1^2(P_0-P_2)}{P_0P_2-P_1^2}$$

$$P_s=\frac{P_s}{1+m.\log_{e-1}(nt)}$$

$$n=\left(\frac{2.3}{t_1}\right)\log_{10}\left[\frac{P_0(P_s-P_1)}{P_1(P_s-P_0)}\right]$$

<u>Design period</u>

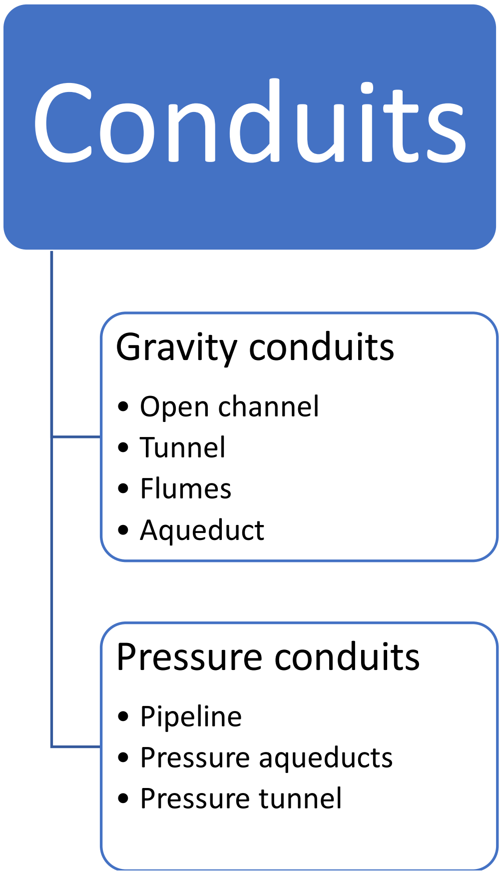
- The number of years for which the design of the water work has been done is known as design period.
- The complete water supply project includes huge and costly construction such as dam, reservoir, treatment work and network of distribution pipelines. These all work cannot be replaced easily or capacities increased conveniently for future expansion.
- Water Supply projects may be designed normally to meet the requirements over a thirty-year period after their completion.
- The time lag between design and completion of the project should also be taken into account which should not exceed two years to five years depending on the size of the project.
- The thirty year period may however be modified in regard to certain components of the project depending on their useful life or the facility for carrying out extensions when required and rate of interest so that expenditure far ahead of utility is avoided.
- Necessary land for future expansion/duplication of components should be acquired in the beginning itself.
- Where expensive tunnels and large aqueducts are involved entailing large capital outlay for duplication, they may be designed for ultimate project requirements.
- Where failure such as collapse of steel pipes under vacuum put the pipe line out of commission for a long time or the pipe location presents special hazards such as floods, ice, and mining etc. duplicate lines may be necessary.

Sl.No.	Data Source	Design period in years
1	Storage by dams	50
2	Infiltration Works	30
3	Pumping	
	i. Pump house (civil works)	30
	ii. Electric motors and pumps	15
4	Water treatment units	15
5	Pipe connection to several treatment units and other small appurtenances	30
6	Raw water and clear water conveting mains	30
7	Clear water reservoirs at the head works, balancing tanks and service reservoirs (overhead or ground level)	15
8	Distribution system	30

Transmission of water

The transport of water from storage facilities to distribution networks takes place through water transmission pipelines**.** Water is conveyed or transported from the source to the residential, commercial and industrial customer to sustain the common necessities of life through various types of conduits. The two types of conduits used are gravity and pressure conduit. The selection of conduits depends on factors such as: topography, construction practices, economic considerations and water quality.

Conduits



Gravity Conduits	**Pressure conduits**
1. The water flows under the action of gravity.	1. The water flow under the action of pressure.
2. In such flow water is subjected to atmospheric pressure	2. In such flow water is subjected to more than atmospheric pressure ($P_w > P_{atm}$)
3. Hydraulic gradient line(HGL) will coincide with water surface.	3. Hydraulic gradient line (HGL) above the water surface.
4. In Gravity conduit less loss	4 In such pipe head loss occur due to friction
5. Includes open channel, tunnel, flume and aqueduct	6. Includes pipeline pressure aqueduct, pressure tunnel.

