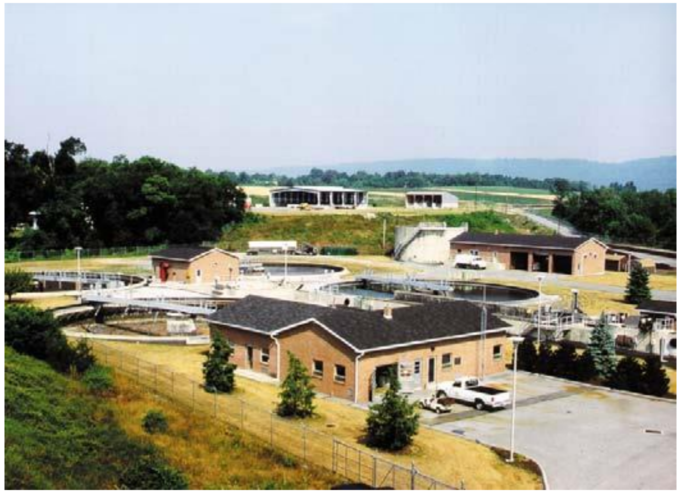
Wastewater Treatment Plant
Operator Certification Training



Module 23
Wastewater Collection Systems
Part I

Revised 2020

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
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Unit 1 – Overview of Wastewater Collection Systems

Learning Objectives

- List and describe three types of collection systems.
- Compare sanitary and combined collection systems.
- Explain the appurtenances associated with wastewater collection systems.
- Describe the regulatory requirements associated with wastewater collection systems.

General Information

Collection and Conveyance

Factors that affect the operation of the collection system and ultimately impact treatment plant performance include:

- *Seasonal flow* and *loading variations* by industrial users.
  - Short-term overloads
  - Changes in process loadings
- Knowledge of *location*, *amount*, and *types* of wastes from major water-using industries enables operator to locate sources of problems in the influent.
- Long *travel times* can result in septicity and hydrogen sulfide generation. Care should be taken as hydrogen sulfide is a corrosive, toxic and explosive gas.
  - Rotten-egg odor
  - Concrete degeneration

Septicity is a condition brought on by the action of anaerobic bacteria in a wastewater devoid of dissolved oxygen. Septic wastewater has a characteristic black color.

Influent is wastewater or other liquid that is raw (untreated) or partially treated that flows into a treatment process or treatment plant.

Types of Collection Systems

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.

Gravity

- The primary type of public sanitary sewer collection system is a gravity system. 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.

Low Pressure

- 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 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.

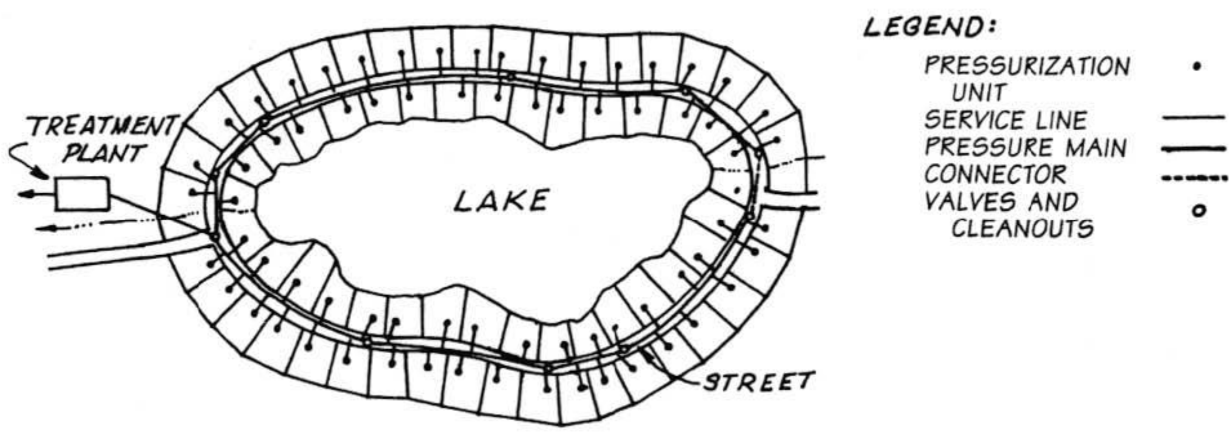


Figure 1.1 A Low-Pressure Sewage System[1]

Vacuum

- Vacuum collection systems are used for the same reason as low-pressure systems. However, it is rare to find a vacuum collection system in use in Pennsylvania as this is a 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.

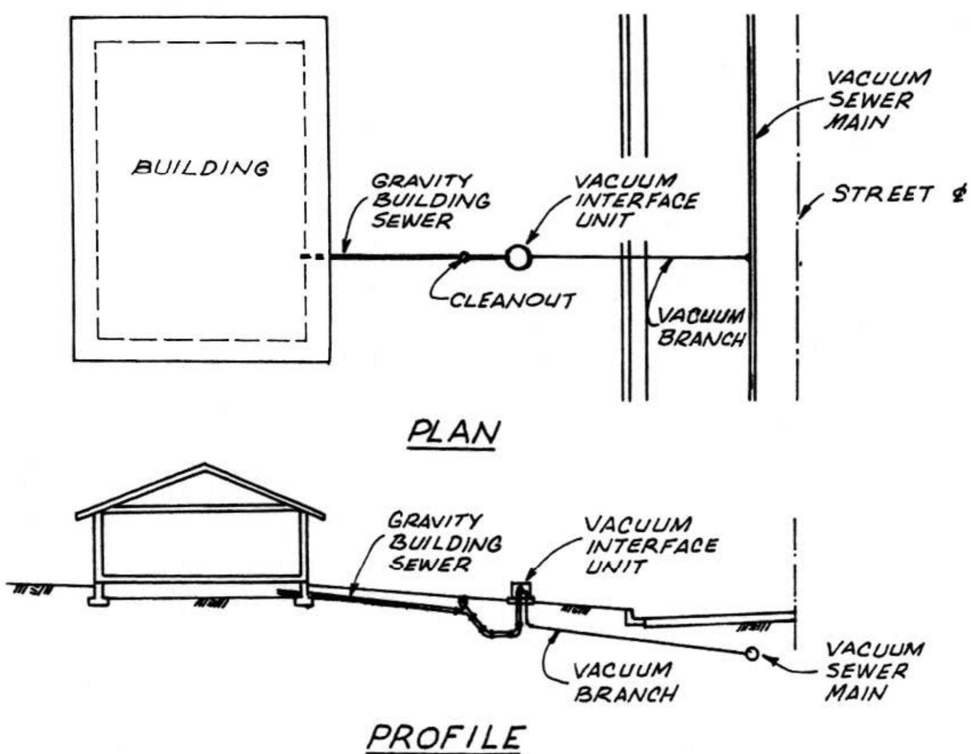


Figure 1.2 A Vacuum Collection System[2]

Sanitary vs. Combined Systems

- A sanitary system can be either a separate sewer system or a combined sewer system.

