Wastewater Collection Systems

PDH: 4.0 Hours

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1. Introduction

This course presents the principles and practices of wastewater collection system. This will outline the preliminary sewer design issues, the hydraulic design of gravity and pressure sewers, sewer system layout, appurtenances, facilities act, regulatory stands, and permitting requirements, structural design of sewer lines, and the essential steps for sewer management and operation. This course will also discuss how to approach evaluation and rehabilitation of existing sewer systems. This course is ideal for civil engineers and other design and construction professionals looking for an introduction to the design, operation, and maintenance of wastewater collection systems.

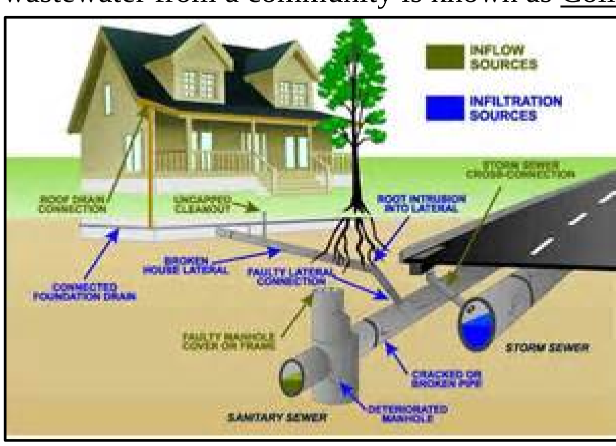
2. Learning Objectives

Upon successful completion of this course, the participants will be able to:

- Define the common terminology used in the wastewater collection systems.
- Describe different types of wastewater collection systems.
- Comprehend the basic considerations of wastewater collection system design.
- Design a circular sewer system.
- Elaborate the construction specifications and contract drawings.
- Discuss the essential steps for sewer management and operation.

3. Wastewater Collection System

The water supply of a community is considered to be wastewater. The individual pipes used to collect and transport wastewater are called ***sewers***, and the network of sewers used to collect wastewater from a community is known as Collection System (Figure 1).



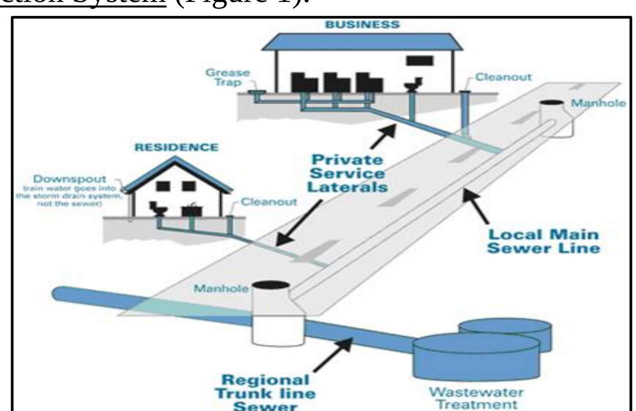


Diagram of a sanitary sewer system

Figure 1: An overview of wastewater collection systems

A sewer collection system includes everything except the sewer plant. All lines, lift stations, pump stations, manholes, and anything that sewage touches on its way to the sewer plant. Generally, the municipality is responsible for maintaining the collection system from the time the sewage leaves the lateral line and enters the main.

4. Definition of Terms

Domestic Sewage: Liquid waste generated from residences, business buildings, and institutions is known as domestic or sanitary sewage.

Industrial Sewage: Liquid waste generated from industrial establishments is known as industrial sewage.

Sewage: Combination of domestic and industrial wastes and stormwater.

Sullage: The water from kitchen, baths, sinks, and similar appliances from buildings which does not contain human or animal excreta is called **sullage**.

Sewer: A pipe carrying sewage is called a **sewer**.

Sewerage: The system of pipes laid for carrying sewage is **sewerage**.

5. Types of Collection Systems

Based on the mode of collection/deliver, the collection systems are classified as Gravity, Low Pressure, and Vacuum collection systems.

5.A Gravity Collection System

The primary type of public sanitary sewer collection system is a gravity system (Figure 3). A gravity system is so named because the wastewater flows down gradient in the sewer, driven by forces of gravity. Various sizes of sewers are generally laid at a minimum slope to ensure open channel flow through the pipe at a minimum velocity of 2.0 feet per second. The minimum velocity is required to ensure that solids do not settle out in the sewer. Gravity sewers are a minimum of 8-inch diameter pipes with manhole structures located at changes in horizontal alignment and vertical slope changes. The maximum distance between manholes is 400 feet.

5.B Low Pressure Collection System

Low pressure sewer systems are used in areas where the use of gravity sewers is impractical due to topography or economic reasons. Low pressure systems (Figure 2) are often found around lakes and in rolling terrain. Wastewater is collected on-site and pumped from a small grinder pump into a small diameter force main. The private force main discharges into a larger public force main. A check valve is used near the end of the private line to prevent wastewater in the public force main from entering the private force main. In most cases, the low-pressure public force main then discharges into a public gravity collection system. Private force main pipes are typically 1-½ to 2-inches in diameter. Public force mains typically vary in size from 2- to 6-inches in diameter. Force mains are designed to maintain minimum velocities of 2.0 feet per second. Low pressure force mains are also used for discharge from pumping stations. Force main pipe from pumping stations typically varies from 4- to 12-inches in diameter, depending on the size of the pumps in the pumping station.

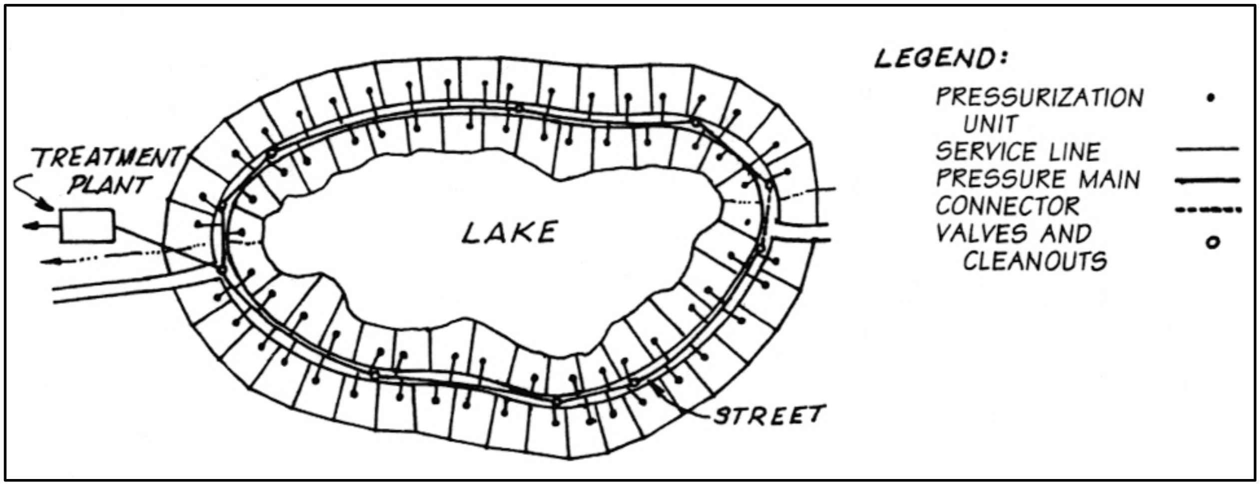


Figure 2: Typical view of low-pressure collection system[2].

5.C Vacuum Collection System

Vacuum collection systems are used for the same reason as low-pressure systems (Figure 3). However, it is rare to find a vacuum collection system in use in Pennsylvania as this is a fairly new collection alternative in the United States, and operation and maintenance is more difficult than a low-pressure system. Wastewater is collected on-site by a valve pit/sump, and a 4-inch vent is located on the service lateral between the residence and the valve pit/sump to provide air into the system. Piping connects the individual valve pit/sump and the collection tank. A vacuum station that includes vacuum pumps produces a vacuum, which transports the wastewater from the vacuum sewer lines to the treatment plant via a pressurized line.

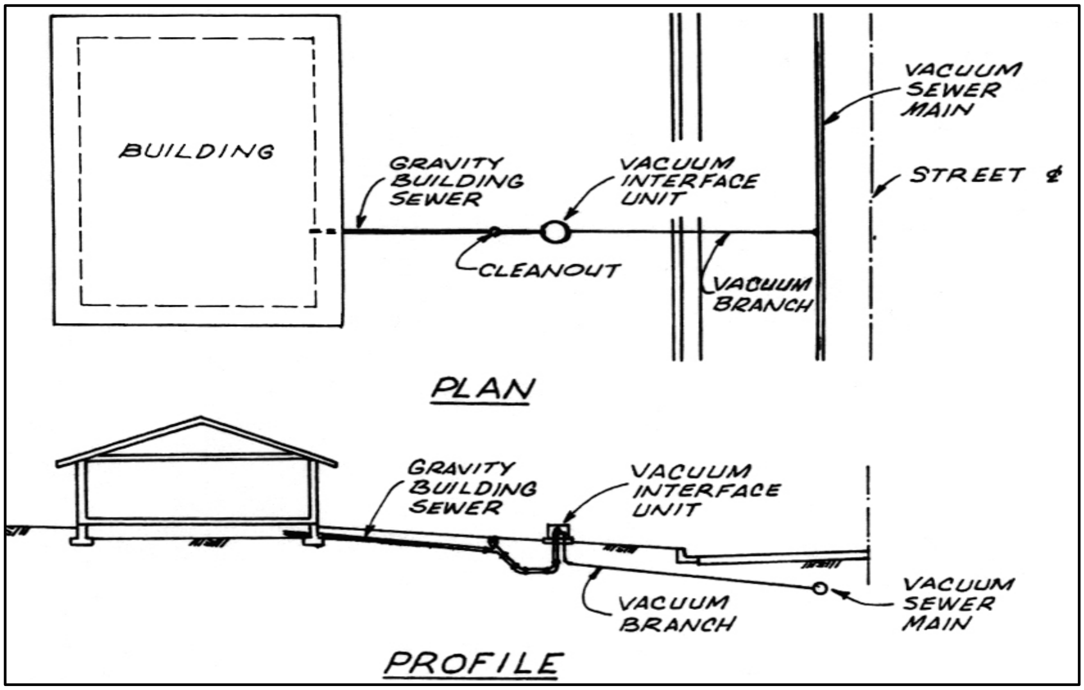


Figure 3: Typical view of vacuum collection system[2].

Based types of wastewater carried by the collection systems, the systems are classified as follows:

a. Separate Sewer System aka Sanitary Sewer (Municipal Sewer)
b. Stormwater Sewer System
c. Combined Sewer System

Separate (or Sanitary) Sewer: Identified as separate sewers and it is developed to mainly remove domestic sewage from residential areas. Sanitary sewer collection systems are responsible for collecting and conveying wastewater that is generated at residential dwellings and commercial and industrial buildings to the wastewater treatment plant for treatment. Figure 1 shows that household wastewater and roof drain are collected by two sets of pipes: One is draining to lake and the other is draining to wastewater treatment plant (WWTP). It is the system in which storm water is carried separately from domestic and industrial wastewater. This system is preferred when:

- There is an immediate need for collection of sanitary sewage but not for storm water
- When sanitary sewage needs treatment, but the storm water does not.

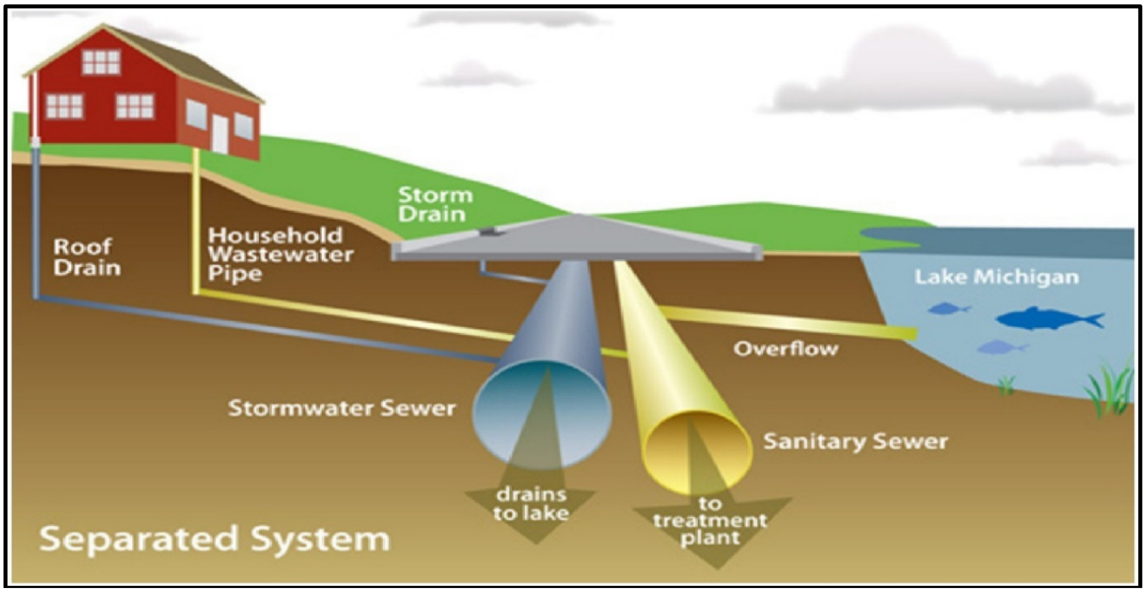


Figure 4: An overview of separate sewer system

Storm Sewer: It is solely used to collect stormwater. Usually larger than sanitary sewer (Figure 1).

Combined Sewer: It is the type of system in which sewer carries both the sanitary and storm water. Combined system is favored when

- Combined sewage can be disposed off without treatment
- Both sanitary and storm water need treatment
- Streets are narrow and two separate sewers cannot be laid.

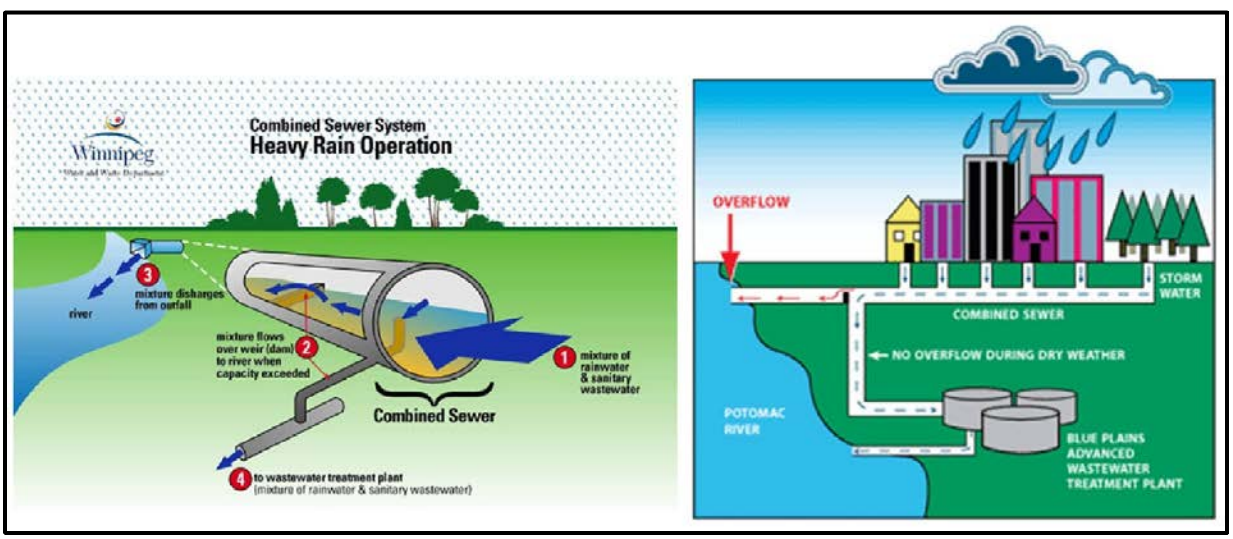


Figure 5: An overview of combined sewer system

6. Types of Sewers

The types of sewers vary with size collection system and the location of the wastewater treatment plants. The principal types of sewers are:

a. **Building Sewers –** Sometimes called building connections that are used to convey Wastewater from buildings to lateral or branch sewers or any other sewers except another building sewers.

b. **Lateral or branch Sewers –** 1st element of the Wastewater collection system that are used to convey Wastewater from one or more building sewers to the main sewers.

c. **Main Sewers –** are used to convey Wastewater from one or more lateral sewers to trunk sewers or to intercepting sewers.

d. **Trunk Sewers –** are the large sewers in the collection system that are used to convey Wastewater from main sewers to treatment plants or to larger intercepting sewers.

e. **Intercepting Sewers –** are the larger one that are used to intercept a few main or trunk sewers and convey wastewater to the treatment plants.

