Wastewater Collection System

Content

- Estimation of wastewater;
- Wastewater collection systems;
- Hydraulics of sewer;
- Design, construction and maintenance of (i) sanitary sewer and (ii) storm drainage system;
- Sewer appurtenances;

Important Terms

- ***Sanitary sewage*** is the liquid waste which originates in the sanitary conveniences, e.g., water closets (wc), urinals, baths, sinks etc. of dwellings, commercial or industrial facilities, and institutions. This is sometimes also referred to as **black water**.
- ***Industrial wastewater*** includes the liquid discharges from spent water in different industrial processes such as manufacturing and food processing.
- ***Sullage*** is the liquid discharge from kitchens, wash basins etc. and excludes discharge from WCs and urinals. Sullage, also known as **grey water**, is less foul than sanitary sewage and can be discharged through open surface drains in unsewered areas.
- ***Infiltration*** is the water which enters the sewers from the ground through leaks or faulty joints.

Important Terms

- ***Storm water*** is the surface runoff obtained during and immediately after the rainfall, which enters sewers through inlets. Storm water is not as foul as sanitary or industrial sewage and hence can be carried through open drains or channels and disposed of in natural rivers or streams without any treatment.
- ***Sewer*** is a pipe or conduit, generally closed but normally not flowing full, which carries sewage.
- ***Sanitary sewer*** carries sanitary sewage and is designed to exclude storm sewage, infiltration, and surface inflow. Industrial waste may be carried in sanitary sewers, depending upon its characteristics.
- ***Storm sewer*** carries storm sewage and any other waste which may be discharged into the streets or onto the surface of the ground.

- Sewage: It is the Liquid Waste or Wastewater produced as a result of water use.
- Sewer: It is a pipe or conduit for carrying sewage. It is generally closed and flow takes place under gravity .





- Sewerage: Sewerage is the system of wastewater collection and conveying it to the point of disposal with or without treatment.

Conventional Sewerage System

Basic Functional Elements

- the house connections for **collection** of household or institutional wastewater,
- a network of sewer systems for collection and **conveying** the wastewater,
- a **treatment** plant for processing the wastewater,
- the receiving environment (water or land) for **disposal** of the treated wastewater.

Types of Collection Systems

There are three different sewage collection systems:

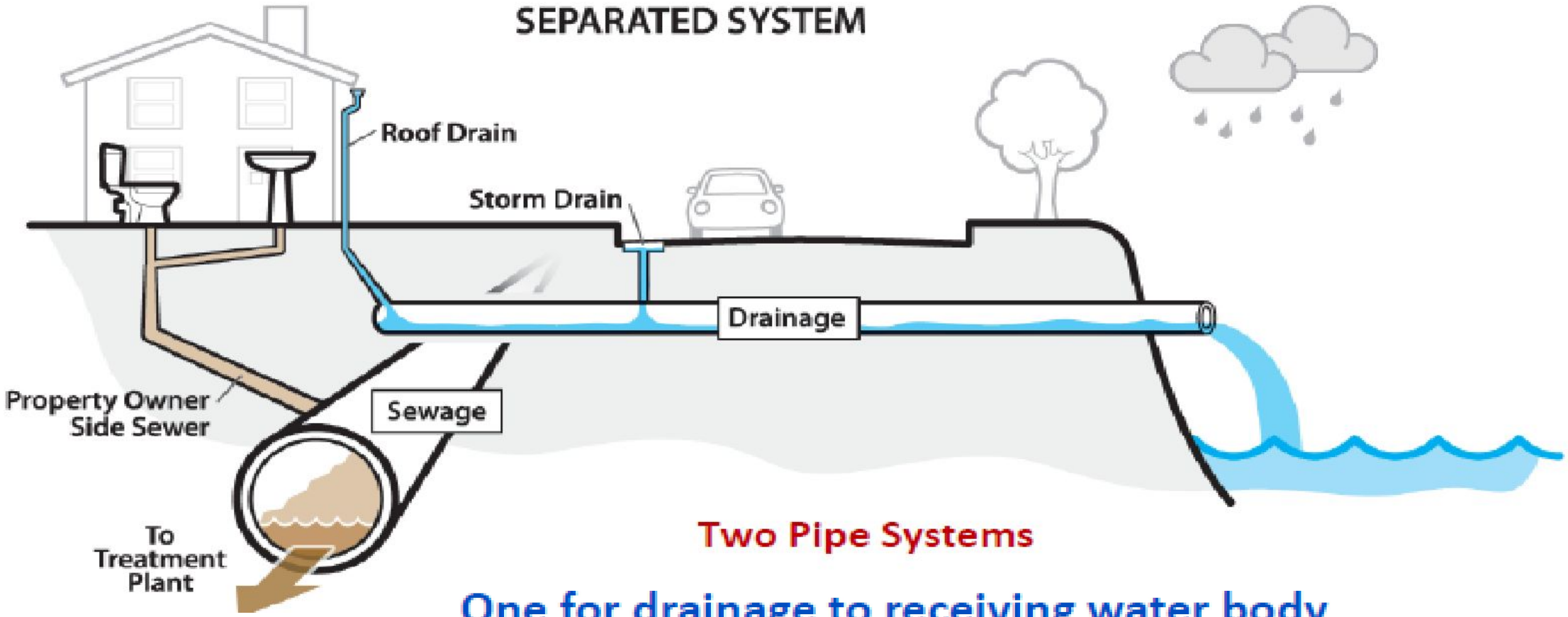
1. Separate Sewerage System: In this system sanitary sewage and storm waste are collected and conveyed separately through two different systems

Advantages

- Sewers are of smaller sizes;
- Only sanitary sewage is treated;
- Storm water can be discharged without treatment;
- Sewage lifting is less costly because of less volume.

Disadvantages

- Two sets of sewers may prove costly;
- Smaller sewers may be difficult to clean.



Two Pipe Systems

One for drainage to receiving water body

One for sewage to Treatment Plant

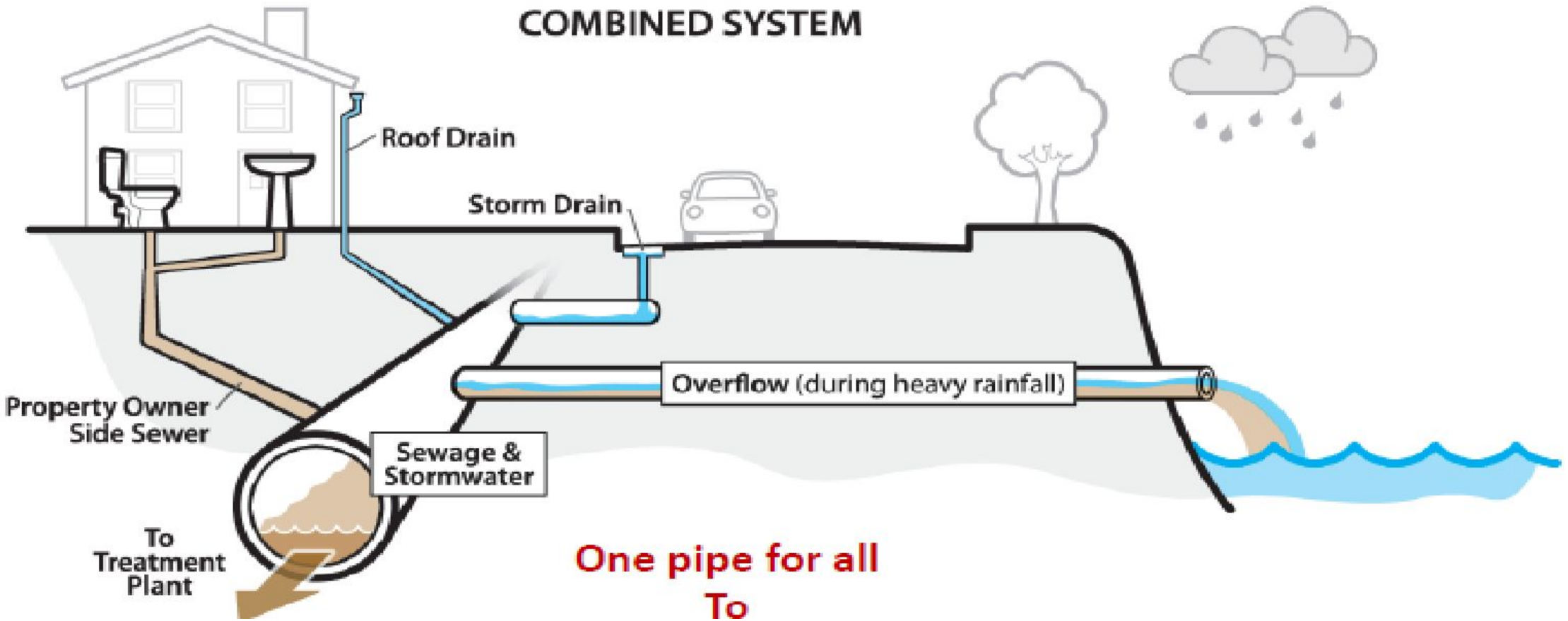
2. Combined Sewerage System: In this system both sanitary sewage and storm water are collected and carried together through a single set of sewers.

Advantages

- Only one set of sewers might prove economical;
- Larger sewers are easy to clean;
- Strength of sewage diluted with storm water.

Disadvantages

- Increased load on treatment plant;
- Larger volume requires to be lifted;
- Heavy rains may cause overflow and thus create a nuisance;
- Storm water is polluted unnecessarily;
- More difficult to properly treat the wastewater to high quality standards;
- Flow during the dry period may cause difficulties in maintaining minimum flow.



One pipe for all

To

Treatment Plant

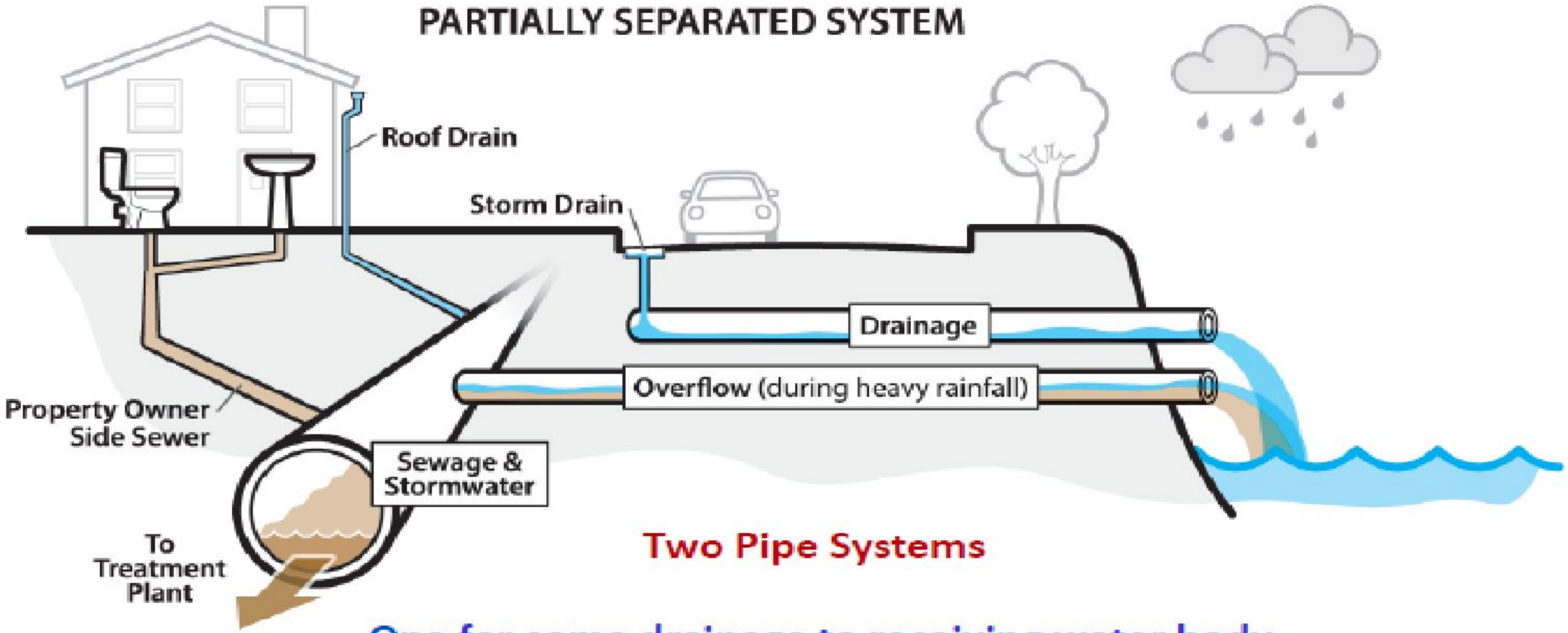
3. Partially Combined or Partially Separate System: In this system only one set of sewers is laid to carry sanitary sewage as well as storm water during low rainfall. During heavy rainfall excess storm water is carried separately e.g., through open drains to natural channels.

Advantages

- Sizes of sewers is not very large;
- Advantages of both separate and combined systems;
- Minimal solids deposition problem;
- Problems of storm water discharges from homes are simplified.
- Where pumping is required at short intervals.

Disadvantages

- Velocity of flow may be low during the dry period;
- Increased load on pumps & treatment unit.



Two Pipe Systems

One for <u>some</u> drainage to receiving water body

One for sewage/stormwater to Treatment Plant

Suitable Conditions for Separate System

- In flat areas a separate system is economical as deep excavations are not required.
- When sufficient funds are not available for two sets of sewer systems, only a sanitary sewerage system may be installed.
- Where rainfall is not uniform throughout the year a separate system is suitable.
- In areas near rivers or streams, only a sanitary system may be installed; storm water may be disposed of into rivers untreated, through open drains.
- Where pumping is required at short intervals.

Suitable Conditions for Separate System

- In rocky areas where large combined systems may be difficult to install.
- If sewers are to be laid before actual development of the area, a separate system is desirable.

Suitable Conditions for Combined System

- Where rainfall is uniform throughout the year, a combined system is economical.
- Where pumping is required for both sanitary sewage and storm water.
- Where sufficient space is not available for two separate sets of sewer systems.

What is the difference between Separate and Combined Sewerage system?

Which sewerage system is suitable for Dhaka City and explain why?

Types of Sewers

Sewerage is converging network of sewers (building connections, lateral sewers, main sewers, trunk sewers and intercepting sewers)

- Building sewers/building connections – begins beyond a building foundation conveying sewage from the building to (lateral) sewer
- Lateral/branch sewer – first element of the sewerage system – receives sewage from buildings and conveys to main sewers
- Main sewer – receives sewage from lateral sewers and conveys to trunk sewers or intercepting sewers
- Trunk sewers – large sewers conveying sewage from main sewers to STP or disposal facilities or to large intercepting sewers
- Intercepting sewers – large sewers used to intercept a number of main or trunk sewers and convey sewage to STP/disposal facilities
- **Outfall Sewer: There are the lengths of main or trunk or interceptor sewers which lie between connections and the final point of disposal or treatment plant.**