Gravity conduits:

Gravity conduits are those in which the water flows under the mere action of gravity. In such a conduit, the gradient line will coincide with the water surface and will be parallel to the bed of the conduit. The bet of gravity conduit is provided with a gradual slope.
Gravity conduit includes open channel, tunnel, flume and aqueduct each of which is describe below:

1. **Open channel (canals):**
   - design to convey water under conditions of atmosphere pressure.
   - May be covers of open
   - If the soil is pervious the channel should lined to prevent seepage.
   - the potential of pollution hazard and evaporation losses should be considered
2. **Tunnels:**
   - Where it is not possible to by a pipeline on the surface or provided an open channel a tunnel is selected.
   - It may be circular or horse shoe in cross-section
   - Tunnel is most suited to mountain areas.
   - They may be designed as gravity conduits or pressure conduits.
3. **Flumes:**
   - A flume is an open channel of concrete, steel, or wood laid on the ground surface or supported on trestles or piers.
   - Flumes are generally used to carry water across natural streams, drains or minor depressions
   - Flumes are generally rectangular in cross-section but may also have circular or semicircular cross-section.
   - A flume of circular cross-section runs only partly full.
4. **Aqueducts:**
   - An aqueduct is a closed conduits of masonry or RCC built
   - Water flows through it under gravity only
   - Aqueducts with circular or horse-shoe cross-section are in common use.
   - Aqueducts with horse- shoe cross section are in common use.
   - It is economical in the use of the construction material and is easy to build.

Pressure conduits: The pressure conduits are those in which water flows under pressure above the atmospheric pressure. The hydraulic grade for such conduits can be obtained by joining the water surface level in the piezometer installed in the conduit at different points. These conduit can therefore follow the natural ground surface and can be taken up and down hills or can dip and taken up and down hills or can dip and taken along valleys, thereby requiring lesser lengths of the conduits. Generally a pressure conduit lies below the hydraulic grade line but sometime it can rise above the hydraulic grade line when the pressure in the conduits becomes negative or sub-atmospheric. A pressure conduit when taken along a hell may rise above the hydraulic grade line and it is called a siphon.

1. **Pipeline**:
   - Usually built where topographic conditions preclude the use of channels
   - May be laid above or below ground or partly buried
   - Pressure conduits are built of concrete, steel, cast iron or plastic
   - The potential of pollution hazard and evaporation losses should be considered
2. **Pressure aqueducts and pressure tunnel :**
   - The pressure aqueducts may be in the form of closed pipes or closed aqueducts and tunnels are called pressure aqueducts or pressure tunnels
   - The aqueducts as well as tunnel section are generally kept circular cross-section.

Advantage of pressure conduit over gravity Conduit:

i. The water flowing through the pressure conduits is not exposed to atmosphere and hence there are no chances of its getting polluted.

ii. In case of gravity conduits considerable quantity of water is lost due to seepage and evaporation which can be saved if instead of gravity conduits pressure conduits are used

iii. In general pressure conduits are more economical than the gravity conduits, because the pressure conduits can follow the direct routes which always being shorter will require lesser lengths of conduits and consequently the construction costs will be less.

iv. The maintenance cost of pressure conduits are generally less than those for the gravity conduits.

Pipe hydraulics:

When water flows through pipes, head loss takes place. Total head loss is composed of the following items:

1. **Head loss due to friction**: head loss due to friction may be computed from the following formulae:

   a. Darcy-weisbach formula:

$$H_f = \frac{f'.L}{D}.\frac{V^2}{2g}$$

H_f= head loss due to friction (m)

f' =Darcy's coefficient of friction

L=length of the pipe (m/s)

V=average velocity of flow (m/s)

D=internal diameter of pipe (m)

G= acceleration due to gravity=9.81 m/s^2

Table 2.1 Values of C in Hazen-William's Formula

Type of pipe	Condition	C 10 cm dia.	C 30 cm dia.	C 60 cm dia. and over
Cast iron	Smooth and new	125	130	135
	Ordinary	95	105	115
	Old	70	80	90
	Very rough	55	65	75
Spun Iron	Add 5 to value of *C* for cast iron pipe of same age or condition			
Welded Steel	Subtract 5 from value of *C* for cast iron pipe of same age or condition			
Riveted Steel	Subtract 10 from value of *C* for cast iron pipe of same age or condition			
Spun concrete or bitumen lined	Smooth and new	140–150		
Concrete or concrete lined	Average	120–140		
Asbestos cement	Average	140		
Wood stave	Smooth and clean	120		
Masonry	Smooth and clean	120		
Vitrified clay	Good condition	110		
Ordinary brick	Good condition	100		

b. Hazen Williams formula:

This is the most widely used formula, relating velocity of flow, hydraulic mean radius and hydraulic gradient

$$V = 0.849CR^{0.63}S^{0.54}$$

V=mean velocity of flow in pipe m/sec.

