WASTEWATER AND STORM WATER COLLECTION SYSTEM

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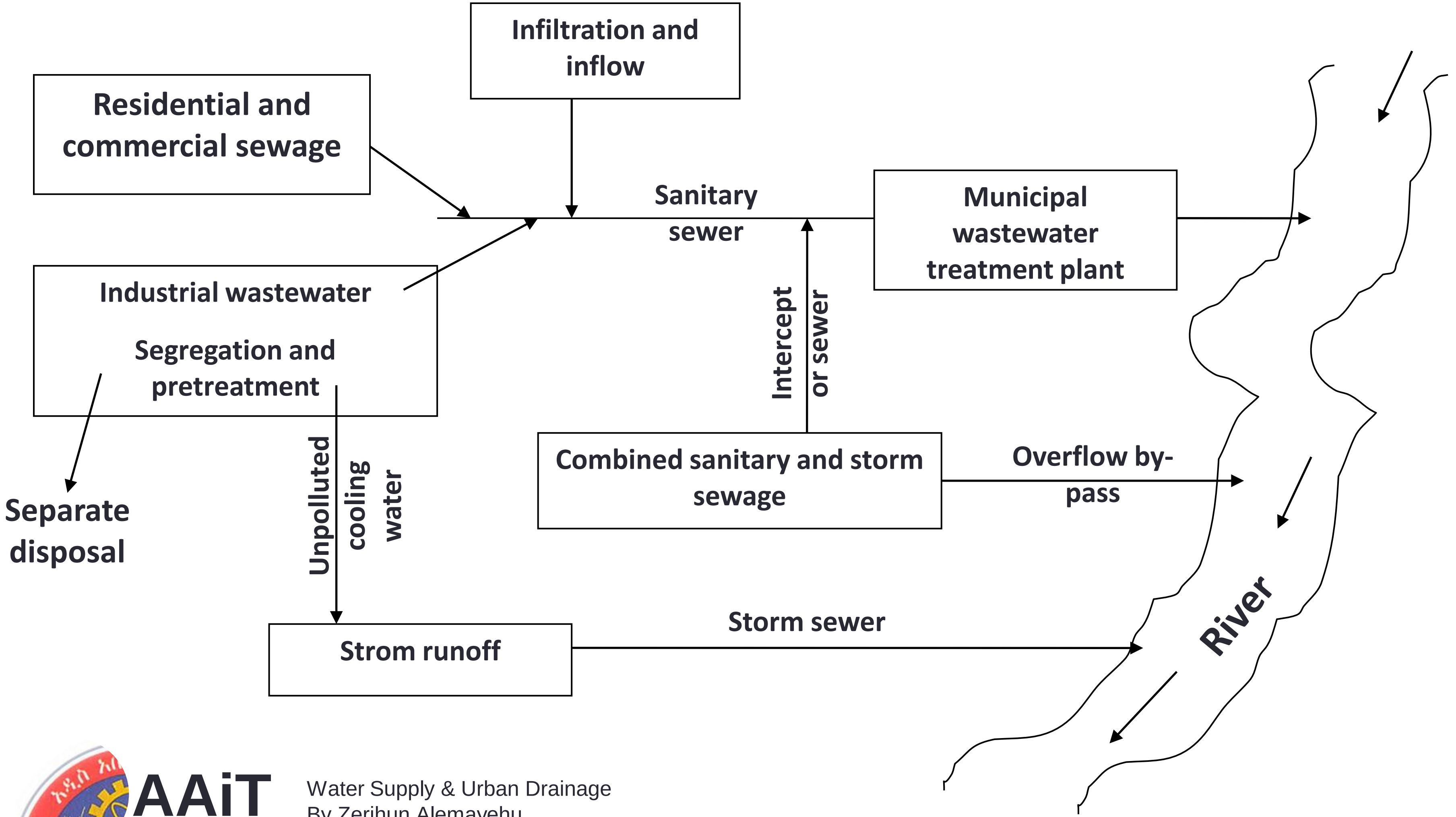
WASTEWATER AND STORM WATER

Sewage municipal wastewater and storm runoff.

Sewer: individual pipe line used to collect sewage

Sewerage: the system that is used for collecting sewage

Sources and quantities of sewage



Sources and quantities of sewage

- ***Domestic sewage***
  - From residential and commercial districts
  - Other sources include institutional and recreational facilities.
  - **The net quantity** = accounted water supplied + unaccounted private water supplies + infiltration – (water losses + water not entering the sewerage)
  - 70 to 130 percent of accounted water supplied

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Sources and quantities of sewage

- ***Industrial waste water***
  - without internal reuse: 85-95% of the water used will probably become wastewater.
  - with internal water reuse → separate estimates must be made.
  - Average wastewater may vary from 30 - 95 l/capita/d.

Sources and quantities of sewage

- ***Infiltration/inflow***
  - *groundwater entering sewers through defective joints, and broken or cracked or broken pipes and manholes.*
  - High during wet period, especially sewers constructed in or close to streambeds
  - Quantity ← type of construction & GW level
  - Quantity may vary from 35 to 115 m^3/km.

Infiltration and Infow

- ***Infiltration:*** *groundwater entering sewers through defective joints, and broken or cracked or broken pipes and manholes.*
  - High during wet period, especially sewers constructed in or close to streambeds
- ***Inflow.*** *The water discharged into a sewer system, including service connections from such sources as roof downspouts; basement, yard, and area drains; manhole covers; surface runoff; street wash water; etc.*
  - Quantity may vary from 35 to 115 m^3/km.
  - Units: L/ha/day, L/km length, or L/cm diameter

Sources and quantities of sewage

- ***Storm sewage***
  - hydrological analysis: Rational method, the SCS technique, hydrograph technique and computer simulation techniques
  - Depends on the type of precipitation, the intensity and duration of rainfall, the rainfall distribution, the soil moisture deficiency, catchments characteristics, etc

Fluctuations in sewage flow

- The magnitude of the peak flow relative to the mean flow depends on the size of the contributing population;
- the larger the population, the lower the peaking factor since flow fluctuations are smoothed out during the time of travel in the sewer.
- The overall variation in the sewage is maximum in the smaller size sewers than large sizes.

Fluctuations in sewage flow

Types of Sewer	Ratio of Max/Avg flow
Small size sewers including laterals	4
Sewers up to 25 cm in diameter	4
Branch sewers up to 50 cm in diameter	3
Main sewers up to 100 cm in diameter	2
Trunk sewers up to 125 cm in diameter	1.5