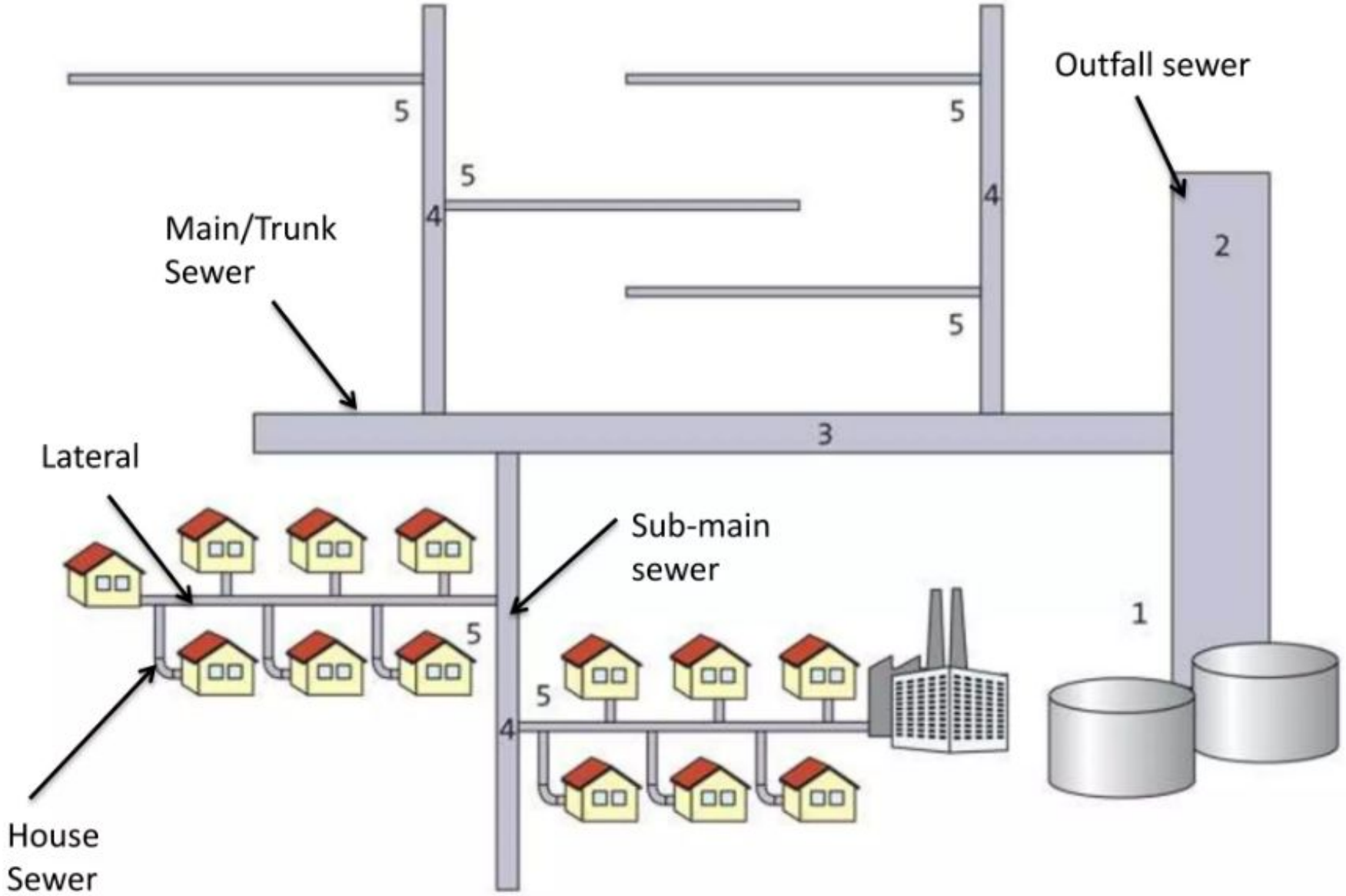
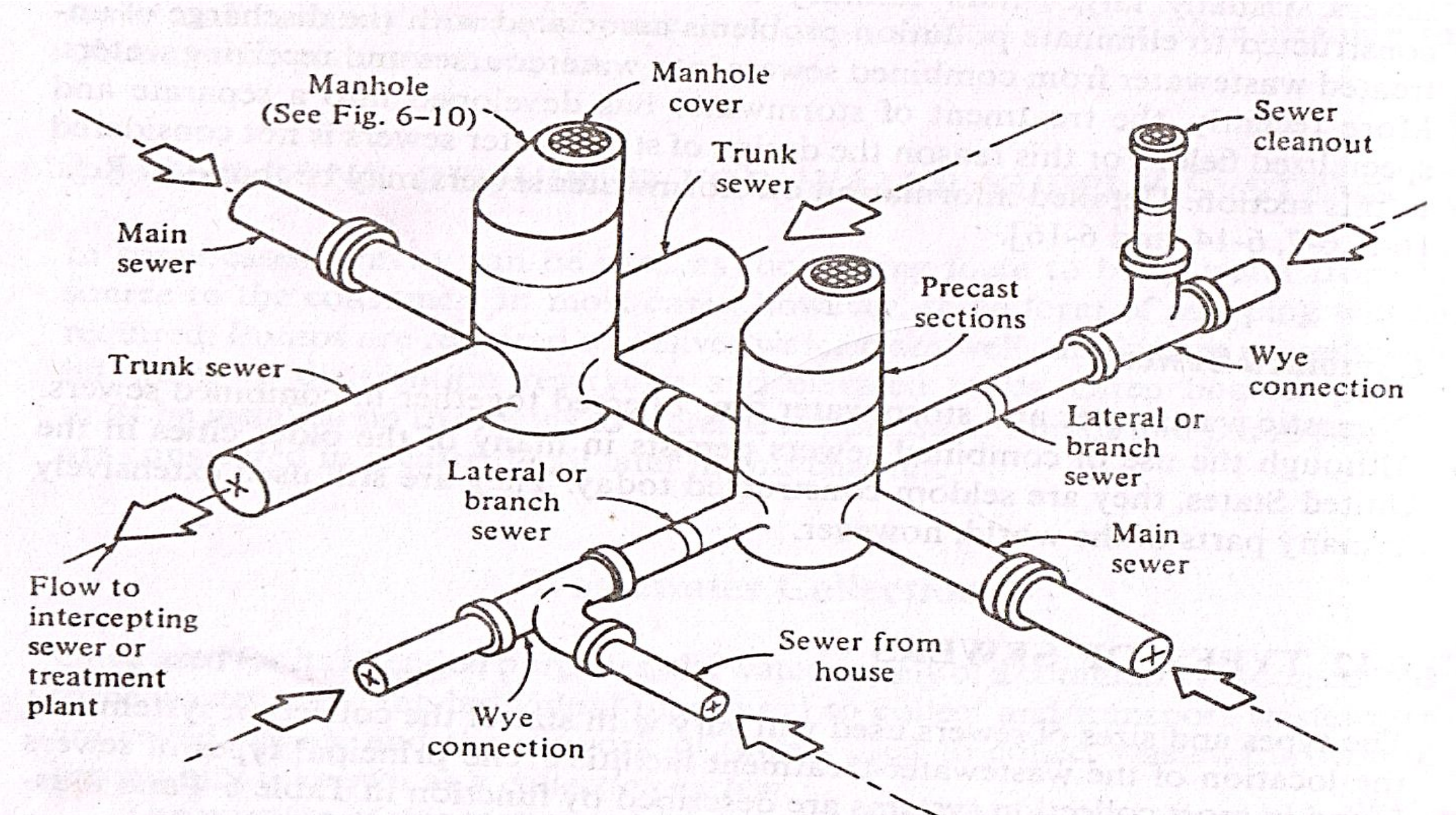


Fig: Types of Sewers



Definition sketch of different types of sewers (peavy et al. 1986)

Design of Sanitary Sewer System

The important objectives of the design of a sanitary sewer system are:

- to ensure ease of operation;
- to minimize maintenance requirements.

Two major factors

- Quantity/Estimation of wastewater flow
- Flow hydraulics

Quantity Estimation of Sewage

Very high discharge estimated will lead to larger sewer size affecting economy of the sewerage scheme

Lower discharge actually flowing in the sewer may not meet the criteria of the self cleansing velocity and hence leading to deposition in the sewers.

Since sewers are design to serve for some more future years, engineering skills have to be used to accurately estimate the sewage discharge.

Estimation/Quantity of Sanitary Sewage

The sewers are designed to carry:

- Spent water from a community
- Some groundwater as infiltration
- Fraction of the storm water
- Industrial wastewater for small establishments

- The sanitary sewers are designed to carry the wastewater from the above sources to a sewage/wastewater treatment plants
- Carrying capacity of the sewers depends on: 1. Present and 2. Future quantities of flow rate expected.
- Important to estimate the design flow rate for the sewers to be constructed.

Estimation of Sewage Flow rate

Two Parameters:

1. The contributing population, and
2. Per capita (per person) flowrate of sewage

Both of these quantities depend on the design period

- Design period: The length of the time up to which the capacity of a sewer will be adequate is called a design period.
- Normally design period for a sewerage system is considered as **30 years**
- But, mechanical rotating equipment such as pumps are designed for **15 years**

Estimation of Waste Water Flows

Population Estimates: often made using the following simple equation $\mathbf{P = P_0 [1 + r]^n}$

Relation to water use: estimate would be

- too high for a residential community with hot, dry summers
- too low for a community containing industries, or commercial institutions with private water supplies.

Also affected by factors affecting water use:

- characteristics (economic level) of the population
- metering of water supply;
- other factors (e.g., climate, quality, pressure, and conservation programs).

Per Capita Sewage Flow rate

- Ideally the entire amount of water used by a community should appear as the total flow in a sanitary sewer
- Water is lost due to:
  - Evaporation Loss
  - Seepage into ground
  - Leakages
- The dry weather flowrate is slightly less than the per capita water consumption
- For very dry and arid regions,
  - Average sewage flowrate ≥ 40% of the consumption rate
- In well-paved and well-developed areas,
  - Average sewage flowrate ≈ 90% of the consumption rate
- Conservative estimate is 80% of water consumption rate

Design Flows

The unit quantities of wastewater for which the sewer sizes have to be designed are called the **design flows**.

Wastewater flow is not uniform throughout the day and throughout the year.

- It varies during the day due to the varying use of water for domestic, commercial and industrial purposes.
- Variations throughout the year are due to seasonal variation of rainfall and rainfall intensity.

Due to such variations in wastewater flow, some terms are used:

ADWF (Average dry weather flow)**:**

- Is the average of the daily dry weather flow to the sewer system
- Not affected by storm infiltration
- Reflects the wastewater discharges from domestic, industrial and commercial fixtures.

PDWF (Peak dry weather flow):

- The wastewater flow during the day is not uniform.
- During normal daily flows, two distinct peaks usually occur - the morning peak and the evening peak.
- The ratio of peak to average dry weather flow is termed as the “peak factor” and is a variable and depends greatly on population size and density.
- Generally, the ratio will fall as the number of contributor increases.

PWWF (Peak Wet weather flow):

- Is the maximum flow to be considered in designing the capacity of sewers
- Is the sum of the maximum peak dry weather flow plus the storm contribution during wet weather period.

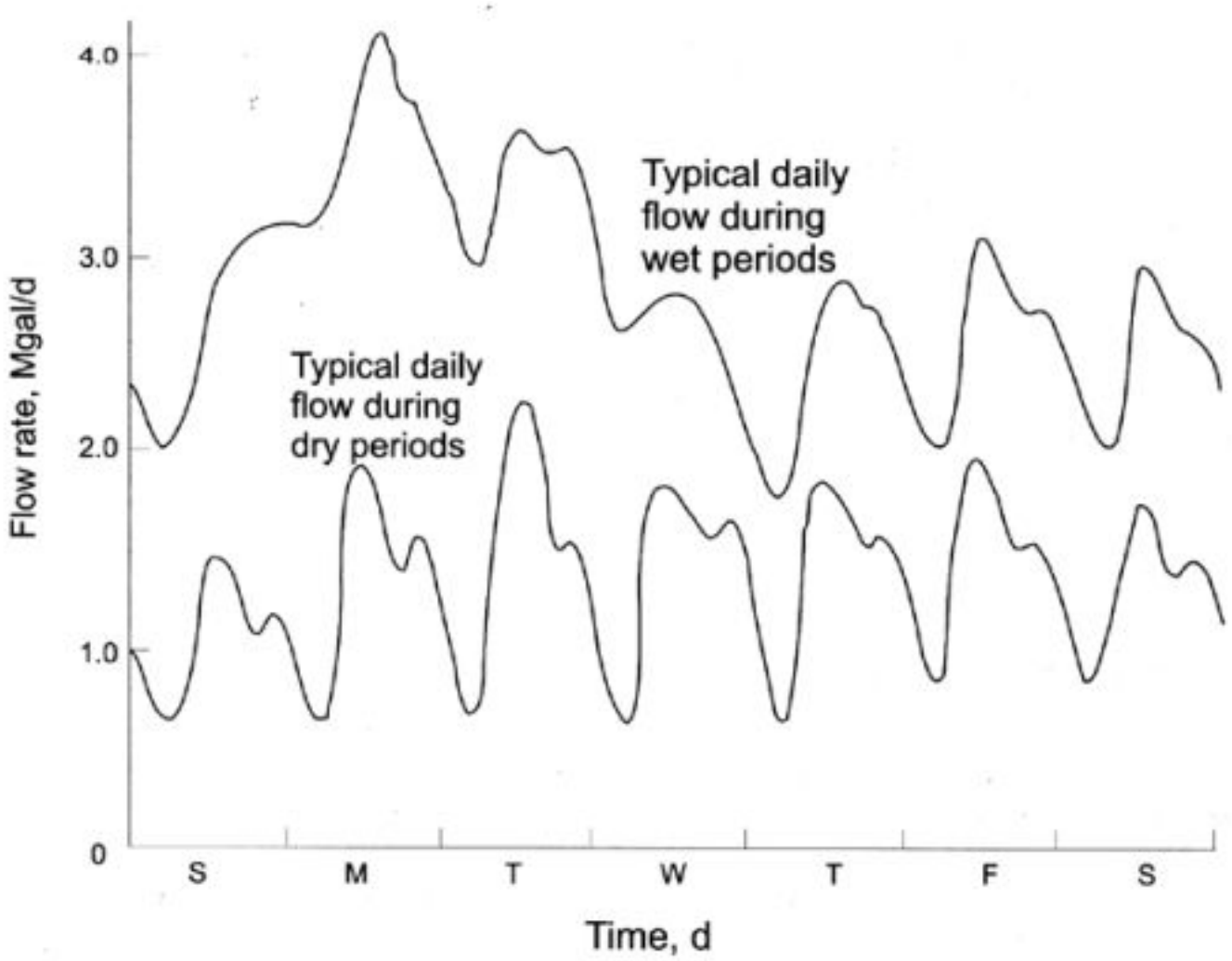
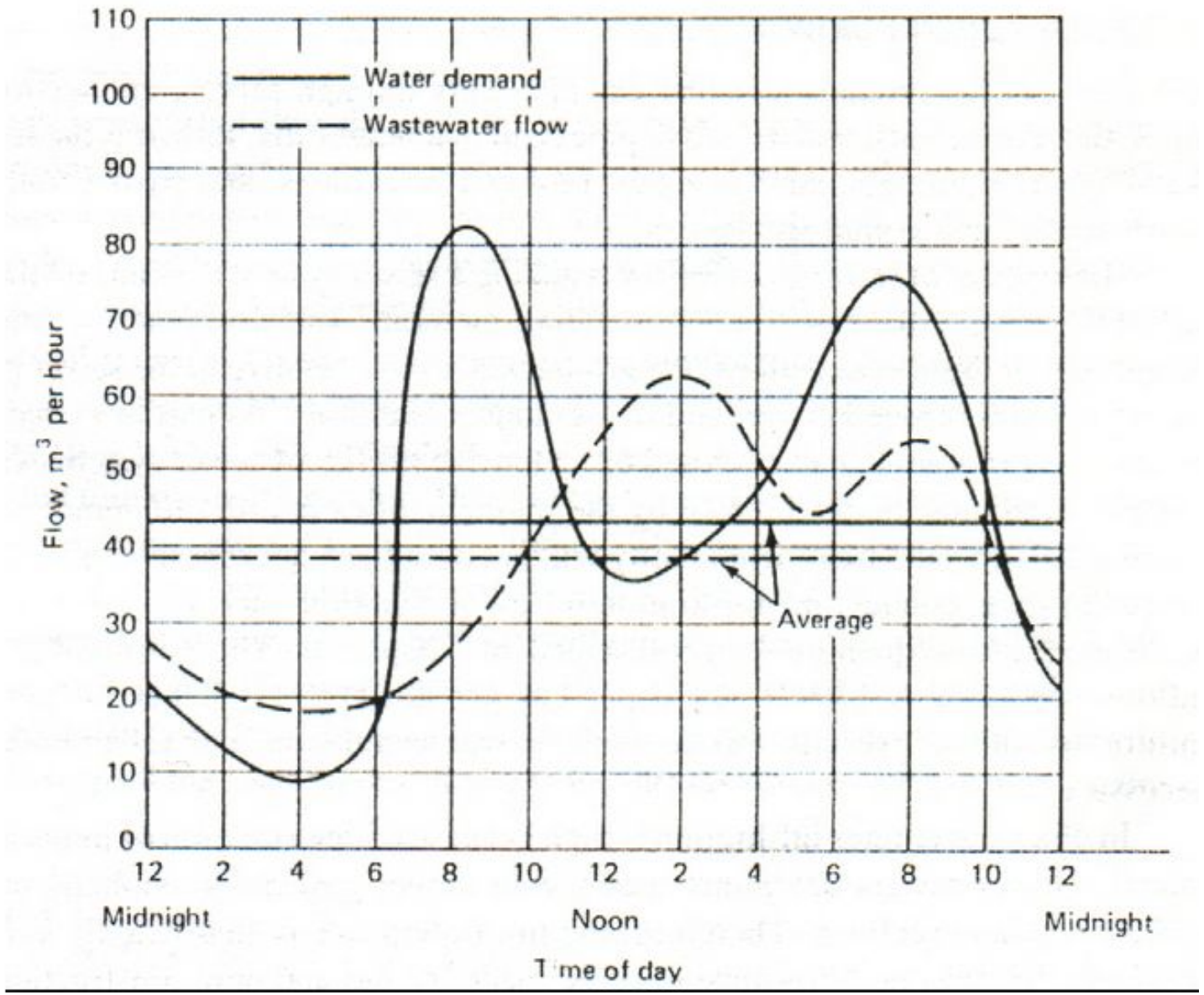


Figure 4.2: Typical dry and wet weather hydrographs

Variation in Sewage Flow



Design Flows

- For design purpose, sewers are always designed to carry maximum or peak flow rates, rather than designing it for average flowrate.

$$\text{Peak Factor (PF)} = \frac{\text{Maximum wastewater flow rate}}{\text{Average flow rate of wastewater}}$$

Population	Peak factor
< 20,000	3.0
20,000 – 50,000	2.5
50,000 – 7,50,000	2.25
> 7,50,000	2.0

Groundwater infiltration

The presence of a high groundwater table results in seepage into the sewers through the joints and in an increase in the quantity of wastewater.

The rate and quantity of infiltration depends on a number of factors:

- Depth at which sewer is laid
- Materials of the sewers
- Length of sewer below groundwater table
- Nature and types of soils
- Types of joints
- Workmanship

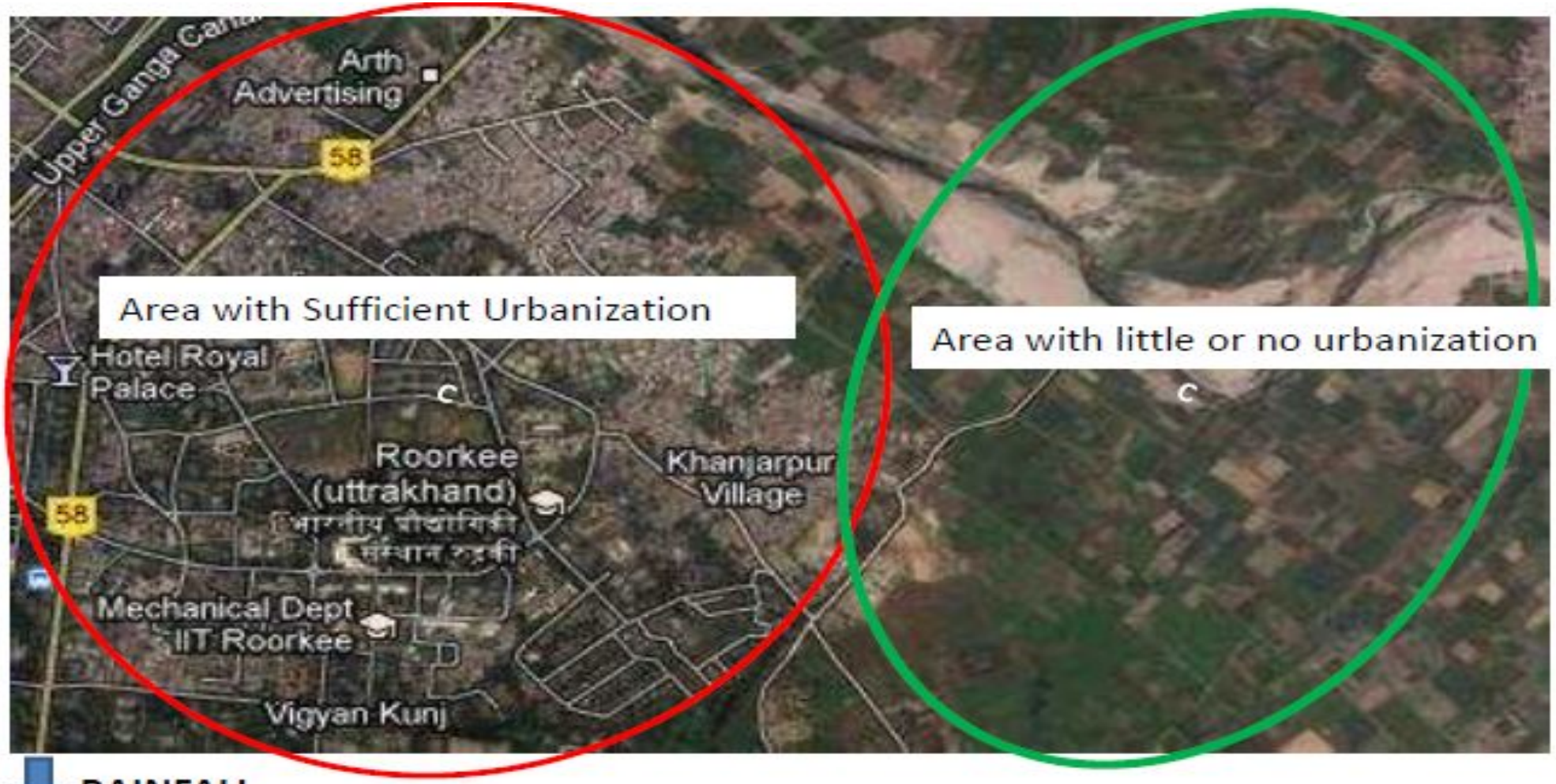
Groundwater infiltration

Usually, for a sanitary sewer below the groundwater table the following values are taken,

	Minimum	Maximum
Liters/ha.d	5000	50000
Liters per day/ manhole	250	500

PEAK FLOW RATE or MAXIMUM FLOW RATE

Maximum sanitary flow rate = Average domestic flow rate X PF + infiltration flow rate



RAINFALL

More paved surface, higher imperviousness, less absorption by soil

High volume of water on the surface, High runoff, needs quick evacuation to avoid flooding/ inundation

How to evacuate this increased runoff?