- A separate sewer system carries sanitary wastewater with minor quantities of ground, storm and surface waters that are not intentionally admitted.

- A combined sewer conveys both runoff and storm water from inlets along the streets and wastewater. The combined system is designed with overflows that discharge both storm water and wastewater to a receiving stream when the flow in the pipe exceeds the design capacity. Combined systems are not permitted in new developments.

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]

Manholes

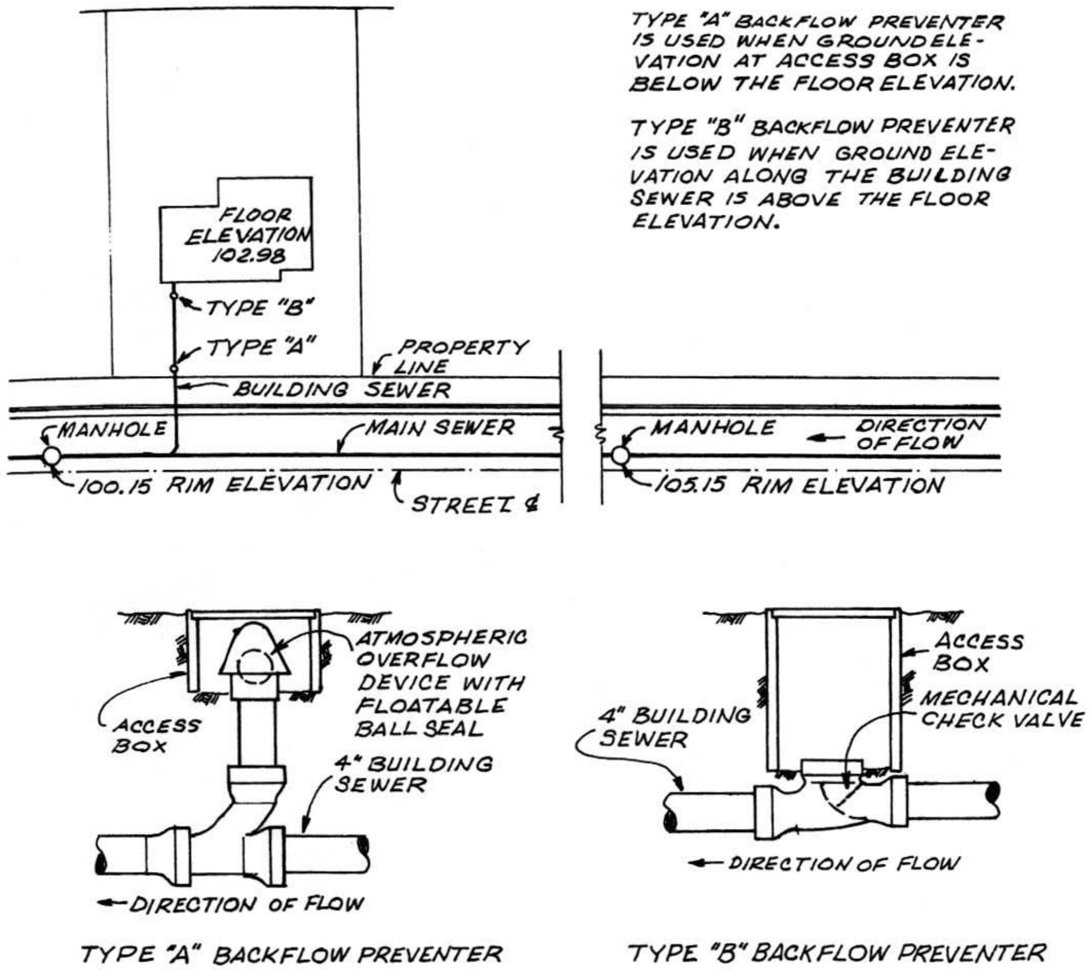
- Manholes are the key appurtenance included in a sanitary sewer system. The manholes are typically round concrete structures, 4- to 5-feet in diameter. Older systems often contain brick manholes that can be a source of groundwater infiltration. Newer systems use precast concrete manholes. Manholes are typically 200 to 400 feet apart. Manholes are placed at changes in sewer line direction, slope, elevation, pipe sizes and junctions.

- Most manholes have a 2 to 3-feet diameter cover, which can be removed. Steps are usually cast into the manhole walls to facilitate entry. The manhole acts as the entry point to the sanitary sewer system. Maintenance personnel and investigation equipment can enter the sanitary system at these key locations.

- Drop manholes are used when the difference in the elevation of an incoming and outgoing sewer line cannot be accommodated by a drop in the manhole channel without creating excessive turbulence and splashing of wastewater.