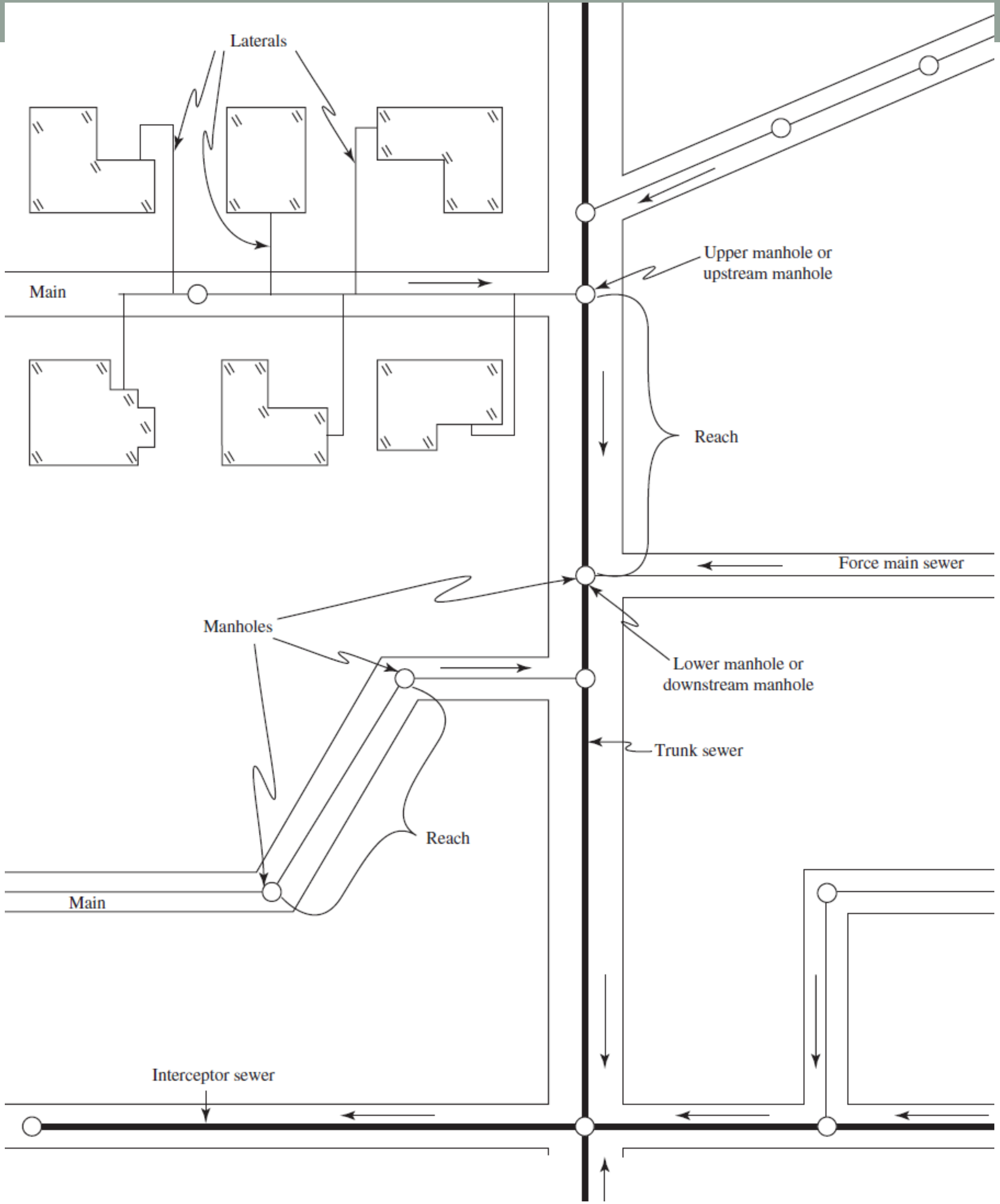
Sewerage systems

Combined system: a system composed of sewers that carry both domestic, with or without industrial wastewater, and storm sewage.

Separate system: a system composed of sewer that segregates the storm water from sanitary sewers.

Sewerage systems

- A ***house sewer***- conveying an individual structure to a common sewer or other point of disposal.
- *A* ***lateral sewer-*** a common sewer collects flow from house sewers.
- *A* ***submain sewer-*** collects sewage *from* one or more laterals as well as house sewers.
- *A* ***main or trunk sewer-*** collects flow from several sub-mains as well as laterals and house sewers.
- ***Force mains-*** pressurized sewer lines, which convey sewage from a pumping station to another main or to a point of treatment or disposal.
- ***An intercepting sewer-*** separates dry weather flow and conveys it to a wastewater treatment plant
- *A* ***relief sewer-*** a sewer, which is built to carry a portion of the flow in a system with inadequate capacity.
- *An* ***outfall sewer***- a sewer, which carries the collected waste to a point of treatment or disposal.

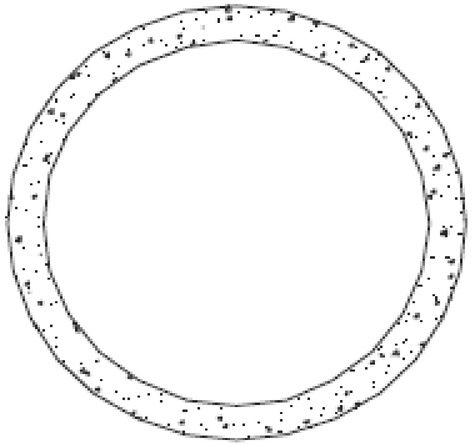


Laterals
Main
Upper manhole or upstream manhole
Reach
Force main sewer
Manholes
Lower manhole or downstream manhole
Trunk sewer
Reach
Main
Interceptor sewer

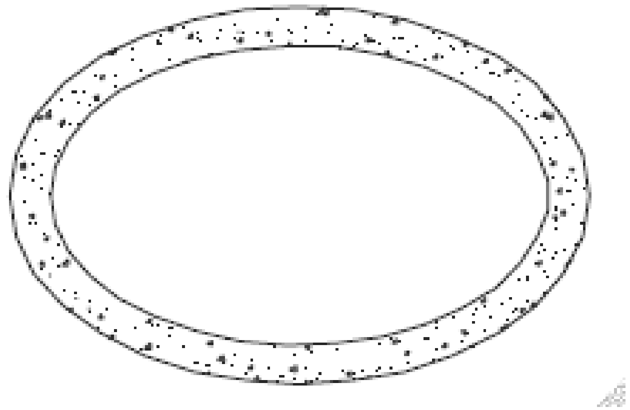
Sewer materials

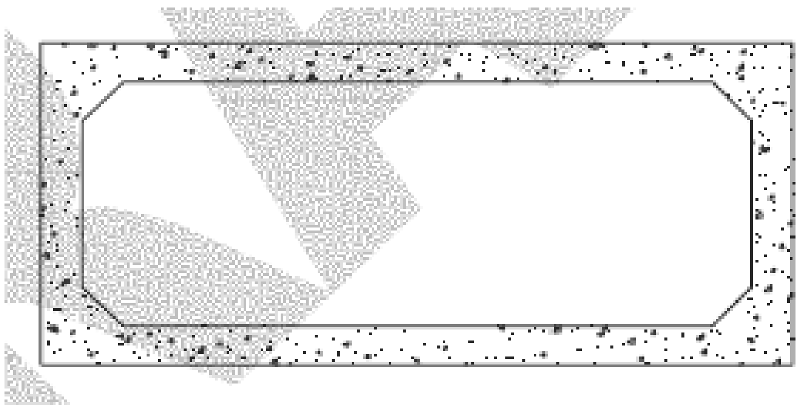
- Must be durable and strong to resist the abrasive and corrosive properties of the wastewater.
  - **Vitrified Clay Pipe (VCP)**
  - **Polyvinyl Chloride Pipe (PVC)**
  - **Ductile Iron Pipe (DIP)**
  - **High-Density Polyethylene (HDPE)**
  - **Reinforced Concrete Pipe (RCP)**
  - **Truss Pipe**