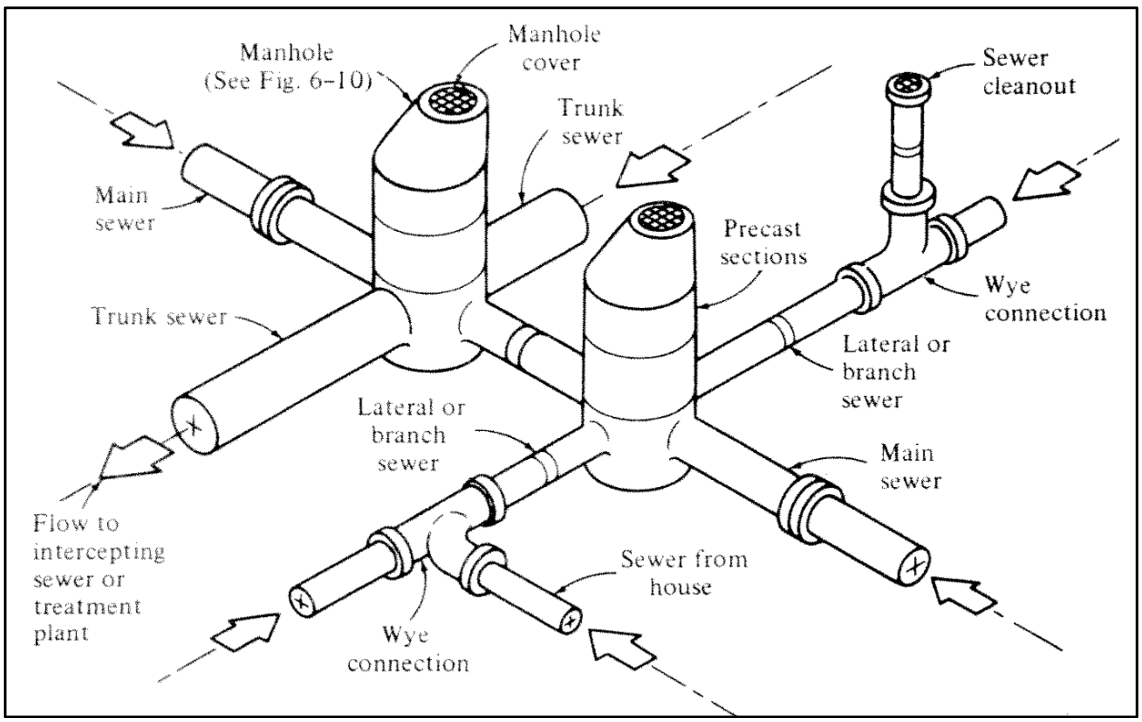


Figure 6: Definition sketch for types of sewers used in collection systems[1].

7. Shapes of Sewers

There are five shapes of sewers that are usually used in wastewater collection system design and construction. The five shapes are rectangular, circular, semi-elliptical, horse-shoe and egg-shaped.

Rectangular – RCC and may be pre-cast or cast in-situ

Circular – commonly used – may be concrete or HDPE

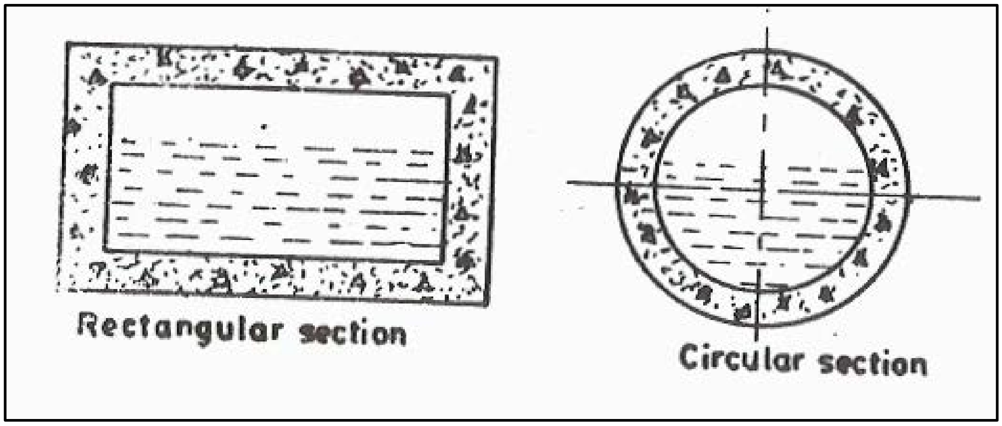


Figure 7: Typical rectangular and circular sewers[1]

Semi-elliptical – Made of mainly RCC and very stable

Horse-shoe - suitable for heavy discharge

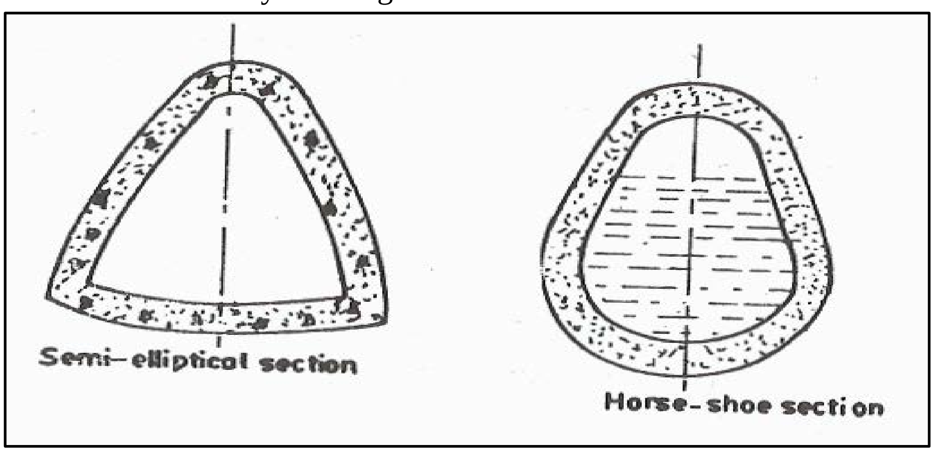


Figure 8: Semi-elliptical and horse-shoe sewers[1]

Egg-shaped – Gives good hydraulic properties even better than circular

Figure 9: Typical egg-shaped sewer

8. Collection System Appurtenances

Appurtenances are machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended but are not considered to be a part of the main structure.[3] The primary appurtenances of sanitary sewers are:

a. Manholes
b. Drop inlets to manholes
c. Building connections, and
d. Junction chambers
e. Backflow preventers,

f. Cleanouts,

g. Laterals,

h. Inverted siphons and

i. Flow regulators

- **Manholes - Manholes are provided**
  - ✓ At every change in alignment
  - ✓ At every change in gradient
  - ✓ At every junction of two or more sewer lines
  - ✓ At heads of all sewers or branches
  - ✓ At every change in size of sewer
  - ✓ At regular intervals in the sewerage system (Table 1)

Table 1: Manhole spacing

Pipe Diameter (inch)	Spacing (ft)
up to 6	150
6 - 20	250
20 - 36	300
> 36	As provided by the authority

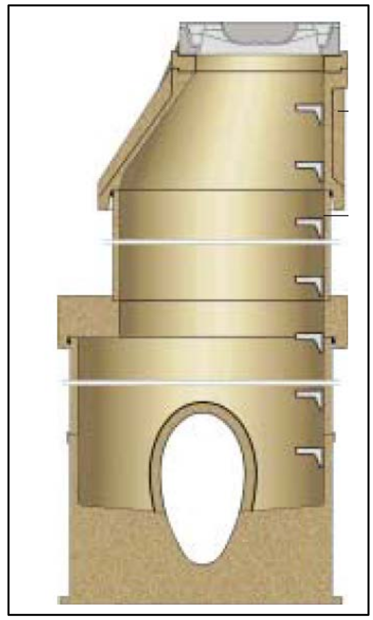


Figure 10: Typical manhole

- **Typical drop inlets to manholes**

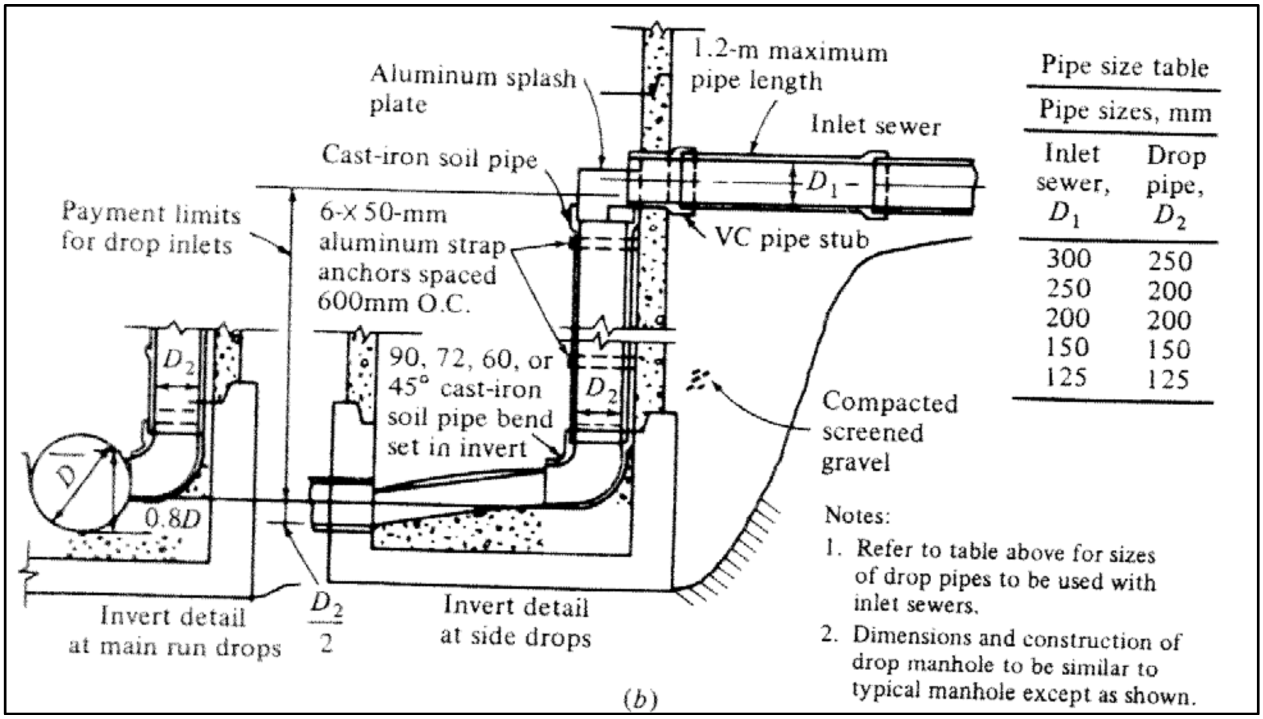


Figure 11: Typical drop inlet to manhole[1].

- **Typical Building Connections**

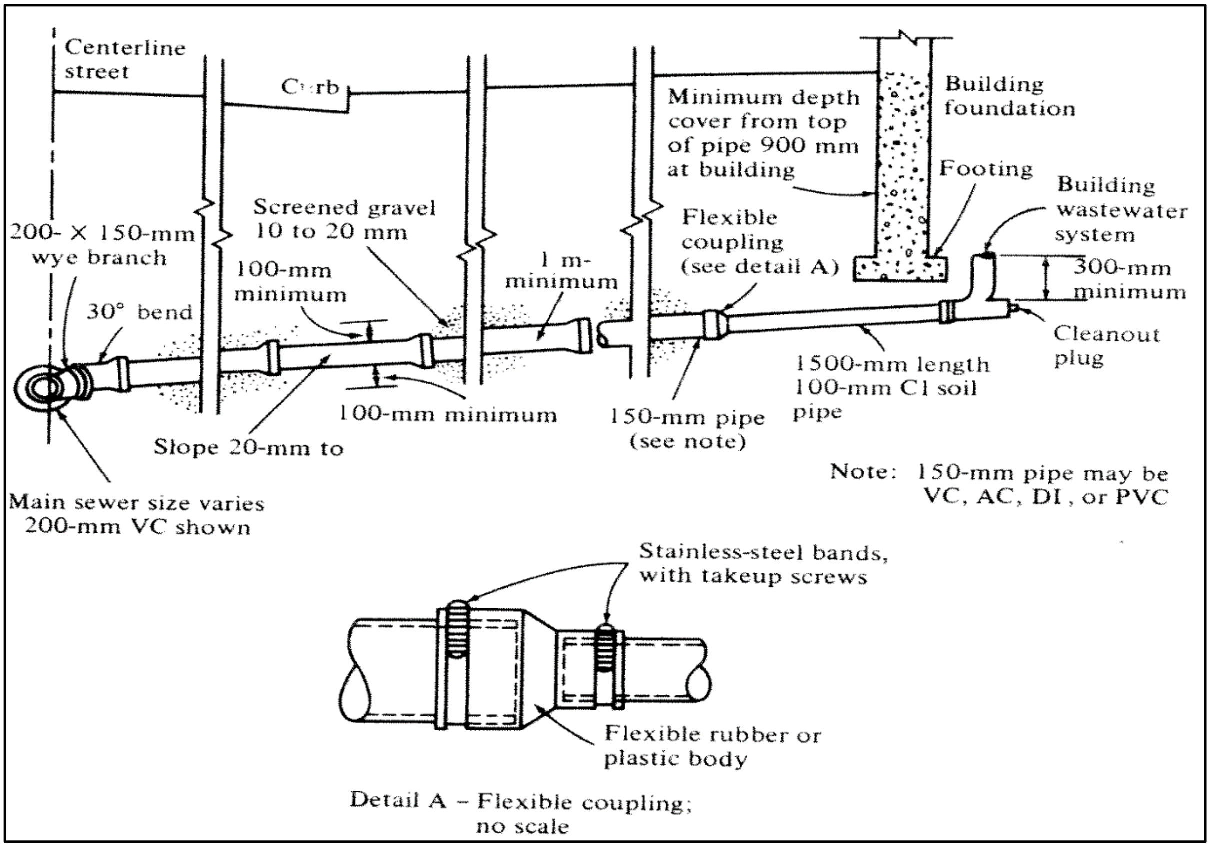


Figure 12: Typical building connections[1].