Backflow Preventers

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

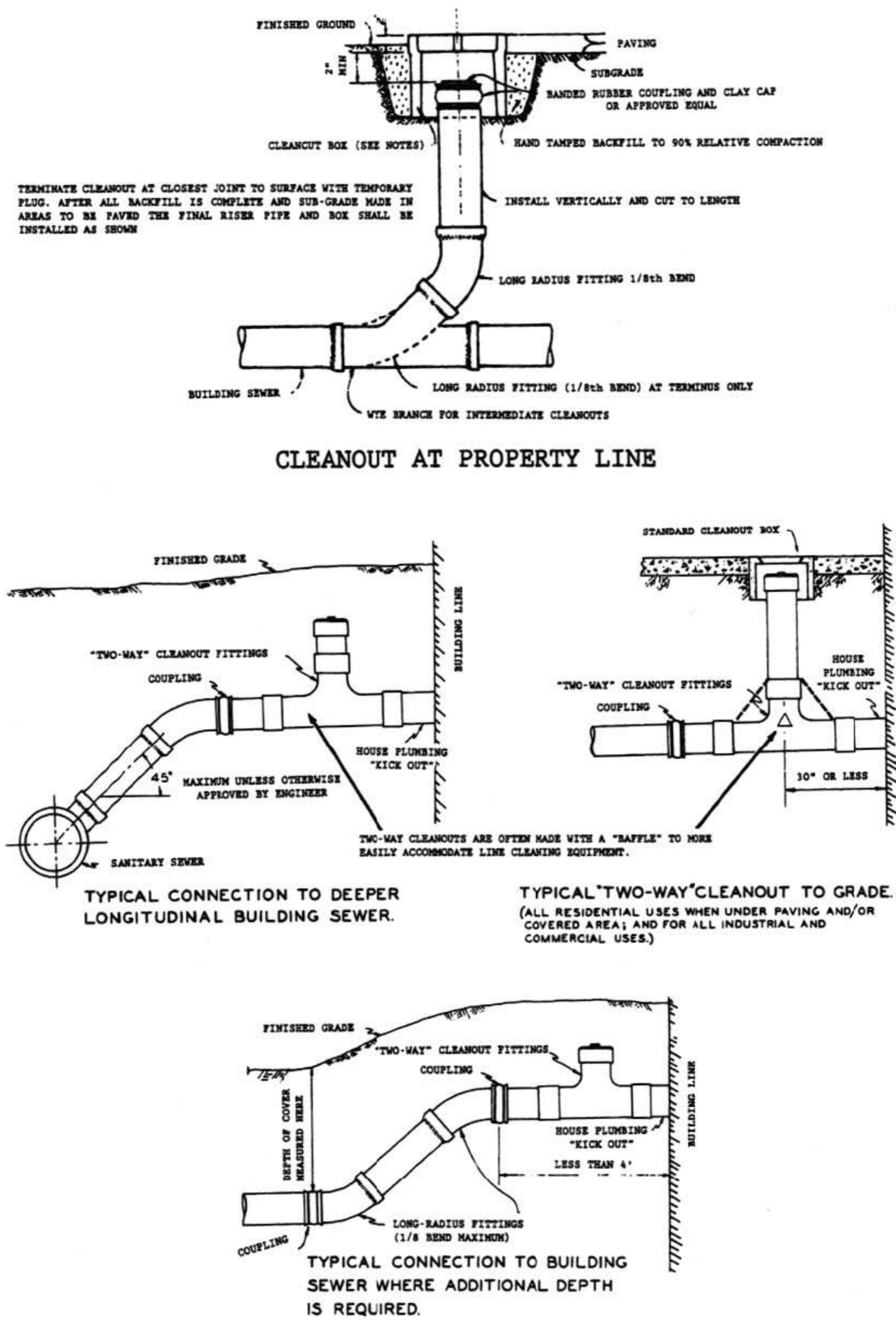


NOTE: There should be a written agreement between the property owner and the sewer district regarding who is responsible for the maintenance of backflow preventers. Grease deposits or rags can prevent their proper operation and they should be cleaned every six months.

Figure 1.3 Backflow Preventers[4]

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.



NOTES:

1. Cleanouts should be extended to surface so they are accessible without excavation in order to reduce maintenance costs and customer complaints regarding operators disturbing their yards.
2. "Two-Way" cleanout fittings may be difficult to push equipment through because of the right-angle entrance instead of a gradual entrance.

Figure 1.4 Cleanouts[5]

Lateral

- 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.

Inverted Siphon

- An inverted siphon 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.

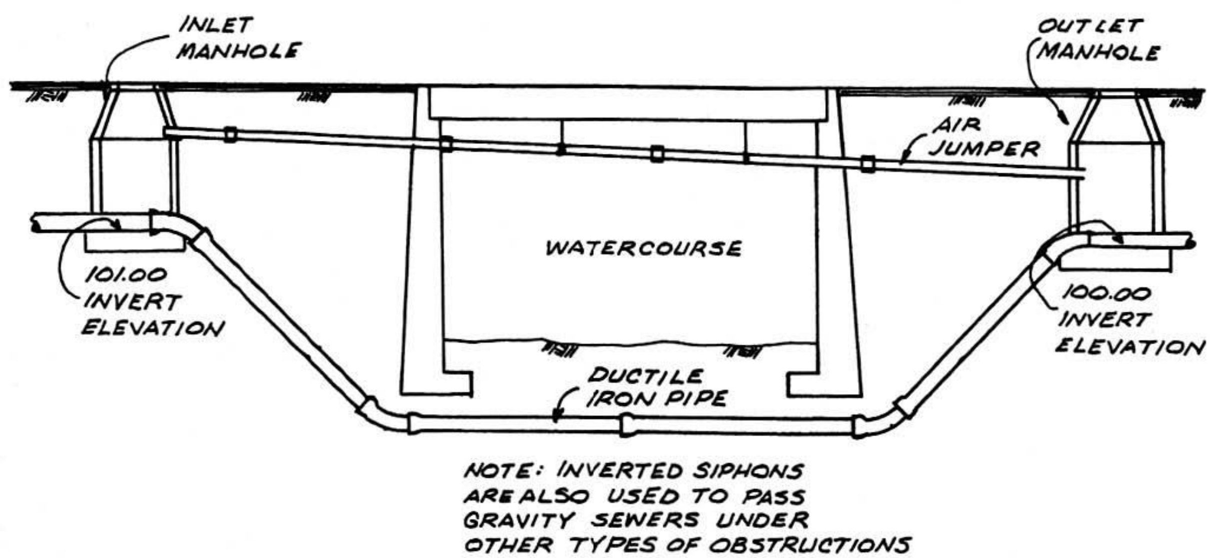


Figure 1.5 An Inverted Siphon[6]

Flow Regulators

- Flow regulators 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.