Sewer materials

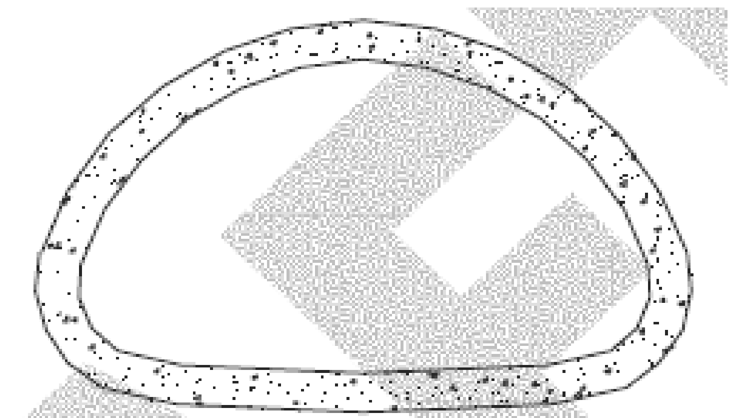


Circular



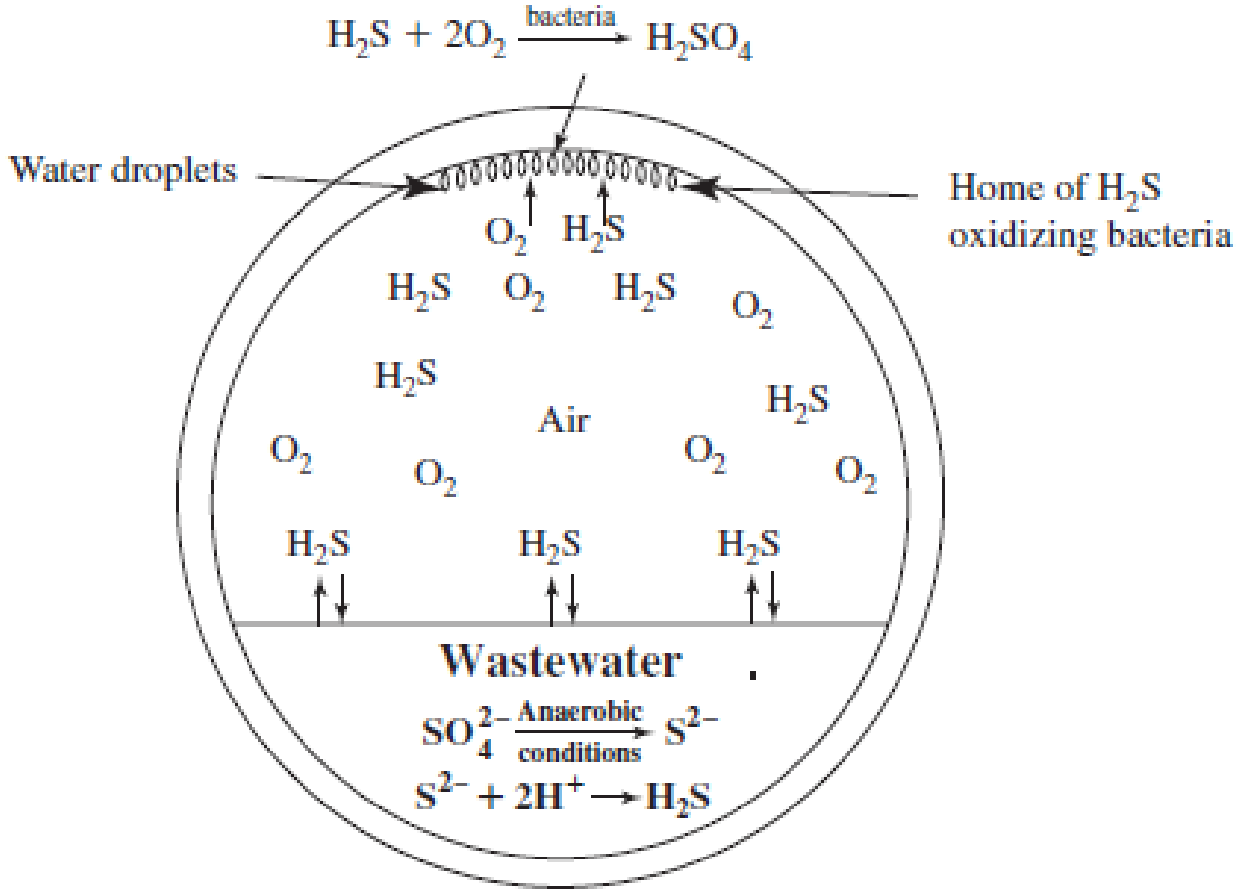


Rectangular



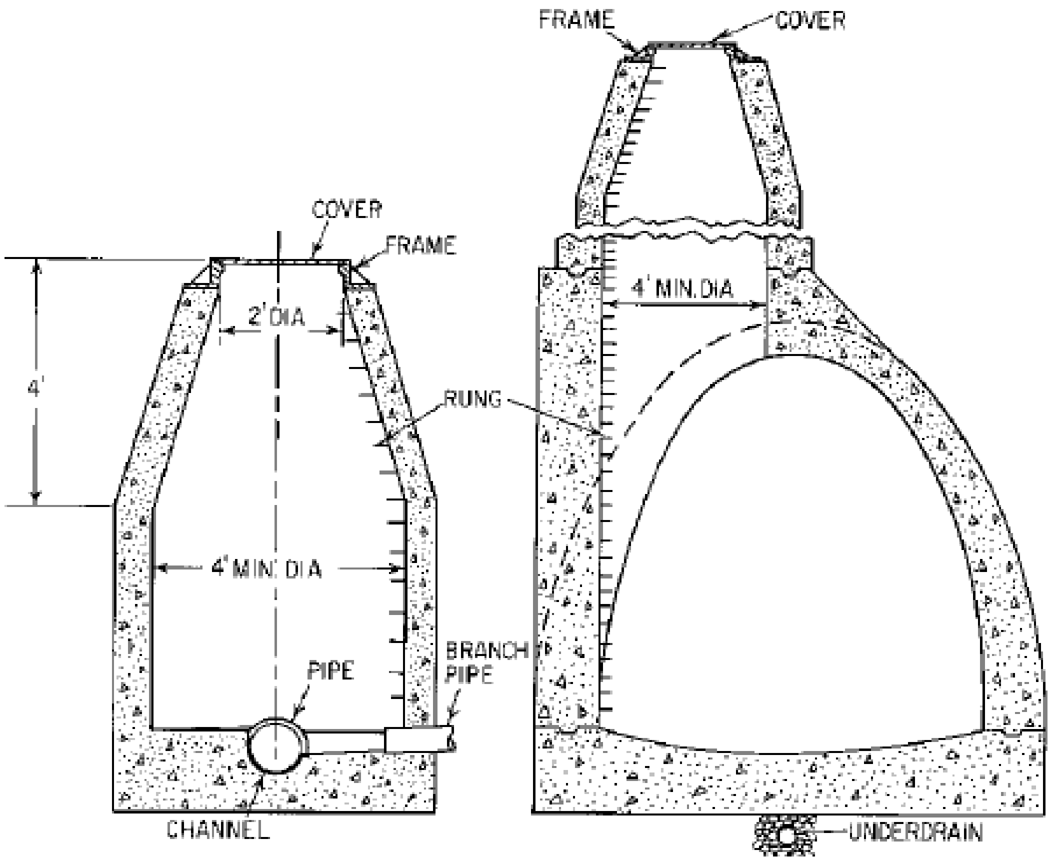
Arch

Crown Corrosion



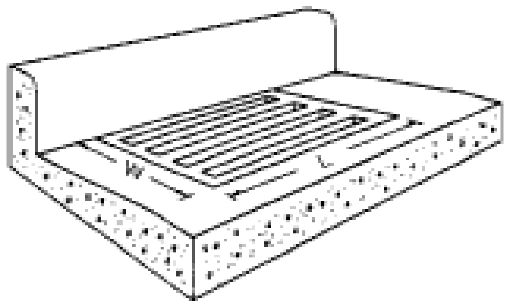
Sewer Appurtenances

- ***Manholes:***
  - used to allow a means of access into a sewer system for inspection, repair and cleaning.
  - placed at changes in direction, pipe size, grade and elevation, and at junctions, and at intervals of 90-120 m

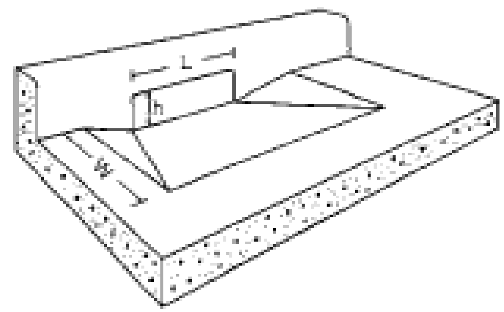


Sewer Appurtenances

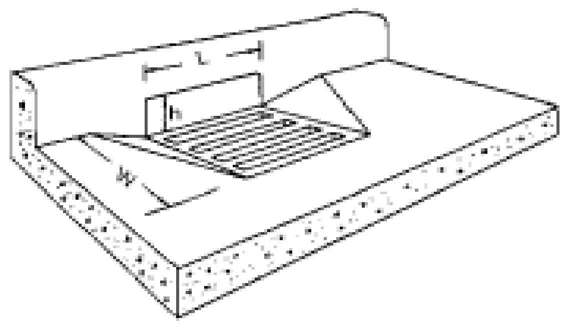
- ***Street Inlets***:
  - an opening into sewer for entrance of storm runoff.
  - placed at intersections and at intervals of 20 to 100 m.