BUILD EFFICIENT STORM SEWER SYSTEM

Quantity of Storm Water

The quantity of storm water that goes to the system depends upon:

(a) **Area to be drained off (catchment area):** larger the catchment area larger the storm water

(b) **Topography and Nature of the surface:** Steep slope produce larger amount of storm water

(c) **Intensity of the rainfall**: If intensity is high, less time duration of rainfall, small evaporation, thus more storm water

(d) **Extent of rainfall**: greater rainfall greater storm water

(e) **Antecedent condition**: If soils are already wet, then more storm water

(f) **Obstructions**: Obstruction in areas and depressions decrease the quantity of storm water to be drained out.

Methods for Estimation of Quantity of Storm Water

1. Rational Method

2. Empirical formulae method

In both the above methods, the quantity of storm water is considered as function of intensity of rainfall, coefficient of runoff and area of catchment.

Time of Concentration: The period after which the entire catchment area will start contributing to the runoff is called as the time of concentration.

The rainfall with duration lesser than the time of concentration will not produce maximum discharge.

Methods for Estimation of Quantity of Storm Water

The runoff may not be maximum even when the duration of the rain is more than the time of concentration. This is because in such cases the intensity of rain reduces with the increase in its duration.

The runoff will be maximum when the duration of rainfall is equal to the time of concentration and is called as *critical rainfall duration*.

The time of concentration is equal to sum of inlet time and time of travel.

Time of concentration = Inlet time + time of travel

Methods for Estimation of Quantity of Storm Water

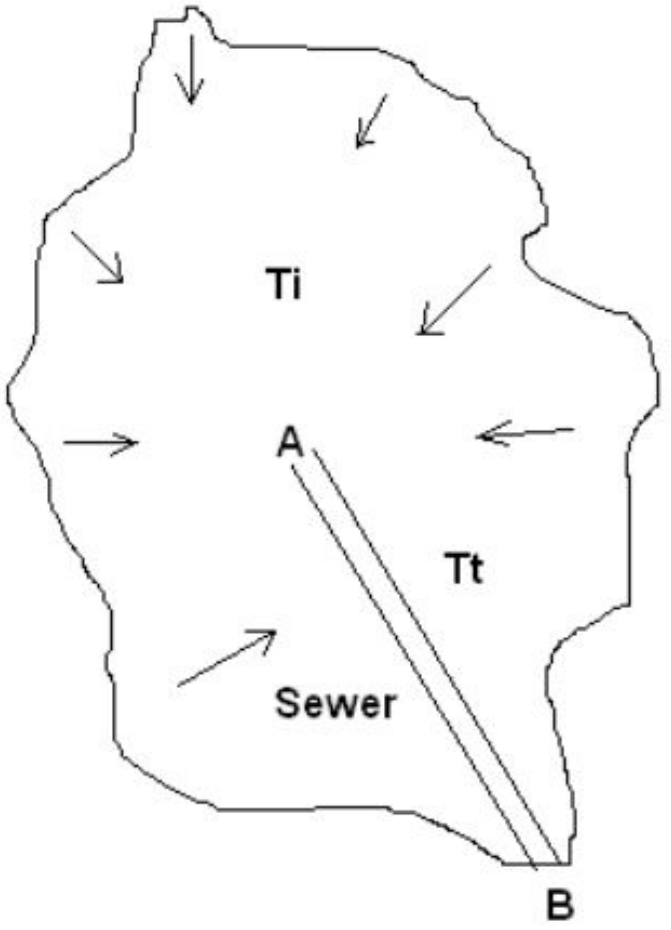


Figure 6.1 Runoff from a given catchment

Methods for Estimation of Quantity of Storm Water

Inlet Time: The time required for the rain in falling on the most remote point of the tributary area to flow across the ground surface along the natural drains or gutters up to inlet of sewer is called inlet time.

The inlet time 'Ti' can be estimated using relationships similar to following.

These coefficients will have different values for different catchments.

$$Ti = [0.885\ L^3/H]^{0.385}$$

Methods for Estimation of Quantity of Storm Water

Where, Ti = Time of inlet, minute

L = Length of overland flow in Km from critical point to mouth of drain

H = Total fall of level from the critical point to mouth of drain, m

Time of Travel: The time required by the water to flow in the drain channel from the mouth to the point under consideration or the point of concentration is called as time of travel.

Time of Travel (Tt) = Length of drain/ velocity in drain

Time of concentration Tc = Ti + Tt

Rainfall Intensity

- Amount of rainfall in a specific time expressed as mm/hour, cm/hour etc.
- The intensity of a rainfall is the rate at which it is falling
- The duration is the time for which it is falling with that given intensity
- Frequency is the number of times it occurs
- The intensity of rainfall over short periods has been observed to be greater than the average for the whole day.

- $I\ (cm/hr) = 76.2 / (t + 10)$ for $t = 5 – 20$ minutes

  $= 101.6 / (t + 20)$ for $t = 20 – 100$ minutes

Time of Concentration

The maximum time taken by water to travel from the extreme catchment boundary to the catchment outlet is known as time of concentration.

Bransby-Williams formula:

$$t_c = \frac{FL}{A^{0.1} S^{0.2}}$$

Where, t_c = time of concentration in minutes

F = Factor of proportionality
= 58.5 when A in km^2 = 92.7 when A in 'ha'

L = Mainstream length

A = Catchment area

S = Mainstream slope (m/km)

RUN-OFF ESTIMATE

Rational formula

Peak discharge, $Q = FCIA$

Where, Q = peak discharge in l/s

F = Factor of proportionality = 27.8 (when A in ha and I in cm/hr)
C = run-off coefficient (is a function of area type, soil)
I = Rainfall intensity, cm/hr
A = Catchment area, ha

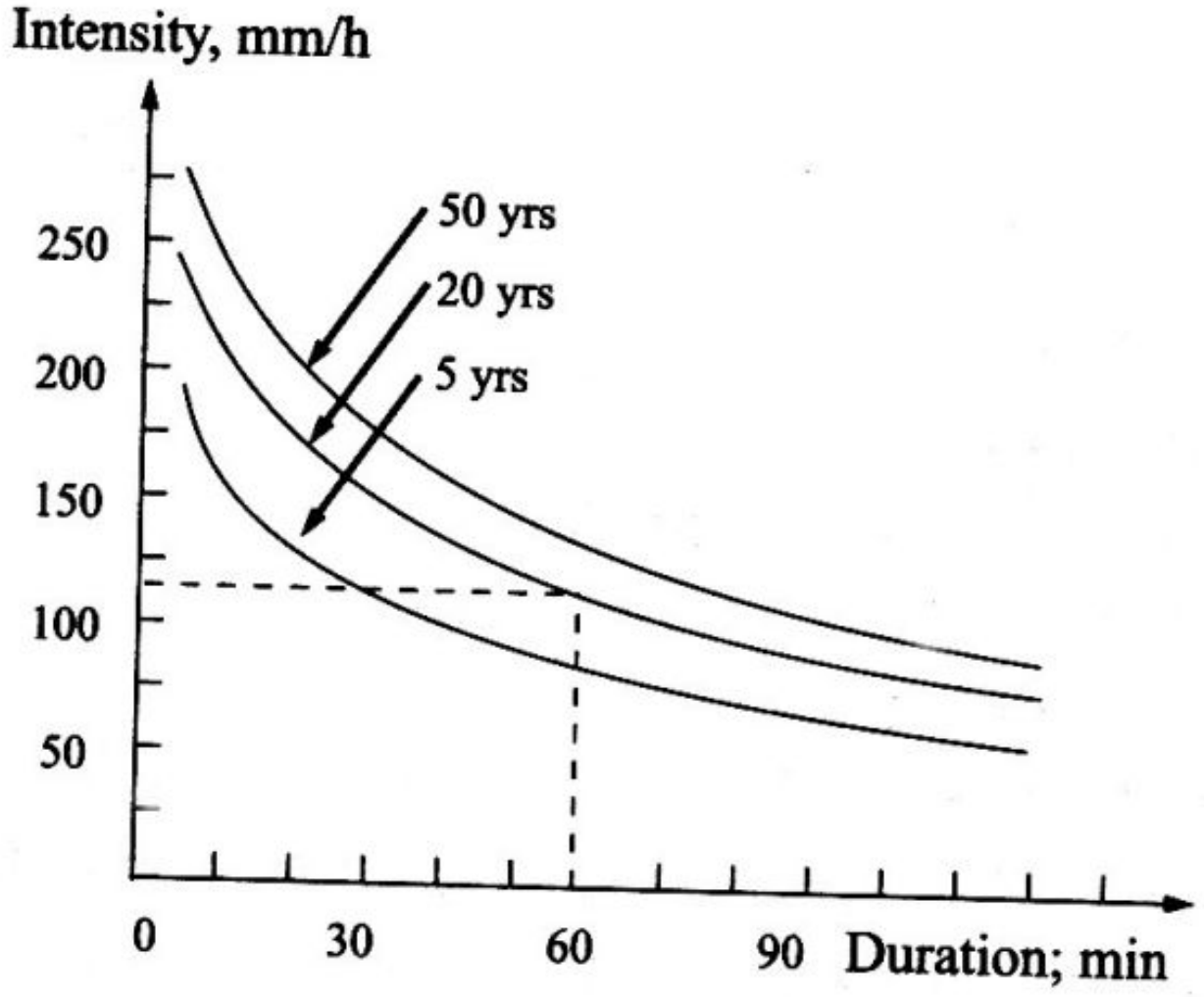


Fig: Rainfall Intensity-Duration-Frequency Curves

SURFACE DRAINS

An ideal drain section should meet the following requirement:

1. It should develop self-cleansing velocity

2. It should not develop high velocity to scour the sides

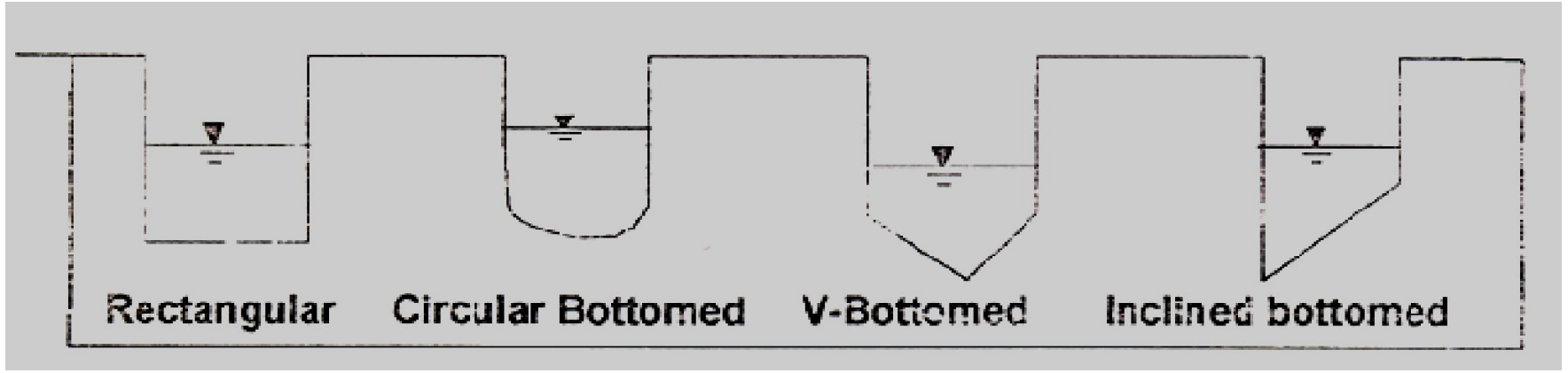
3. It should possess structural stability

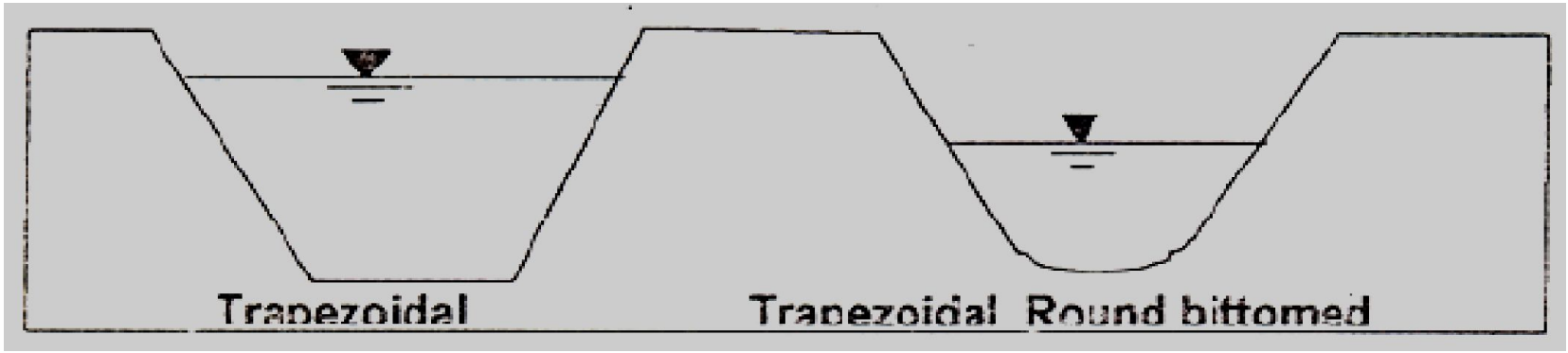
4. It should be of inexpensive construction and easy and cheap to maintain

5. It should prevent weathering action and wearing action

6. It should have smooth interior surface

7. It should be capable of being cleaned easily


Rectangular
Circular Bottomed
V-Bottomed
Inclined bottomed


Trapezoidal
Trapezoidal Round bittomed


V- Shaped
Semi-Circular

Estimation of Design Flow

Based on the rational approach, the design flow consists of the sum of the PDWF plus wet weather additive and may be expressed as **$Q = \Sigma D.\ d + \Sigma I.\ i$**

ΣD = sum of all dry weather flow components; d = peak dry weather factor; ΣI = basic wet weather additive; i = appropriate infiltration factor

- **$\Sigma D = P.\ q_r + A_c.\ q_c + A_i.\ q_i$**

P = population; q_r = residential discharge rate (say, 100 – 400 lpcd); A_c = commercial area; q_c = commercial discharge rate (say, 0.25 - .5 l/sec/ha for sub-urban business areas, but may be up to 8.0 l/sec/ha in high-rise business area); A_i = industrial area; q_i = industrial discharge rate (depends on industry type, e.g., 0.25 – 0.35 l/sec/ha)

Estimation of Design Flow

- $\Sigma I = A_r . K + A_c . K/4 + A_i . K/4$

A_r = residential area; A_c = commercial area; A_i = industrial area; K = ground constant (higher values for clayey soils and lower values for sandy soils).

- d = vary from 3.0 for small areas and 0.7 for large areas

- i = varies from 1.0 for small area to 0.5 for large areas in a manner similar to decrease of rainfall intensity with increasing area

Sewers are usually designed to have a capacity ≥ Q

Self-cleansing velocity

- The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity.
- Minimum velocity should at least develop once in a day so as not to allow any deposition in the sewers.
- If such deposition takes place, it will obstruct free flow causing further deposition and finally leading to the complete blocking of the sewers.
- For removing the impurities present in sewage i.e., sand up to 1 mm diameter with specific gravity 2.65 and organic particles up to 5 mm diameter with specific gravity of 1.2, it is necessary that a minimum velocity of about 0.45 m/sec and an average velocity of about 0.9 m/sec should be developed in sewers.

Self-cleansing velocity

- While finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge.
- While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for ½ to ¾ full, the velocity at 'designed discharge' (i.e., ½ to ¾ full) will even be more than 0.8 m/sec.

  Thus, the minimum velocity generated in sewers will help in following ways:
  - Adequate transportation of suspended solids,
  - Keeping the sewer size under control; and
  - Preventing the sewage from decomposition by moving it faster, thereby preventing evolution of foul gases.

Maximum Velocity or Non-scouring Velocity

- The interior surface of the sewer pipe gets scoured due to the continuous abrasion caused by suspended solids present in sewage. The scouring is pronounced at higher velocity than what can be tolerated by the pipe materials.
- This wear and tear of the sewer pipes will reduce the life span of the pipe and their carrying capacity.
- In order to avoid this, it is necessary to limit the maximum velocity that will be produced in sewer pipe at any time. This limiting or non- scouring velocity mainly depends upon the material of sewer.

Maximum Velocity or Non-scouring Velocity

Sewer Material	Limiting velocity (m/sec)
Vitrified Clay	5.5
Cast iron	4.5
Cement concrete	3.0
Stone ware	4.5
Brick lined	2.5

- The problem of maximum or non-scouring is severe in hilly areas where ground slope is very steep and this is overcome by constructing drop manholes at suitable places along the length of the sewer.

Sewer gradients are affected by:

- Slope of the ground: The gradient should as far as possible follow the slope of the ground along the same direction to minimize excavation.
- Gradient should not be steeper than 1 in 20.
- For house connections 1 in 40 to 1 in 80
- Minimum gradient 1 in 100
- Minimum and Maximum velocities
- Diameter of the sewer and the quantity to be discharged

Hydraulic design of sewers

- ***Chezy's formula***
- ***Manning's formula***
- ***Hazen-William formula***

Manning's Formula: $V = 1.486/n\ R^{2/3}\ S^{1/2}$

Where,

V is velocity in fps, R=hydraulic radius in ft, S=hydraulic gradient, n=Manning's roughness co-efficient.