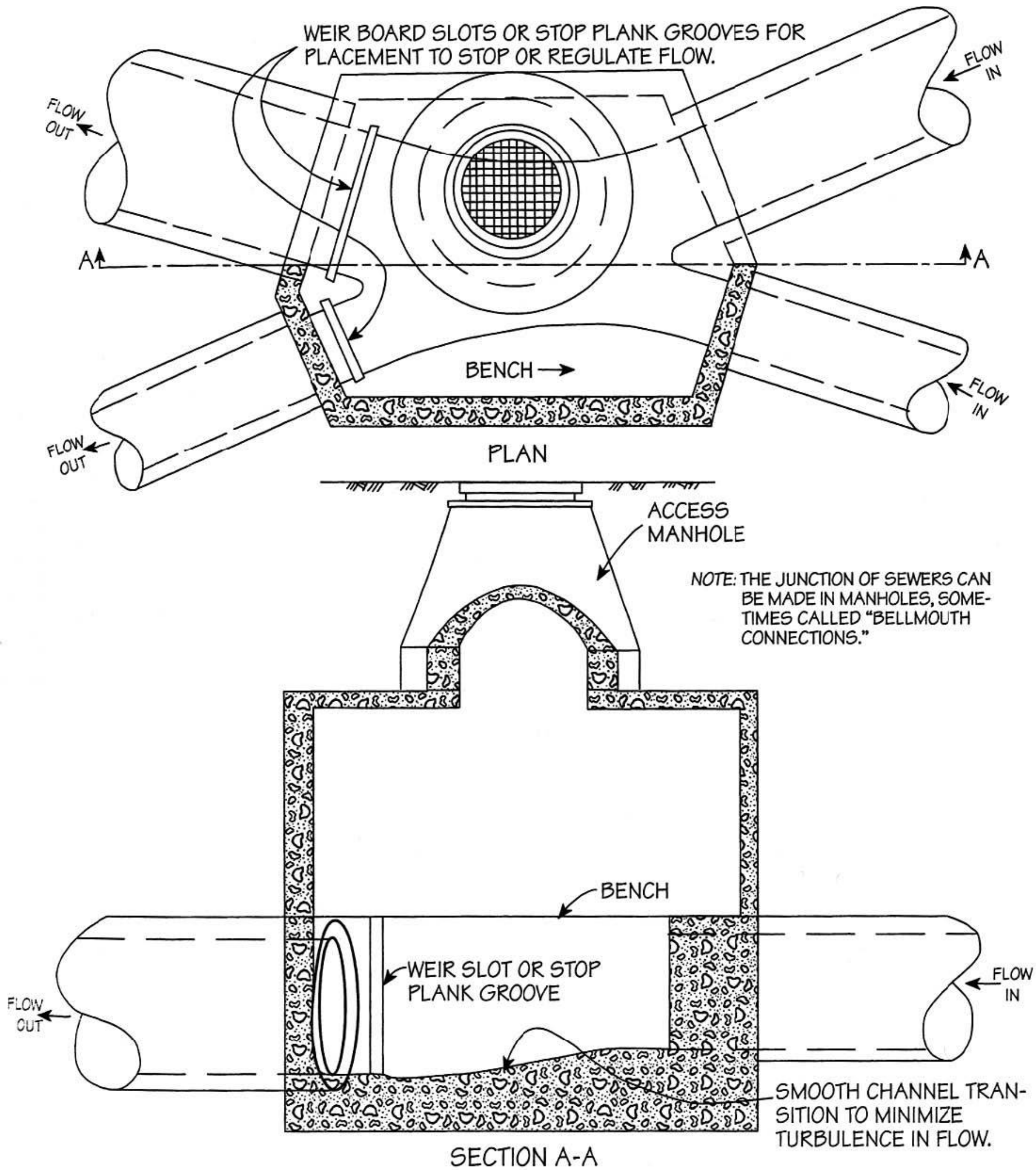


Figure 1.6 Flow Regulator[7]

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.*"

Key Points for Unit 1 – 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 form 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.
- Six types of appurtenances: manholes, 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.

Exercise for Unit 1 – Overview of Wastewater Collection Systems.

1. List three types of collection systems and explain how they each operate.

   a. ____
   ____
   ____

   b. ____
   ____
   ____

   c. ____
   ____
   ____

2. List six types of appurtenances used in collection systems.

   a. ______________________

   b. ______________________

   c. ______________________

   d. ______________________

   e. ______________________

   f. ______________________

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

4. Act ______ is commonly called the Sewage Facilities Planning Act.

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

[1] Steve Goodman, "Wastewater Collection Systems (Purpose, Components and Design)," in *Operation and Maintenance of Wastewater Collection Systems: A Field Study Training Program*, Vol I, (Sacramento California: California State University, Sacramento Foundation, 1999), p. 48.

[2] Goodman, p. 48.

[3] George Freeland, "Collection System Words," in *Operation and Maintenance of Wastewater Collection Systems: A Field Study Training Program*, Vol I, (Sacramento California: California State University, Sacramento Foundation, 1999), p. 505.

[4] Goodman, p. 51.

[5] Goodman, p. 54.

[6] Goodman, p. 60.

[7] Goodman, p. 59.

Additional Resources Used

Domestic Wastewater Facilities Manual from the Commonwealth of Pennsylvania Department of Environmental Protection, p. 6.

Gravity Sanitary Sewer Design and Construction.

American Society for Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 60.

Water Pollution Control Federation (WPCF) Manual of Practice No. FD-5, Chapter 1, pp. 1-2.

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Unit 2 – Design and Construction

Learning Objectives

- List and explain three types of flows.
- Describe the regulatory requirements associated with the design and construction of a collection system.
- List and explain five factors that are important to the layout of a collection system.
- List three factors that should be considered when installing a wastewater collection system and explain the importance of each.
- Identify and explain two important construction factors.
- Identify and explain two important construction testing factors.

Residential Land Use

- Residential land use produces a relatively predictable volume of wastewater. The flows generated in a residential area are directly related to the type of residential property allowed in the area. The type of property permitted will determine the anticipated built-out population and wastewater flow in the area.

Table 2.1 Flow Rates from Residential Sources[1]

Source	Unit	Flow, gal/unit · d Range	Flow, gal/unit · d Typical
Apartment:			
High-rise	Person	35–75	50
Low-rise	Person	50–80	65
Hotel	Guest	30–55	45
Individual residence:			
Typical home	Person	45–90	70
Better home	Person	60–100	80
Luxury home	Person	75–150	95
Older home	Person	30–60	45
Summer cottage	Person	25–50	40
Motel:			
With kitchen	Unit	90–180	100
Without kitchen	Unit	75–150	95
Trailer park	Person	30–50	40

[a] Adapted in part from Ref. 7.