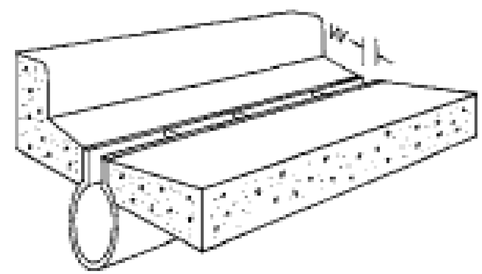
a. Grate



b. Curb-opening Inlet



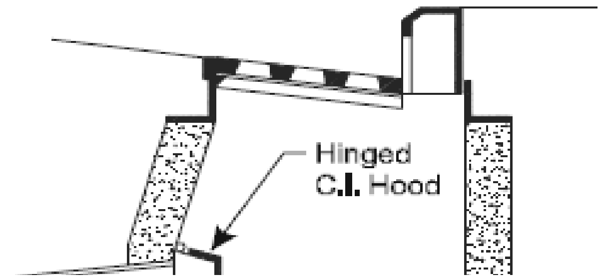
c. Combination Inlet



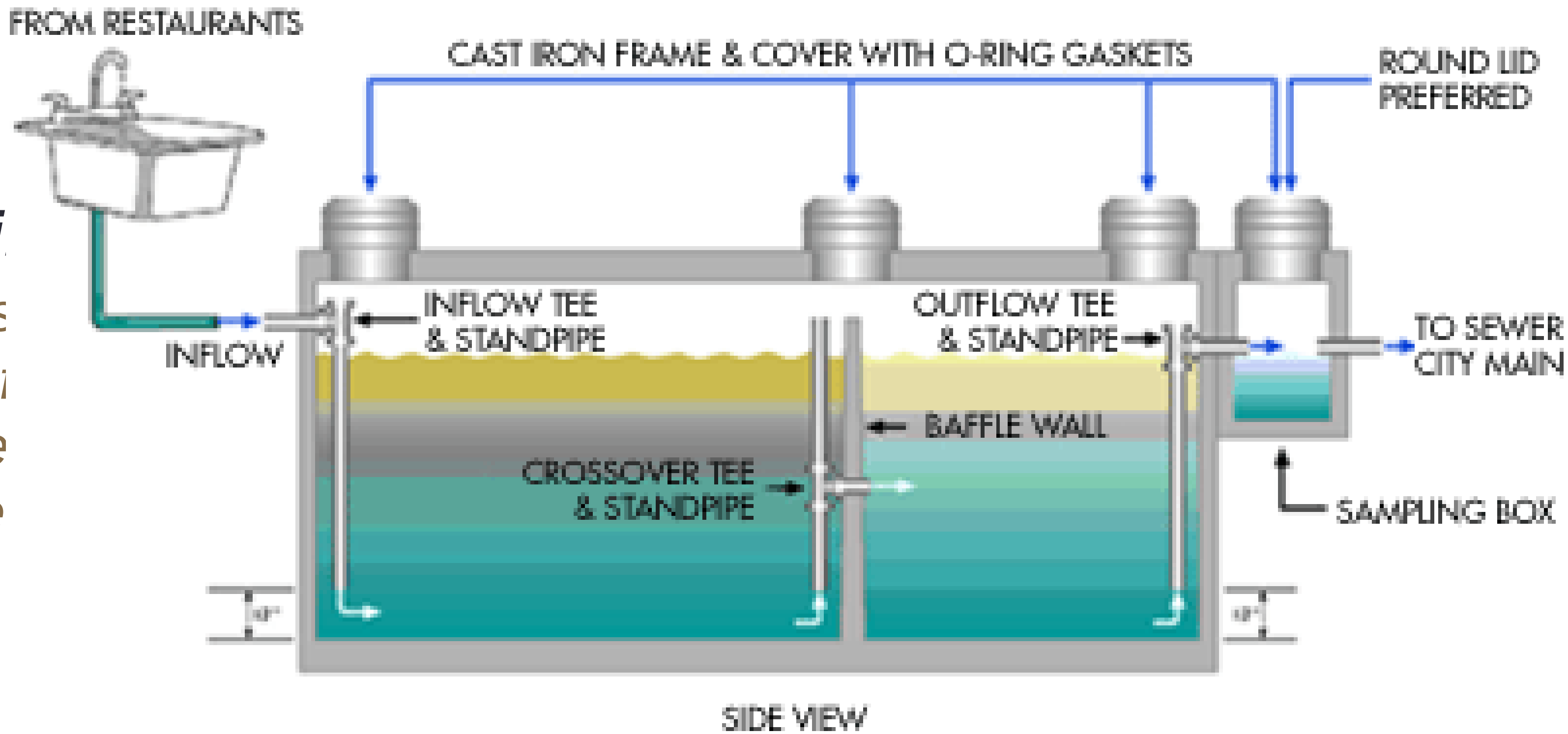
d. Slotted Drain Inlet

Sewer Appurtenances

- ***Catch Basins**:*
  - *inlets with a Basin, which allow debris to settle out*.



- ***Sand, Oi***
  Traps: *us*
  clogging o
  wastewate
  oil and gre



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Design of sanitary sewer systems

- Public sanitary sewers perform two primary purposes
  - Safely carry the design peak discharge
  - Transport suspended materials to prevent deposition in the sewers
- Wastewater sources are:
  - Domestic
  - Commercial
  - Industrial
  - Inflow & Infiltration

Design of sanitary sewer systems

- In designing a sewer system, the designer must
  - conduct preliminary investigations,
  - review design considerations and select basic design data and criteria,
  - design the sewers which include preparation of a preliminary sewer system and design of individual sewers, and
  - prepare contract drawings and specifications.