Choice of suitable n is the most important factor in design.

1)Vitrified clay, concrete, asbestos-cement and corrugated steel pipe with smooth asphaltic lining, a co-efficient ranging from 0.012 for clear water to 0.015 for strong sewage, 0.013 being a common design value for sanitary sewers.

2) Cast iron pipes, a co-efficient ranging from 0.015 to 0.035 is generally used.

Substituting Q=AV, where $A=0.785D^2$ and hydraulic radius R=D/4=0.25D for a circular sewer flowing full the required diameter is:

$$D=(2.16Qn/\sqrt{S})^{3/8}$$

the required slope is:

$$S=(Vn/1.486R^{2/3})^2$$

Sewers flowing partly full

Let. D = full depth (sewer diameter)

V = velocity of flow during full flow

A= cross sectional area

P = perimeter

Q = average discharge while flowing full

When sewer is flowing partly.

Let. d = flow depth (sewer diameter) v = velocity of flow during partial flow

a= cross sectional area of flow p = wetted perimeter

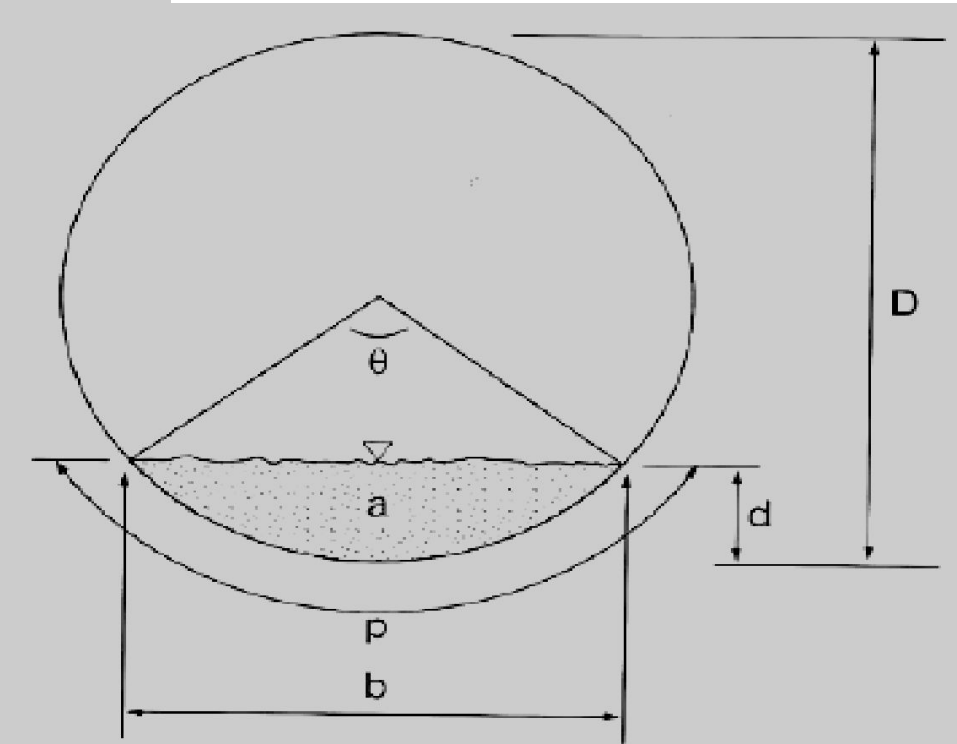
q = average discharge of partial flow

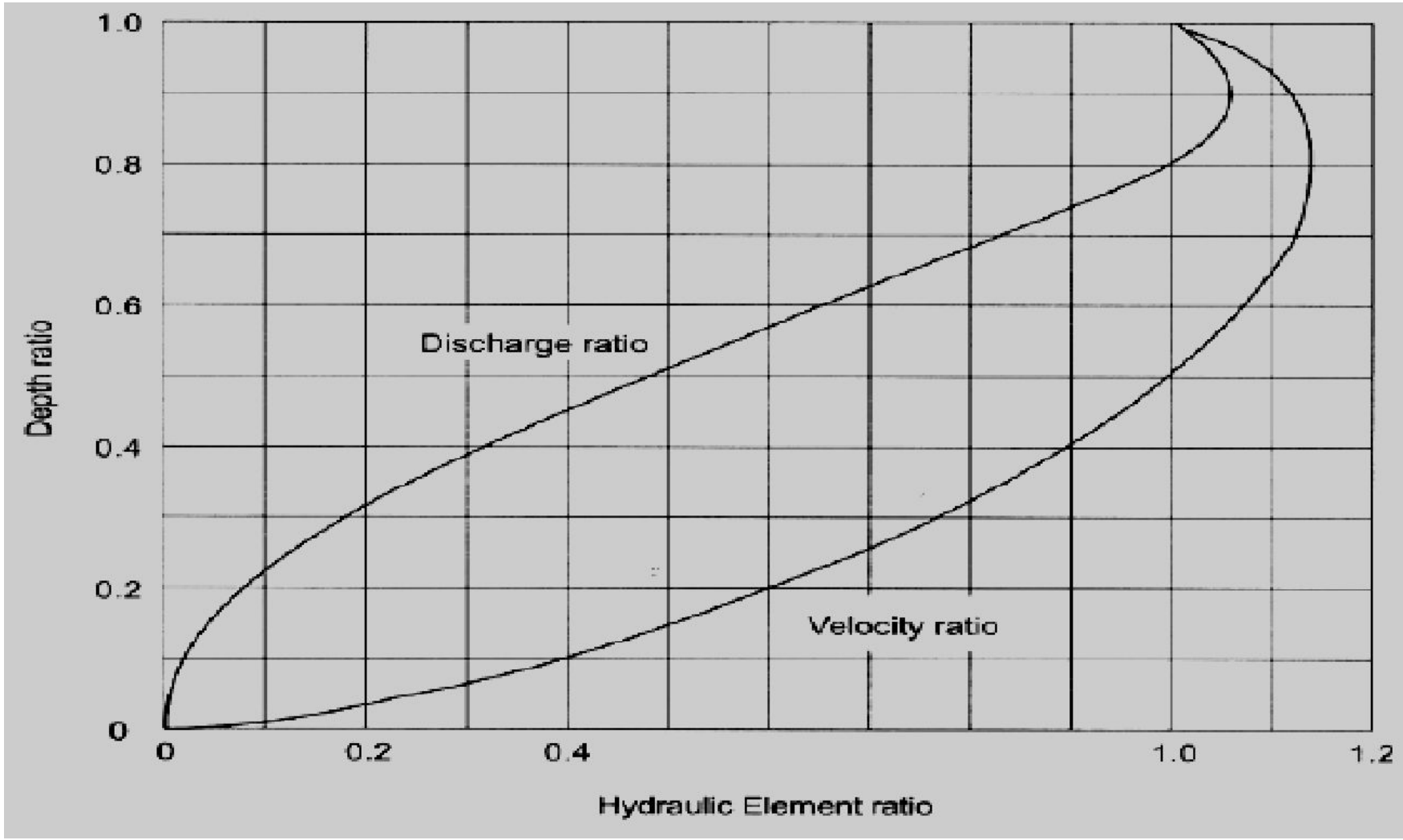
- $d/D = \frac{1}{2}(1 - \cos\frac{\theta}{2})$

$$\theta = 2\cos^{-1}\left(1 - \frac{2d}{D}\right)$$

- $a/A = (\theta/360 - \sin\theta/2\pi)$
- $p/P = \theta/360$
- $r/R = (1 - 360\sin\theta/2\pi\theta)$
- $v/V = (1 - 360\sin\theta/2\pi\theta)^{2/3}$
- $q/Q = (\theta/360 - \sin\theta/2\pi)(1 - 360\sin\theta/2\pi\theta)^{2/3}$

Only 'θ' is variable e.g. depth of flow





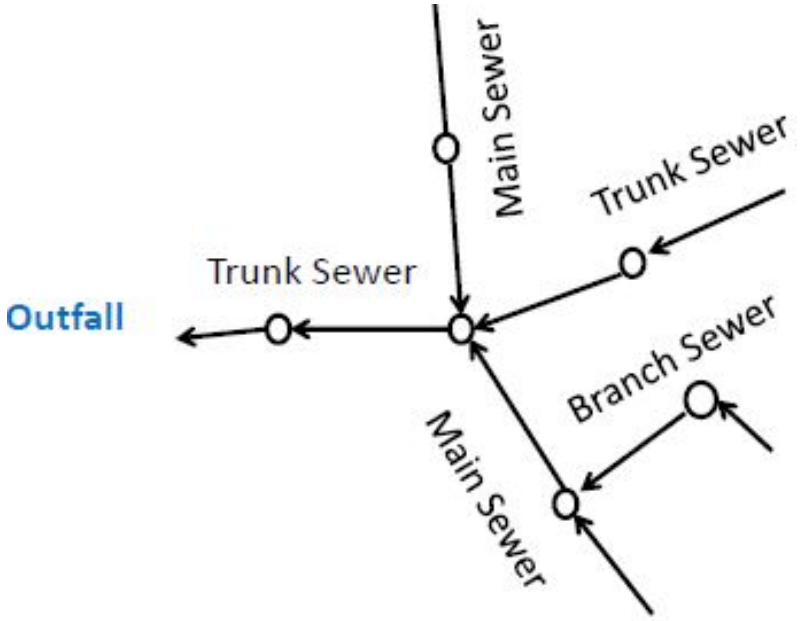
- **Velocity under full flow and half full flow conditions are equal, i.e. *v=V* at both *d/D= 0.5 and d/D= 1***
- ***Maximum velocity at d/D = 0.81 which is v/V = 1.14***
- ***Maximum flow at d/D = 0.94 which is q/Q = 1.07***

Layout of Sewer Lines

Steps followed for making the layout:

- Selection of an outlet or disposal points
- Fixing limits to the drainage area or zone boundaries
- Finalizing the location of Trunk and Main sewers
- Finalizing the location of Pumping stations wherever necessary

- Trunk sewer is with the largest diameter in the network that extends farthest from the sewage outfall
- All other sewers are considered as branches
- Whenever two sewers meet at a point, the incoming one with larger diameter is called the main sewer.



Laying of Sewer Pipes

All the sewer pipes are generally laid starting from their outfall end towards their starting. *The laying of a new sewer pipes consists of the following 9 steps:*

1. **Marking of alignment**
   - The center line of the sewer is marked along the road with a theodolite and invert tap. The position of the manhole is also marked.
2. **Setting benchmark**
3. **Establishment of grade lines**
4. **Excavation of trench**
   - The excavation may be carried out either by manual labor or by machines like power shovels, track excavators etc. The width of the trench at the bottom is generally kept 15 cm more than the dia of sewer pipe.
5. **Dewatering of trench if need**
   - If water is met with during excavation, it is removed by pumping or any other suitable method.

Laying of Sewer Pipes

6. Bedding

- For soft soil, the bed of the sewer is prepared by plain concrete (1:3:6). The thickness of concrete varies from 15 to 20 cm. The bedding layer is not required in case of rocky or hard soil.

7. Laying and joining of pipes

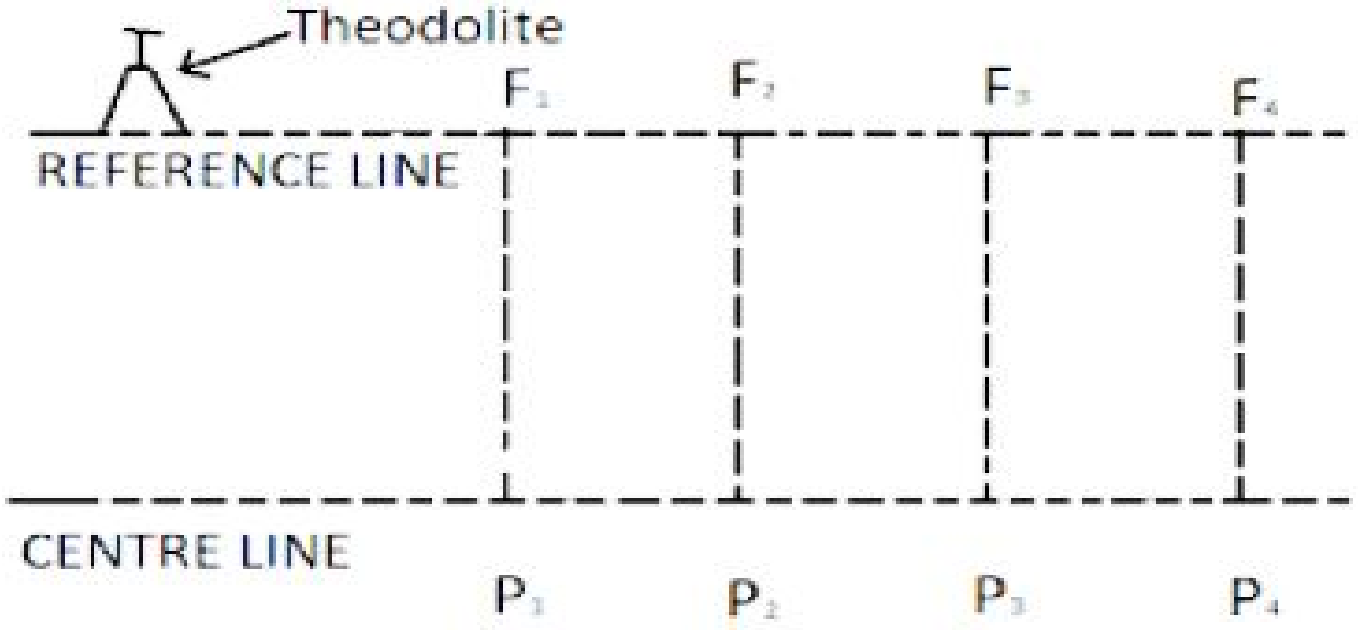
- The sewers are laid along the trench very carefully. Then the joining of the sewer is done as per requirements. After joining, both sides of the pipe are finished with concrete.

8. Inspection of leakage

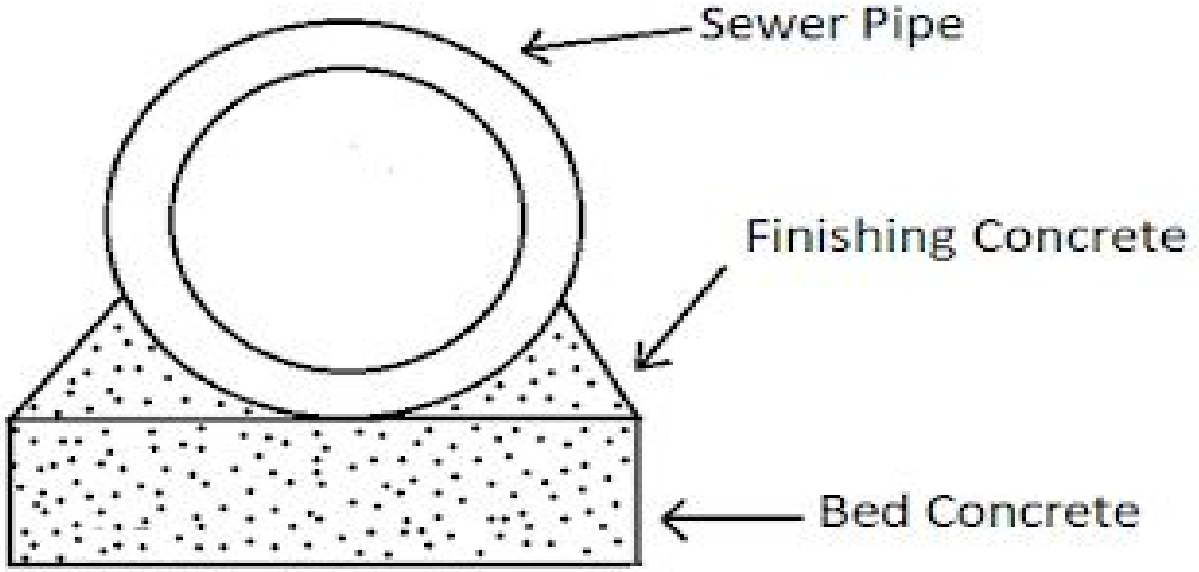
- The leakage in the pipe joints or any other points is tested by water test or air test.

9. Backfilling of trench

- Lastly, the trenches are filled up with the excavated earth in layers of about 15 cm thick. Each layer is properly watered and rammed.



Marking of the Alignment



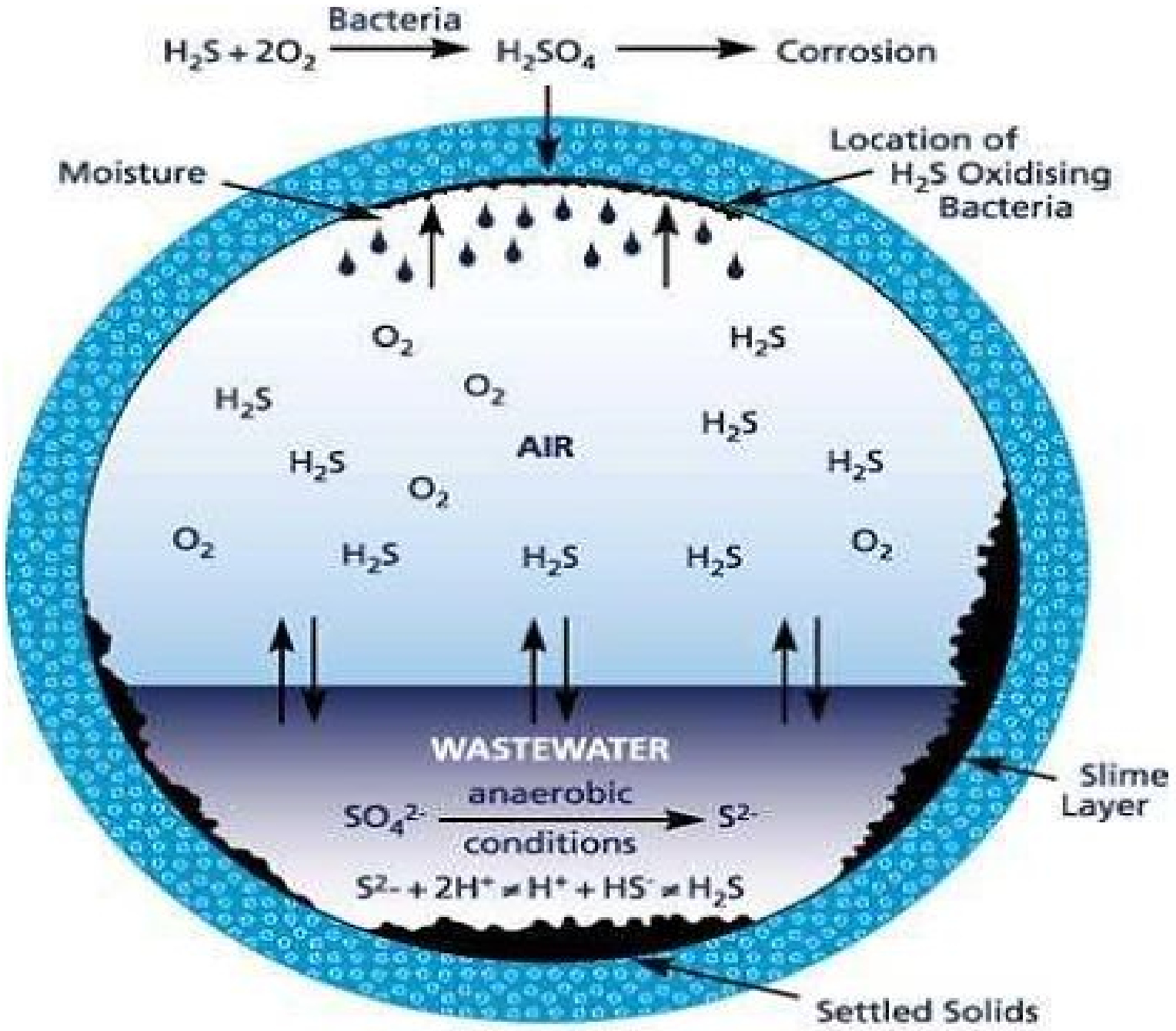
Laying and Joining of Pipes

Maintenance of Sewerage System

- Maintenance of sewers consists mainly of the removal or prevention of stoppages, cleaning of sewers and other sewer appurtenances and repair works.
- Maintenance of sewers becomes costly when they are laid on flat gradients and tree roots find easy entrance in sewers through defective joints.
- The maximum expenditure in maintenance comes on the cleaning of sewers,
- Which have been clogged due to deposition of silt, grease and oily materials.