- **Typical Junction Chambers** – They are the larger forms of manholes. As the diameter of the intercepting sewers continues to increase as wastewater from more of the service areas is collected, precast manholes may not be big enough to be used. In this case, special junction chambers are constructed on-site to connect the intercepting sewers.

- **Typical Backflow preventers -** Backflow preventers are used in a sanitary sewer lateral to prevent the accidental backflow of wastewater into buildings.

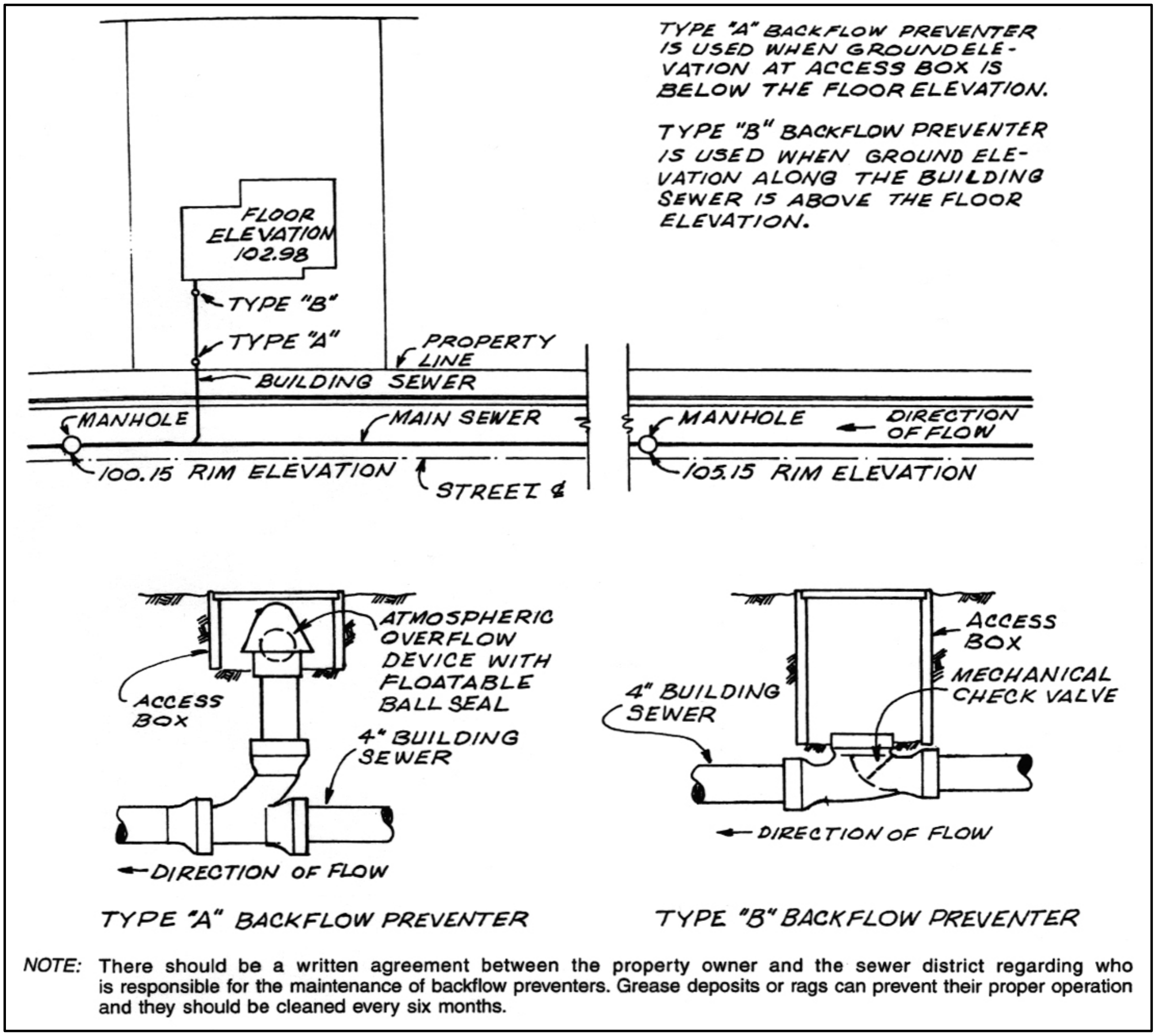


Figure 13: Typical backflow preventer[2].

- **Typical Cleanouts -** Cleanouts are used in a sanitary sewer lateral to permit access for the removal of solids that result in blockages. At least two cleanouts should be provided; one approximately 3 feet from the building foundation, and one at the property line.

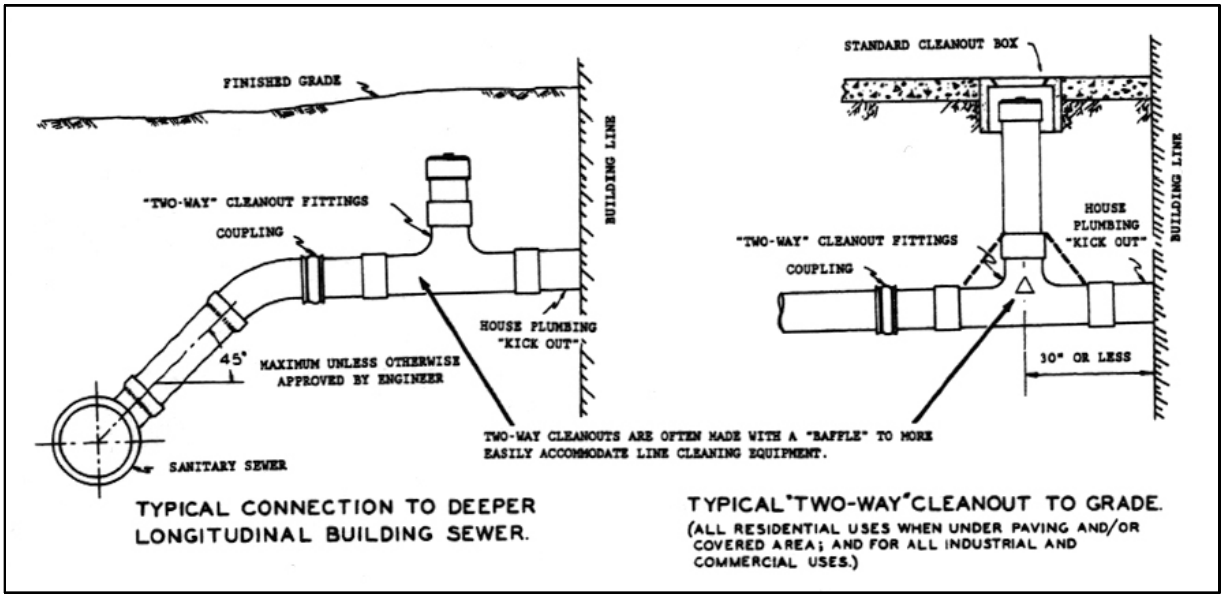


Figure 14: Typical cleanouts[2].

- **Typical Laterals -** The lateral is the piping that connects the public sewer to the building. The size of the lateral is typically 4 to 6 inches in diameter (Figure 6).

- **Typical Inverted siphons -** An inverted siphon (Figure 15) is generally used in situations where there is a depressed obstruction, typically a watercourse, in the path of the gravity sewer. Wastewater is pushed up the downstream end of the siphon by the velocity of the wastewater. Additional maintenance is typically required to remove solids.

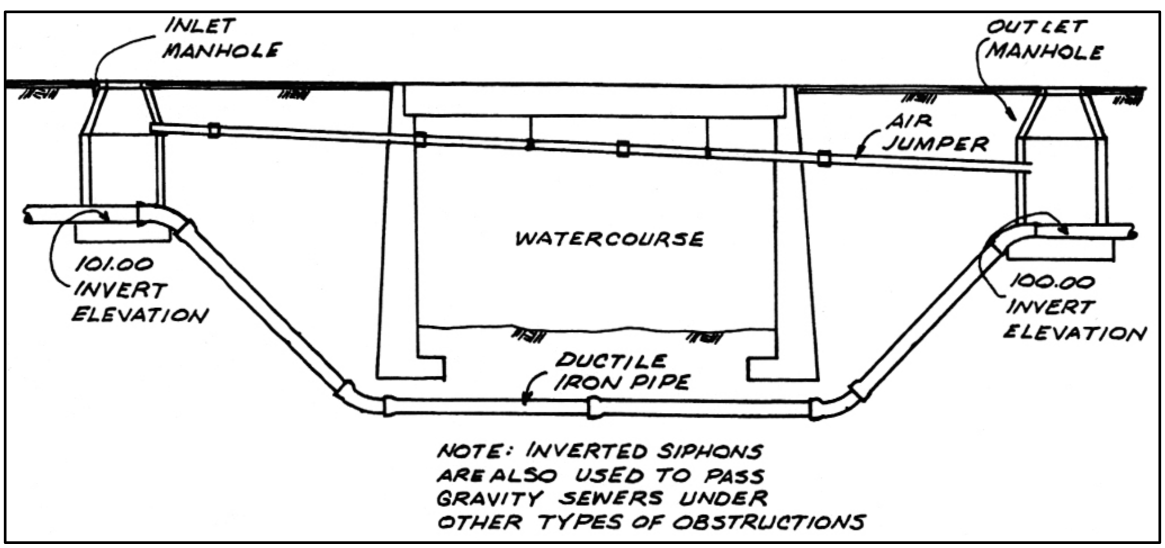


Figure 15: Typical inverted siphon[2].

- **Typical Flow regulators** - Flow regulators (Figure 16) are used to divert flow from one sewer line to another to prevent overloading the system. An example of a flow regulator is a weir in a manhole.

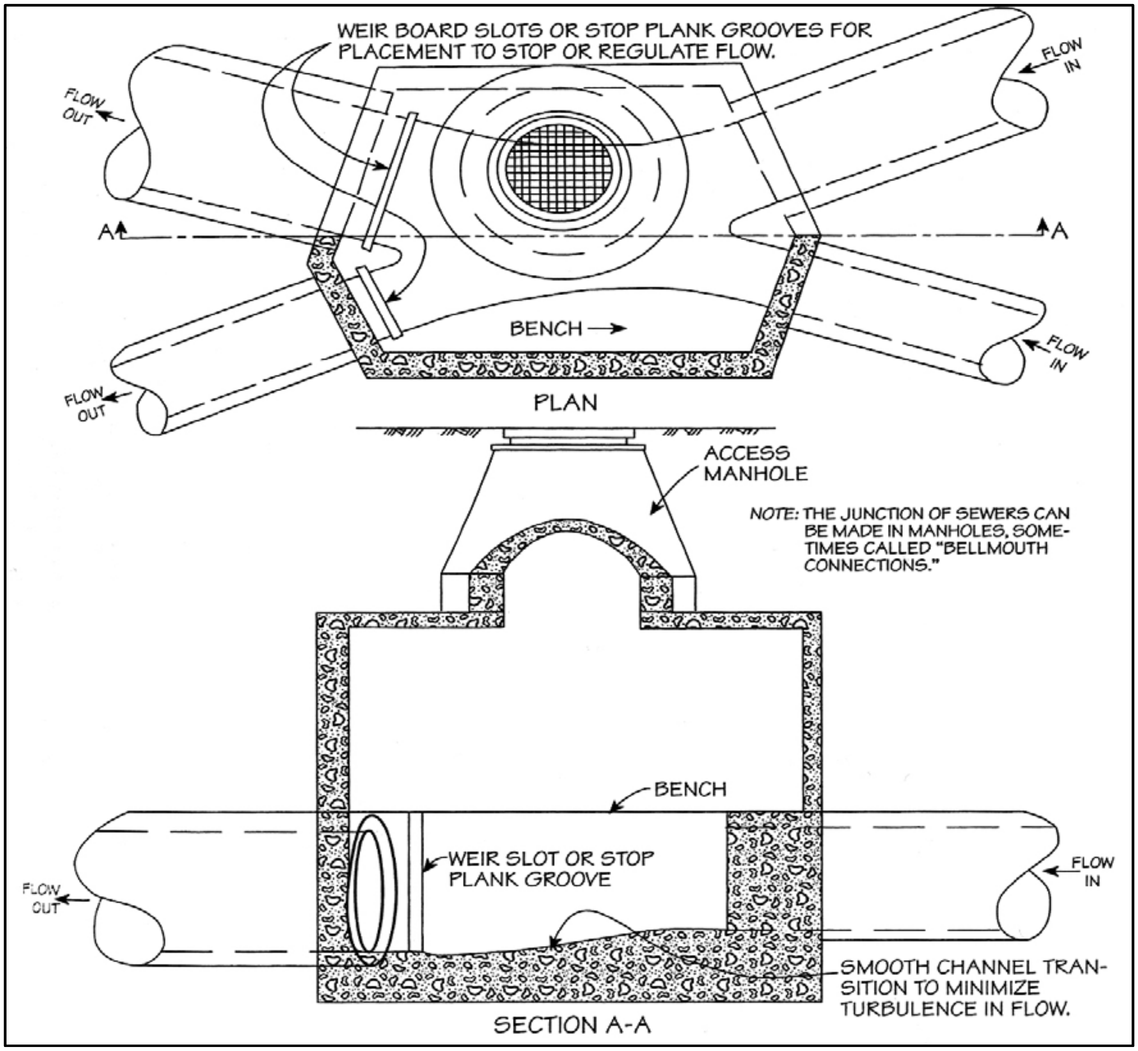


Figure 16: Typical flow regulator[2].

9. Basic Considerations of Sewer Design

The basic considerations are as follows:

- Estimation of wastewater design flow rates
- Selection of design parameters

  a. Hydraulic design equation

  b. Sewer pipe materials

c. Minimum sizes

d. Maximum and minimum flow velocities

- Selection of appropriate sewer appurtenances
- Evaluation of alternative alignments
- Evaluation of the use of curved sewers, if necessary.
- Estimation of wastewater design flow rates

✓ The flow rates of sewage may consist of:

- Infiltration
- Dry weather flow which is domestic and industrial sewage during dry weather; and
- Stormwater – *for combined sewers only.*

✓ **Infiltration/Inflow (I/I)**

- **Infiltration** is groundwater entering into the sewer system through faults in the sewer line, lateral or manhole. During dry weather there will be no infiltration and hence only domestic sewage and industrial waste will be conveyed.
- **Inflow** is the direct discharge of non-sanitary water into the sewer system.
- **Infiltration and Inflow (I/I)** is the total quantity of flow from both infiltration and inflow sources.
- During rains, the infiltration will be due to the rise in groundwater table and from roofs. The infiltration depends on:
- Height of groundwater level
- Type of soil in which sewers are laid
- Workmanship of laying pipes.
- It is nonexistent during dry weather but increases during rainy season.
- Water and Sanitation Agency (WASA) Lahore uses the following infiltration rates for the design of sewer system.