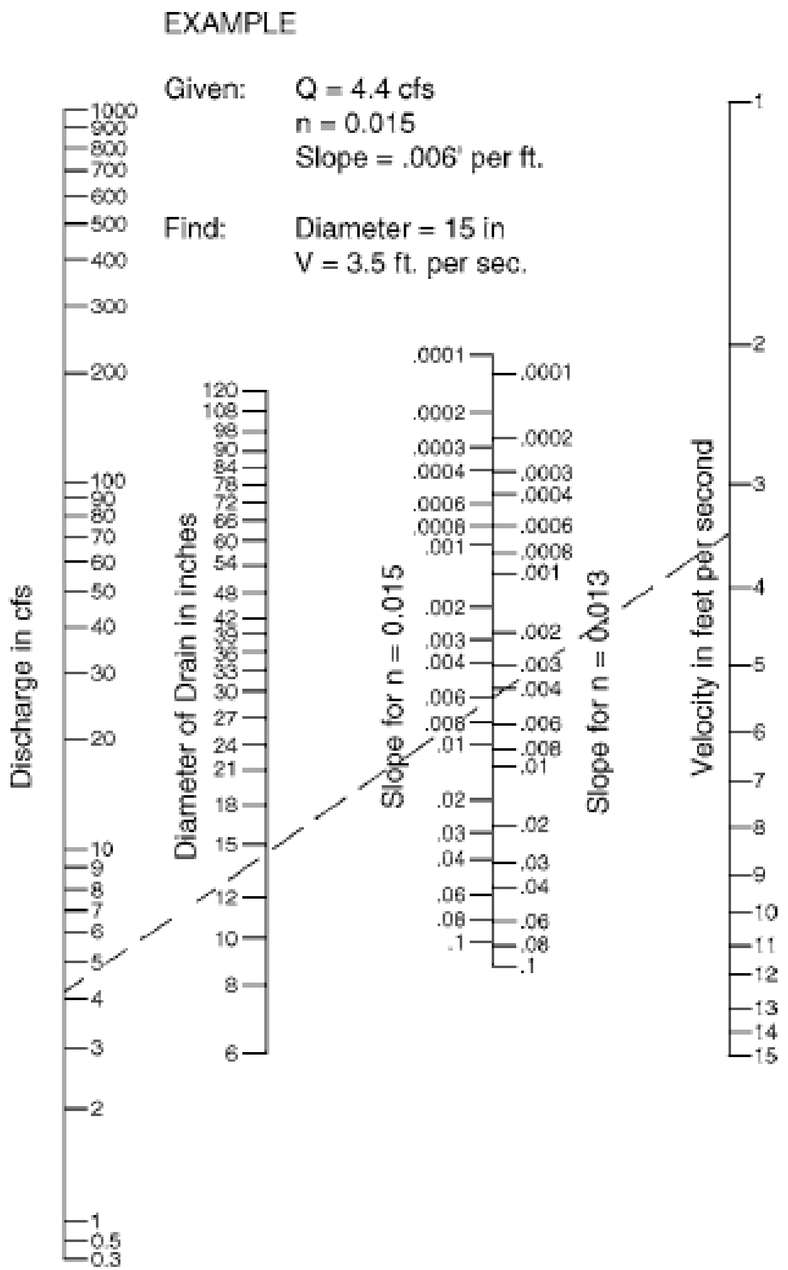
Design of sanitary sewer systems

- Designing a sanitary sewer involves
  - estimation of waste flow rates for the design data and evaluation of any local conditions;
  - the selection of the hydraulic-design equation,
  - alternative sewer pipe materials and minimum and maximum sizes,
  - minimum and maximum velocities and slopes;
  - the evaluation of alternative alignments or designs.

Design of sanitary sewer systems

- *Design flow*: peak hourly flow and peak infiltration allowance
  - $PF = 15.05\ Q^{-0.167}$
  - Where Q is in m^3/d
- *Hydraulic design equation:* Manning equations
  - $V=(1/n)R^{2/3}\ s^{1/2}$
- *Sewer Material and sizes:*
  - To avoid clogging > 200 mm dia. should be used.
- *Minimum and Maximum Velocity:*
  - minimum velocity of 0.6 m/s with flow at one half- full or full depth.
  - mean velocity of 0.75 m/s
  - maximum mean velocities of 2.5 to 3.3 m/s
- *Minimum slope* :to maintain self cleaning velocity of 0.6 m/s

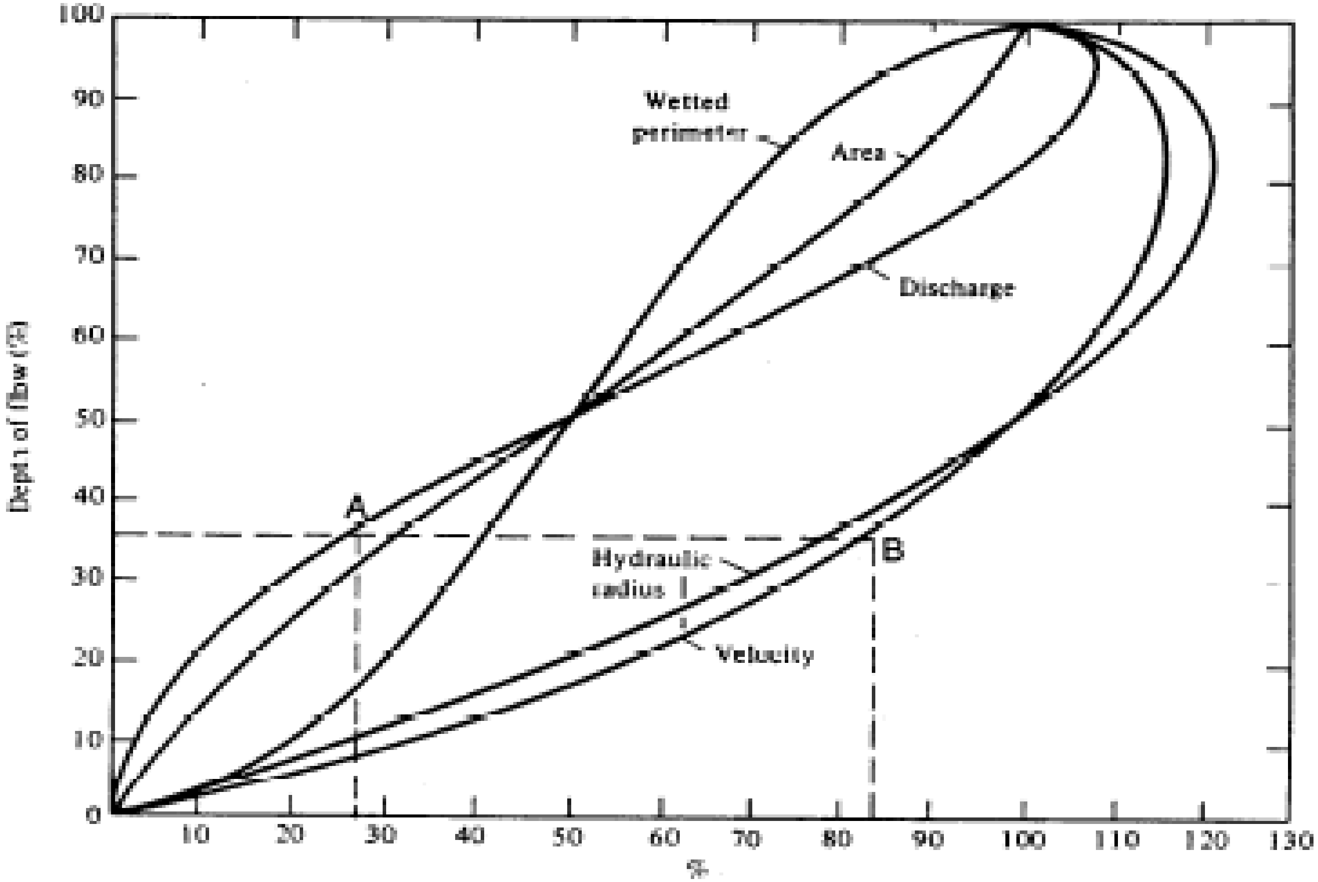
Design of sanitary sewer systems



Nomograph for solution of Manning's formula

Design of sanitary sewer systems

Hydraulic Elements For Circular Sewers



Hydraulic Elements $\frac{V}{V_f}$, $\frac{Q}{Q_f}$, $\frac{A}{A_f}$ and $\frac{R}{R_f}$

Examples 1: Design flow for sewer

A 40 hec drainage basin containing 24 hec net residential area with average 5 dwelling units per hec with 4 residents, and 16 hec zoned commercial area. Determine the design flow for a sewer servicing this area.