Note: gal × 3.7854 = L

- The flows from residential properties experience a diurnal flow pattern. The minimum wastewater flow occurs in the early morning when most residents are sleeping with the maximum amount of flow occurring in the morning and in the evening.

- The effect of the flow pattern is that the residential flow has a peaking factor that is calculated by dividing the maximum flow by the minimum flow. A typical peaking factor (maximum flow/average flow) for residential land is 2.5. The use of the peaking factor is important to ensure that the collection system is large enough to convey the flow.

Commercial Land Use

- Commercial land use can produce a wide variety of flows. Therefore, it is important for the designer to be informed of the proposed development.

- Flow estimates for commercial land use are typically based on gallons per acre. The following table shows typical flow values for various types of commercial establishments.

Table 2.2 Flow Rates from Commercial Sources[2]

		Flow, gal/unit · d	
Source	**Unit**	**Range**	**Typical**
Airport	Passenger	2–4	3
Automobile service station	Vehicle served	7–13	10
	Employee	9–15	12
Bar	Customer	1–5	3
	Employee	10–16	13
Department store	Toilet room	400–600	500
	Employee	8–12	10
Hotel	Guest	40–56	48
	Employee	7–13	10
Industrial building (sanitary waste only)	Employee	7–16	13
Laundry (self-service)	Machine	450–650	550
	Wash	45–55	50
Office	Employee	7–16	13
Restaurant	Meal	2–4	3
Shopping center	Employee	7–13	10
	Parking space	1–2	2

[a] Adapted in part from Ref. 2.

Note: gal × 3.7854 = L

Industrial Land Use

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

Table 2.3 Sewer Capacity Allowances for Commercial and Industrial Areas[3]

City	Year Data Published Or Obtained	Commercial Allowances (GPD/acre)	Industrial Allowance (GPD/acre)
Cincinnati, OH	1980	Case-by-case determination after consultation with the Directors of Sewers.	
Dallas, TX	1960	30,000 added to domestic rate for downtown; 60,000 for tunnel relief sewers.	
Grand Rapids, MI	1980	Offices, 40 - 50 GPD/cap[b]; hotels, 400 - 500 GPD/room; hospitals, 200 GPD/bed; schools, 200 - 300 GPD/room.	
Hagerstown, MD	——	Hotels, 180 - 250 GPD/room; hospitals, 150 GPD/bed; schools, 120 - 150 GPD/room.	
Houston, TX	1960	Peak flows: offices 0.36 GPD/sq ft; retail 0 - 20 GPD/sq ft; hotels 0.93 GPD/sq ft.	
Las Vegas, NV	——	Resort hotels, 310 - 525 GPD/room; schools, 15 GPD/cap.	
Los Angeles, CA	1980	Commercial, 100 GPD/1,000 sq ft gross floor area; hospitals, 500 GPD/bed (surgical), 85 GPD/bed (convalescent); schools, elementary or junior high schools, 10 GPD/student; high schools, 15 GPD/student; universities, 20 GPD/student. The above values give peak flow rates. Divide by 3.0 to obtain average flow rates.	15,500
Los Angeles Co. San. District, CA	1980	4,000 - 6,000	
Lincoln, NE	1962	7,000	
Milwaukee, WI	1980	240,000 (max); 25,800 (min)	
St. Joseph, MO	1962	64,000 (downtown) 25,800 (neighborhood)	
St. Louis, MO	1960	90,000 average, 165,000 peak	
Santa Monica, CA	1980	Commercial, 9,700; hotels, 7,750	13,600
Toronto, Ont., CANADA	1980	Analysis of actual water consumption in the commercial and industrial downtown area is approximately 20,000 GPD/acre.	

[a] *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION*, Water Environment Federation, Alexandria, VA.
[b] Cap. Capita or person. Offices, 40 - 50 gallons/day per person.

Design Flow Calculation

A new subdivision that incorporates residential and commercial land is being proposed at the edge of town. Given the following, calculate the design flow:

Subdivision area: 175 acres.

Subdivision requirements: 150 acres shall be residential with better homes (per census data, assume 3 people per home) with 3 acre lots.

A shopping center is planned on the additional 25 acres with a flow of 4,000 gpd/acre (based on similar centers in the area).

Calculation:

Step 1: Calculate residential flow, using Table 2.2 to determine typical flow per person:

(150 acres) (1home/3acre) (80 gal/person*day) (3 person/home) = 12,000 gpd

Step 2: Determine peak residential flow:

12,000 x 2.5 = 30,000

Step 3: Determine commercial capacity:

(25 acre) (4,000 gpd/acre) = 100,000

Step 4: Determine total design flow

Total Design Flow = 30,000 + 100,000 = 130,000 gpd = 0.13 MGD

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.

Permitting

- An Erosion and Sedimentation (E and S) Control Plan is required for earth moving activity.

- A Department of Environmental Protection Part II Permit Sewer Extensions and Pumping Stations is required for public collection systems that have the potential to serve more than 250 Equivalent Dwelling Units. A copy of this document is included in Appendix B of this module.

- Additional submittal is required if the proposed collection system will be located underneath a waterway.

Slope and Size

The **slope** of a sanitary sewer is the ratio of the change in vertical distance to the change in horizontal distance. For example; if you wish to find the slope of a sanitary sewer between two manholes, you will need to know the invert elevation (a.k.a. – the flow line) at both manholes and the distance between them. (Rise or fall/Run)

- Providing adequate slope of the sewer is necessary to provide the necessary velocity, typically 2.0 feet per second or more, to ensure that solids do not settle out.

- The slope of the sanitary sewer should follow the grade of the land as much as possible for economic reasons. In certain cases, the grade may not be able to be followed due to the sewer becoming too shallow or not meeting the required minimal slope.

- A sanitary sewer should be sized to be one-half full when conveying peak dry weather flow. 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.

- The sanitary sewer must also be large enough to allow cleaning. The standard minimum size of a gravity sanitary sewer in Pennsylvania is 8-inches in diameter. The required size of the sewer is dependent on the slope of the sewer and the contributing flow into the sewer.