Sewer

- Most sewers are **circular** in section. Other shapes such as **egg-shaped, rectangular** etc. were formerly used, especially in combined sewers.
- **Clay, concrete, cast-iron, asbestos** and **PVC** pipes were generally used as sewer pipes. Due to health hazards use of asbestos has been banned.
- Concrete is somewhat susceptible to corrosion by H_2SO_4 from H_2S gas generated in sewers or from industrial wastes.
- In case of sewage is strong, stable and very warm hasten the bacterial activities, thus generation of hydrogen sulfide. It is advisable to use clay pipe for diameter smaller than 24 inches and concrete pipes for cast in-situ plastic linings for larger sizes.
- The smallest sizes are 3-4 inches for house connections.


Bacteria
$H_2S + 2O_2$
H_2SO_4
Corrosion
Moisture
Location of
H_2S Oxidising
Bacteria
O_2
H_2S
AIR
WASTEWATER
anaerobic
conditions
SO_4^{2-}
S^{2-}
$S^{2-} + 2H^+ \rightleftharpoons H^+ + HS^- \rightleftharpoons H_2S$
Slime
Layer
Settled Solids

Sewer lines



Brickwork sewer line



HDPE sewer pipe



RCC sewer pipes



A view inside a sewer in London

Small Bore Sewerage (SBS) System

- High cost of conventional sewerage has stimulated interest in alternative low-cost proposals to extend adequate sanitation services to medium and low-income communities.
- Small Bore Sewerage (SBS) system is a recent sanitation technology.
- This system offers all the advantages of conventional sewerage systems at a much lower cost.

Three basic elements of SBS system:

- septic tanks;
- small bore sewer network;
- treatment plant

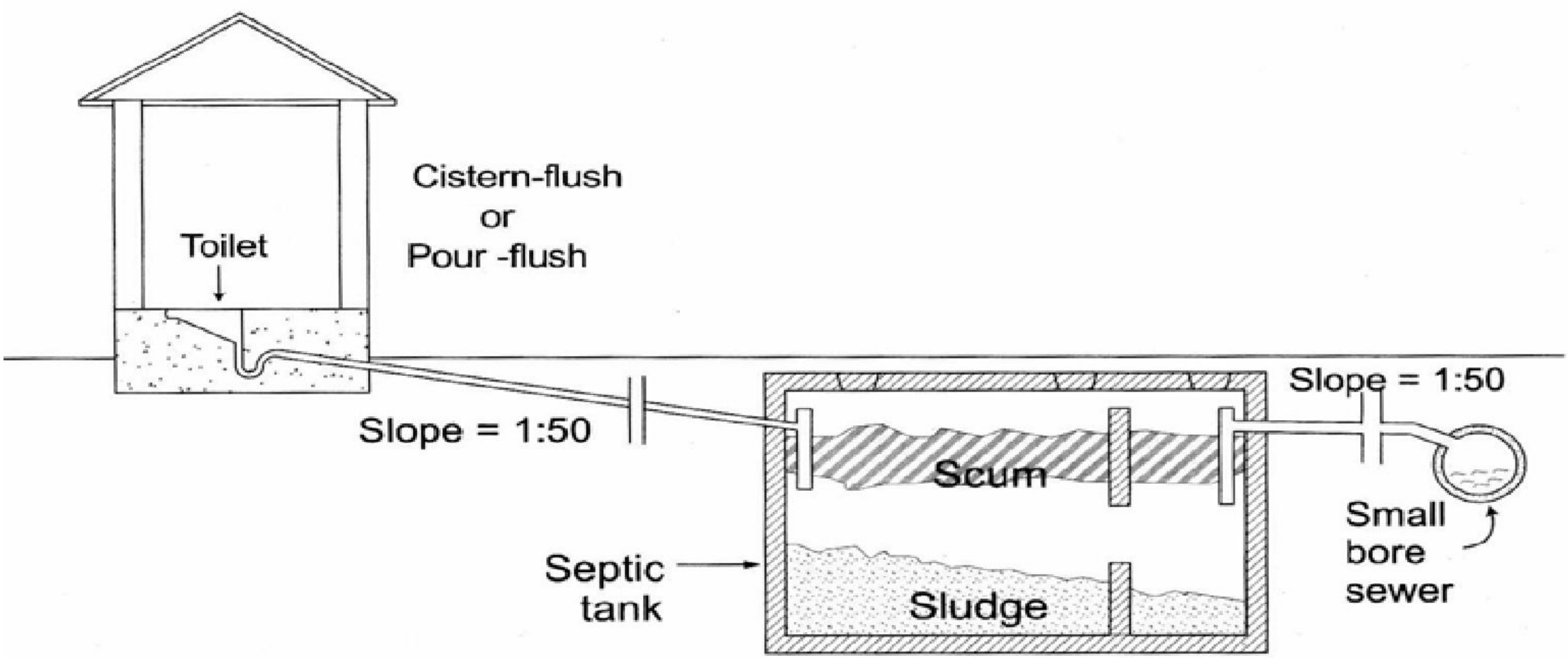


Figure: Elements of small bore sewerage system

Small Bore Sewerage (SBS) System

- They are designed to carry only the liquid part of the domestic sewage generated for off-site treatment or disposal.
- Solids are separated at a septic tank or at the aqua-privies before the sewage reaches the sewers.

Advantages:

- Sewer sizes can be reduced because each septic tank tends to act as a balancing tank, largely eliminating surge.
- Since the wastewater contains minimum solids, self-cleansing velocities are not necessary and hence sewer grades can be substantially reduced.
- Sewer blockages are minimal as septic tanks retain most of the solids content.

Small Bore Sewerage (SBS) System

Advantages:

- Volume of excavation is considerable reduced because of smaller sewers and lower sewer grades.
- Solids handling at the secondary treatment site is minimum.
- Rapid construction is possible because of lesser volume of excavation and fewer number of manholes to be constructed.

The small bore sewer system outfall can be any of the following:

a)The conventional sewer system

b) Waste stabilization ponds

c) Any other low cost treatment systems followed by fish ponds or land based disposal with precautions

Small Bore Sewerage (SBS) System

Limitations:

- Interceptor tank requires periodical cleaning and disposal of solids
- Any illegal connection without any interceptor tank shall ruin the system. So, strict vigilance is required.
- Septic tank installation is mandatory which is not required in conventional sewerage system.
- Inspection and desludging of septic tank are additional burden.
- The SBS system needs frequent flushing.

Basic Difference with Conventional Sewerage System

- Incorporation of septic tanks within the individual premises.
- The wastewater from septic tank is transported through a network of sewers to a treatment plant comprising a series of stabilization lagoons.
- In the case of an existing septic tank system the sewer installation commences immediately downstream, and
- New developments must install septic tanks to be able to connect to the SBS system.

Design Criteria for SBS

Design Flows:

- **Wastewater flows**: 40-80 lpcd with yard tap supplies and 80-120 lpcd with multiple tap in-house supplies.
- **Design Flow** Peak Factor: peak factor of 2 should be adopted for SBS.
- **Groundwater Infiltration and Surface Inflow**: Can be eliminated in SBS system by using solvent jointed UPVC as sewer materials

Sewer Diameter:

- SBS system can employ a minimum sewer size of as low as 50 mm
- if flow is more than 60% of full capacity next higher size should be adopted
- a minimum diameter of 100 mm may be recommended in case of unavailability of cleaning equipment.

Sewer Gradients:

- it is not necessary to maintain a self-cleansing velocity in SBS
- grades can be substantially reduced in SBS by reducing the volume of excavation

Manholes:

- requires less maintenance due to minimal solids content
- a fewer number of manholes are installed.

Simplified Sewerage System

- Low-cost sanitation technology particularly suited to high-density, low-income urban areas in developing countries.
- These are modification of surface drain with covers and consist of a network of pipe laid in the areas away from the places where heavy sewage loads are expected.
- Receives all household wastewater without settlement in septic tanks.
- Pipes are laid in flat gradients following the natural slope of the ground. The minimum depth is 0.4 m.
- Laid flatter gradient than conventional sewerage- slope is determined by tractive tension (not by minimum velocity).
- Sewers are not beneath the central roads, but within the property boundaries and beneath the sidewalks.
- Capital cost is lower (50-80% lesser than conventional sewerage) and operating costs are lower.

Simplified Sewerage System

System contains:

a) House connections

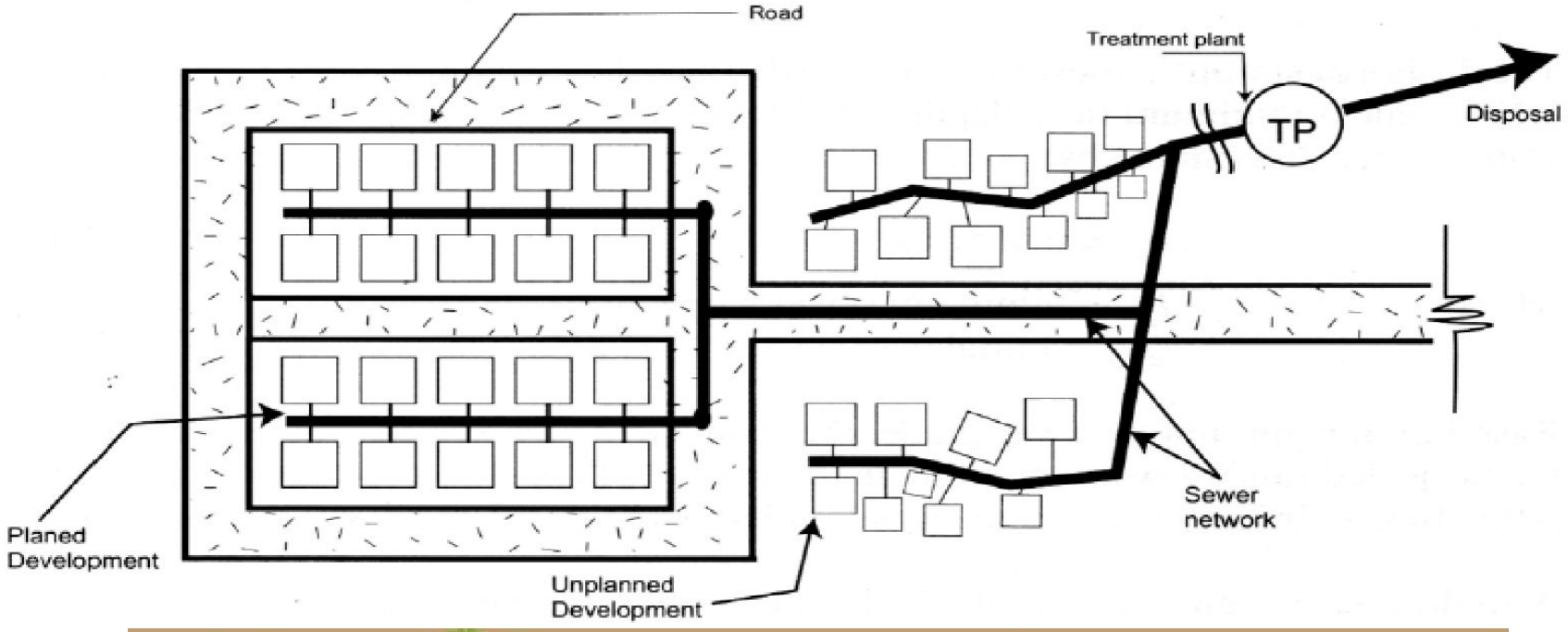
b) Inspection chambers

c) Laterals (minimum diameter of 100 mm)

d) Street-collector sewers (minimum diameter of 150 mm)

e) Pumping stations

Model layout of a small simplified sewerage scheme





Simplified Sewerage System

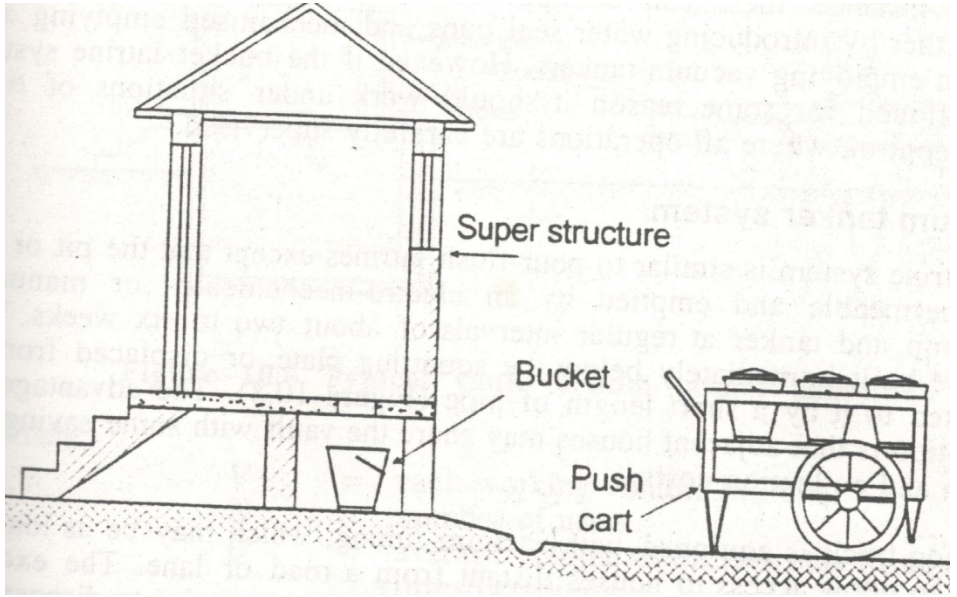
Suitability of the system:

- High density habitats such as slums or squatter settlements (with population density more than 170 per ha)
- Ground-condition is adverse and on-site disposal is not possible
- Sewage has to be disposed of and minimum water consumption is 25 lpcd.

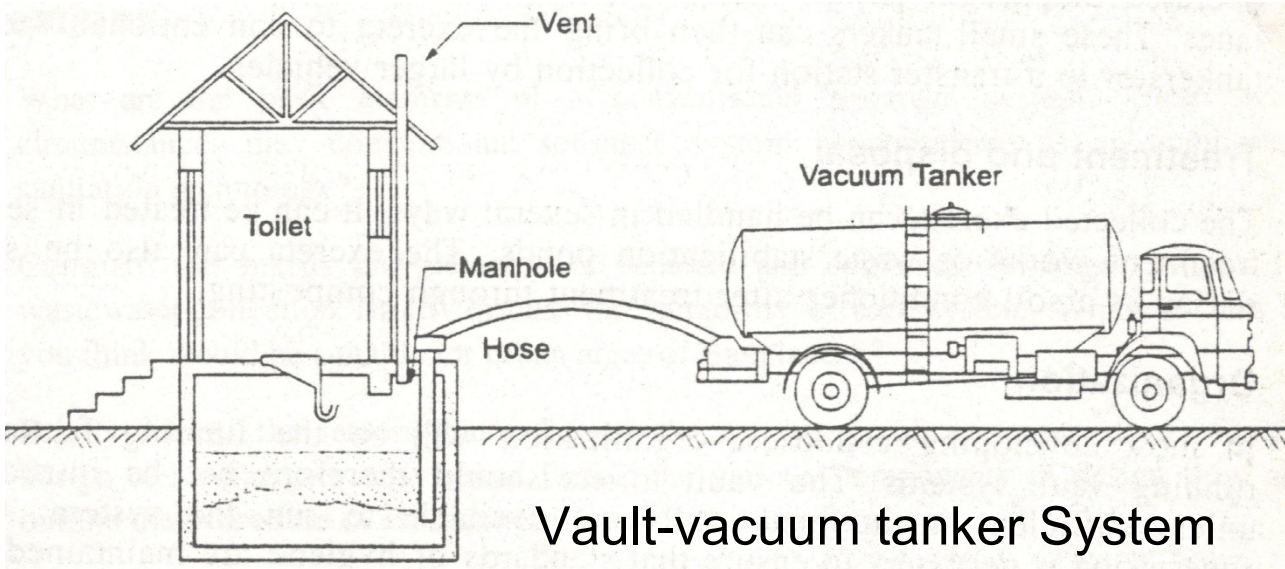
Limitations:

- It is suitable when suitable ground slope is available
- Unless flushed out at peak flow rates, there is a possibility of solids deposition if there is not enough ground slope available
- May require frequent cleaning

Non-sewered Transportation of Wastewater



Bucket Latrine System



Vault-vacuum tanker System

Sewer Appurtenances

- The structures, which are constructed at suitable intervals along the sewerage system to help its efficient operation and maintenance, are called as sewer appurtenances.
- They include manholes, lamp holes, street inlets, catch basins, inverted siphons etc.

Manholes

- Man holes are the openings of either circular or rectangular in shape constructed on the alignment of a sewer line to enable a person to enter the sewer for inspection, cleaning and flushing.
- They serve as ventilators for sewers, by the provisions of perforated man-hole covers. Also they facilitate the laying of sewer lines in convenient length.
- Man-holes are provided at all junctions of two or more sewers, whenever diameter of sewer changes, whenever direction of sewer line changes and when sewers of different elevations join together.
- For straight sewer line manholes are provided at regular interval depending upon the diameter of the sewer.