Take wastewater generation for

Residential = 300 l/capita/day

Commercial = 1800 l/hec/day

Peak I & I allowance = 9000 l/hec/day

Example 1 solution

- ADF for residential area

  (24 hec x 5 DU/hec x 4 Res./DU x 300 l/Res) = 144m^3/day
- ADF for commercial area

  (16 hec x 1800 l/Hec) = 288 m^3/day
- ADF from Res. And Comm area

  = 144 m^3/day + 288 m^3/day = 432 m^3/day
- Calculate peaking factor

  PF= 15.05 $Q^{-0.167}$ =15.05x $(432)^{-0.167}$ = 5.45

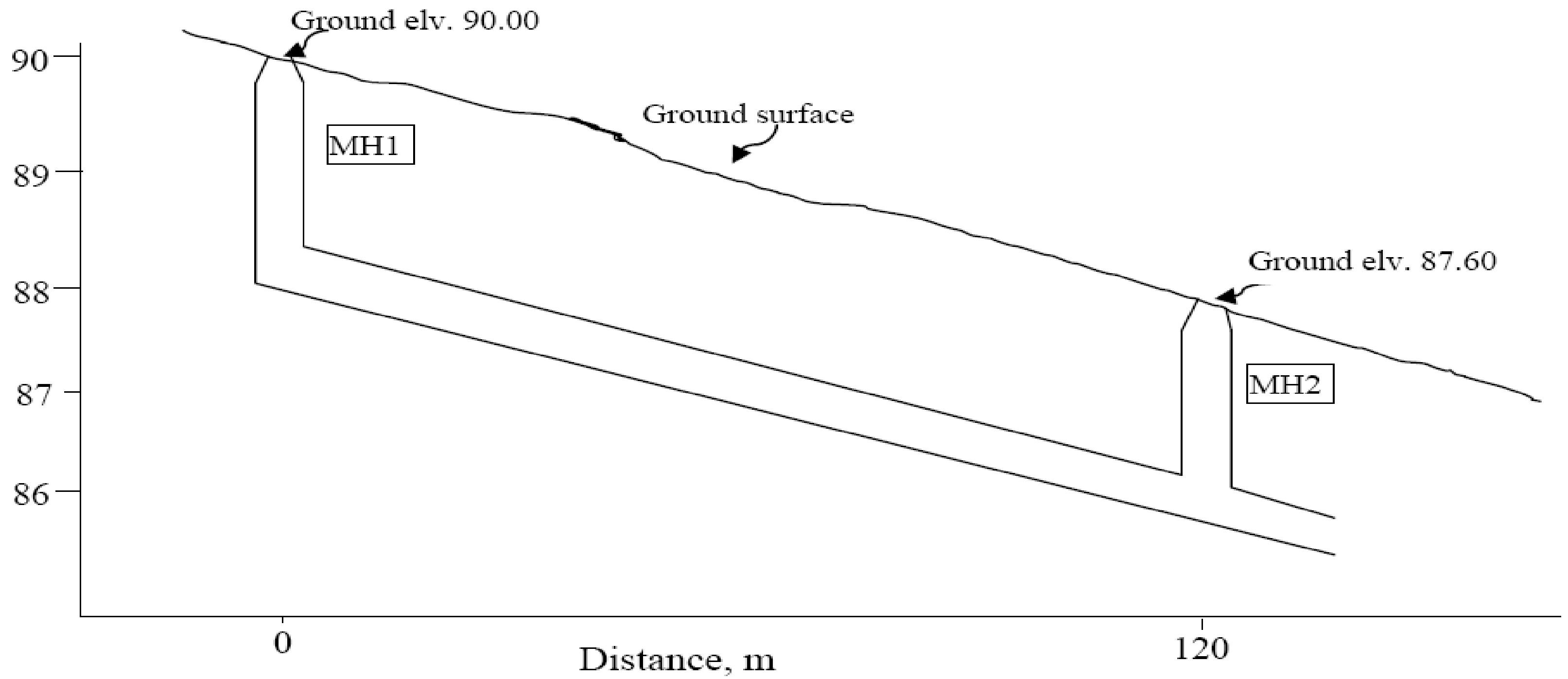
- Calculate PDF

PDF = 5.45 x 432 + I & I = 2354.4 + 9 x40=2714.4 m^3/day

= 0.0314m^3/sec = 1.885 m^3/min

Example 2

A 120 m reach of sewer is to be designed with a flow capacity of 100 L/s. The street elevation at the upper manhole is 90.00 m and the lower manhole is 87.60 m, as shown below. Determine an appropriate pipe diameter and slope for this reach, and establish the pipe invert elevations at the upper and lower manholes. Assume a minimum earth cover of 2 m above the crown of the pipe.



Example 2 Solution

- ground slope = (90 – 87.6)/120 = 0.02
- Enter the Manning's monograph with s = 0.02 and Q = 100 L/s
- We read d = 260 mm → take standard dia. of 250mm → but the slope has to be steeper, about 0.03 to have a capacity of 100 L/s
- If the slope is 0.03 the drop will be 0.03 x 120 = 3.6 m which means extra cover of 3.6 – 2.4 =1.2 m
- ∴ select a larger dia. Of 300 mm at 0.02 slope → full-flow capacity would be 135 L/s.
- → we have partial flow condition
- → q/Q_f =100/135 = 0.74 → we read d/D = 0.63 from partial flow diagram → d = 0.63 x 300 = 190 mm of depth of flow
- The full flow velocity = 1.95 m/s
- For d/D = 0.63 → v/v_f = 1.06 → v = 1.06 x 1.95 = 2.1 m/s
- ∴ **select 300 mm dia. at 0.02 slope**

Example 2 Solution cont.

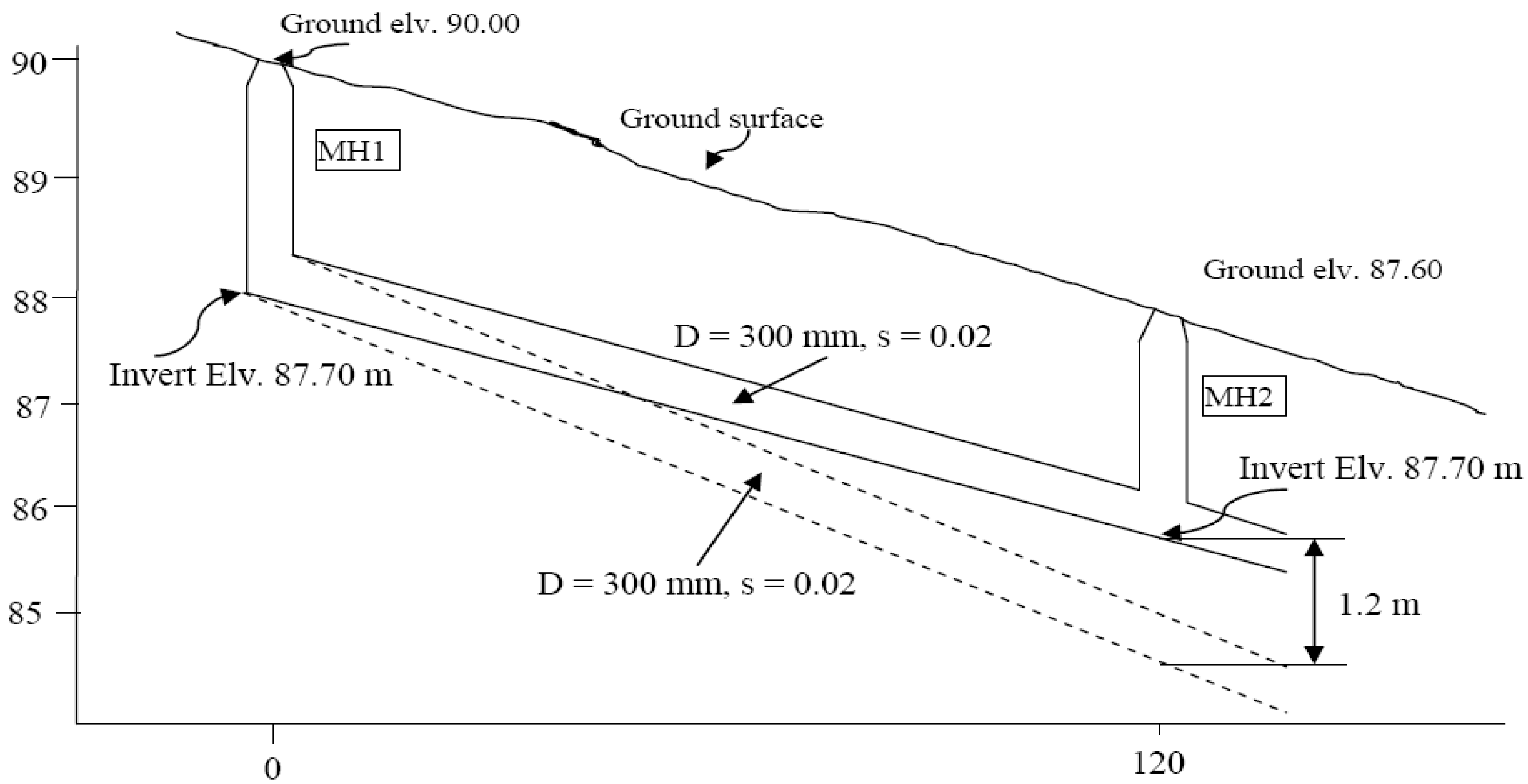
- Calculate the invert elevation
- Upper invert elevation = ground elv. - cover - pipe diameter