Table 2: Infiltration estimate[2]

Sewer Diameter	Infiltration
225 mm to 600 mm	5 % of Avg. Sewage Flow
> 600 mm	10 % of Avg. Sewage Flow

✓ **Sanitary sewers are designed for the following flows:**

- Peak flows from industrial, commercial, institutional, and industrial sources for the entire service area
- Peak infiltration allowance for the entire service area
- Peak factor may be selected according to the following table:

Population	Peak Factor
Upto 20,000	3.50
20,000 – 50,000	2.50
50,000 – 750,000	2.25
> 750,000	2.00

Estimation of Stormwater flow rates

- **Rational Method –** This formula estimates the peak rate of runoff at any location in a drainage area. The formula is expressed as:

$$Q = CIA \qquad (1)$$

Where, Q = *maximum rate of runoff, cfs (cubic ft/sec.)*
C = *dimensionless runoff coefficient, dependent on land use*
I = *design rainfall intensity, inch/hr, for a duration equal to the time* ***of concentration*** ***(***t_c***)****of a watershed.*
A = *drainage area in acres.*

– **Time of concentration** ***(***t_c***):*** the time required for runoff to travel from the hydrologically distant point in the watershed to the outlet.

- **Rational Method – Assumptions:**
  - Under steady rainfall intensity, the maximum discharge will occur at the watershed outlet at the time when the entire area above the outlet is contributing runoff.
  - The time of concentration is equal to the minimum duration of peak rainfall.
  - The frequency or return period of the computed peak discharge is the same as the frequency or return period of rainfall intensity (design storm) for the given time of concentration.
  - The fraction of rainfall that becomes runoff is independent of rainfall intensity or volume.
  - The peak rate of runoff is sufficient information for the design of storm water detention and retention facilities.
- **Rational Method –** Limitations
  - Because of the assumptions discussed above, the rational method should only be used when the following criteria are met:

- The given watershed has a time of concentration, t_c, less than 20 minutes;
- The drainage area is less than 20 acres.

Table 3: List of "C" values for land use[3]

Land use	"C" Value
Business, Commercial, and Industrial	0.09
Apartments	0.75
Schools	0.60
Residential - lots of 10,000 sq. ft.	0.50
- lots of 12,000 sq. ft.	0.45
- lots of 17,000 sq. ft.	0.45
- lots of 1/2 acres or more	0.40
Parks, cemeteries, and unimproved areas	0.34
Paved and roof areas	0.90
Cultivated area	0.60
Pasture	0.45
Forest	0.30
Steep grass slope (2:1)	0.70
Shoulder and ditch areas	0.50
Lawns	0.20

Example 1: Estimate the maximum runoff from a drainage area of 20,000 sq. ft. of which 25% is residential with lot size of 1,200 sq. ft, 30% is forest, 10% is lawns, and 35% is industrial and commercial for a design rainfall intensity of 4.5 inch/hr, for a duration equal to the time of concentration (t_c) of the drainage area.

	Total Area =	20,000	sq. ft.	I =	4.5	inch/hr =	0.000104	ft/s

Surface characteristics	% Area	Area (sq. ft)	"C" Value	AC (sq. ft.)	$Q = CIA$ (cfs)
Residential	25%	5000	0.45	2,250	0.2344
Forest	30%	6000	0.30	1,800	0.1875
Lawns	10%	2000	0.20	400	0.0417
Industrial & Commercial	35%	7000	0.09	630	0.0656
∑	**100%**	**20,000**	**----**	**5,080**	**0.529**

The maximum runoff, Q = ∑CIA = **0.529** ft^3/s ANS.

Selection of design parameters - <u>design equation</u>

- Currently Manning's equation is the widely used one to design sewer system. The Manning's Equation is[4]:

$$V = \frac{k}{n} R_h^{2/3} S^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2a)$$

where,

V = flow velocity (ft/s in FPS, m/s in SI)
k = 1 for SI and 1.486 for PFS
R_h = hydraulic radius = flow area/wetted perimeter, ft (FPS), m (SI)
S = channel slope or slope of energy grade line (ft/ft, m/m), and
n = Manning's roughness coefficient (it depends on channel materials, surface irregularities, variation in shape and size of the cross-section, vegetation, flow conditions, channel obstruction, and degree of meandering).

$$Q = AV = \frac{k}{n} A R_h^{2/3} S^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2b)$$

- n can be obtained from tables or from following equations:

$$n = 0.038 d^{\frac{1}{6}} \text{ (Proposed by Meyer -- Peter and Muller (1948))}$$

$$n = 0.0417 d^{\frac{1}{6}} \text{ (Proposed by Strickler (1923))}$$

where, d = 90-percentile size of bed material. …….. (3)

Table 4: The Manning's Roughness Coefficient (*n*) Values[3]

Type	Characteristics	Minimum n	Normal n	Maximum n
Earth, straight, and uniform	Clean, recently completed	0.016	0.018	0.020
	Clean, after weathering	0.018	0.022	0.025
	Gravel, uniform section, clean	0.022	0.025	0.030
	with short grass, few weeds	0.022	0.027	0.033
Earth, winding, and sluggish	No vegetation	0.023	0.025	0.030
	Grass, some weeds	0.025	0.030	0.033
	Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
	Earth bottom and rubble sides	0.028	0.030	0.035
	Stony bottom and weedy banks	0.025	0.035	0.040
	Cobble bottom and clean sides	0.030	0.040	0.050
Dragline-excavated or dredged	No vegetation	0.025	0.028	0.033
	Light brush on banks	0.035	0.050	0.060
Rock cuts	Smooth and uniform	0.025	0.035	0.040
	Jagged and irregular	0.035	0.040	0.050
Channels not maintained, weeds and brush uncut	Dense weeds high as flow depth	0.050	0.080	0.120
	Clean bottom, brush on sides	0.040	0.050	0.080
	Same, highest stage of flow	0.045	0.070	0.110
	Dense brush, high stage	0.080	0.100	0.140

Source: Chow (1959).

- **Selection of design parameters - Sewer pipe materials**
  - The principal materials that are sued for sewer system are:
    - ✓ Asbestos cement
    - ✓ Ductile iron
    - ✓ Reinforce cement concrete (**RCC**)
    - ✓ Polyvinyl chloride (**PVC**)
    - ✓ High density Polyethylene (**HDPE**)
- **Selection of design parameters - Minimum sizes**
  - ✓ The minimum sizes are usually specified in the local building codes.
  - ✓ The smallest size used should be larger than building sewer connections so that objects passed through the building sewer do not clog the sanitary sewer.
    - ➢ Building sewer connection: 4–6 inch (100 -150 mm)
    - ➢ The recommended minimum diameter for sanitary sewer: 8 inches (200 mm). Sometimes 6 inches (150 mm) are used.
- **Selection of design parameters - Maximum and minimum flow velocities**

Sewer diameter Self-cleansing velocity

6 – 10 inch	3.0 ft/sec. (0.9 m/s)
12 – 24 inch	2.5 ft/sec. (0.75 m/s)
> 24 inch	2.0 ft/sec. (0.6 m/s)

Therefore, if ***Q*** is the discharge, ***V*** is the velocity of flow, and ***A*** is the area of x-section of a sewer:

Q = A x V

- Knowing the discharge and velocity, area of the sewer can be calculated.
- In general, the recommended minimum flow velocity is ***2.0 ft/sec (0.6 m/s)*** to avoid deposition and the recommended maximum flow velocity is ***10.0 ft/sec (3.0 m/s)*** to avoid damaging sewers.

- **Selection of appropriate sewer appurtenances**

  Based on the sizes of the sewer system, as discussed before, all 9 appurtenances may be necessary to successfully complete the sewer design and construction. The 9 appurtenances are:
    - Manholes
    - Drop inlets to manholes
    - Building connections,
    - Junction chambers - junction chambers are seldom necessary
    - Backflow preventers,
    - Cleanouts,
    - Laterals,
    - Inverted siphons and
    - Flow regulators

- **Evaluation of alternative alignments**
    - Sometimes alternative alignments can be easier to construct or economical. As a result, alternative alignment may need to be evaluated.

- **Evaluation of the use of curved sewers, if necessary.**
    - Curved sewer may be used as it is found necessary, economic, and feasible.
    - Flow velocity may not be the same in all section of the sewer due to bending which needs to be verified, especially for high velocity that may cause damage to the bending sewer.

- **Design Period**
  - ✓ **Sewer System:** Period of design is indefinite. The system is designed to take care for the maximum development of the area. But we take design period of 20 years for our sewer system.
  - ✓ **Sewer Pumping Station:** Design period is 10-years. Rate of Flow are average daily, peak and minimum flow including Infiltration.

10. Design of Sanitary Sewers

Sewer system plays a vital role in the economic development of a country. Sewers are must for the drainage of wastewater. In order to have an effective sewage system the sewers should be properly designed, and more care should be taken in finding the invert levels otherwise whole design may get wrong. Design of Sewer System. Sewers are designed for the drainage of wastewater coming from houses, industries, streets, runoff etc. to protect the environment and people from serious diseases, as more than 50 diseases spread from sewage. So for a good living, the sewers should be properly designed, and the sewage should be treated properly before discharging it into the river.
Water mains carry water under pressure, while flow in sewers is under gravity. If the sewage is to be conveyed under pressure, elaborate pumping equipment is necessary. Hence sewers are designed as open channels using Manning's equation. The design of sewers consists of determining the diameter of sewer to carry the estimated quantity of sewage at a velocity that is equal to the **self-cleansing** velocity. Self-cleansing velocity is a velocity that is required to prevent silting and depositing in sewers.

Example 2: Using Manning's equation calculate the velocity of flow (*V*) and discharge (*Q*) in a sewer of *1.5 ft* diameter laid at a gradient of *1 in 400*. Assume sewer run half-flow and *n = 0.012*.

Solution: Manning's equation in FPS

$$V = \frac{1.486}{n} R_h^{2/3} s^{1/2}$$

where, *V* = Velocity of flow in ft/sec.
D = diameter of sewer pipe = 1.5 ft
R_h = hydraulic radius in ft. = D/4 = 1.5/4 = 0.375 ft.
s = slope of the sewer line = 1/400 = 0.0025 (given)
n = roughness coefficient = 0.012 (given)
Area of flow, $A = ½ \times \pi (1.5)^2/4 = 0.8836$ *sq. ft.* [half-flow]
$V = (1.486/0.012) \times (0.375)^{2/3} \times (0.0025)^{1/2} =$ ***3.2285 ≈ 3.23 ft/sec. Ans.***
$Q = A \times V = 0.8836 \times 3.23 =$ ***2.8526 ≈ 2.85 ft³/sec (cfs). Ans.***

Example 3: Design a sanitary sewer to serve a population of 5,000 people, if the average consumption is 400 liters per capita per day (lpcd). How many extra persons can be served if the slope is doubled? Using "***n***" value of 0.013 in the Manning's formula & the return flow as 70%. Check the minimum self-cleaning velocity. Neglect infiltration & inflow (I/I).

Given Data:
Population (P) = 5,000 persons; Average water consumption (q) = 400 lpcd
Manning's coefficient (n) = 0.013; Return flow = 70%
Assume slope = 0.5% = 0.005

Required:
1. Find the Velocity (***V***) =? Also check minimum self-cleansing velocity
2. When the slope is doubled find the extra population to be served =?

PART 1

Average wastewater flow (q_w) = P x Return flow (%) x q

= 5000 x 0.7 x 400

= 1,400,000 lpcd

= 0.0162 m^3/s [1 m^3 = 1000 L, 1 day = 86,400 sec]

Let take peaking factor (P.F.) = 3.5

Peak Hourly Wastewater Flow = 3.5 x 0.0162 m^3/s

= 0.0567 m^3/s

Now finding the diameter of sewer pipeline. Using Manning's discharge formula;

$Q = AV \Rightarrow Q = (\pi/4)(D^2)(1/n)(R^{2/3} S^{1/2})$ $\quad \therefore D = 1.548\left(\frac{nQ}{S^{0.5}}\right)^{0.375}$ *[using, R = D/4]*

$\therefore D = 1.548\left(\frac{0.013 \times 0.0567}{(0.005)^{0.5}}\right)^{0.375} = 0.234\ m = 0.77\ ft$ Use 9.5 inch (0.24 m) pipe.

Diameter for the average flow,

$\therefore D = 1.548\left(\frac{0.013 \times 0.0162}{(0.005)^{0.5}}\right)^{0.375} = 0.175\ m = 0.57\ ft$

Use **7** inch (0.178 m) pipe

Checking the minimum self-cleansing velocity

V_{avg} = $(1/n)(R^{2/3} S^{1/2})$ where, R = (D/4) for circular pipe

= $(1/0.013) \times (0.178/4)^{2/3} \times (0.005)^{1/2}$ = **0.68 m/s** **Ans.**

$V_{min} = 0.6\ m/s < V_{avg} = 0.68\ m/s < V_{max} = 3\ m/s$ OK.

PART 2

Doubling the slope i.e. S = 2S = 2 x 0.005 = 0.01

$Q = A V = (\pi/4\ D^2)(1/n)(R^{2/3}S^{1/2}) = (0.31/n) \times (D^{8/3}S^{1/2})$ $[(\pi/4)/4^{2/3} = 0.31]$

$= (0.31/0.013) \times (0.178)^{8/3} \times (0.01)^{1/2}$

= 0.0238 m^3/s x (1000 L/ 1 m^3) x (86,400 s/1 day) = 2,053,778 L/d

$Q = P * q_w$

P = Q/q_w where, q_w = Return flow (%) * q = 0.7x400 =280 Lpcd

P = 2,053,778 lpd /280 lpcd = 7,335 persons.

So, if the slope is doubled then total of 2,335 extra persons can be served. **Ans.**

Example 4: A *3.0*-m circular sewer is laid on a slope of *0.0009* m/m. If *n* is equal to *0.012* at all depth of flows, determine[3]:

(a) *Q* and *V* when the sewer is flowing full (b) *V* and depth of flow, *d* when $Q = 1.0$ m^3/s

Solutions of Example 4:

Given, pipe diameter , D =	3	m	*n* =	0.012		
Slope, S =	0.0009	m/m	A_f =	PI x D^2/4 = 3.14159 x3^2/4 =	**7.069**	m^2
For circular pipe flow, full and half, R_h = D/4 =			0.75	m		
(a) Using Mannig's Equation,	$V = \frac{1}{n} R_h^{2/3} S^{1/2}$					
= (1/0.012)(0.75)^(2/3) (0.0009)^(1/2) =				**2.06**	m/s	ANS.
Q = A V =	**14.587**	m^3/s	ANS.			

(b) Give Q =		1	m^3/s	Lets assume that depth of flow for given Q is = d				m	
	Q/Qfull =	1/14.587 =	0.0686						
	From the following Figure, for Q/Qf = 0.0686			d/D =	0.2				
					(red and green arrows)				
	∴ ***d =***	0.2 x 3 =	0.6	m ANS.					
	From the following Figure, for d/D = 0.2			A/Af =	0.13	V/Vf =	0.56		
					(blue and green arrows)		(**black** and green arrows)		
	∴ A =	0.13x 7.069 =	0.919	m^2	∴ V =	0.56 x 2.06 =	1.16	m/s	
	V = Q/A =	1 / 0.919 =	1.09	m/s ANS.					