R=Hydraulic radius (mean depth) in meters = $(\frac{D}{4})$for circular pipes

S=hydraulic gradient

C= coefficient of roughness of pipe

Coefficient C depends upon several factors such as pipe material, age of the pipe and diameter of the pipe. Its value is high for smooth and new pipes and goes on decreasing with age or roughness. Table 2.1 gives the values of C for different pipes.

c. Modified Hazen's- William's formula :

Hazen- William formula which is widely used by the environment engineers is not preferred due to its limitations. Hence, the modified Hazen-william formula has been derived from Darcy-weisbach and Colebrook-white equation and obviate the limitation of Hazen-william.s formula:

$$V = \frac{3.83C_R[D^{0.6575}(g.s^{0.5525})]}{v^{0.105}}$$

Where,

C_R= dimensionless coefficient of roughness

D= Pipe diameter

G= acceleration due to gravity (9.81m/s^2)

S= friction slope = $\frac{H_f}{L}$

ν = Viscosity of liquid (For water at 20°C=10^{-6} m^2/s)

Eq. Reduced to:

$$V=143.534C_R R^{0.6575}.S^{0.5525}$$

Where,

R= hydraulic mean depth=$\frac{A}{P}$

S= Friction slope=$\frac{H_f}{L}$

Where S is substituted by $\frac{H_f}{L}$, R=$\frac{D}{4}$ and V=$\frac{Q}{\frac{\pi}{4}D^2}$ for circular conduits the above equation gives:

H_f= friction head loss=$\frac{L.(\frac{Q}{C_R})^{1.81}}{994.62D^{4.81}}$

D=internal diameter of pipe in m

Q= flow in pipes

d. Manning's Formula: head loss according to Manning's equation is given by:

$$H_f = \frac{n^2}{0.157}.\frac{LV^2}{D^{\frac{4}{3}}}$$

Where,

H_f=head loss (m),

L= length of pipe (m)

V= mean velocity of flow(m/s)

D=diameter of pipe (m)

n= manning's coefficient of roughness

The values of coefficient n for various types of pipes are given in table,

Table 2.2 Values of Manning's *n*

	Types of Pipe	n
1.	Brass and glass pipe	0.009 to 0.013
2.	Asbestos cement pipe	0.010 to 0.012
3.	Wrought iron, welded steel, wooden stave	0.010 to 0.014
4.	Concrete pipe, very smooth	0.011 to 0.012
5.	Concrete pipe with rough joints	0.016 to 0.017
6.	Vitrified sewer pipe	0.013 to 0.015
7.	Riveted steel pipe	0.013 to 0.017
8.	Corrugated iron pipe	0.020 to 0.022

2. **Local losses** :
In addition to the friction head loss(H_f) which is quite prominent in long pipe line, other losses take place, such as (i) entry loss($=0.5V^2/2g$), (ii) Velocity head loss($V^2/2g$) and (iii)head loss due to construction such as valve, pipe line transition, etc. These losses are also known as minor losses(H_m) and can be expressed as

$$H_m = K\frac{V^2}{2g}$$

Where V is in m/s and g is in m/sec^2
The value of K are given in table 2.3
The local losses are also some time known as minor losses (H_m), since they are small in comparison to head loss(H_f) due to friction. Thus total $H_L = H_f + H_m$ where $H_m = H_L$+entry loss +velocity head loss.