  = 90.00 - 2.00 - 0.3 = 87.70 m
- Drop in the elevation of sewer
  - Fall of sewer = 0.02 x 120 = 2.40 m

  = 90.00 - 2.00 - 0.3 = 87.70 m
- ∴ lower invert elevation = Upper invert elevation – fall of sewer

  = 87.70 - 2.4 = 85.30 m

Example 2 Solution cont.



Design of Strom Sewer

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Design of Strom Sewer

- Main purpose
  - To provide safe passage of vehicles
  - To collect, convey and discharge storm water
- Design involves
  - Layout of the sewer lines
  - Estimation of runoff from and area
  - Design of the sewer

Design of Strom Sewer

- Design methods
  - **Rational Method** - only for drainage areas less than 50 hectares (0.5 kilometer^2);
  - **SCS and other Unit Hydrograph Methods** - for drainage areas greater than 50hectares;
  - **Suitable Computer Programs** - such as HYDRAIN's HYDRO, HEC 1, and TR-20 will be used to facilitate tedious hydrologic calculations.

Rational Method

- Assumption
  - Peak flow occurs when the entire watershed is contributing
  - Constant and uniform rainfall
  - Storm duration is equal to the time of concentration

Rational Method

$$Q = kCiA$$

- where
  - Q = runoff, m^3/sec
  - C = runoff coefficient
  - i = design rainfall intensity, mm/hr
  - A = area, ha
  - k = unit conversion constant, k = 1/360

Rational Method Cont.

- If an area that drains to a manhole consists of n land uses, the combined C value needs to be calculated by

$$C = \frac{\sum_{i=1}^{n} CiAi}{\sum_{i=1}^{n} Ai}$$

Type of surface	C
Watertight roofs	0.70-0.95
Asphalted cement streets	0.85-0.90
Portland cement streets	0.80-0.95
Paved driveways and walks	0.75-0.85
Gravel driveways and walks	0.15-0.30

Rational Method Cont.

- design rainfall intensity ← return period, and duration of rainfall (:time of concentration).
- rainfall of 2-5 years return period → for residential areas;
- Rainfall of 5-15 years return period → business and high value areas.
- The time of concentration refers to the time at which the whole area just contributes runoff to a point.

$$t_c = t_e + t_f$$

- Where,
  - t_c = time of concentration
  - t_e = time of entry to the inlet (usually taken as 5 – 10 min)
  - t_f = time of flow in the sewer

Concentration time

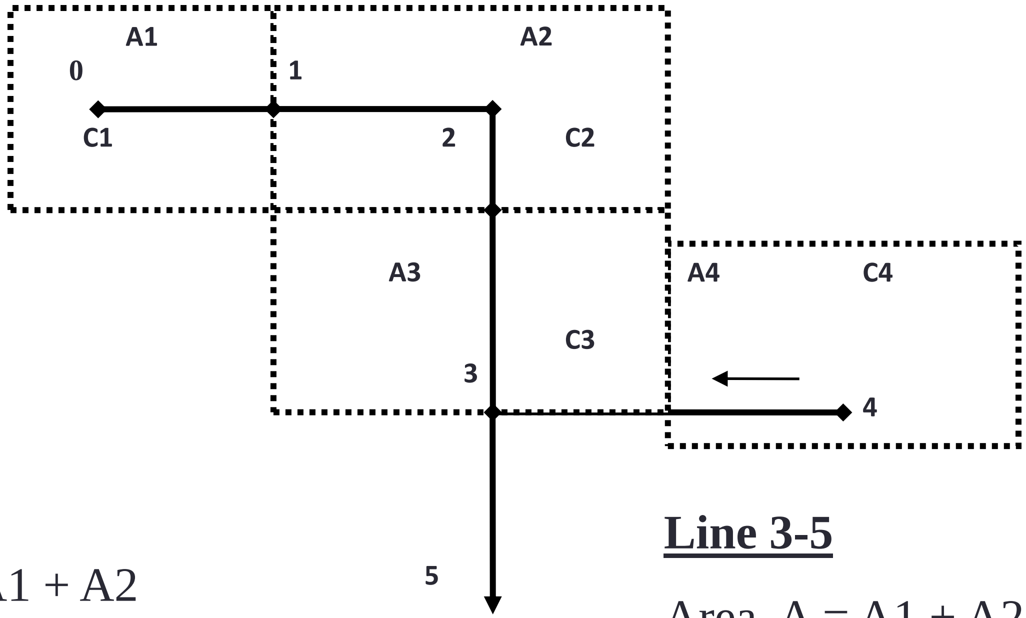
- ***Time of entry*** *(inlet time or overland flow):* is the time required for water to reach a defined channel such as a street gutter, plus the gutter flow time to the inlet.
- Kirpich's equation can also be used to calculate inlet time as

$$t_e = \frac{0.00032L^{0.77}}{S^{0.385}}$$

- ***Channel flow time***: is the time of flow through the sewers to the point at which rate of flow is being assessed.

$$inlet\ time = \frac{Channel\ length}{flow\ velocity}$$

Rational Method Cont.



Line 2-3

Area, A = A1 + A2

$C = (C_1A_1 + C_2A_2)/(A_1 + A_2)$

t_{c2} = greater of ($t_{eo} + t_{f0\text{-}2}$ or t_{e2})