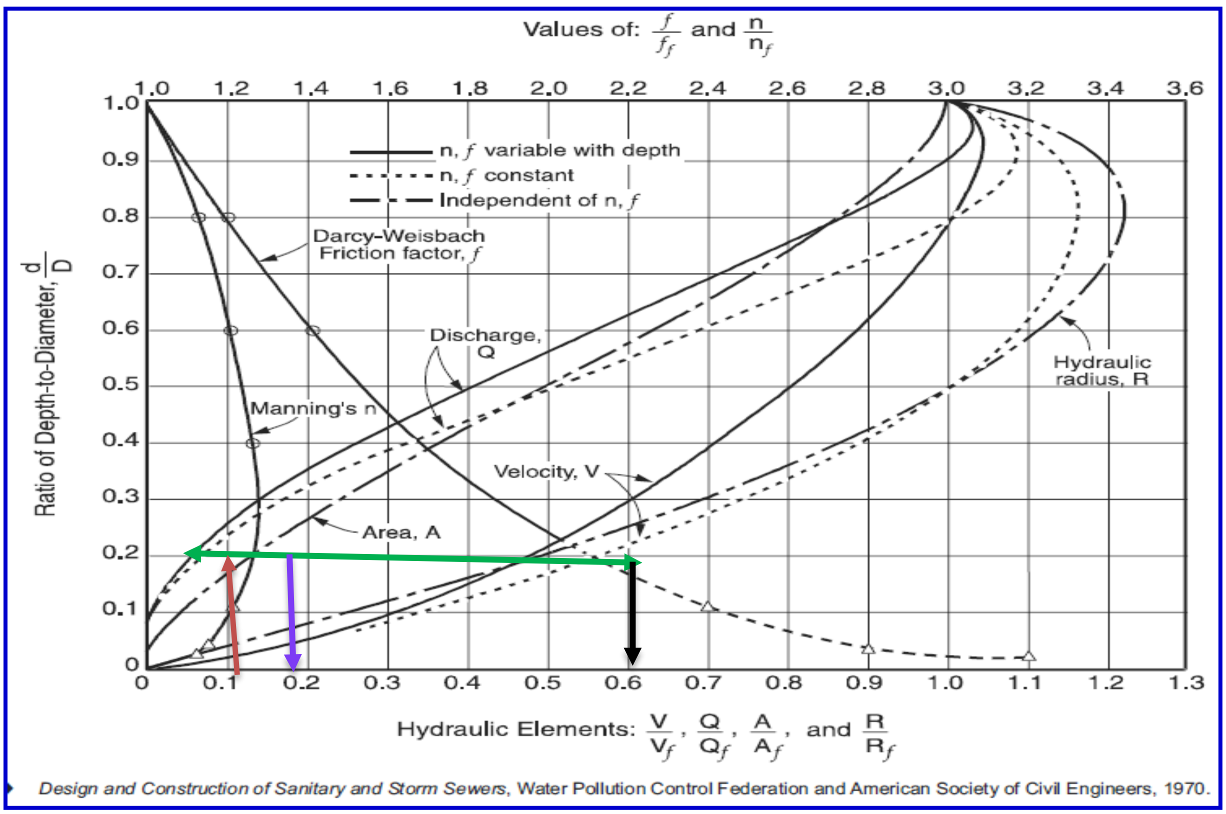


Figure 17: Design diagram from FE Exam Handbook[4]

11. Preparation of Contract Drawings and Specifications

Contract drawings and specification define the work that is to be performed. The contract drawings provide a graphical representation of the work. Contract drawings such as plans and profiles are prepared to show the details of the design for bidding and construction purposes. The drawing are very important to be accurate and precise for proper estimation and construction. Accurate drawings lead less change order in contract activities and assure the smooth construction and timely finishing of the project. The typical contract drawings (plans and profiles) are shown in Figure n.

11.A Contract Drawings

Contract drawings typically consist of several sheets including:

- Title sheet stating the name of the project.
- Index of sheets.
- Legend.
- Location map.

Additional sheets that include the plan and profile view of the proposed sewer system and specific notes relevant to the sections shown on each sheet. A plan view is a drawing showing the top view of sewers, manholes and streets. A profile view is a drawing showing the side view of sewers and manholes.

An additional sheet that shows details such as bedding and backfill, stream crossing and manholes.

11.B Specifications

Specifications state the qualitative requirements for the projects. The requirements typically cover the material and the workmanship involved in the manufacturing and installation of the equipment.

Specifications for sewer system typically follow the Construction Specifications Institute (CSI) format, which includes 16 divisions. Division 1 covers general requirements of the project, and Divisions 2 through 16 covers the material and workmanship requirements. The CSI Divisions that are typically utilized for a sewer system project include:

CSI Division 1 – General Requirements.
CSI Division 2 – Site Work.
CSI Division 3 – Concrete.
CSI Division 5 – Metals and
CSI Division 9 – Finishes.

The specifications contain language requiring that the contractor submit shop drawings to ensure the quality of the material being proposed by the contractor. Shop drawings are typically catalog cuts, which illustrate that the material proposed by the contractor is what was specified or is equivalent to what was specified. The engineer must approve the submitted shop drawings prior to construction of the project. A copy of the approved shop drawing is forwarded to the owner, construction inspector and contractor.

During construction of the project, the specifications must be followed to ensure that the project is being constructed as designed. The shop drawings would be at the project site to ensure that the material being placed in the ground is what was approved.

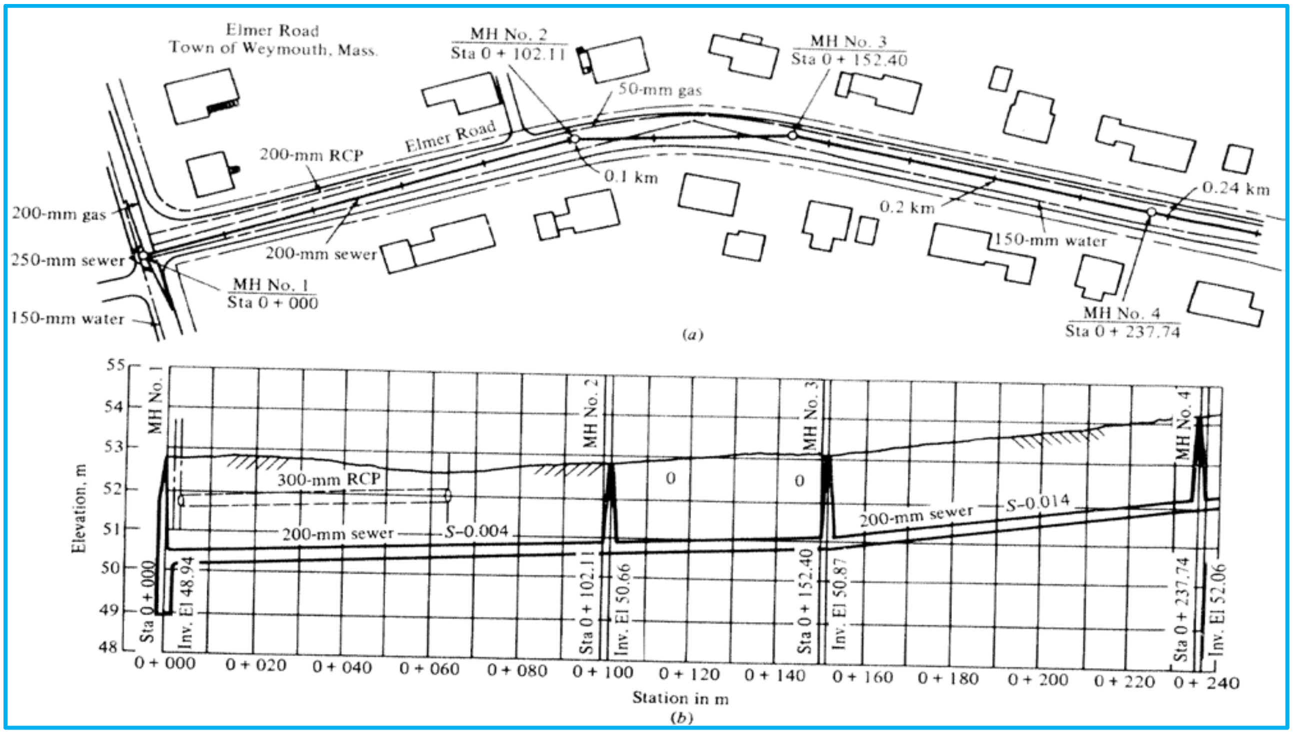


Figure 18: Typical (a) plan and (b) profile view of a sewer line[1].

12. Construction of Sewers

The construction and layout of sewers consist of the following operations:

- Setting out the alignment for sewer laying
- Excavation of trenches
- Branching and dewatering of sewer
- Laying pipe, and joining the pipes
- Testing, and

- Backfilling

13. Maintenance of Sewers

Keeping sewers clear of obstructions and in proper working order. Cleaning with special tools where flushing is inadequate to remove an obstruction. Providing proper ventilation for removing explosive gases (CH_4, CO_2) as they form due to decomposition of waste.

14. Cleaning the Collection System with Mechanical Devices

Sewer Jets: A sewer jet is a high-pressure water system used to clean sewer lines. It may be truck or trailer mounted. It consists of a high-pressure hose of up to 500 feet mounted on a hydraulic reel and a pump. The hose is either ¾ or one inch in diameter. The trucks usually carry a 1,000-gallon tank that is filled at a fire hydrant to supply water to the pump. The trailer-mounted units may have a smaller tank, or they may hook directly to a fire hydrant. Depending on size, the pumps will generate between 1,200 and 2,000 psi at 35 to 65 gallons per minute. Some sewer jets are larger, but they all work the same way.

The hose is inserted into the sewer line through a manhole at the downstream end of the blockage or section to be cleaned. The hose has a steel head on the end shaped like a bullet. The head has small holes on the end near the hose. These holes, usually about eight in number, (known as orifices) are at various angles, ranging from 15 to 35 degrees. The water is pumped through the hose causing into be driven upstream, usually to the next manhole. When it arrives at the upstream manhole, the hydraulic reel pulls it back to the machine. All the while, the pressure is maintained. This allows the water to scrub the walls of the pipe, removing the grease. Sewer jets can be used for a variety of jobs. They are valuable pieces of equipment.

Municipal Vacuum Trucks: Unlike the trucks used to pump septic tanks, which pull a vacuum, a municipal vacuum truck is an air conveyer. It pulls a column of air through their system. Whatever is caught in the air stream is lifted to the truck. The advantage of this truck is that it can vacuum both wet and dry material such as those found in catch basins. It is a more versatile piece of equipment than a standard septic truck.

Some municipalities will run a truck that is a combination sewer jet and vacuum truck. Vacuum trucks are expensive. You will find that many municipalities do not own them.

Rodders: A rodder is a piece of equipment used to clean grease from sewer lines when a sewer jet is not available. It consists of a reel of wire up to 500 feet in length. This wire, known as a rod, is at least 5/16 inch in diameter. There is also an auxiliary motor. The rodder can be either truck or trailer mounted. The end of the wire is fitted with cutters of different sizes and types, depending on the job. To operate a rodder, the cutter is inserted in the line in the same manner as the sewer jet hose. The auxiliary motor is turned on. This causes the reel of wire to rotate and unwind the rod, allowing the operator to send the rod up the line

Rodders are ineffective against grease. They cannot remove it; they can only punch holes in it. They can open a plugged line, but they cannot clean a pipe. Rodders are more effective removing hard objects such as roots.

Rodders are unforgiving pieces of equipment. Because of the torque being generated by the reel, if the rods hit a hard object, it can snap very easily. When that happens, the operator is forced to retrieve the broken rod from the line. This is not an easy task and sometimes takes quite a bit of time.

Some municipalities do not own any sewer cleaning equipment. When they need this equipment, they hire a private contractor or rent from a neighboring town

When you get an emergency blockage, the crew may have to use hand rods. These are 5/16- or 3/8-inch rods. The hand rods are made of wood, metal and fiberglass. They come in three, four, five, and sixteen-foot lengths with connectors on each end. They are pushed down the blocked line by hand, one length at a time. To say this is brutal work, is putting it mildly. Not only is it very difficult to shove a couple of hundred feet of rod up a sewer line, but it must be done in the confines of a manhole, usually while you are on your knees. It generally requires at least two people. Since all this is done from the downstream side, when they finally break up the blockage, guess who gets hit with the flood of sewer water that is released! After the flood, they have to take the rod out of the line the same way they put it in, one length at a time. Only now, the sewer is running.

Keep in mind that most sewer line blockages occur at off-hours, generally around dinner time or later. Except for possible overtime pay, the guys down that manhole pushing the rod are not happy campers. That unhappiness is even greater in the wintertime.

15. Sewage Facilities Act

For a collection system to be permitted, the proposed development must comply with Act 537 (Sewage Facilities Act) Planning.

The act states: "All proposed wastewater facilities must demonstrate consistency with local wastewater facilities plans and conform to state laws. This is accomplished in part by the municipality updating its official sewage plan or by the municipality, owner, subdivider, or agent of the proposed land completing *Planning Modules for Land Development.*" A copy of the *Planning Modules for Land Development* is available in the state website[2].

16. Regulatory Standards

There are basic standards that must be met for the design of a sanitary sewer collection system in Pennsylvania. New systems that are designed as a combined system to carry both wastewater and storm water will generally not be allowed.

Separate sanitary sewers shall exclude extraneous water (i.e., roof drains, street, foundation drains, etc.).

Collection system shall be designed to serve the projected population in the area and the population in areas surrounding the project area that could connect to the system.

The minimum size of a sanitary sewer shall typically be 8-inches in diameter.

Sewers shall be deep enough to prevent freezing. A typical minimum depth for collection sewers is 4 feet.

Sewers shall be laid in a uniform slope between manholes. The minimum slope for an 8-inch diameter sewer is 0.40%. Sewers on steep slopes, 20% or greater, should be anchored with concrete anchors.

Manholes shall be pre-cast concrete, fiberglass, PVC or poured-in-place concrete.

Inlet and outlet pipes from manholes shall have a watertight connection.

Sanitary sewers should be 10 feet horizontally from existing or proposed water mains. If the sewer must cross under a water main, there should be 18-inches of vertical clearance.

Three feet of cover should be provided over sanitary sewers that are crossing a stream. Sewers crossing streams should be constructed of cast or ductile iron.

Testing shall be performed on the constructed sanitary sewer system. Deflection tests, joints and leakage tests shall be performed on installed sanitary sewers and an exfiltration test shall be performed on manholes.

17. Permitting

An Erosion and Sedimentation (E and S) Control Plan is required for earth moving activity. Most of the State's Department of Environmental Protection, Permit Sewer Extensions and Pumping Stations is required for public collection systems that have the potential to serve more than 250 Equivalent Dwelling Units. It may vary from state to state. A copy of this document is included available in the state website[2]. Additional submittal is required if the proposed collection system will be located underneath a waterway.

18. Overview of Wastewater Collection Systems

The three types of collection systems include gravity, low pressure and vacuum collection systems.

A gravity sewer is a pipe or conduit intended to carry wastewater flowing with a minimum velocity of 2 ft/sec from a higher elevation to a lower elevation due to the force of gravity.

Gravity sewers are a minimum of 8-inch diameter pipes with manhole structures located at changes in horizontal alignment and vertical slope changes.

A force main is a pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

In vacuum sewers the wastewater is drawn or sucked by vacuum to the WWTP.

A sanitary sewer system can be either a separate system or a combined system in that a separate sewer system is designed to carry only wastewater while a combined system is designed to carry both wastewater and storm or surface water runoff.

Nine types of appurtenances: manholes, drop inlets to manholes, building connections, junction chambers, backflow preventers, cleanouts, laterals, inverted siphons, and flow regulators.

Manholes are typically between 200 to a maximum of 400 feet apart and are required where the sewer changes direction, where pipe slope changes and where several sewer lines meet.

The lateral is the piping that connects the public sewer to the building. The size of the lateral is typically 4 to 6 inches in diameter.