Manholes

- For sewer up to 0.3 m diameter or sewers which cannot be entered for cleaning or inspection the maximum spacing between the manholes recommended is 30 m, and 300 m spacing for pipe greater than 2.0 m diameter.
- A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers.
- Depending upon the depth the manholes can be classified as: (a) Shallow Manholes, (b) Normal Manholes, and (c) Deep Manholes

Manholes



Brickwork



HDPE

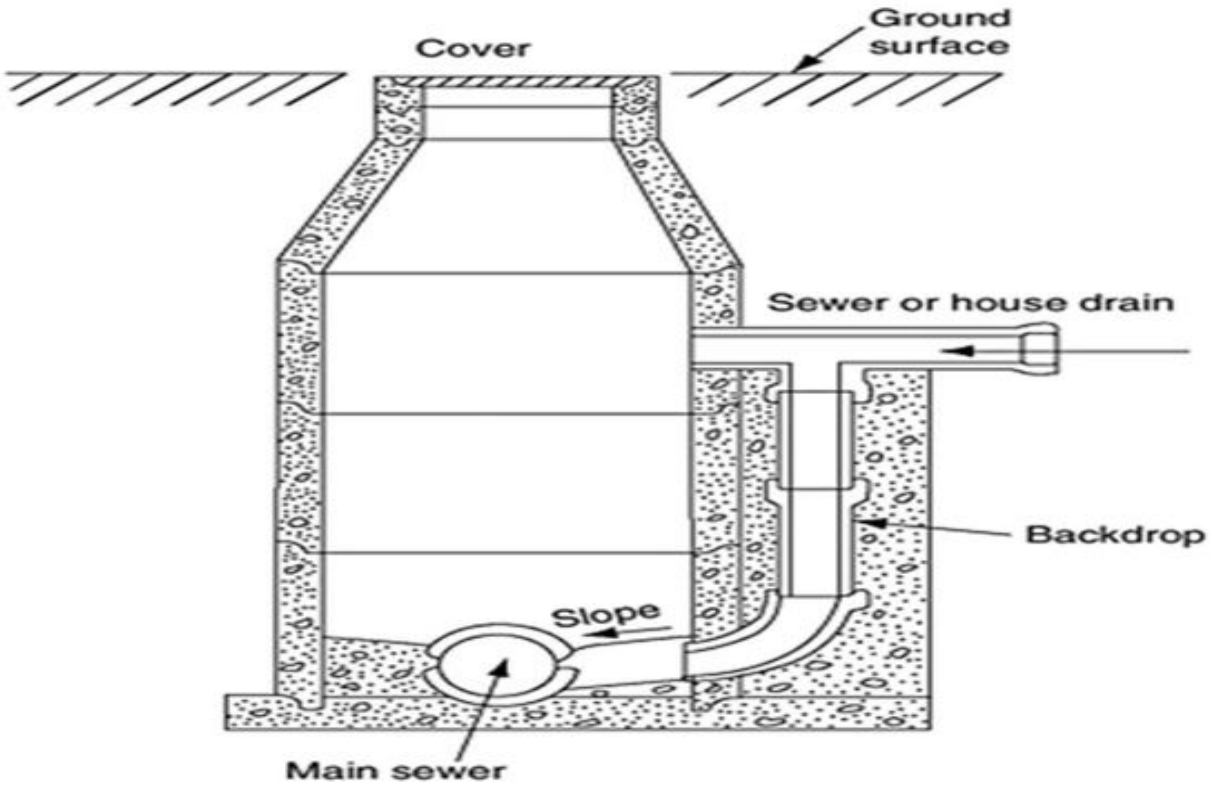


RCC precast



RCC precast

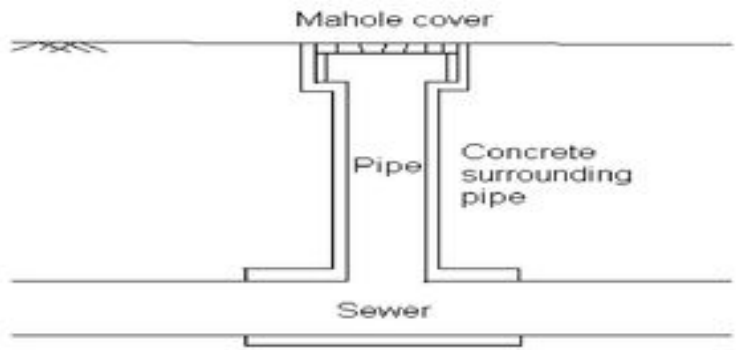
Manholes


Ground surface
Cover
Sewer or house drain
Backdrop
Slope
Main sewer



Lamp Hole

It is an opening or hole constructed in a sewer for purpose of lowering a lamp inside it. It consists of stoneware or concrete pipe, which is connected to sewer line through a T-junction. The pipe is covered with concrete to make it stable. Manhole cover of sufficient strength is provided at ground level to take the load of traffic. An electric lamp is inserted in the lamp hole and the light of lamp is observed from manholes. If the sewer length is unobstructed, the light of lamp will be seen. It is constructed when construction of manhole is difficult. In present practice as far as possible the use of lamp hole is avoided. This lamp hole can also be used for flushing the sewers. If the top cover is perforated it will also help in ventilating the sewer, such lamp hole is known as fresh air inlet.

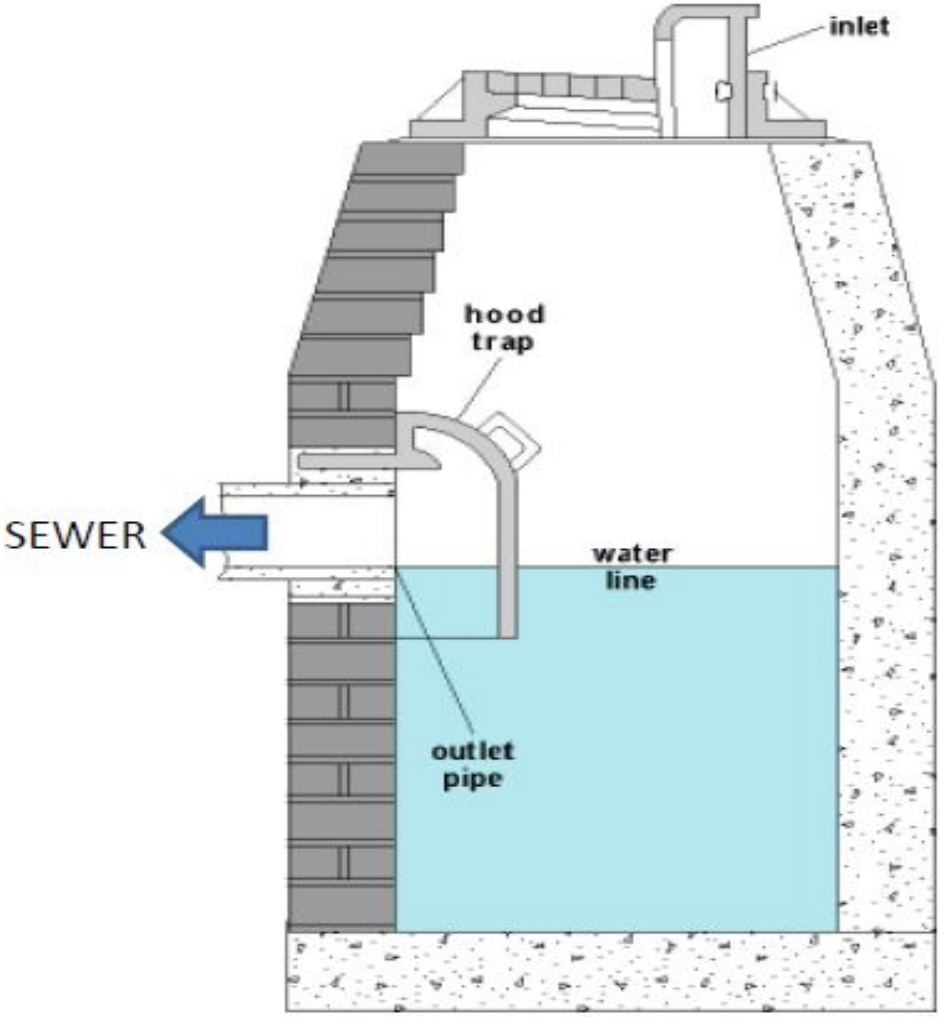


STORMWATER INLETS

Storm water inlets are provided to admit the surface runoff to the sewers. These are classified in three major groups viz. curb inlets, gutter inlets, and combined inlets. They are provided either depressed or uniform slope flush with respect to the elevation of the pavement surface. The structure of the inlet is constructed with brickwork with cast iron grating at the opening. Where the traffic load is not expected, fabricated steel grating can be used. The clear opening shall not be more than 25 mm. The connecting pipe from the street inlet to the sewer should be minimum of 200 mm diameter and laid with sufficient slope. A maximum spacing of 30 m is recommended between the inlets, which depends upon the road surface, size and type of inlet and rainfall.

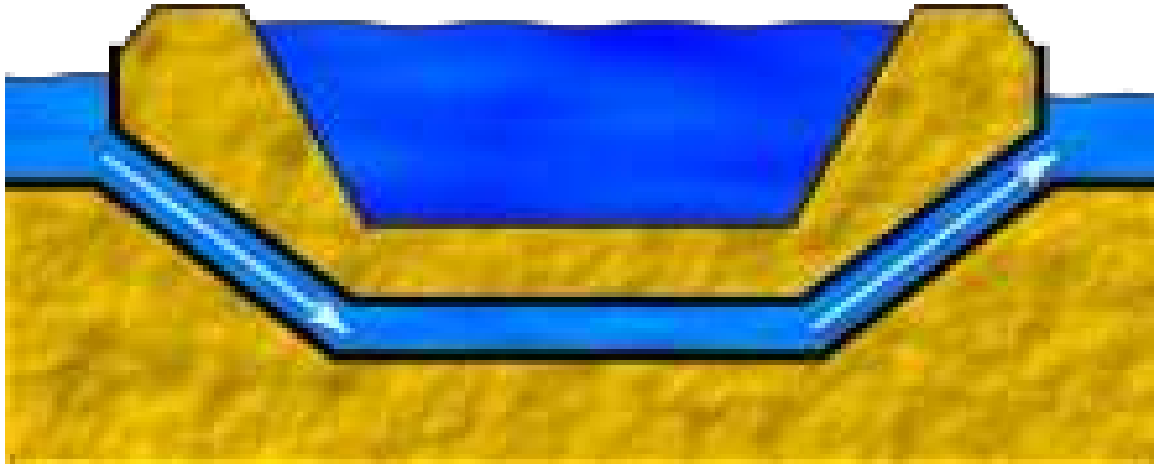


Catch Basins: Catch basins are small settling chambers of diameter 60 - 90 cm and 60 - 75 cm deep, which are constructed below the street inlets. They are provided to stop the entry of heavy debris present in the storm water into the sewers and allow grit, sand, debris to settle in the basin. At the bottom of the basin space is provided for the accumulation of impurities. Perforated cover is provided at the top of the basin to admit rain water into the basin.





Inverted Siphons: Inverted siphons are pipes that allow wastewater to flow under obstructions or low-lying areas, such as rivers, utilities, or highways. They are used when gravity flow is not possible. The pipe is lowered below the obstacle, then rises back to its original level. The liquid in the pipe is completely filled and flows under pressure.



SEWAGE PUMPING STATIONS

These are required to elevate and transport wastewater when Continuation of gravity flow is no longer feasible due to any obstacle lies in the path of sewer (e.g. river, canal etc) and/or receiving stream is higher than the sewer.

Pumps for Sewage:

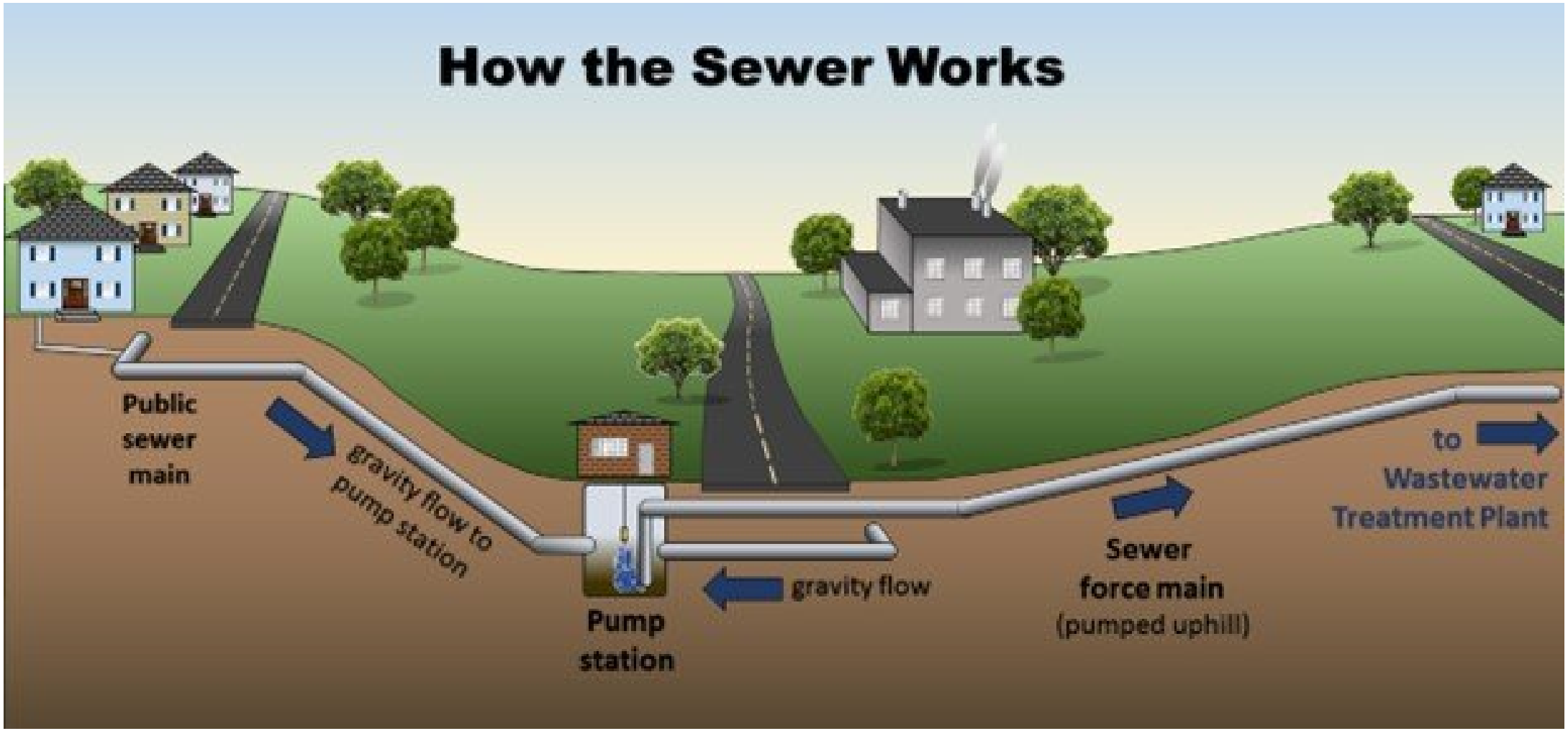
Centrifugal, single suction, non-clogging type pumps are normally used. They have impellers

Having two or three vanes. Pump suction pipe is usually larger than the discharge pipe by about 25%. Smallest discharge pipe =75mm ,while smallest suction pipe =100 mm.

Components of Sewage Pumping Station

Screens: To screen out large floating matters which can damage the pumps
Dry well: To house the pump and **Wet well:** for receipt of wastewater.

i. More than one pump should be provided to cope with variable discharge. Two pumps for small Pumping Station and more than two for large Pumping Station should be used.


How the Sewer Works
Public sewer main
gravity flow to pump station
Pump station
gravity flow
Sewer force main
(pumped uphill)
to Wastewater Treatment Plant

Description of flow	Ratio to average
Maximum daily	2.5 to 1
Maximum hourly	3 to 1
Minimum daily	0.67 to 1
Minimum hourly	0.33 to 1

Problem 1. Estimate the maximum **hourly, average daily and minimum hourly residential sewage flows** from an area occupied by 750 people having average per capita sewage flow of 59 gpcd. Consider the length of the sewer and house connections to be 1.3 miles and infiltration to be 30,000 gpd per miles.

Solution

Design Flows:

Qav (san) = 100 % of water use (60 –80% for developed country)

Qav (design) = Qav (san) + Infiltration + Storm Inflow

Qmax (design) = 3 Qav (san) + Infiltration + Storm Inflow

Qmin (design) = 0.33 Qav (san) + Infiltration + Storm Inflow

No of people to be served = 750

Average sanitary sewage flow, Qavg (san) = 750 × 59 = 44250 g/d = 1843.75 g/h

Infiltration = 30000 × 1.3 = 39000 g/d = 1625 g/h

Qav (daily) (design) = Qav (san) + Infiltration = 44250 + 39000 = **83250 g/d**

Qmax (hourly) (design) = 3 Qav (san) + Infiltration = 3× 1843.75 + 1625 = **7156.25 g/h**

Qmin (hourly) (design) = 0.33 Qav (san) + Infiltration = 0.33× 1843.75 + 1625 = **2233.44 g/h**

Problem 2. A drainage area, having rain falls during four months of the year only, has an area of 15 ha, with 30 houses/ha. The area has the following surface characteristics:

(i) The average area of the roof is 80 m^2/house, with runoff coefficient of 0.9.

(ii) The roads occupy 25% of total area. The main roads are tarred and interior ones are of water bound macadam. Impermeability factor for these roads could be taken as 0.6.

(iii) The remaining area is open space whose coefficient of runoff may be taken as 0.12.

If the rainfall records show that the intensity of an ordinary rainstorm is 4.5 cm/h, what will be the discharge from this district? Determine the dry weather flow from the area if the population is 300 persons/ha and the rate of water supply is 250 lpcd. Also find the ratio of storm sewage to dry weather flow and indicate the suitability of separate sewerage scheme in the area in preference to combined sewerage scheme.