Location, Alignment and Depth

- The sanitary sewer layout begins by determining the connection point to the existing sewer system and the area to be sewered.

- The preliminary layout can be based on topographic maps with the proposed sewer following the grade of the land.

- Sewers are typically constructed in the middle of public streets to permit convenient access for maintenance. In addition, sewers will typically have a gradient in the same direction as the street or ground surface.
  - With sewers in streets, manholes are typically placed every 400 feet or at locations where the slope or alignment changes and at street intersections where separate sewer lines join.

- Sewers can also be placed in easements or rights-of-way in areas where the grade of road or the street alignment prohibits placement.
  - In easements or rights-of-way, manholes should not be in low areas due to the possibility of surface water inflowing.
  - When manholes are placed in easements or rights-of-way, the rims should be above ground to allow the location to be more readily identified during future maintenance activities.
  - The placement of sewers in easements should be minimized due to the difficulty in gaining access to maintain the sewer system.

- A sanitary sewer is typically a minimum of 4-foot deep to avoid freezing. The actual depth of a proposed sewer line may be much deeper than the minimal depth. A sewer line should be of sufficient depth to permit proposed buildings to have basement sewer service and to be under other proposed underground utilities.

Exercise for Unit 2 – Flows, Regulatory Standards, & Layout.

1. It is important to use a peaking factor for residential flow volumes to ensure that the collection system is large enough to convey the flow.
   a. True   b. False

2. Flow estimates for commercial land use are generally based on ____________ per ______. The actual values used depend on the type and size of the business occupying the land in question.

3. Determine the peak residential flow for a subdivision of 75 acres with homes on 1 acre lots and assume 3 people per home.
   ____
   ____
   ____
   ____

4. The minimum size of a new sanitary sewer shall be
   a. 6 inches   b. 8 inches   c. 10 inches   d. 12 inches

5. If a sanitary sewer must cross under a water main, there must be at least 18 inches of vertical clearance.
   a. True
   b. False

6. Which of the following statements are true?
   a. An Erosion and Sedimentation (E&S) control plan is needed for earth moving activity.
   b. Sanitary sewers should be 10 feet horizontally from existing or proposed water mains.
   c. The slope of a sanitary sewer is often called Rise/Run.
   d. All the above.

7. The minimum depth of a sanitary sewer is ____ feet.

8. The invert elevation at manhole one is 263.47 feet and the invert elevation for manhole two is 271.94 feet. The pipe length between the two is 400 feet. What is the slope of the sanitary sewer? _______

9. Sanitary sewers are often constructed to run in the middle of streets to provide easy access and manholes are typically placed about every ________ feet.

Pipe Strengths

There are two major types of pipes in use today for collection systems. When installing the selected piping, it is important to ensure that the loading does not exceed the limits of the piping material.

- Rigid pipe requires less support during installation; however, it is subject to cracking when subject to excessive loads. RCP is also subject to hydrogen sulfide corrosion. Three types of rigid pipes are Cast-Iron Pipe (CIP), Reinforced Concrete Pipe (RCP) and Vitreous Clay Pipe (VCP).

- Flexible pipe will not normally crack when excessive loads are applied however it will bend or bulge from a load if it is not adequately supported. Two common types of flexible pipe are Ductile Iron Pipe (DIP) and Polyvinyl Chloride (PVC).

Pipe Deflection

A common problem that occurs with flexible pipe is deflection.

Pipe deflection is when the pipe has changed direction, either up, down, right or left, from the direction it was originally laid.

- Deflection occurs when backfill compaction causes unequal pressures on various sides of the pipe. The pipe will deflect to the location where the pressure is the least. Therefore, it is important that backfill is compacted uniformly.

Bedding

Adequate bedding must be provided in the trench when installing sewer pipe. Bedding generally consists of well-graded crushed stone or well-graded gravel and is located underneath the pipe in the trench. Specific types of bedding are required for rigid and flexible pipe.

Bedding Required for Rigid Pipe

- There are three typical classes of bedding that is used for rigid pipe. Please note in Figure 2.1 that Class D bedding is typically not permissible for use as pipe bedding.

- Each class of bedding has a load factor that determines the ability of the bedding to assist in supporting the rigid pipe. The standard strength of the pipe and the load factor are required to ensure that cracking of the pipe will not result from excessive loads.