Act 537, The Sewage Facilities Planning Act, requires proper planning of all types of sewage facilities, permitting of individual and community on-lot disposal systems (OLDS), as well as uniform standards for designing OLDS.

19. Overview of Design and Construction of Collection Systems

Flow is defined as the continuous movement of a liquid from one place to another with there being three types of flows, residential, commercial and industrial which contribute flows to a wastewater collection system. The following are the summary of design and construction of collection systems[2].

Wastewater generated in a typical home averages 70 gal/day/person.

The residential flow has a peaking factor, used in design to ensure that the collection system is large enough to convey the flow, which is calculated by dividing the maximum flow by the average flow. A typical peaking factor (maximum flow/average flow) for residential land is 2.5.

Commercial land use can provide a wide variety of flows ranging from a restaurant providing a typical flow of 3 gal/meal to a self-service laundry mat providing average flows of 550 gal/machine.

Industrial land use can also produce a wide variety of flow and is typically based on historical data for the type of industry proposed.

Sewers shall be deep enough to prevent freezing. A typical minimum depth for collection sewers is 4 feet.

Sewers shall be laid in a uniform slope between manholes. The minimum slope for an 8-inch diameter sewer is 0.40%. Sewers on steep slopes, 20% or greater, should be anchored with concrete anchors.

Sanitary sewers should be 10 feet horizontally from existing or proposed water mains. If the sewer must cross under a water main, there should be 18-inches of vertical clearance.

The required size of the sewer is dependent on the slope of the sewer and the contributing flow into the sewer.

A sanitary sewer should be sized to be one-half full when conveying peak dry weather flow with the remaining one-half of the sanitary sewer permits a flow of air that may help decrease sulfide generation, which can lead to corrosion of the sewer.

Pipe deflection means the pipe has changed direction from the direction it was laid.

Bedding material must be appropriate for the type of pipe used.

Specification and contract drawings define the work that is to be performed. The contract drawings provide a graphical representation of the work.

During construction air testing or water testing is done to ensure the system does not leak and mandrel testing is done to ensure the pipe is in its proper alignment.

20. System Evaluation and Problems

Sewer systems need to be evaluated to determine the major areas of a municipality's system and to determine where problems exist. High levels of I/I in a system and structural deterioration lead to expensive treatment costs, building relief sewers, backing up sewage into residences and overflowing sewage into waterways.

20.A Flow Metering and Analysis

Flow metering is used to determine the amount of I/I present in the system and is the first step in performing a hydraulic analysis. Flow metering consists of temporary and permanent meters. Temporary meters are located at areas of interest and typically provide most of the metering data. Permanent meters, located at pumping stations and the treatment plant, provide backup data.

The following factors should be considered when choosing sites for the temporary meters:

- Flow depth.
- Sediment load.
- Pipe size and shape.
- Accessibility.
- Manhole location.
- Surcharge potential.

The use of weirs and flumes may increase the accuracy of flow metering; however, additional maintenance is required to ensure that debris does not affect the reading.

Flow data evaluation involves processing the information obtained from each meter. The data is analyzed on preset intervals, typically 15 minutes, 30 minutes or 60 minutes. The flow rates for each interval are determined and then a total daily value is calculated. Hydrographs are constructed with the intervals to provide a graphical representation.

In order to have a realistic evaluation of what is occurring, precipitation and groundwater levels should be measured during the metering period. This data will help in evaluating the causes of high flow.

20.B Condition Assessment

The condition of the system should be assessed. The system should be mapped, and the map should be kept up-to-date with new extensions added when constructed. The system should be assessed by surface inspection and internal inspections.

Surface inspections involve walking the pipeline length and recording any sunken areas, areas of ponded water and water leakage from the soil, which are indicators of sewer defects. In addition, stream crossing conditions and manhole conditions should be recorded.

Suspect areas found during flow metering and surface inspections should be internally inspected. Typically, CCTV is used to determine the condition. Reports and videotape should be produced during televising to maintain a record of defects encountered.

20.C Prioritizing Rehabilitation

Based on the findings, a list of needed repairs should be prepared. The list should be based on the physical and operational conditions of the system.

The listing should include all problems by general groupings such as:

- Near Collapse.
- Frequent Failures.
- Troublesome.

The next step would involve a cost analysis to determine what course of action should be taken for each problem. There are typically four courses of action: maintain, rehabilitate, relieve and replace.

The process for setting priorities may involve evaluation of the following factors: sewer performance, capacity, consequence of failure and condition and costs. All these factors should be considered when prioritizing rehabilitation.

20.D Rehabilitation Methods

There are several methods of rehabilitation that can be used on sewer lines. The method is often based on the problem involved and/or cost of the rehabilitation.

Excavate/Replace: This is the oldest and most common method of rehabilitation. It is used when there is severe structural deterioration or severe misalignment of the sewer. This method should not be considered when excavation disruption is considered unacceptable.

Chemical Grouting: Chemical grouting is used to seal pipe joint and circumferential cracks. Two types of chemical grouts are gels and foams. For grouting to be successful, joints must be clean, free of roots and not significantly deteriorated. The service life of grout is questionable when attempting to seal joints and cracks that are actively leaking during the grouting process.

Trenchless Technology: Several methods have been developed that allow sewers to be rehabilitated without excavation.

Sliplining: Sliplining involves pulling or pushing a new flexible liner pipe of a slightly smaller diameter into the existing pipeline. The lateral connections to the sewer line are reconnected by excavation. The method can only be used on pipe that is not excessively deteriorated. An additional limitation is that this method results in a substantial loss of cross-sectional area of pipe.

Cured-in-Place: Cured-in-place involves the installation and curing of a resin-saturated flexible fabric liner inside the existing pipe. The line must be televised with lateral locations recorded and cleaned; and have roots removed and cracks grouted prior to beginning work.

Once the preparation work is completed, the flexible tube is impregnated with resin (a hardening material) and is typically inserted through a manhole. The tube is installed in the existing sewer by pulling it or inverting it under air or water pressure. The tube is then pressed against the wall of the existing sewer, and the resin cures and forms a hard liner against the existing sewer. The force used to press the liner against the wall forms dimples where the laterals are located. Once the resin sets, the downstream end is cut, and the remaining tube is removed. A cutting device attached to a CCTV is pulled through the line and the lateral connections are cut open.

This method requires no excavation but does require a trained crew with specialized equipment. It is expensive and cannot be used on a sewer that has severe structural deterioration.

Deformed and Reshaped: This method involves inserting a pipe that has been reduced in size into the existing sewer line at manholes or insertion pits. Once the deformed pipe is inserted, it is restored to its original size using heat or pressure. The laterals are reconnected to the pipe with the use of a cutter. The reduced pipeline capacity is minimal, and no grouting is required.

This method requires a trained crew with specialized equipment. Sewer lines with severe structural deterioration can cause problems.

Pipe Bursting: Pipe bursting involves inserting a Pipeline Insertion Machine (PIM) that breaks out the existing sewer line and pulls a new pipe through the bore formed by the PIM. The method may result in an increase in line capacity by allowing the new pipe to be a size bigger than the existing sewer line.

The method requires excavation for laterals, disconnection and reconnection. In addition, nearby underground utilities may be damaged, and a trained crew with specialized equipment is required.

20.E Rehabilitation of Manholes

Manholes are necessary to a sewer system to permit access locations for maintenance and repair. Manhole rehabilitation is required to eliminate I/I and repair structural defects to ensure that the sewer is a safe access point.

Grouting: Grouting is used to repair leaks in the manhole walls. Grouting of manholes is performed by drilling holes through the manhole wall and pumping grout into the soil outside the manhole to fill the cracks. It is important to note that grouting does not add to the structural integrity of the manhole and should not be used to rehabilitate manholes with severe structural deterioration.

Coating: The application of coating can rehabilitate a deteriorated manhole structure for several years. The coating is comprised of a cementitious material containing Portland cement, finely graded mineral fillers and chemical additives. The walls of the manhole should be cleaned, and then the coating applied in one or more coats.

Lining: Lining is used to structurally rehabilitate a manhole. A cast-in-place protective plastic lining can be installed inside a manhole. Lining is typically not cost competitive with grouting and coating based on initial cost; however, it is less costly than excavation and replacement.

20.F Rehabilitation of Appurtenances

Laterals are appurtenances that require rehabilitation. Typically, rehabilitation of laterals is complicated because the portion from the building to the right-of-way line is privately owned. However, laterals can be a significant source of I/I to the system and can cause backups if structurally deteriorated.

Many of the rehabilitation methods that are used for sewer lines can also be used on laterals; however, rehabilitation is often more difficult based on the limited space available, root problems and landscaping over the lateral.

21. Overview of Management and Operations

A community which has only a sewer system is not required to have a permit but those with a WWTP must have an NPDES permit which is renewed every 5 years.

A Chapter 94 report to include a variety of collection system information is required annually to be submitted to the PaDEP[2].

The proposed EPA CMOM regulations directs collection system owners to take a pro-active position to correct existing problems and prevent future problems and includes a combined sewer overflows policy and a long term control plan that a municipality will follow to ultimately obtain full compliance with the Clean Water Act.

There are three (3) mechanical cleaning methods: power bucket cleaning, power rodding and hand rod cleaning.

There are five (5) hydraulic (involve the use of water) cleaning methods: balling, high-velocity cleaning, flushing, sewer scooters, and the use of kites, bags and poly pig.

There are 5 inspection techniques: closed circuit televisions, smoke testing, dye testing, lamping and manholes.

Infiltration and Inflow (I/I) is the total quantity of flow from both infiltration (groundwater entering the sewer system through faults in the sewer line, lateral or manhole) and inflow (the direct discharge of non-sanitary water into the sewer system) water sources.

There are three (3) rehabilitation methods of collection systems including excavate/replace, chemical grouting and a variety of trenchless technologies.

Manhole rehabilitation methods include grouting, coating, and lining.

22. Summary

In this course we have defined several terms related to wastewater collection system, discussed the different types of collections systems, types of sewers, shapes of sewers, collection system appurtenances, facilities act, regulatory standards, permitting requirements, and the essential steps for sewer management and operation, the approach to evaluation and rehabilitation of existing sewer systems. We have also analyzed the basic considerations of sewer design and worked out a few simple design problems using widely used Manning's equation and graphs from FE Handbook.

23. References

1. Environmental Engineering by Howard S. Peavy, Donald R. Rowe, and George Tchobanoglous, McGraw-Hill Book Company, International Edition, 1985.
2. Wastewater Treatment Plant Operator Certification Training, Module 23, The Pennsylvania State Association of Township Supervisors (PSATS).
3. Hydrology and Hydraulic Systems by Ram S. Gupta, Waveland Press, Inc., Third Edition, 2008.
4. NCEES FE Exam Handbook.

<u>Appendix A: Example Specifications</u>

SECTION 02500

HIGH DENSITY POLYETHYLENE PIPE AND APPURTENANCES

PART 1 - GENERAL

1.01 WORK INCLUDED

The work covered under this section includes the furnishing of all labor, equipment, and materials, and completing all operations in connection with the installation of the High Density Polyethylene (HDPE) Pipe and Appurtenances for the leachate collection piping system including HDPE manholes.

1.02 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements that affect the work of this Section.

B. Other specification sections that contain requirements that relate to the work of this section include, but are not limited to, the following:

1. Section 02200 Earthwork

2. Section 02400 Polyethylene Geomembrane

3. Section 02420 Geotextile

1.03 STANDARDS

A. Work shall comply with codes and standards of the Plastic Pipe Institute (PPI).

1.04 REFERENCES

A. ASTM International (ASTM)

1. ASTM D638 Tensile Properties of Plastics

2. ASTM D790 Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

3. ASTM D1238 Flow Rates of Thermoplastics by Extrusion Plastometer

4. ASTM D1248 Polyethylene (PE) Plastics Molding and Extrusion Materials

5.	ASTM D1505	Density of Plastics by the Density-Gradient Technique
6.	ASTM D2837	Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
7.	ASTM D3035	Polyethylene (PE) Plastic Pipe Based on Controlled Outside Diameter
8.	ASTM D3261	Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
9.	ASTM D3350	Specification for Polyethylene (PE) Plastics Pipe and Fittings Materials
10.	ASTM F714	Standard Specifications for 3" - 63" Polyethylene (PE) Pipe
11.	ASTM F477	Standard Specifications for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

1.05 SUBMITTALS

A. The CONTRACTOR shall submit evidence of the qualifications required by the CQA Plan and any other such pre-qualification data, references and project experience information as requested for the Project.

B. CONTRACTOR shall provide Manufacturer's technical data sheets for the following:

1. HDPE Pipe,
2. HDPE Appurtenances, and
3. HDPE Manhole.

C. Provide all test results of the HDPE piping system and manhole prior to substantial completion of the Project.

1.06 LABELING, DELIVERY, STORAGE AND HANDLING

A. Labeling – Pipe (including manhole) delivered to the site shall be new, clean and labeled by the Manufacturer with the following:

1. Manufacturer's name,
2. Nominal pipe size,
3. Plastic type,

4. Standard Dimension Ratio (SDR), and

5. Extrusion date, period of manufacture or lot and/or batch number.

B. Delivery – The pipe shall be packaged and shipped by appropriate means to prevent damage to the material and to facilitate off-loading. Transportation of the pipe to the site shall be the responsibility of the Manufacturer or Distributor.

Upon delivery to the site, the CONTRACTOR and the OWNER or ENGINEER shall have the right to complete an inspection of all pipe for apparent defects and damage. The OWNER or ENGINEER shall indicate to the CONTRACTOR the following:

1. Pipe that should be rejected due to irreparable damage.

2. Pipe that should be re-inspected upon placement due to a suspected repairable damage.

Piping damaged en route to the site or during the unloading will be rejected and shall be removed from the site and replaced with new pipe that meets these Technical Specifications.

C. Storage – The CONTRACTOR shall be responsible for all on-site storage of the pipe and appurtenances. The CONTRACTOR shall provide a suitable storage site that will protect the pipe and appurtenances from marring, crushing or puncture damage. Pipe and appurtenances shall be unloaded and stored on-site on pallets in accordance with the Manufacturer's recommendations. Limit maximum stacking height to six feet. The storage place should be protected from theft and vandalism, and if possible should be adjacent to the work area to facilitate installation and minimize handling.

A Manufacturer's representative shall have the right to verify that the pipe and appurtenances are stored in accordance with the Manufacturer's recommendations.

D. Handling – The CONTRACTOR shall be responsible for all on-site handling of the pipe and appurtenances. The pipe and appurtenances are to be handled so as to prevent damage.

A Manufacturer's representative shall have the right to verify the following:

1. Proper handling equipment exists on-site that does not pose any danger to installation personnel or risk of damage to the pipe and appurtenances.

2. CONTRACTOR's personnel are knowledgeable in the methods for handling the pipe and appurtenances with care.

E. Pipe and appurtenances damaged or otherwise determined to be unsuitable by the OWNER or ENGINEER following initial storage and acceptance by the Manufacturer's representative and/or CONTRACTOR shall be replaced by the CONTRACTOR at no additional cost to the OWNER.

1.07 REQUIREMENTS

A. The CONTRACTOR shall have at least five years experience with installation of the HDPE and Appurtenances. In addition, the CONTRACTOR shall have completed a minimum of five projects with the same material and of similar scope to that indicated for this project. The CONTRACTOR shall have a successful installation and maintenance record of in-service performance.

B. The CONTRACTOR is required to demonstrate compliance to the above requirements to the satisfaction of the OWNER or ENGINEER.