Solution

For the area of 1 ha,

Roof area, A1 = 30 × 80 = 2400 m^2

Equivalent roof area, A1 C1 = 2400 × 0.9 = 2160 m^2

Road area, A2 = 0.25 × 1 = 0.25 ha = 2500 m^2

Equivalent road area, A2 C2 = 2500 × 0.6 = 1500 m^2

Open space area, A3 = (10000 – (2400 + 2500) = 5100 m^2

Equivalent open space area, A3 C3 = 5100 × 0.12 = 612 m^2

$$\text{Now, } C = \frac{A_1C_1 + A_2C_2 + A_3C_3}{A_1 + A_2 + A_3}$$

$$C = \frac{2160 + 1500 + 612}{10000} = 0.43$$

Q = FCIA = 27.8 ×0.43 × 4.5 × 15 = 807 l/s

Total population to be served = 300 persons / ha = 300 × 15 = 4500 persons

Average daily sewage contribution = 80% of average water supply = 0.8 × 250 × 4500

= 900000 l/d = 10.42 l/s

Assuming that the sewer is a branch/ lateral sewer, the maximum discharge of dry weather flow,

Q max = 2.5 × 10.42 = 26.05 l/s

Now, ratio of storm sewage to max dry weather flow = 807/26.05 = 31

From this problem, it is clear that if a combined sewer is adopted for the given area, the sewer would carry only **1/ 31 th** of total discharge for about 8 months of a year. Thus, a separate sewerage scheme is most suitable for the area given in this problem. However, the modern trend for well-planned cities is to adopt combined schemes for their overall merits over separate sewerage schemes.

Storm Sewer

Determine the peak discharge for use in the design of a highway crossing a canal. The catchment has the following characteristics:

Mainstream length $L = 3.0$ km
Catch area $A = 7.5$ km^2
Mainstream slope $S = 5.0$ m/km
Catchment type: medium soil, ($C = 0.48$)
A recurrence interval of 5 years is assumed to be suitable for the crossing.

Solution: The time of concentration,

$$t_c = \frac{FL}{A^{0.1}\ S^{0.2}}$$

$$= \frac{58.5 \times 3.0}{(7.5)^{0.1} \times (5.0)^{0.2}} = \frac{58.5 \times 3.0}{1.22 \times 1.38} = 104 \text{ mins or } 1.7 \text{ hrs}$$

The design rainfall intensity for a duration of 104 minutes and recurrence interval of 5 years in an area located close to the crossing is

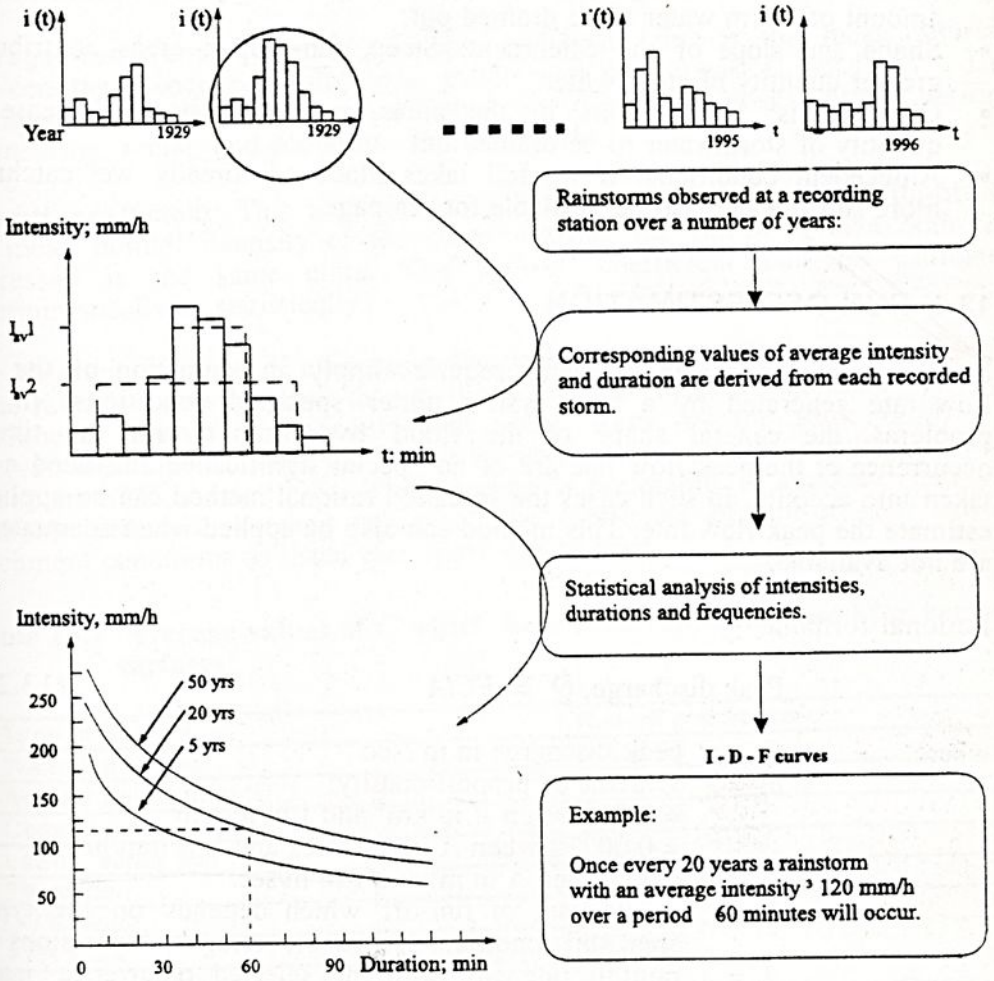
$I = 70$ mm/hrs [from intensity - duration - frequency curve]

The peak discharge can be found by using the rational formula,

$$Q = FCIA$$
$$= 0.278 \times 0.48 \times 70 \times 7.5$$
$$= 70.0 \text{ m}^3/\text{sec}$$

$$t_c = \frac{FL}{A^{0.1} S^{0.2}}$$

where t_c = time of concentration in minutes
F = factor of proportionality,
58.5 when A in km^2,
92.7 when A in hectares
L = mainstream length (km)
A = catchment area
S = mainstream slope (m/km)



IDF Curve

Example 2

Also determine the diameter of the storm sewer crossing the highway, for the above example, with sewer material having $n = 0.013$ and laid at a slope of 0.001. The velocity at full flow should be less than 3.0 m/sec.

Solution:

Discharge $Q = AV$

$$= \frac{\pi D^2}{4} (1/n\ R^{2/3}\ S^{1/2}) \quad \text{[using Manning's equation]}$$

$$\text{or,} \quad 70.0 = \frac{\pi D^2}{4} \times \frac{1}{0.013} (D/4)^{2/3}\ (0.001)^{1/2}$$

$$= D^2 . D^{2/3} . \pi/4 \times 1/0.013 \times (1/4)^{2/3} \times (0.001)^{1/2}$$

$$= D^{8/3} \times 0.76$$

$$\therefore \quad D^{8/3} = 70/0.76 = 92.10$$

$$\therefore \quad D = 5.5 \text{ m}$$

Use 5500 mm diameter storm sewer.

Check for velocity:

$$V = Q/A = \frac{70.0 \times 4}{\pi \times 5.5 \times 5.5}$$

$$= 2.95 \text{ m/sec. } 3.0 \text{ m/sec. Hence the velocity is o.k.}$$

Example:

A combined sewer was designed to serve an area of 60 sq. km with an average population density of 185 persons/hectare. The average rate of sewage flow is 350 L/Capita/day. The maximum flow is 50% in excess of the average sewage flow. The rainfall equivalent of 12 mm in 24 h can be considered for design, all of which is contributing to surface runoff. What will be the discharge in the sewer? Find the diameter of the sewer if running full at maximum discharge.

Solution:

Total population of the area = population density x area

$= 185 \times 60 \times 10^2$

$= 1110 \times 10^3$ persons

Average sewage flow $= 350 \times 11.1 \times 10^5$ Liters/day

$= 4.5$ m^3/sec

$= 388.5 \times 10^5$ L/day

Storm water flow $= 60 \times 10^6 \times (12/1000) \times [1/(24 \times 60 \times 60)]$

$= 8.33\ m^3/sec$

Maximum sewage flow $= 1.5 \times$ average sewage flow

$= 1.5 \times 4.5 = 6.75\ m^3/sec$

Total flow of the combined sewer = sewage flow + storm flow

$= 6.75 + 8.33 = 15.08\ m^3/sec$

Hence, the capacity of the sewer $= 15.08\ m^3/sec$

Hence, diameter of the sewer required at the velocity of 0.9 m/s can be calculated as

$\pi/4\ (D)^2 \times 0.90 = 15.08\ m^3/s$

Hence, $D = 4.62$ m

Example:

A 300 mm diameter sewer is to flow at 0.3 depth on a grade ensuring a degree of self cleansing equivalent to that obtained at full depth at a velocity of 0.9 m/sec. Find the required grade and associated velocity and rate of discharge at this depth. Assume Manning's rugosity coefficient n = 0.013. The variation of n with depth may be neglected.

Solution:

Manning's formula for partial depth

$$v = \frac{1}{n} r^{2/3} s^{1/2}$$

For full depth

$$V = \frac{1}{N} R^{2/3} S^{1/2}$$

Using V = 0.90 m/sec, N = n = 0.013 and R = D/4 = 75 mm = 0.075 m

$$0.90 = \frac{1}{0.013} 0.075^{2/3} S^{1/2}$$

S = 0.0043

This is the gradient required for full depth.

and, $Q = A.V = \pi/4\ (0.3)^2 \times 0.90 = 0.064\ m^3/s$

At depth d = 0.3D, (i.e., for d/D = 0.3) we have a/A = 0.252 and r/R = 0.684 (neglecting variation of n)

$\gamma_w \cdot r \cdot s_s = \gamma_w \cdot R \cdot S$

Hence,

$s_s = (R/r)\, S$

Or $\dfrac{s_s}{S} = \dfrac{R}{r}$

$d/D = \frac{1}{2}\left(1 - \cos\dfrac{\theta}{2}\right)$

$r / R = (1 - 360 \sin \theta / 2\pi\, \theta)$

$a/A = (\theta/360 - \sin\theta/2\pi)$

Now for the sewer to be same self cleansing at 0.3 depth as it will be at full depth, we have the gradient (s_s) required as $s_s = (R/r)S$

Therefore, $s_s = S / 0.684$

$= 0.0043 / 0.0684 = 0.0063$

Now, the velocity v_s generated at this gradient is given by

$$v_s = V\frac{N}{n}\left(\frac{r}{R}\right)^{1/6}$$

$= 1 \times (0.684)^{1/6} \times 0.9$

$= 0.846$ m/s

The discharge q_s is given by

$$q_s = Q\frac{N}{n}\frac{a}{A}\left(\frac{r}{R}\right)^{1/6}$$

$q_s = 1 \times (0.258) \times (0.939) \times (0.064)$

$= 0.015$ m^3/s

$$\frac{v_s}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}\left(\frac{s_s}{S}\right)^{1/2}$$

OR, by substituting $r/R = S/s_s$

$$\frac{v_s}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{1/6}$$

And

$$\frac{q_s}{Q} = \frac{N}{n}\frac{a}{A}\left(\frac{r}{R}\right)^{1/6}$$

Example:

Design a sewer running 0.7 times full at maximum discharge for a town provided with the separate system, serving a population 80,000 persons. The water supplied from the water works to the town is at a rate of 190 LPCD. The manning's n = 0.013 for the pipe material and permissible slope is 1 in 600. Variation of n with depth may be neglected. Check for minimum and maximum velocity assuming minimum flow 1/3 of average flow and maximum flow as 3 times the average.

Solution

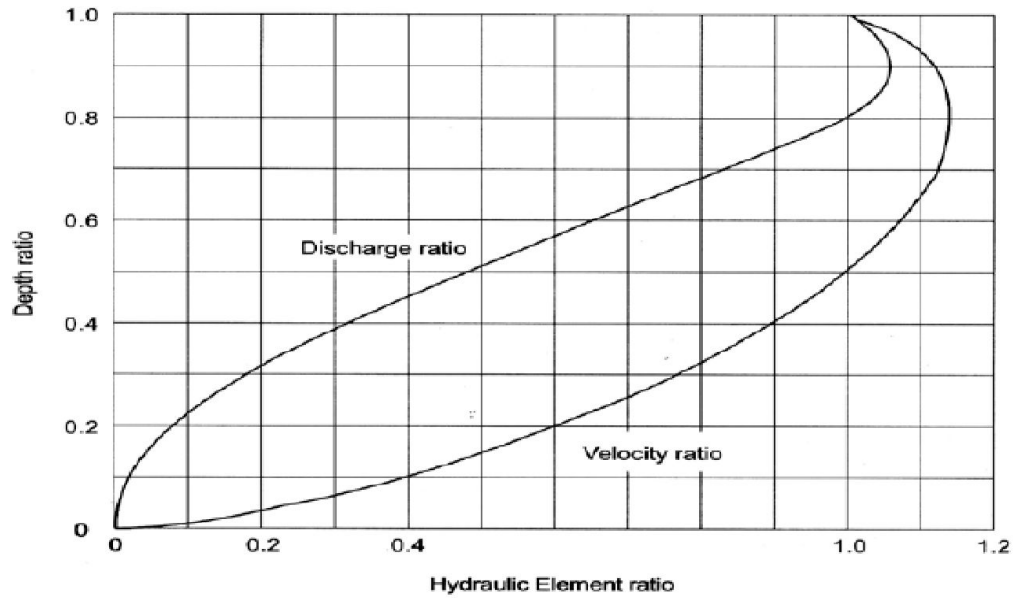
Average water supplied = 80000 x 190 x (1/24 x 60 x 60 x 1000) = 0.176 m^3/sec

Sewage production per day, (considering 80% of water supply) = 0.176 x 0.8 = 0.14 m^3/sec

Maximum sewage discharge = 3 x 0.14 = 0.42 m^3/sec

Now for d/D = 0.7, q/Q = 0.838, v/V = 1.12

Therefore, Q = 0.42/0.838 = 0.5 m^3/sec



Now

$$Q = \frac{1}{n}\frac{\pi D^2}{4}\left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$$Q = \frac{1}{0.013}\frac{\pi D^2}{4}\left(\frac{D}{4}\right)^{2/3}\left(\frac{1}{600}\right)^{1/2}$$

Therefore, D = 0.78 m

V = Q/A = 1.04 m/sec

Now, v/V = 1.12

Therefore v = 1.12 x 1.04 = 1.17 m/sec

This velocity is less than limiting velocity **3 m/s** hence, OK

Check for minimum velocity

Now $q_{min} = 0.14/3 = 0.047$ m^3/sec

$q_{min}/Q = 0.047/0.5 = 0.09$

From proportional chart, for q/Q = 0.09, d/D = 0.23 and v/V = 0.65

Therefore, the velocity at minimum flow = 0.65 x 1.04 = 0.68 m/sec

This velocity is greater than self cleansing velocity **0.6 m/s** hence OK

$d_{min} = 0.23 \times 0.78 = 0.18$ m

Assignment: Solve the above problem with population 100000 persons and pipe flowing 0.75 full at maximum discharge. The rate of water supply is 150 LPCD, n = 0.013, and permissible S = 1 in 600.

Problems to Solve:

1. An 18 inch sewer with n=0.013 is laid on a slope of 0.015.
   a) What is the capacity when flowing half full?
   b) What will be the velocity when the depth of flow is 4.5 inch.

Problem: Determine the rate of discharge and discharge velocity in a 30 cm circular sewer with n = 0.013, slope = 0.004 and depth of flow equal to 7.5 cm, using both of the Nomograms and Partial flow diagram, given below.

Solution

From the nomograms –

for slope =0 .004 (m/m) = 4m/ 1000 m and diameter, D = 30 cm,

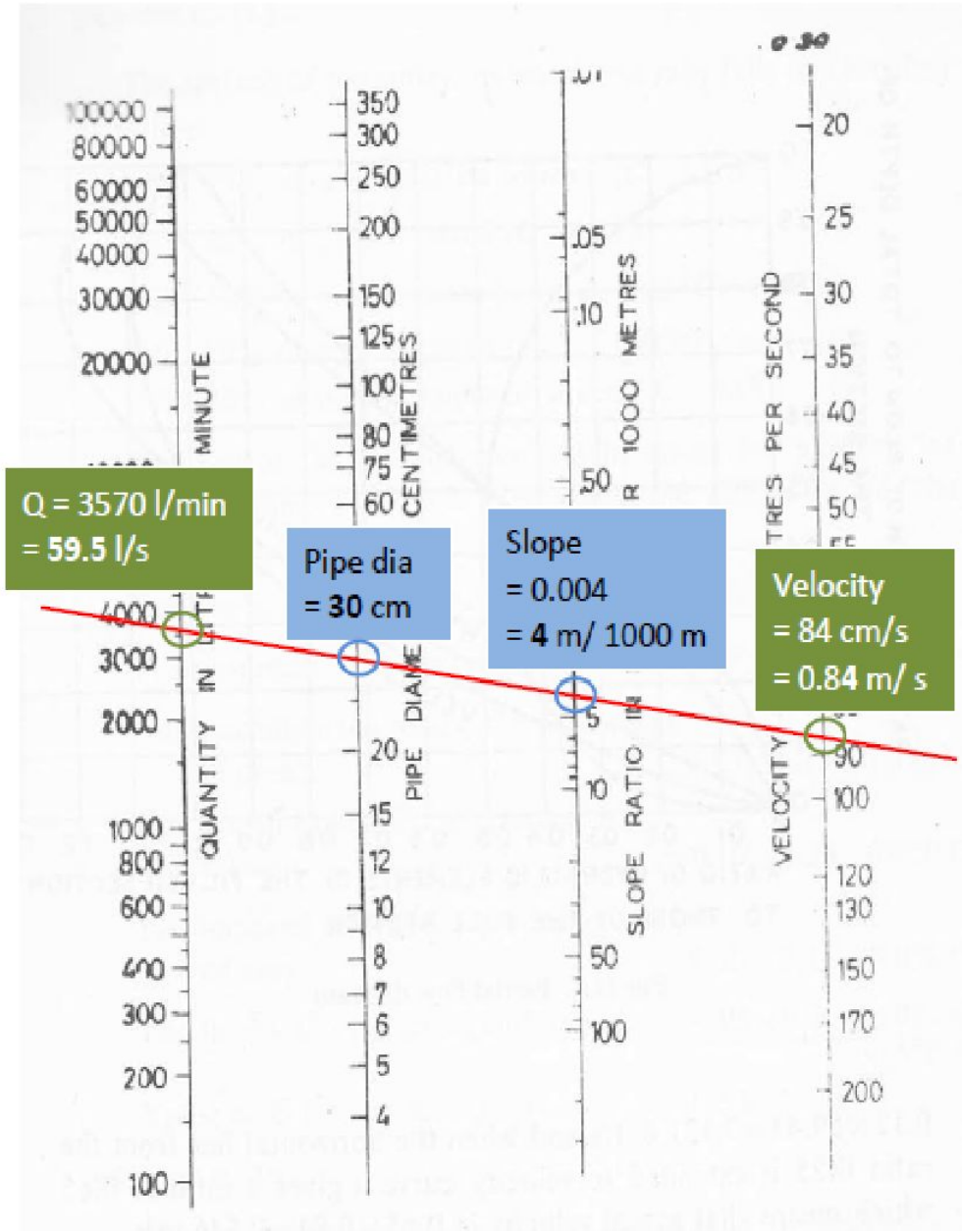
Discharge, Q = 3570 l/min = 59.5 l/s and Velocity, V = 84 cm/s = 0.84 m/s