Table 2.3 Value of K for different Fittings

Type of fitting	Value of K
1. Sudden contractions	0.3*–0.5
2. Entrance (shape well rounded)	0.5
3. Elbow (*i*) 90°	0.5–1.0
(*ii*) 145°	0.4–0.75
(*iii*) 22°	0.25–0.50
4. Tee (*i*) 90°	1.5
(*ii*) straight run	0.3
(*iii*) coupling	0.3
5. Gate valve (open)	0.3**–0.4
6. With reducer and increaser	0.5
7. Globe	10.0
8. Angle	5.0
9. Swing check	2.5
10. Meter venturi	0.3
11. Orifice	1.0

*Varying with area ratios **Varying with radius ratios.

a. Pipes in Series:
When pipes of different cross-sections are connected end to end to form a pipeline, so that the fluid flows through each in turn, the pipes are said to be in series. The total loss of head for the entire pipeline would, obviously, be the sum of the friction and minor losses for each pipe together with the losses that might occur at their junctions. The discharge would be the same in all these pipes which have been connected in series.

b. Pipes in parallel:
When two or more pipes are connected so as to first divide the flow and subsequently bring it together as shown in Figure (a)the pipes are said to be in parallel.

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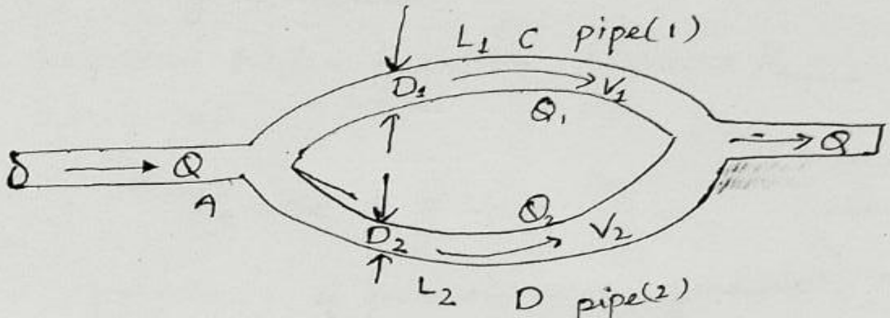
Laying the pipes in parallel may be necessary due to the following reasons:

i) To increase the capacity of the line
ii) To facilitate repairs without closing down the complete supply.
iii) To use smaller diameter pipe, by laying them in parallel if one single large diameter pipe is not available



⇒ head loss through each pipe will be the same.
⇒ Total discharge (Q) will be equal to the sum of the discharge in each pipe. Thus

$$Q = Q_1 + Q_2$$

⇒ The flow of water in pipe (1) & (2) take place under the difference of head between the section A & B

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WATER HAMMER PRESSURE

When the velocity of water in the pipe is abruptly stopped by closing of a valve, etc. the velocity of the water column behind is retarded and its momentum gets dissipated due to the conversion of kinetic energy into elastic energy.

The rise of pressure in some cases may be so large that the pipe may even burst.

The maximum Water Hammer Pressure $P_{h\,max}$ is given by the expression:

$$P_{h,\,max} = \frac{\omega}{g} U_p \cdot V_o \quad \text{—— (a)}$$

where U_p = velocity of pressure wave generated

$$P_{h,\,max} = \frac{V_s}{\sqrt{1 + \frac{k}{E_p} \cdot \frac{d}{t}}} \quad \text{—— (b)}$$

$$V_s = \sqrt{\frac{E_w}{\rho}} = \text{Velocity of sound wave in water} \quad \text{—— (c)}$$

$$= 1433 \ m/s$$

$$\rho = \frac{W}{g}$$

E_W = bulk modulus of water $(2.07 \times 10^8 \ kg/m^2)$
E_p = modulus of elasticity of pipe material (kg/m^2)
d = diameter of pipe (m)
t = Thickness of pipe (m)
V_o = ~~init~~ Normal velocity of flow in the pipe line (m/s) before sudden closure

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from equation a, b and c, we get

$$P_{h,max} = \frac{W}{g} \cdot \frac{V_s}{\sqrt{1 + \frac{K_w}{E_p} \cdot \frac{d}{1}}} \cdot V_o$$

$$P_{h,max} = \frac{1000}{9.81} \times \frac{1433}{\sqrt{1 + \frac{K_w}{E_p} \cdot \frac{d}{t}}} \cdot V_o$$

$$= 14.6 \times 10^4 \frac{V_o}{\sqrt{1 + \frac{K_w}{E_p} \cdot \frac{d}{t}}} \; kg/m^2$$

$$P_{h,max} = \frac{14.6\, V_o}{\sqrt{1 + \frac{K_w}{E_p} \cdot \frac{d}{t}}} \; kg/cm^2$$

The above expression has been divided, considering the elasticity of pipe. If However, elasticity of pipe is neglecting, then

$$P_{h,max} = \frac{1000}{9.81} \times 1433 V_o = 14.6 \times 10^4 V_o \; kg/m^2$$

If the actual time of Closure (T) is greater than the Critical time (T_c), the water hammer Pressure (P_h) is reduced approximately in the ~~por~~ proportion (T_c/T).