PART 2 - PRODUCTS

2.01 SOLID WALL PIPE

A. Acceptable Manufacturers

1. Plexco EHMW PE 3408

2. Phillips Driscoplex 8700 PE 3408

3. Poly Pipe 3408

4. Approved Equal

B. Materials

1. Material shall be extra high molecular weight HDPE pipe (Type 3408 resin).

2. Pipe shall be ASTM D1248, Type 111, Class C, Category 5, P34 of the SDR indicated on the Construction Drawings or in the Technical Specifications. Pipe shall conform to all applicable referenced standards.

3. ASTM D3350 minimum cell classification value 345434C.

4. All pipe and fittings shall be provided by a single manufacturer and be manufactured according to ASTM D3035 and ASTM F714.

5. The HDPE pipe shall have the following typical physical properties listed in Table 1, as determined by the appropriate test method.

Table 1: Typical Physical Properties for HDPE Pipe

Property	Test Method	Typical Value
Density	ASTM D1505	0.955 g/cm^3
Melt Flow Index	ASTM D1238 (190°C, 2.16 kg)	≤ 0.15 g/10 min, Condition E
Tensile Yield Strength	ASTM D638	3,200 psi
Tensile Modulus of Elasticity	ASTM D638	110,000 psi
Flexural Modulus	ASTM D790	120,000 psi
Hydrostatic Design Stress	ASTM D2837 (@73°F)	1,600 psi

C. Fittings

1. Fittings shall be ASTM D3350 butt heat fusion molded or factory fabricated.

2. Fittings shall be pressure rated to match the system piping to which they are fused. All backing flanges are to be stainless steel or epoxy coated.

3. Dimensions of fittings shall conform to standard dimensions and tolerances in accordance with ASTM D3261. Fittings shall conform to all applicable reference standards.

D. Flexible Mechanical Couplings

Flexible mechanical couplings for buried and exposed service pipe connections shall be stainless steel suitable for use with HDPE pipe.

E. Perforations

Perforated HDPE pipe shall have shop-fabricated holes of the size, spacing and location indicated on the Construction Drawings.

F. Gaskets

Gaskets shall be polyisoprene or approved equal satisfying the requirements of ASTM F477.

2.02 HDPE MANHOLE

A. Base Materials: The riser shaft, bottom plate, and top opening shall be made of polyethylene plastic compound meeting the requirements of Type III, Class C, cell classification 345434C as defined in ASTM D3350. The polyethylene plastic compound shall contain a minimum of 2% carbon black to provide protection against ultraviolet light. The manufacturer shall certify that the materials used to manufacture HDPE manholes meet these requirements.

B. Gaskets: Rubber or elastomeric gaskets shall comply in all aspects with the physical requirements specified in the nonpressure requirements of ASTM F477. Gaskets shall be flexible and form a positive, waterproof seal. Gasket material shall be weather resistant and suitable for the specified temperature ranges. These gasket requirements apply to the manway opening and cover connection only.

C. Thermal Welding Material: The material used for thermally welding any part(s) of an HDPE manhole shall meet the requirements established above for the base material.

D. Workmanship: The interior and exterior of HDPE manholes shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other injurious defects or materials. HDPE manholes not meeting these conditions in the opinion of ENGINEER shall be clearly marked "Rejected," removed from site, and replaced at no additional cost to OWNER.

E. Manway Frame/Covers: Frame/covers shall be of the size and in the location shown on Contract Drawings and shall be Neenah casting No. R-1557 or equivalent approved by ENGINEER. The frame and cover shall be ductile iron, easily removable, equipped with handles, and shall be gasketed to form a waterproof seal with the opening.

F. Equipment/Pipe Supports: CONTRACTOR shall coordinate the fabrication of integral support systems for valve stems and other appurtenances as shown on Contract Drawings. These support systems shall be welded or fastened to the HDPE manhole walls in a manner that will not structurally weaken or puncture the HDPE manhole. All connections shall be non-penetrating.

G. Concrete Cap: CONTRACTOR shall provide and install reinforced concrete pre-cast cap and pre-cast grade rings as shown on Contract Drawings that meet or exceed requirements of H-20 loading.

H. Rungs: The rungs shall be fiberglass reinforced plastic (FRP) and will be attached by means of HDPE brackets extrusion welded to the structure wall. All hardware shall be 316 stainless steel.

PART 3 - EXECUTION

3.01 GENERAL

A. The CONTRACTOR shall have an individual experienced in the installation of the HDPE Pipe and Appurtenances on-site at all times during the installation. The designated individual shall be responsible for ensuring that the HDPE Pipe and Appurtenances are installed according to this specification and the Construction Drawings. The appointment shall be subject to approval by the OWNER or ENGINEER.

B. The CONTRACTOR shall provide all required Manufacturer's certifications and technical data sheets for all HDPE Pipe and Appurtenances.

C. The CONTRACTOR shall visually inspect in-place all pipes (i.e., pipe lengths and associated welds) and appurtenances for holes, blemishes, penetrations or other detrimental defects.

3.02 QUALITY CONTROL

A. Pipe may be rejected for failure to conform to the Technical Specifications, or any of the following:

1. Fractures or cracks passing through pipe wall, except for a single crack not exceeding two inches in length at either end of pipe that can be cut off and discarded. Pipes within one shipment shall be rejected if defects exist in more than five percent of the shipment or delivery.

2. Cracks sufficient to impair strength, durability or serviceability of pipe.

3. Defects indicating improper proportioning, mixing and molding.

4. Damaged ends, where such damage prevents making a satisfactory joint.

5. Damage due to handling or installation. Scratches and gouges exceeding 10 percent of the wall thickness shall be considered excessive and may be rejected by the OWNER or ENGINEER.

B. Acceptance of fittings, stubs or other specially fabricated pipe sections shall be based on visual inspection at the job site and documentation of conformance to these Technical Specifications.

C. A professional land surveyor licensed in the Commonwealth of Virginia and approved by the OWNER or ENGINEER shall as-built survey all pipes and fittings placed. Top of pipes shall be surveyed every 50 feet on center. Inverts at manhole shall be surveyed as well as base and rim elevations. The as-built survey shall be submitted to the OWNER or ENGINEER within five days of installation.

3.03 INSTALLATION

A. General

1. Layout piping as shown on the plans. Any deviation from the layout shown must be approved by the ENGINEER.

2. Piping shall be cut from measurements taken at the site and not from the plans. All necessary provisions shall be taken in laying out piping to provide for expansion and contraction caused by temperature fluctuations.

3. Pipe shall be carried manually or by mechanical equipment with flat forks or fabric slings. Cables and chains shall not be used. Pipe shall be assembled and welded immediately adjacent to its final location and set or carefully rolled into position. Pipe shall not be dragged on the ground.

B. Inspection of Piping

1. Carefully inspect all pipe and fittings before installation, removing all dirt. The pipe shall be installed with markings up for visual inspection and verification.

2. Solid wall pipes shall have smooth exterior and interior surfaces, be first quality, free from cracks, blisters and other imperfections, and true to shape or form throughout each length. Piping judged by the OWNER or ENGINEER to be unacceptable shall be removed from the site, and new undamaged pipe shall be provided at no extra cost to the OWNER.

3. The interior of the pipeline shall be kept free from all dirt, joint material and other foreign materials as the work progresses. Tight-fitting stoppers or bulkheads shall be securely placed at the ends and any other openings of the pipe when work is stopped temporarily or at the end of the day's work. This is to prevent dirt, trash or animals from entering the pipe.

C. Solid Wall Pipe Jointing

1. The CONTRACTOR shall provide qualified fusion operators and weld in accordance with the Manufacturer's recommendation for butt fusion methods.

2. Butt fusion equipment for joining procedures shall be capable of meeting conditions recommended by the Pipe Manufacturer (i.e., temperature requirements, alignment and fusion pressures).

3. For cleaning pipe ends, solutions such as detergents and solvents, when required, shall be used in accordance with the Manufacturer's recommendations. Solvents shall not be used unless approved by the OWNER or ENGINEER.

4. Do not bend pipe to greater degree than minimum radius recommended by the Manufacturer for type and grade.

5. Do not subject pipe to strains that will overstress or buckle piping or impose excessive stress on joints.

6. Before butt fusing pipe, inspect each length for presence of dirt, sand, mud, shavings and other debris or animals. Remove debris from pipe.

7. Cover open ends of fused pipe at the end of each working day. Cap ends to prevent entry by animals or debris.

8. Use compatible fusion techniques when polyethylene pipes of different melt indexes are fused together. Refer to Manufacturer's specifications for compatible fusion.

9. During fusion procedures, check the heater plate temperature routinely to ensure the proper temperature is maintained. Flexible mechanical couplings shall only be used at the specific locations indicated on the Construction Drawings or as approved by the OWNER or ENGINEER.

D. Pipe Placement

1. Grade control equipment shall be of a type to accurately maintain design grades and slopes during installation of pipe.

2. Unless otherwise specifically stated, install pipe in accordance with Manufacturer's recommendations.

3. Maximum lengths of joined pipe to be handled as one section shall be placed according to Manufacturer's recommendations as to pipe size, pipe SDR and topography so as not to cause excessive gouging or surface abrasion. Maximum length of fused pipe to be handled as one section shall not to exceed 400 feet.

4. Cap pipe sections longer than single joint (typically 40 feet) on both ends during placement except during fusing operations.

5. Remove dirt or debris from inside of pipe before backfilling.

6. Notify the OWNER or ENGINEER prior to installing pipe into trench, and allow time for inspection. Correct irregularities found during inspection.

7. Complete tie-ins within trench whenever possible to prevent overstressed connections.

8. Allow pipe sufficient time to adjust to trench temperature prior to testing, fusion welding, segment tie-ins or backfilling activity.

9. When placing pipe in trench allow for thermal contraction and expansion (minimum 12 inches per 100 feet).

3.04 PLACEMENT OF HDPE MANHOLES

A. HDPE manhole bedding around the base of the manhole and pipe penetrations shall be prepared in the same manner as that for HDPE Pipe. Backfill around the remainder of the manhole shall be clean, compactable backfill. The backfill shall be free of large chunks, stones, and debris. Backfill material shall be favorably reviewed by ENGINEER prior to use.

B. Prior to the installation of the manhole, CONTRACTOR shall prepare the bedding for favorable review by ENGINEER. After favorable review of bedding placement by ENGINEER, HDPE manholes shall be placed plumb and aligned for proper piping connections as shown on construction drawings with inverts/bottom elevations established and verified.

C. Placement of HDPE manholes shall be coordinated with construction of piping, valve(s), and appurtenances contained within the manhole.

3.05 EMBEDMENT AND BACKFILL

A. Trench excavation and backfill shall conform to Section 02200.

B. HDPE pipe and fittings shall be installed in full compliance with the Manufacturer's recommendations.

C. The pipe shall be completely surrounded with bedding, haunching and initial backfill materials that provide stable and permanent support to the pipe.

D. Care should be taken to ensure that the haunching of the pipe is completed without disturbing the pipe. Initial backfill shall be placed in four-inch lifts and hand tamped to assure compaction.

3.06 FORCEMAIN TESTING

A. General

1. The total test time, including initial pressurization, initial expansion and time at test pressure shall not exceed eight hours. If the test is not completed in eight hours, the pressure in the test section shall be released and the section allowed to "relax" for at least eight hours before initiating another test.

2. Pipe lines shall be pressure tested in the presence of the OWNER or ENGINEER prior to backfilling. Provide a minimum of seven days notice to the OWNER or ENGINEER before completing test.

3. Provide necessary piping connections between the section of line being tested and nearest available source of water or air supply, together with test pressure equipment, meters, pressure gauge and other equipment, materials and facilities necessary to make specified tests.

4. Provide bulkheads, flanges, valves, bracing, blocking or other temporary sectionalizing devices required.

B. Preparation

1. Remove or isolate valves, flowmeters, and instruments that may not withstand the required test pressure from within the test sections. Reconnect pipes with temporary fittings. Vent isolated equipment.

2. Flush the pipe with clean water until the pipe section to be tested is clean and free of dirt, sand, pipe shavings or other foreign material.

3. Plug pipe outlets with test plugs, blind flanges or other devices suitable for the test pressure. Brace securely to prevent blowouts. Verify that the test pressure does not exceed any component of the pipe system.

4. Restrain or remove expansion joints.

5. Pressurizing equipment shall include a regulator set to avoid over-pressurizing and damaging an otherwise acceptable line.

C. Test Procedure

1. Complete test in accordance with OSHA requirements. Provide adequate safety equipment, and implement appropriate procedures to avoid injury or damage.

2. Verify that the specified test pressure did not exceed the allowable pressures recommended by the Manufacturers of the test section components.

3. Allow sufficient time for pipe and test media temperatures to equilibrate with ambient temperature.

4. Add water or air slowly to test section. Purge all trapped air. Vent high spots as needed. Inspect connections and retighten or otherwise correct any visible leaks.

5. The test consists of an initial expansion and test periods.

D. Acceptance

1. Test shall be accepted if the pressure drop over the 20-minute test period is less than five percent of the pressure at the beginning of the test period, or below the amount recommended by the Manufacturer, whichever is less.

2. All visible leaks shall be repaired regardless of test results. Section shall be retested if correcting leaks requires disassembly.

E. Test Pressures

1. HDPE leachate forcemain: 10 psi air for a period of 20 minutes.

2. In no case shall test pressure exceed maximum allowable pressure for any pipeline component, including valves, fittings and instruments.

3. If pressure test is not accepted, correct leaks or defects in the pipe and retest. All visible leaks shall be repaired regardless of test results. Section shall be retested if correcting leaks requires disassembly.

4. Remove temporary sectionalizing devices after tests are complete.

F. Test Report

1. Prepare and submit test report for each piping system tested. Include the following information in the test report.

   a. Date of test,

   b. Description and identification of the piping system tested,

   c. Type of test completed,

   d. Test fluid,

   e. Test pressure,

   f. Type and location of leaks detected,

   g. Corrective action taken to repair leaks,

   h. Results of the test / retest,

   i. Name of person completing the test, and

   j. Signature of the OWNER or ENGINEER that witnessed the test.

3.07 HDPE MANHOLE HYDROSTATIC TESTING

A. All HDPE manholes shall be subject to hydrostatic testing after installation of piping and completion of pipe penetration seals.

B. Hydrostatic testing shall consist of the following:

1. CONTRACTOR shall fill HDPE manholes with clean, potable water. Fill the HDPE manhole to the bottom (maximum of one-inch of freeboard space) of the manway opening.

2. Measure and record starting water level in HDPE manhole; this measurement shall be made in presence of the ENGINEER. Measurements shall be made to the nearest 0.10 inch.

3. Place the lid on the HDPE manhole, and wait a period of 24 hours.

4. Measure and record the final water level in the HDPE manhole after the 24-hour period; this measurement shall be made in presence of ENGINEER.

5. The passing test criterion is a drop in water level of 0.2 inches or less.

6. The CONTRACTOR shall remove all water from the HDPE manhole at completion of the hydrostatic test.

by the CONTRACTOR to remedy leakage. The CONTRACTOR shall submit corrective action to ENGINEER for favorable review prior to modifying or repairing the HDPE manhole. After the corrective action has been completed, the HDPE manhole shall be retested as described above until passing criterion is met.

* * * * * END OF SECTION * * * * *

SECTION 02520

MANHOLES/DROP BOXES/VAULTS

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. CONTRACTOR shall furnish all materials, labor, tools and appurtenances required to complete the precast concrete manholes, concrete valve boxes and concrete vaults as described herein and/or shown on the Contract Drawings. CONTRACTOR shall provide a "Competent Person" to implement, supervise, and inspect all work.