i = intensity corresponding to t_{c2}

Line 3-5

Area, A = A1 + A2 + A3 + A4

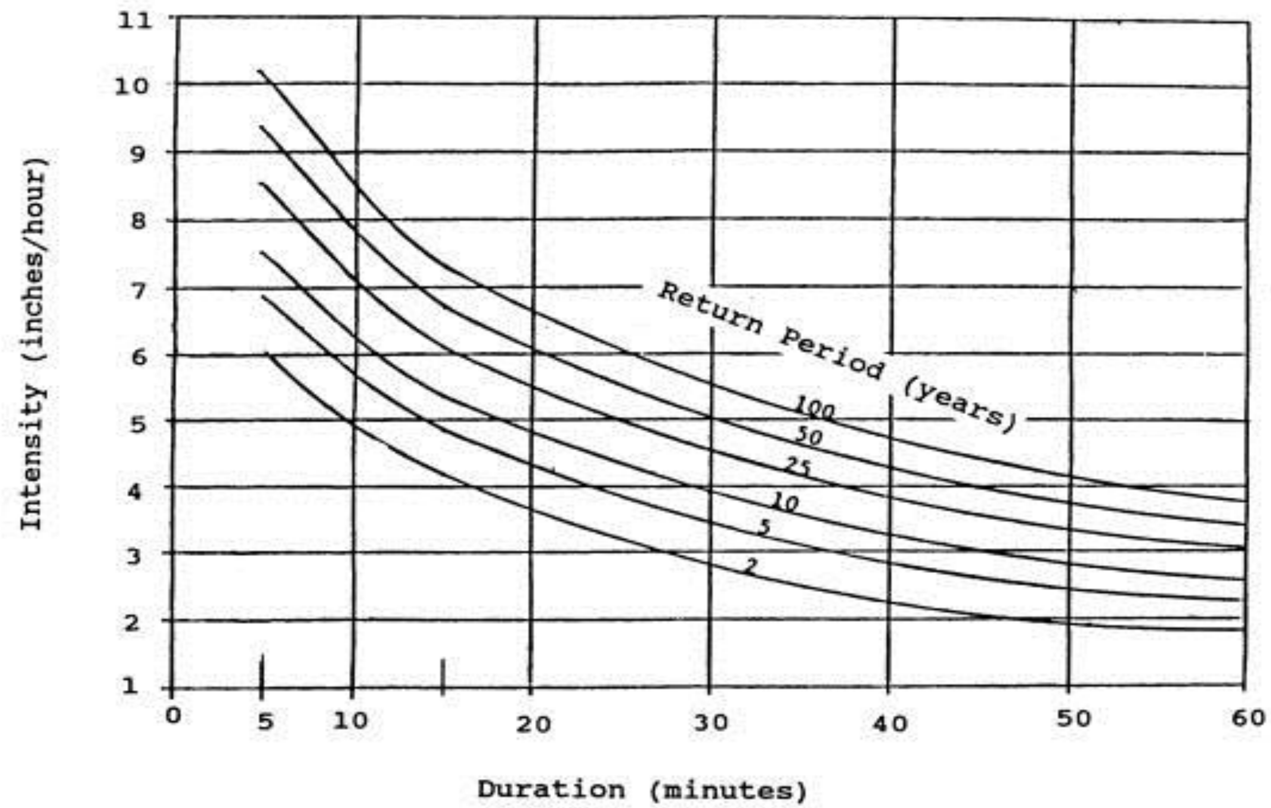
$C = (C_1A_1+C_2A_2+C_3A_3+C_4A_4)/(A_1+A_2+ A_1+A_2)$

t_{c3} = greater of ($t_{eo}+t_{f0\text{-}3}$, t_{e3} or $t_{e4}+t_{f4\text{-}3}$)

i = intensity corresponding to t_{c3}

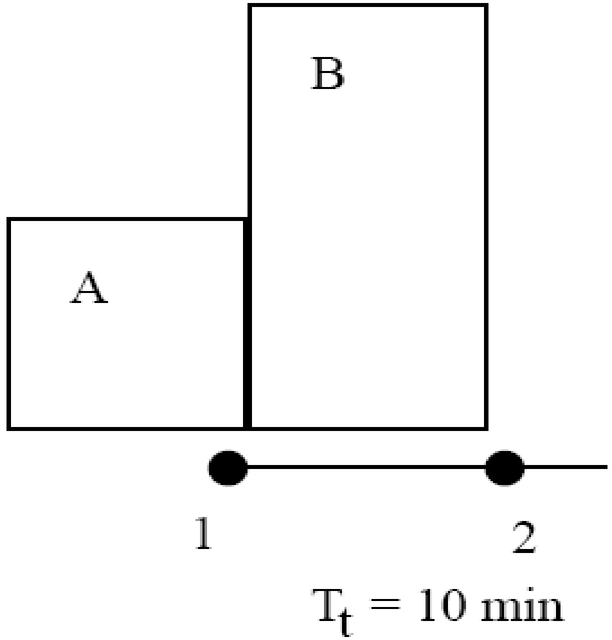
Rational Method Cont.

- The rainfall intensity can be read from the IDF curve or calculated by using a relevant formula.



Example 3

A storm sewer is proposed to drain a 12 hectares drainage area shown in the figure below. With given data in the table below determine the design discharge needed to convey 5-year peak discharge.



Site	Area (ha)	C	Inlet time (min)
A	4	0.8	10
B	8	0.5	30

i = 2700/(t + 15), for 5-year intensity

Where I in mm/hr and t in min

Example 3 Solution

- ***Upstream Area (Manhole 1):***

  A = 4 ha

  C = 0.8

  tc = 10 min

  i = 2700/(10+15) = 108 mm/hr

  Qp = *CiA/360* = (0.8)(108)(4)/360 = 0.96 m^3/sec

- ***Downstream Area (Manhole 2):***

  A = 4 +8 = 12 ha

  C = (0.8 x 4 + 0.5 x 8)/ 12 = 0.6

  Time from A – 1 – 2 : 10 + 10 = 20 min

  Time from B – 2 : 30 min (**max**)

  tc = 30 min

  i = 2700/(30+15) = 60 mm/hr

  Qp = *CiA/360* = (0.6)(60)(12)/360 = 1.2 m^3/sec

- **Example:** From a topographic map and field survey, the area of the drainage basin upstream from the point in question is found to be 35 hectares. Determine the maximum rate of runoff for a 10-year. The following data were measured:
- Length of overland flow = 45 m Average overland slope = 2.0%
- Length of main basin channel = 700 m
- Slope of channel = 0.018 m/m = 1.8 %
- Manning's Roughness coefficient (n) of channel is, n = 0.090
- Hydraulic radius = A/P, can be approximated by average depth, = 0.6m
- Land Use and Soil Data
  - Residential (multi-units, attached) 40%
  - Undeveloped (2.0% slope),with lawns, heavy soil cover 60%
- For the undeveloped area the soil group:
  - Lawns, heavy soil100%
- The land use for the overland flow area at the head of the basin was estimated to be:
  - Undeveloped, (Lawns, heavy soil, 2.0 % slope) 100%

Solution

- Overland Flow
- The runoff coefficient (C) for the overland flow area from Table 4-2 is 0.12-0.17, use 0.14.
- Time of Concentration
- From Kirpich's formula with an overland flow length of 45 m, slope of 2.0 % and a C of 0.14, the inlet time can be calculated as:

$$t_e = \frac{0.00032L^{0.77}}{S^{0.385}}$$

$t_e = 0.00032 \times 45^{0.77} / 0.02^{0.385}$

$t_e = 0.027$ hr = 1.6 min

Solution…

- Channel flow velocity is determined from Manning's formula:
- $V = (1/n)R^{2/3}S^{1/2}$
- Using n = 0.090, R = 0.6 m and S = 0.018m/m, V = 1/1 m/s. Therefore,
- Flow Time = (700 m)/(1.1 m/s)(60 s/min) = 10.61 min and t_c = 1.6 + 10.61 = 12.21 min
-
- <u>Rainfall Intensity</u>
- From the equation given with a duration equal to 12.61 minutes,
- $I_{10} = 375/(12.61+5)^{0.71} = 49$ mm/hr

Solution…

- <u>Runoff Coefficient</u>
- A weighted runoff coefficient (C) for the total catchment area is determined in the following table by using the values from Tables 4-1

Land use	Area	Coefficient	Weighed coefficient
Residential (multi-units, attached)	40%	0.68	0.27
Undeveloped	60%	0.14	0.08
Total Weighted Runoff Coefficient			0.35

<u>Peak Runoff</u>

From the rational equation:

Q_{10} = CIA/360 =0.35 x 49 mm/h x 35 ha/360 = 1.67 m^3/s

THE END

"We are born of all the things we know
And we are forms of all the things we love."