If L is distance of valve from the reservoir, the critical T_c is given by

$$T_c = \frac{2L}{U_p}$$

$$P_h = P_{p,max} \frac{T_c}{T}$$

Control Measures of water hammer pressure:

1. If the actual time of closure(T) is greater that the critical time T_c, the water hammer pressure(P_h) is reduced approximately in the proportion T_c/T.
2. Installing automatic valve with closing time of 20....30 second instead of regular check valve. Pump stop after valve has closed.
3. Stopping pumps slowly with frequency control
4. Preventing of simultaneous stopping of two or more pumps.
5. Installing automatic air relief valve at point where negative pressure occurs.

Rising Main of intake towers:

A vertical pipe that carries water directly from the mains to the elevated reservoir. There are two types of rising main:

1. **Wet Riser:** A wet riser is a pipe kept permanently charged with water, which is immediately available for use on any floor at which a hydrant outlet (landing valve) is provided.
2. **Dry Riser:** a dry riser is simply a vertical pipe which is normally kept empty of water, fitted with outlets at various floor levels in the building. It is not connected to a water supply, but is charged when required by means of fire service pumps. It enable an upper floor level to be attacked by the fire brigade with a line of standard hose without the loss of time. A dry riser is charged through inlets at ground level. An air valve is usually fitted at the highest point in the pipe to allow contained air to discharge to atmosphere when the riser is charged with water.

PIPES (PRESSURE PIPES):

Pipe is a circular closed conduit through which the water may flow either under gravity or under pressure. When pipes do not run full, they run under gravity, such as in sewer lines. However, in supply pipes mostly run under pressure. The following are the pipes that are generally used for the conveyance of water supply schemes:

i. Asbestos cement pipe:

- An asbestos cement pipe is primarily used to transport drinking water. It's also used to carry wastewater, fumes, and gases.
- These are manufactured from asbestos fibre and cement combined under pressure to form a dense homogeneous structure having strong bond between cement and the fibre.

ii. Cast iron pipe:

- Cast iron pipe is pipe made predominantly from gray cast iron.
- It was historically used as a pressure pipe for transmission of water Cast iron pipes are a type of piping material that is made from iron and carbon, with other elements added to improve their strength and durability.
- They were commonly used for plumbing and sewage systems in buildings before the advent of newer materials like PVC, PEX, and copper.
- Cast iron pipes come in various shapes and sizes, including straight pipes, elbows, tees, and reducers.
- They are known for their durability and resistance to corrosion, making them ideal for underground installations and harsh environments.
- However, they can be heavy and difficult to install, and they may also become brittle over time, leading to cracking and leaks.

- Due to their potential for environmental hazards like lead contamination, cast iron pipes are slowly being phased out in favour of safer and more efficient materials.

Benefits of Cast iron pipe:

- Durability: Cast iron pipes are known for their long-lasting durability, with a typical lifespan of 50-100 years or more.
- Corrosion resistance: Cast iron pipes are highly resistant to corrosion, making them ideal for use in underground installations and harsh environments.
- Soundproofing: Cast iron pipes have excellent soundproofing properties, reducing the transmission of noise through the plumbing system.
- Fire resistance: Cast iron pipes have a high melting point and are non-combustible, making them ideal for use in fire protection systems.
- Environmental sustainability: Cast iron pipes are recyclable and can be melted down and reused, reducing waste and conserving resources.
- Chemical resistance: Cast iron pipes are resistant to many chemicals and substances found in sewage and wastewater, making them ideal for use in sewage and wastewater treatment systems.
- Low maintenance: Cast iron pipes require little maintenance and have a low risk of leaks, reducing the need for costly repairs and replacements.
- However, it is important to note that cast iron pipes can also have some disadvantages, including their weight and difficulty in installation, and their potential for becoming brittle over time.