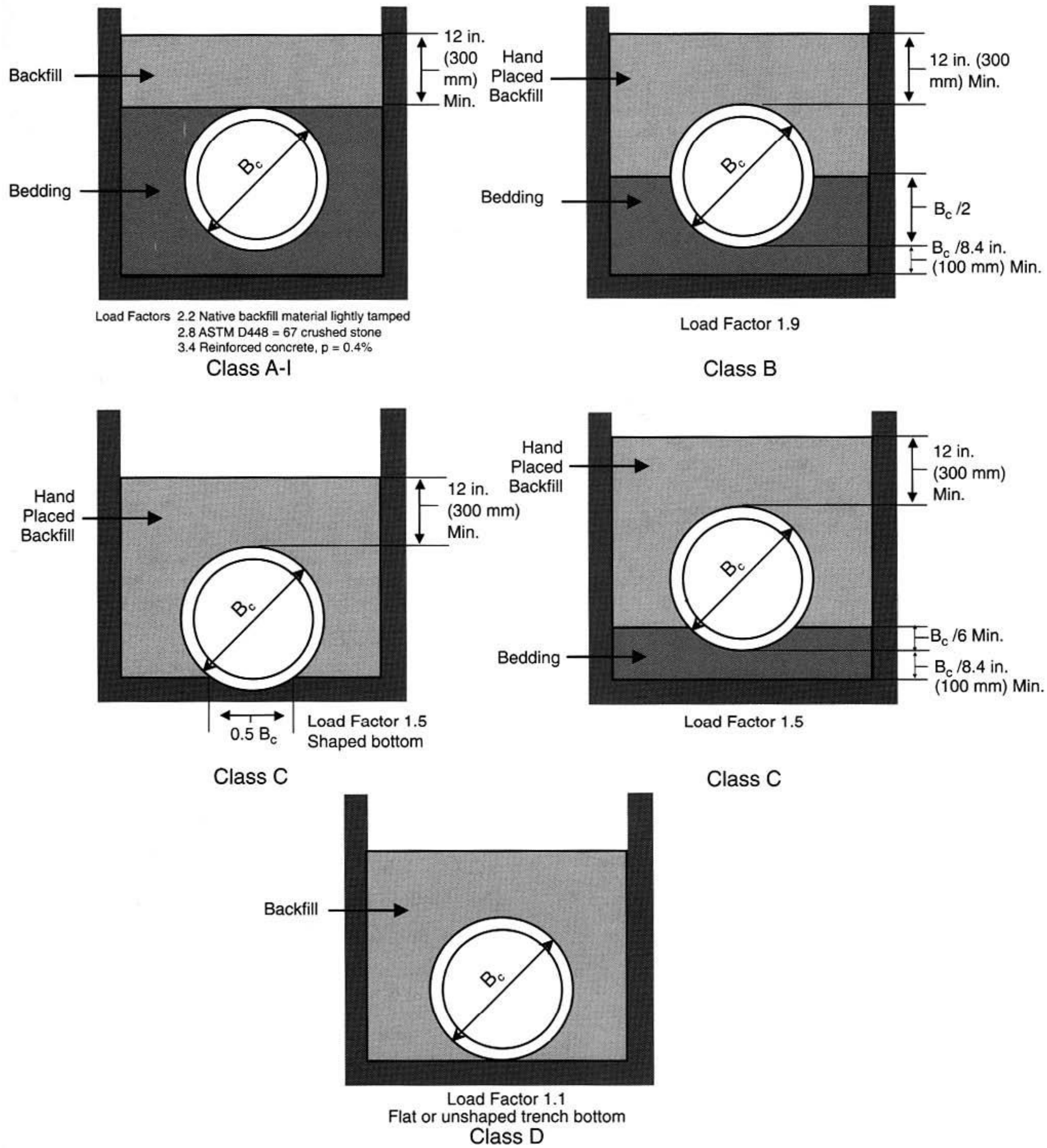


Figure 2.1 Classes of Bedding[4]

Bedding Calculation

An 8-inch diameter Vitrified Clay Pipe (VCP) has a standard strength of 2,000 pounds per foot, and is laid in a Class C trench. What is the total supporting strength?

Total supporting strength = standard strength x Bedding Class Load Factor (see Figure 2.1).

(2,000 lbs/ft x 1.5) = 3,000 pounds per foot

Therefore, the pipe, theoretically, can handle a loading of 3,000 pounds per foot without cracking. When laying rigid pipe, it is important to ensure that the loading is not greater than the total supporting strength of the pipe and bedding.

Bedding Required for Flexible Pipe

- ❑ The bedding around a flexible pipe is important to ensure that the pipe does not deform outward from the load of the backfill.

- ❑ The classification for flexible pipe bedding is based on soil type. Classes I, II and III are allowable for use as bedding for flexible pipe.

Table 2.4 Soil Classifications[5]

Soil Class (1)	Group Symbol (2)	Typical Names (3)	Comments (4)
I		Crushed rock	angular, 6-40 mm
II	GW GP SW SP	Well graded gravels Poorly graded gravels Well graded sands Poorly graded sands	40 mm maximum
III	GM GC SM SC	Silty gravels Clayey gravels Silty sands Clayey sands	
IV	MH, ML CH, CL	Inorganic silts Inorganic clays	Not recommended for bedding, haunching or initial backfill
V	OL, OH PT	Organic silts and clays Peat	

- ❑ In addition to the appropriate bedding material, adequate compaction of the bedding and the backfill material surrounding the pipe is required to minimize pipe deflection.