B. CONTRACTOR shall comply with applicable codes, ordinances, rules, regulations and laws of local, municipal, state or federal authorities having jurisdiction.

1.02 RELATED SECTIONS

A. Section 01550 - Health and Safety Specifications for Construction

B. Section 02540 - Leachate Collection and Conveyance Pipe

C. Section 03100 - Concrete Formwork

D. Section 03120 - Concrete Reinforcement

E. Section 03140 - Cast-In-Place Concrete

1.03 DESIGN REQUIREMENTS

Manholes/drop boxes/vaults shall be constructed of specified materials to the sizes, shapes and dimensions and at the locations shown on the Contract Drawings or as otherwise directed by OWNER. The height or depth of manholes/drop boxes/vaults will vary with the location. The top and bottom elevations of manholes/drop boxes/vaults shall be as shown on the Contract Drawings.

1.04 SUBMITTALS

A. CONTRACTOR shall submit to OWNER shop drawings and engineering data on frames, covers, grates, steps and precast manholes/drop boxes/vaults sections.

B. CONTRACTOR shall submit to OWNER standard (typical) details showing joints and seals between precast manhole/drop box/vault riser sections and showing joints between pipes and manholes/drop box/vault walls.

1.05 QUALITY ASSURANCE

A. Prior to delivery, all basic materials specified herein shall be tested and inspected by an approved independent commercial testing laboratory or, if approved by OWNER, certified copies of test reports prepared by the manufacturer's testing laboratory will be acceptable. All materials which fail to conform to these Specifications shall be rejected.

B. After delivery to the Site, any materials, which have been damaged in transit or are otherwise unsuitable for use in the Work shall be rejected and removed from the Site, at no additional cost to OWNER.

PART 2 - PRODUCTS

2.01 MATERIALS AND CONSTRUCTION

A. Concrete and Reinforcement

1. Concrete used in manhole, drop box, vault construction shall be Class "A" concrete conforming to the requirements of Section 03140 - Cast-In-Place Concrete of these Specifications.
2. Steel reinforcement shall be epoxy coated and conform to the requirements of Section 03120 - Concrete Reinforcement of these Specifications.

B. Precast Concrete Manholes:

1. Precast concrete manholes shall consist of precast reinforced concrete sections, a conical or flat slab top section, and a base slab section conforming with the typical manhole details as shown on the Contract Drawings.
2. Precast manhole sections shall be manufactured, tested and marked in accordance with the latest provisions of ASTM C 478.
3. The minimum 28-day compressive strength of the concrete for all sections shall be 4,000 psi.
4. The maximum allowable absorption of the concrete shall not exceed eight percent of the dry weight.
5. The circumferential reinforcement in the riser sections, conical top sections and base wall sections shall consists of one line of steel and shall be not less than 0.17 square inch per lineal foot.
6. The ends of each reinforced concrete manhole riser section and the bottom end of the manhole top section shall be so formed that when the manhole risers and the top are assembled, they will make a continuous and uniform manhole.

7. Joints of the manhole sections shall be of the tongue and groove type. Sections shall be joined using O-ring rubber gaskets conforming to the applicable provisions of ASTM C443, latest revision, or filled with an approved preformed plastic gasket meeting the requirements of Federal Specifications SS-S-00210, "Sealing Compound, Preformed Plastic for Pipe Joints", Type 1, Rope Form.
8. Each section of the precast manhole shall have not more than two holes for the purpose of handling and laying. These holes shall be tapered and shall be plugged with rubber stoppers or mortar after installation.
9. Stainless steel manhole steps shall be installed in each section of the manhole in accordance with the details on the Contract Drawings.

C. Frames, Covers, Attachments, and Steps:

1. Frames and covers shall be cast iron conforming to the minimum requirements of Federal Specifications WW01-652 or to ASTM A 48 for Class 30 Gray Iron Castings. All castings shall be made accurately to the required dimensions, fully interchangeable, sound, smooth, clean, and free from blisters and/or other defects. Defective castings which have been plugged or otherwise treated shall not be used. All castings shall be thoroughly cleaned and painted or coated with a bituminous paint. Each casting shall have its actual weight in pounds stenciled or painted on it in white paint.
2. Manhole access hatches/doors shall be cast-in-place in concrete top unit and shall be of type and dimension indicated on the Contract Drawings.
3. Interior concrete anchors, embedment plates, and fall protection system connection eyes shall be stainless steel with stainless steel hardware.
4. The contact surfaces of all manhole covers and hatches and the corresponding supporting frames shall be machined to provide full perimeter contact.
5. Interior manhole steps shall be stainless steel or Epoxy coated, and conform to the applicable provisions of ASTM Standard Specification Serial Designation C478.

D. Precast Concrete Drop Boxes and Vaults:

1. Precast concrete drop boxes shall consist of precast reinforced concrete sections, flat slab top section, and a base slab section conforming with the typical drop box details as shown on the Contract Drawings.
2. Precast drop box sections shall be manufactured, tested and marked in accordance with the latest provisions of ASTM C 478.
3. The minimum 28-day compressive strength of the concrete for all sections shall be 4,000 psi.
4. The maximum allowable absorption of the concrete shall not exceed eight percent of the dry weight.
5. The reinforcement in the wall sections, top section and base section shall consist of one line of steel and shall not be less than 0.17 square inch per lineal foot.

6. Each section of the precast drop box shall have not more than two holes for the purpose of handling and laying. These holes shall be tapered and shall be plugged with rubber stoppers or mortar after installation.
7. Joints of the drop box sections, if any, shall be of the tongue and groove type. Sections shall be joined using O-ring rubber gaskets conforming to the applicable provisions of ASTM C443, latest revision, or filled with an approved preformed plastic gasket meeting the requirements of Federal Specifications SS-S-00210, "Sealing Compound", Preformed Plastic for Pipe Joints", Type 1, Rope Form.

PART 3 - EXECUTION

3.01 PLACEMENT OF PRECAST CONCRETE MANHOLES

A. Prior to placing precast manholes, a minimum 9-inch-thick layer of coarse aggregate shall be placed as bedding. After approval of bedding by OWNER, manholes shall be placed and inverts/bottom elevations established and verified.

B. After placing manhole base, inverts shall be constructed using Class "A" concrete in accordance with details on the Contract Drawings and inverts shall have the same cross section as the invert of the culverts which they connect. The manhole invert shall be carefully formed to the required size and grade by gradual and even changes in sections.

C. After the base section has been set, and inverts formed, the precast manhole sections shall be placed thereon, care being exercised to form the incoming and outgoing pipes into the wall of the manhole at the required elevations.

D. The top unit with cast-in-place access hatch/door for the manhole shall be set at the required elevation and properly anchored to the masonry. Where manholes are constructed in paved areas, the top surface of the frame and cover shall be tilted to conform to the exact slope, crown and grade of the existing adjacent pavement.

3.02 PLACEMENT OF PRECAST CONCRETE DROP BOXES AND VAULTS

A. Prior to placing precast concrete drop boxes and vaults, a minimum 9-inch-thick layer of coarse aggregate shall be placed as a level bedding for the drop box.

B. After approval of bedding by OWNER, drop boxes and vaults shall be placed, and their inverts shall be established and verified.

C. Covers, grates, hatches as indicated on the Contract Drawings shall be set at the required elevation and properly anchored to the drop box, as shown on the Contract Documents.

* * * * * END OF SECTION * * * * *

+++++++++++++++ The End of the Course ++++++++++++++

Any questions please contact the instructor at makarim@juno.com

QUIZ for Wastewater Collection Systems

1. The individual pipes used to collect and transport wastewater are called ___________, and the network of sewers used to collect wastewater from a community is known as Collection System.
a. sullage
b. sewers
c. sewage
d. sewerage

2. The water from kitchen, baths, sinks, and similar appliances from buildings which does not contain human or animal excreta is called ____________.
a. sullage
b. sewers
c. sewage
d. sewerage

3. The system of pipes laid for carrying sewage is called ____________.
a. sullage
b. sewers
c. sewage
d. sewerage

4. The combination of domestic, industrial wastes, and stormwater is known as ___________.
a. sullage
b. sewers
c. sewage
d. sewerage

5. There are 3 types of wastewater collection systems and these are:
a. sanitary or municipal sewer
b. stormwater sewer
c. combined sewer
d. all of the above
e. none of the above

6. Intercepting sewers are the larger one that are used to intercept several main or trunk sewers and convey wastewater to the treatment plants.
a. True
b. False

7. The __________ shape sewers are commonly used to collect wastewater and they may be made of concrete or HDPE.
a. rectangular
b. circular
c. semi-elliptical
d. horse-shoe
e. egg-shaped

8. The __________ shape sewers are suitable for heavy discharge.
a. rectangular
b. circular
c. semi-elliptical
d. horse-shoe
e. egg-shaped

9. The __________ shape sewers provide good hydraulic properties even better than circular shaped sewers.
a. rectangular
b. circular
c. semi-elliptical
d. horse-shoe
e. egg-shaped

10. The primary appurtenances of sanitary sewers are:
a. manholes
b. drop inlets to manholes
c. building connections, and junction chambers
d. all of the above
e. none of the above

11. Manholes are provided at
a. every change in alignment
b. every change in gradient
c. every junction of two or more sewer lines
d. heads of all sewers or branches
e. all of the above
f. none of the above

12. During rains, the infiltration will be due to the rise in groundwater table and from roofs. The infiltration depends on:
a. Height of groundwater level
b. Type of soil in which sewers are laid
c. Workmanship of laying pipes
d. All of the above
e. None of the above

13. The principal materials that are used for sewer system are:
a. wood, regular plastic, rubber, and lead
b. asbestos cement, ductile iron, reinforce cement concrete (RCC), polyvinyl chloride (PVC), and high-density polyethylene (HDPE)
c. all of the above
d. none of the above

14. The self-cleansing velocity for 12 – 24 inch diameter sewer is:
a. 3.0 ft/s (0.9 m/s)
b. 2.5 ft/s (0.75 m/s)
c. 2.0 ft/s (0.6 m/s)
d. 1.0 ft/s (0.3 m/s)

15. The maximum velocity of __________ is recommended to avoid damaging sewers.
a. 10.0 ft/s (3 m/s)
b. 3.0 ft/s (0.9 m/s)
c. 2.5 ft/s (0.75 m/s)
d. 2.0 ft/s (0.6 m/s)

16. The minimum velocity of __________ is recommended to avoid deposition in the sewers.
a. 10.0 ft/s (3 m/s)
b. 3.0 ft/s (0.9 m/s)
c. 2.5 ft/s (0.75 m/s)
d. 2.0 ft/s (0.6 m/s)

17. In order to carry a wastewater flow rate of 2.5 ft^3/s (0.0708 m^3/s) through a sewer line with a self-cleansing velocity of 2.5 ft/s (0.75 m/s), the diameter of the sewer line to be provided is nearly:
a. 6 inch (150 mm)
b. 8 inch (200 mm)
c. 14 inch (350 mm)
d. 18 inch (450 mm)

18. A gravity sewer pipe or conduit is designed to carry wastewater flowing at 2 ft/sec.
a. True
b. False

19. Act ______ is commonly called the Sewage Facilities Planning Act.
a. 523
b. 537
c. 547
d. 557

20. The minimum size of a sanitary sewer shall typically be ___-inches in diameter.
a. 4
b. 6
c. 8
d.10

21. Sewers shall be deep enough to prevent freezing. A typical minimum depth for collection sewers is ____ feet.
a. 2
b. 4
c. 6
d. 8

22 Sewers shall be laid in a uniform slope between manholes. The minimum slope for an 8-inch diameter sewer is _______.
a. 0.20%
b. 0.40%
c. 0.60%
d. 0.80%

23. Sewers shall be laid in a uniform slope between manholes. Sewers on steep slopes, _______ or greater, should be anchored with concrete anchors.
a. 20%
b. 40%
c. 60%
d. 80%

24. Sanitary sewers should be _______ feet horizontally from existing or proposed water mains.
a. 2
b. 6
c. 10
d. 14

25. If the sewer must cross under a water main, there should be _____-inches of vertical clearance.
a. 6
b. 12
c. 18
d. 24

26. ________ feet of cover should be provided over sanitary sewers that are crossing a stream. Sewers crossing streams should be constructed of cast or ductile iron.
a. Three
b. Five
c. Seven
d. Nine

27. A gravity sewer is a pipe or conduit intended to carry wastewater flowing with a minimum velocity of ______ ft/sec from a higher elevation to a lower elevation due to the force of gravity.
a. 2
b. 4
c. 6
d. 8

28. Gravity sewers are a minimum of _____-inch diameter pipes with manhole structures located at changes in horizontal alignment and vertical slope changes.
a. 2
b. 4
c. 6
d. 8

29. The lateral is the piping that connects the public sewer to the building. The size of the lateral is typically ____ to ____ inches in diameter.
a. 2 to 4
b.4 to 6
c. 6 to 8
d. 8 to 10

30. Sewers shall be deep enough to prevent freezing. A typical minimum depth for collection sewers is ____ feet.
a. 2
b.4
c. 6
d. 8

31. The contract drawings provide a _________________ representation of the work to be done.
a. linguistic written
b. graphical
c. visual
d. natural

32. Flow data evaluation involves processing the information obtained from each meter. The data is analyzed on preset intervals, typically ____ minutes, _____ minutes or _____ minutes.
a. 5, 10, 20
b. 10, 20, 40
c. 15, 30, 60
d. 20, 40, 80

33. The flow rates for each interval are determined and then a total daily value is calculated. Hydrographs are constructed with the intervals to provide a ________ representation.
a. linguistic written
b. graphical
c. visual
d. natural

34. A community which has only a sewer system is not required to have a permit but those with a WWTP must have an NPDES permit which is renewed every ____ years.
a. 3
b. 5
c. 10
d. 15

35. Depending on size, the sewer jet pumps will generate between 1,200 and 2,000 psi at ____ to _____ gallons per minute. Some sewer jets are larger, but they all work the same way.
a. 15 to 25
b. 25 to 45
c. 35 to 65
d. 45 to 75

36. Cleaning the sewers with special tools where flushing is inadequate to remove an obstruction. Providing proper ventilation for removing explosive gases (_____, _____) as they form due to decomposition of waste.
a. NH_4, CO_2
b. CH_4, CO
c. CH_4, CO_2
d. SO_4, CO

37. The design of sewers consists of determining the diameter of sewer to carry the estimated quantity of sewage at a velocity that is equal to the ___________ velocity.
a. minimum
b. maximum
c. self-cleansing
d. average

38. Rational Method formula estimates the peak rate of runoff at any location in a drainage area. The limitation of rational method is that the drainage area is less than _____ acres.
a. 10
b. 20
c. 30
d. 40

39. Flow regulators are used to divert flow from one sewer line to another to prevent overloading the system.
a. True
b. False

40. Cleanouts are used in a sanitary sewer lateral to permit access for the removal of solids that result in blockages. At least two cleanouts should be provided; one approximately ____ feet from the building foundation, and one at the property line.
a. 3
b. 5
c. 10
d. 15

41. Backflow preventers are used in a sanitary sewer lateral to prevent the accidental backflow of wastewater into buildings.
a. True
b. False

42. Chemical grouting is used to seal pipe joint and circumferential cracks. Two types of chemical grouts that are used in chemical grouting to seal pipe joint and circumferential cracks are gels and foams.
a. True
b. False