Disadvantages of cast iron pipes:

Cast iron pipes have some disadvantages, including:

- Heavy weight: Cast iron pipes are heavy and difficult to handle, which can make installation more labor-intensive and costly.
- Brittle over time: Cast iron pipes can become brittle over time due to aging and exposure to extreme temperatures, which can lead to cracking and leaks.
- Limited flexibility: Cast iron pipes are not flexible and cannot be bent, which can make them challenging to install in tight spaces or around obstacles.
- Environmental hazards: Cast iron pipes can pose environmental hazards if they contain lead or other toxic materials that can leach into the water supply.
- Cost: Cast iron pipes can be more expensive than other types of piping materials, which can make them less cost-effective for some applications.
- Corrosion: While cast iron pipes are generally resistant to corrosion, they can still corrode over time in certain environments, which can lead to leaks and other issues.

Overall, cast iron pipes can be a durable and reliable choice for certain applications, but they may not be the best choice for all situations. It is important to weigh the pros and cons of different piping materials and consider factors such as cost, durability, and environmental impact when selecting a pipe for a specific project.

(iii)Cement concrete pipe:

Cement concrete pipes are a type of piping material that are made from a mixture of cement, aggregates, and water, with steel reinforcement for added strength. They are commonly used in underground drainage and sewer systems, as well as for water supply and irrigation.

Cement concrete pipes come in various sizes and shapes, including circular and rectangular profiles, and they can be reinforced or non-reinforced. They are known for their durability and strength, with a typical lifespan of 50-100 years or more.

Some of the benefits of cement concrete pipes include:

- Durability: Cement concrete pipes are highly durable and can withstand heavy loads and harsh environments.
- Strength: The steel reinforcement in cement concrete pipes provides added strength, making them ideal for underground installations and high-pressure applications.
- Corrosion resistance: Cement concrete pipes are highly resistant to corrosion and can withstand exposure to a wide range of chemicals and substances.
- Low maintenance: Cement concrete pipes require minimal maintenance and have a low risk of leaks, reducing the need for costly repairs and replacements.
- Environmentally sustainable: Cement concrete pipes are made from natural materials and can be recycled or reused, reducing waste and conserving resources.

However, it is important to note that cement concrete pipes can also have some disadvantages, including their weight and difficulty in handling and installation, as well as their susceptibility to cracking if not properly reinforced or installed.

Cement concrete pipes have some disadvantages, including:

- Heavy weight: Cement concrete pipes are heavy and difficult to handle, which can make installation more labor-intensive and costly.
- Susceptible to cracking: Cement concrete pipes can be susceptible to cracking if not properly reinforced or installed, which can lead to leaks and other issues.
- Limited flexibility: Cement concrete pipes are not flexible and cannot be bent, which can make them challenging to install in tight spaces or around obstacles.
- Cost: Cement concrete pipes can be more expensive than other types of piping materials, which can make them less cost-effective for some applications.
- Environmental impact: The manufacturing process for cement concrete pipes can be resource-intensive and can generate greenhouse gas emissions.
- Installation challenges: Installing cement concrete pipes can be challenging due to their weight and size, requiring specialized equipment and expertise.

Overall, cement concrete pipes can be a durable and reliable choice for certain applications, but they may not be the best choice for all situations. It is important to consider factors such as cost, durability, and environmental impact when selecting a pipe for a specific project.

(iv) Galvanised Pipes:

Galvanized pipes are steel pipes that have been coated with a layer of zinc to protect them from corrosion. The zinc coating helps to extend the lifespan of the pipes and makes them more resistant to rust and other forms of corrosion.

Some benefits of galvanized pipes include:

- Corrosion resistance: Galvanized pipes are highly resistant to corrosion and can withstand exposure to a wide range of chemicals and substances.
- Durability: The zinc coating on galvanized pipes provides added durability and can help to extend the lifespan of the pipes.
- Low maintenance: Galvanized pipes require minimal maintenance and have a low risk of leaks, reducing the need for costly repairs and replacements.

- Cost-effective: Galvanized pipes can be a cost-effective option for piping, especially for outdoor applications or in environments with high humidity or moisture.
- Easy to install: Galvanized pipes are easy to install and can be cut and threaded on-site, making them a popular choice for plumbing and other applications.