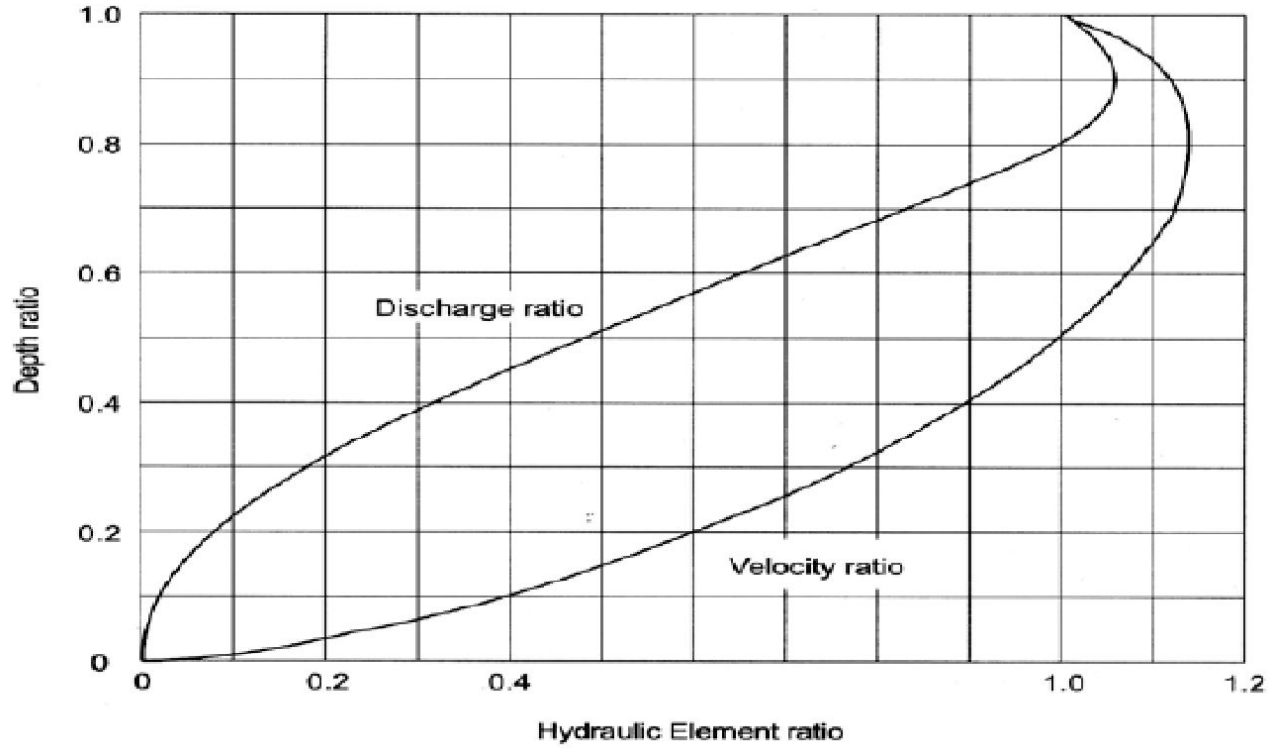
Now, depth ratio, d/D = 7.5 / 30 = 0.25

From the partial flow diagram, q/Q = 0.12

Therefore, q = 0.12 × 59.5 = **7.14 l/s**

Again, v = 0.65 × 0.84= **0.55 m/s**


Q = 3570 l/min
= 59.5 l/s
Pipe dia
= 30 cm
Slope
= 0.004
= 4 m/ 1000 m
Velocity
= 84 cm/s
= 0.84 m/ s
QUANTITY IN LITRES PER MINUTE
PIPE DIAMETER IN CENTIMETRES
SLOPE RATIO IN 1000 METRES
VELOCITY IN METRES PER SECOND


Depth ratio
Discharge ratio
Velocity ratio
Hydraulic Element ratio
0
0.2
0.4
0.6
0.8
1.0
1.2



Infiltration



Inflow

I & I

Problem: A trunk sewer is to be sized for a 25 km^2 (2,500 ha) city with a naturally sloped towards the major river with a gradient of 1 in 1000. It will be 60% residential, 30% commercial, and 10% industrial. The residential area will have 40% large lots, 55% small single family lots, and 5% multi-story apartments. The average domestic wastewater flow rate is 800 L/d/capita (9.26×10^{-6} m^3/sec/person), the average commercial flow rate is 25,000 L/D/ha ($2.89 \times I0^{-4}$ m^3/sec/ha), and the average industrial flow rate is 40,000 L/d/ha ($4.63 \times I0^{-4}$ m^3/sec/ha). I & I is 1,000 L/d/ha for the entire area. Estimate the peak and minimum flows to be handled by the trunk sewer. Given: $Q_{peak}/Q_{avg} = 5.5/(p^{0.18})$ and $Q_{min}/Q_{avg} = 0.2(p^{0.16})$,where *'p' is the total city* population in thousands. Also design the sewer based on the estimated flow and the saturation densities for the residential areas given in the table below:

Type of area	**Density (Persons/ha)**
Large lots	5-7
Small lots, single-family	75
Small lots, two-family	125
Multistory apartments	2,500

Type	Area(ha)	Density (persons/ha)	Population	Flow (m^3/s)
Large lots	0.4(1500)= 600	6	3,600	0.03
Small single family lots	0.55(1500) = 825	75	61,875	0.57
Multistory apartments	0.05(1500) = 75	2500	187,500	1.74
Total			**252,975**	**2.34**

Commercial sector = 30% of 2500 ha = 750 ha
Average flow from commercial sector = 750x25,000 L/d= 0.22 m^3/s

Industrial sector = 10 % of 2500 ha = 250 ha
Average flow from industrial sector = 250x40,000 L/d = 0.12 m^3/s
Thus,
Average wastewater flow (excluding I/I) = 2.34+0.22+0.12 = 2.68 m^3/s
Assuming total population is equal to residential population, i.e.

P= 252,975

Then,

$$\frac{Q_{peak}}{Q_{ave}} = \frac{5.5}{(P/1000)^{0.18}} = \frac{5.5}{(252.975)^{0.18}} = 2.0$$

$$\frac{Q_{\min}}{Q_{ave}} = 0.2(P/1000)^{0.16} = 0.2(252.975)^{0.16} = 0.48$$

Hence,

Peak flow = Peak factor x wastewater + I/I = 2.0(2.68)+0.03= 5.39 m^3/s

Minimum flow = 0.48(2.68) + 0.03 = 1.32 m^3/s

Using Manning's Equation for a full-flowing pipe (n=0.013 for concrete) at a gradient S=0.001

$$Q = \frac{1}{n} \cdot \frac{\pi D^2}{4} \cdot (\frac{D}{4})^{2/3} \cdot S^{1/2}$$

$$D = \left(\frac{5.39 \cdot 0.013}{0.3117 \cdot \sqrt{0.001}} \right)^{3/8}$$

$$D = \left(\frac{0.07007}{0.009857} \right)^{3/8} \approx 2.278 \text{ m}$$

Velocity Check:

It is essential to ensure the flow velocity (V) is within the self-cleansing range (typically 0.6 m/s to 3.0 m/s)

$$V = \frac{Q}{A} = \frac{5.39}{\frac{\pi \cdot 2.28^2}{4}} \approx 1.32 \text{ m/s}$$

Since 1.32 m/s is greater than 0.6 m/s and less than 3.0 m/s the design is hydraulically stable.

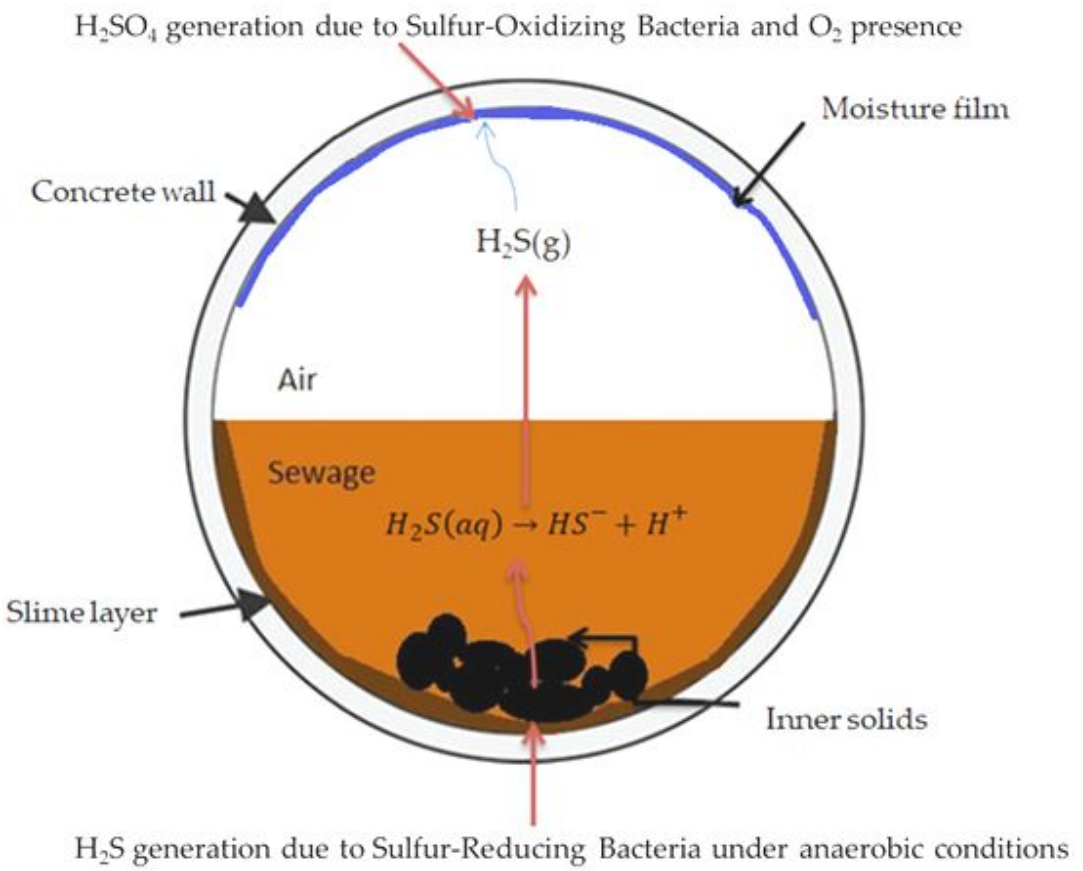
The design requires a sewer pipe with a diameter of **2.28 meters** (or the nearest standard commercial size, such as 2300 mm)

Why does H_2S form in sewers?

H_2S is formed by anaerobic processes in the thin slime layer that develops on the inside of the sewer walls as organic material in the sewage breaks down.

The formation of H_2S in wastewater mainly depends on:

- Flow (velocity) of sewage in pipes
- Slope of the pipe
- Ratio of wetted perimeter of the pipe wall to surface width of the stream
- Temperature of the sewage
- Biochemical oxygen demand (BOD)



Sulfide Generation

$$Z = 0.308 \frac{EBOD}{S_0^{0.5} Q^{0.33}} \times \frac{P}{B}$$

$$EBOD = BOD \times 1.07^{T-20}$$

$BOD =$ 5-day biochemical oxygen demand

$S_0 =$ Slope of the pipe

$Q =$ Discharge through the pipe

$P, B =$ Wetted perimeter and top width of the flow, respectively

$$P = \frac{D\theta}{2}$$

Top Width, B= D sin (θ/2)

Z values	Sulfide Condition
$Z < 5{,}000$	Sulfide rarely generated
$5{,}000 < Z < 10{,}000$	Marginal condition for sulfide generation
$Z > 10{,}000$	Sulfide generation common

Problem: A 2000 mm dia. RCC pipe is laid with a slope of 0.0015 for a design flow of 0.6 m^3/sec when flowing partially full having a width of 1.414m at the top. The sewer pipe provided is designed to carry domestic sewage having BOD_5 of 200 mg/L and a maximum temperature of 30°C. Determine the potential for Sulfide Generation (Z).

Step 1: Calculate the Effective BOD ($EBOD$)

The Effective BOD accounts for the increased biological activity at higher temperatures. It is calculated using the formula:

$$EBOD = BOD_5 \cdot 1.07^{(T-20)}$$

Given,

BOD_5=200 mg/L, T=30^0C

$$EBOD = 200 \cdot 1.07^{(30-20)} = 393.43 \text{ mg/L}$$

Step 2: Determine Geometric Parameters

For a circular pipe with diameter

D=2000 mm =2.0 m

R=1.0 m and a top width of flow B=1.414 m

Find the central angle

B=2Rsin (θ/2)

1.414=2(1.0) sin (θ/2) $\Rightarrow$sin (θ/2)=0.707$\Rightarrow\theta$/2=45^0

θ=90^0 (or π/2 radians).

Find the wetted perimeter

P=$R\cdot\theta$=1.0$\cdot\pi$/2≈1.571 m

Calculate the ratio

P/B =1.571/1.414≈1.111

Step 3: Calculate the Z-index

The Z-index formula is defined as:

$$Z = 0.308 \frac{EBOD}{S_0^{0.5} Q^{0.33}} \times \frac{P}{B}$$

Substitute the given values (S=0.0015, Q=0.6 m^3/sec)

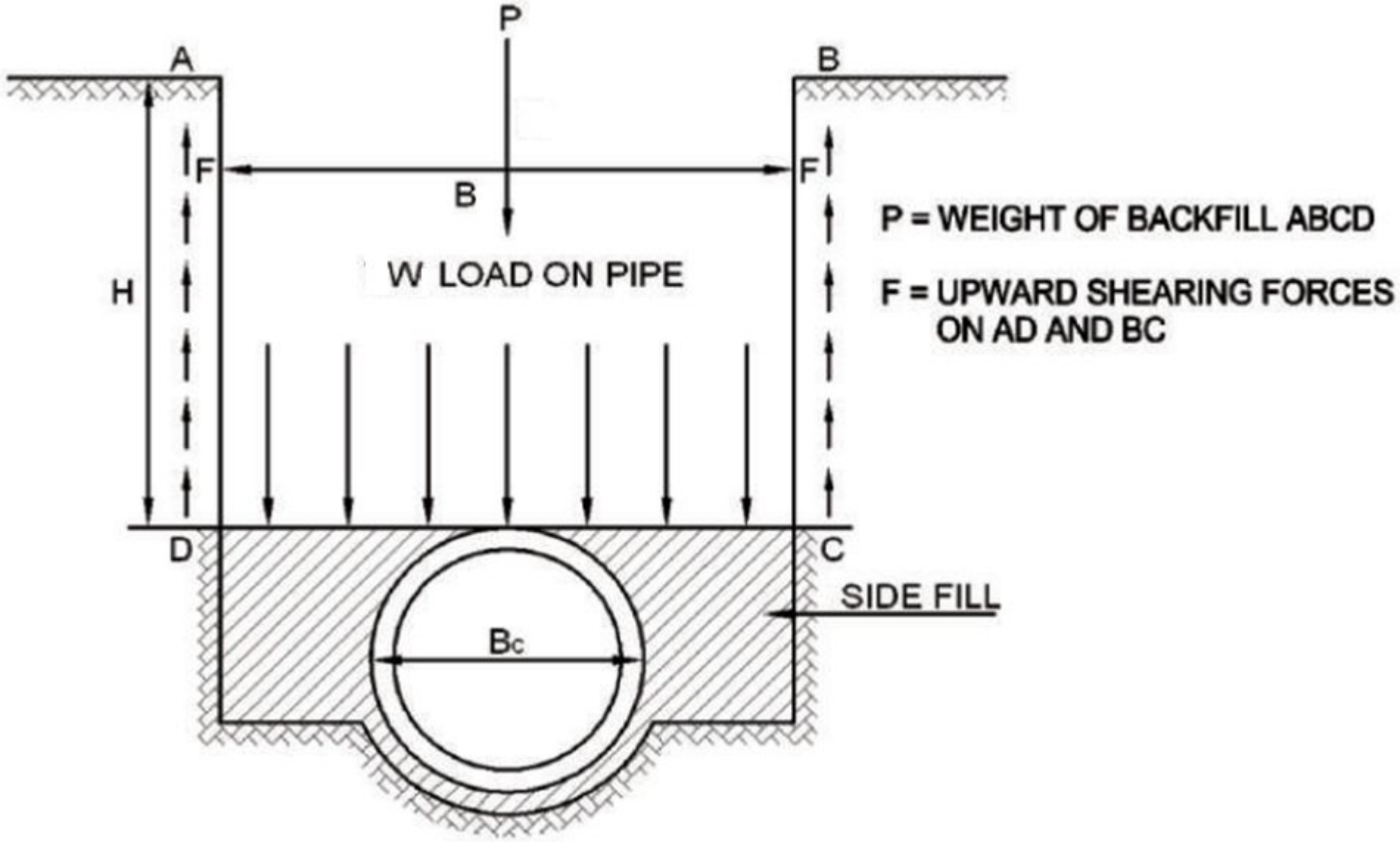
Z = 0.308 (393.43x1.111)/ $(0.0015)^{1/2}$x $(0.6)^{1/3}$

Z= 0.308 (393.43 x 1.111)/(0.03873 x 0.8434) ≈ 134.63/ 0.03266 ≈ 4,122

The potential for Sulfide Generation (Z) is 4,122. Since this value is less than 5,000, sulfide generation is **likely** not to occur.

Loads on Sewer

- In a buried sewer, stresses are induced by external loads and by internal pressure in case of a pressure main.
- The external loads are of two categories viz., load due to backfill material known as backfill load and superimposed load, which again is of two types viz. concentrated load and distributed load.
- The load on a buried conduit is equal to the weight of the prism of earth directly over the conduit, called the interior prism of earth plus or minus the frictional shearing forces transferred to the prism by the adjacent prism of earth.


P
A
B
F
F
B
W LOAD ON PIPE
H
P = WEIGHT OF BACKFILL ABCD
F = UPWARD SHEARING FORCES
ON AD AND BC
D
C
SIDE FILL
Bc

Loads on Sewer

The general form of Marston's formula is

$$W = C\,w B^2$$

Where,

W : Load on the pipe in kg/m

w : Unit weight of backfill soil in kg/m^3

B : Width of trench at the top of the pipe in m and

C : Load coefficient which is a function of a ratio of height of fill to width of trench (H/B) and of the friction coefficient between the backfill and the sides of the trench.