However, it is important to note that galvanized pipes can also have some disadvantages, including their susceptibility to rust and corrosion over time, especially if the zinc coating is compromised. They can also be less suitable for high-pressure applications or for conveying hot water or other fluids, as the zinc coating can break down at high temperatures. Additionally, the zinc coating on galvanized pipes can sometimes affect the taste and odor of water, which may be a concern for some applications.

(v) **Steel pipes**:

Steel pipes are a type of piping material that are made from steel, which is an alloy of iron and carbon. Steel pipes are widely used in various applications, including water supply and drainage, oil and gas transportation, and construction.

Some benefits of steel pipes include:

- Strength: Steel pipes are strong and can withstand high pressure and heavy loads, making them suitable for use in demanding applications.
- Durability: Steel pipes are highly durable and can withstand exposure to a wide range of substances, including chemicals and extreme temperatures.
- Corrosion resistance: Some types of steel pipes, such as stainless steel pipes, are highly resistant to corrosion, which can extend their lifespan and reduce the need for maintenance.
- Cost-effective: Steel pipes can be a cost-effective option for piping, especially for large-scale projects or applications that require high-strength and durability.
- Recyclable: Steel pipes can be recycled and reused, making them a more sustainable choice compared to some other piping materials.

However, it is important to note that steel pipes can also have some disadvantages, including their weight and difficulty in handling and installation. They can also be susceptible to rust and corrosion if not properly coated or maintained, which can lead to leaks and other issues. Additionally, some types of steel pipes, such as carbon steel pipes, can be less suitable for use in certain applications due to their lower corrosion resistance.

(vi) Plastic pipes: are a type of piping material that are made from various types of plastic, including PVC, CPVC, PEX, and others. Plastic pipes have become increasingly popular in various applications due to their durability, ease of installation, and cost-effectiveness.

Some benefits of plastic pipes include:

- Lightweight: Plastic pipes are lightweight and easy to handle, which can make installation faster and more cost-effective.
- Corrosion resistance: Plastic pipes are highly resistant to corrosion and can withstand exposure to a wide range of chemicals and substances, making them suitable for use in various applications.
- Durability: Plastic pipes are highly durable and can withstand exposure to extreme temperatures and other harsh conditions.
- Cost-effective: Plastic pipes can be a cost-effective option for piping, especially for small-scale or residential applications.
- Easy to install: Plastic pipes are easy to install and can be cut and joined using simple tools, reducing the need for specialized equipment or expertise.

- Long lifespan: Some types of plastic pipes, such as PEX pipes, can have a lifespan of up to 50 years, reducing the need for costly repairs or replacements.

However, it is important to note that plastic pipes can also have some disadvantages, including their susceptibility to damage from UV light exposure, which can cause cracking and degradation over time. Some types of plastic pipes may also have limitations in terms of temperature and pressure, which can make them less suitable for certain applications. Additionally, plastic pipes can be more prone to expansion and contraction than other types of piping materials, which can lead to leaks or other issues if not properly installed or maintained.

(vii) **Wrought iron pipes:**

- Wrought iron pipes are a type of piping material that were widely used in the past, but have largely been replaced by other materials such as steel and plastic. Wrought iron pipes are made from a type of iron that is low in carbon content and has a fibrous structure.
- Some benefits of wrought iron pipes include:
- Durability: Wrought iron pipes are highly durable and can withstand exposure to extreme temperatures and other harsh conditions.
- Corrosion resistance: Wrought iron pipes are highly resistant to corrosion and can withstand exposure to a wide range of chemicals and substances.
- Strength: Wrought iron pipes are strong and can withstand high pressure and heavy loads, making them suitable for use in demanding applications.
- Aesthetic appeal: Wrought iron pipes have a unique, decorative appearance that can be an appealing feature in certain applications.

However, wrought iron pipes also have some disadvantages, including their weight and difficulty in handling and installation. They can also be susceptible to rust and corrosion if not properly coated or maintained, which can lead to leaks and other issues. Additionally, wrought iron pipes can be more expensive than other types of piping materials, which can make them less cost-effective for some applications. Finally, due to its brittle nature and difficulty in casting large sections, wrought iron pipes have limited availability in large sizes, which can limit their use in certain applications.