Specifications

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

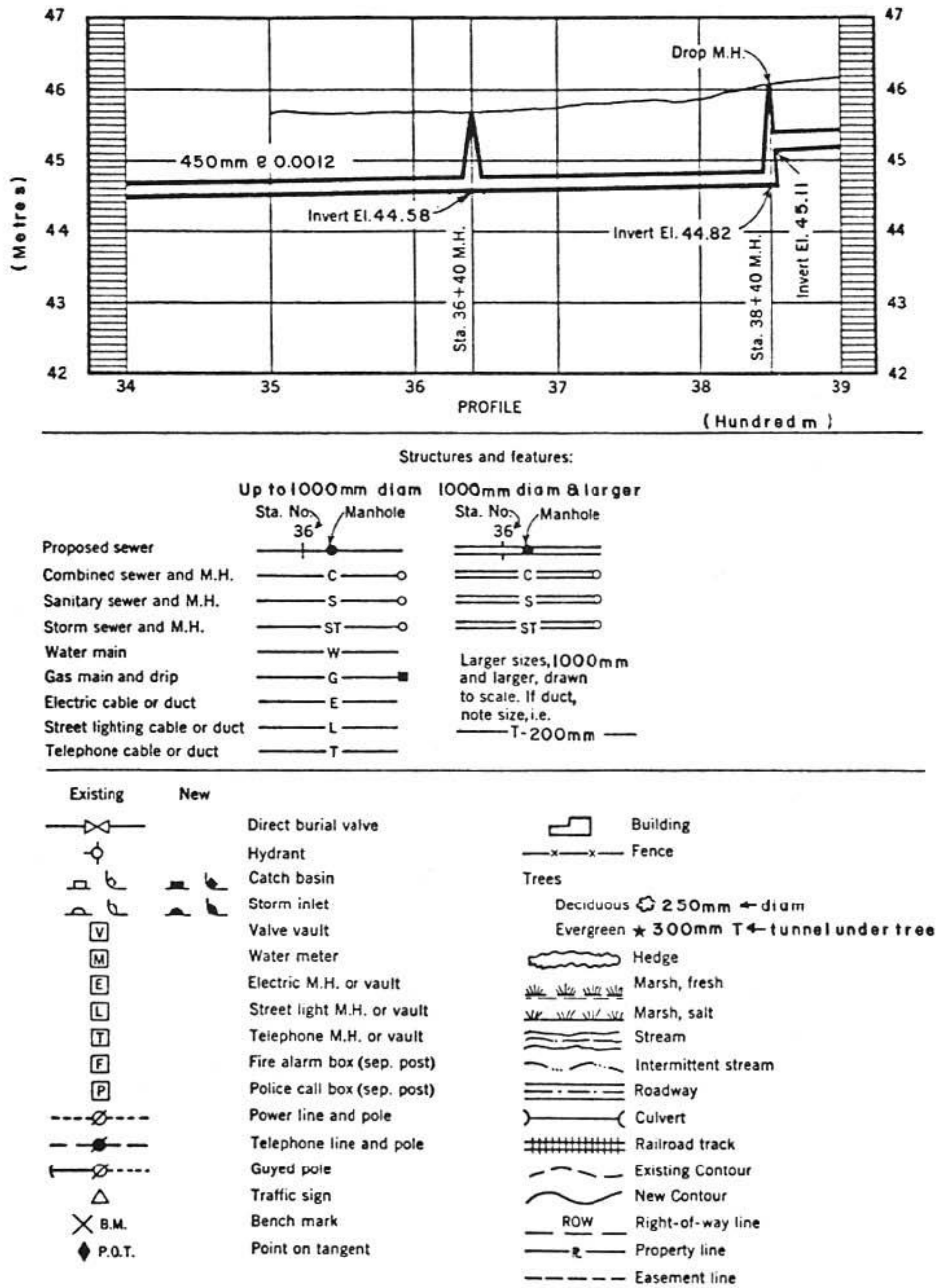


Figure 2.2 Sewer Plan Legend[6]

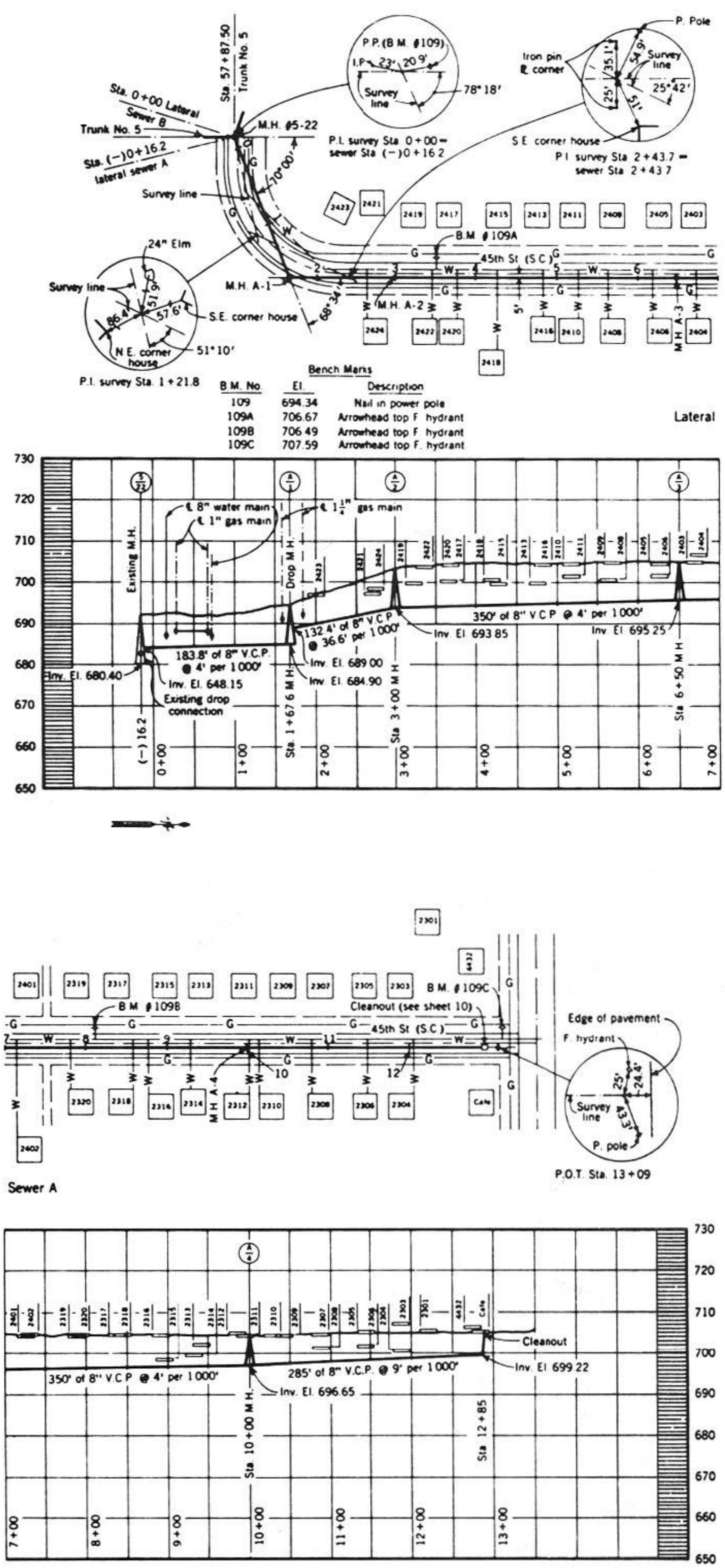


Figure 2.3 Gravity Sanitary Sewer Design and Construction[7]

Contract Drawings

Contract drawings typically consist of several sheets including:

- Title sheet stating the name of the project.
- Index of sheets.
- Legend.
- Location map.
- PA One Call information for underground utilities and survey control information.
- 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 including elevations.
- An additional sheet that shows details such as bedding and backfill, stream crossing and manholes.

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.

Records

- During construction of a project, it is important that sufficient records are obtained to adequately represent the underground sewer.

- Daily reports -- An inspector at the project site monitors the daily activities of the contractor and maintains records. The inspector should prepare daily reports stating the progress of the work, work conditions and any problems encountered.

INSPECTOR'S DAILY REPORT

Job ____________ No. ________ Date ________

Contractor ____________ Weather ____________

	WORK	ITEM	LOCATION		QUAN
			STREET	STA. LIMITS/@STA. OR ST.	
1	Trench Exc. (1)			TO	
2	Laying 6"– – P.			TO	
3	" " – – P.			TO	
4	"4" – – P. Lots			TO	
5	B'fill, Longt. (2)			TO	
6	" , Lat. (2)			TO	
7	Manholes				
8	Compact, Longt. (3)				
9	Compact, Lat. (3)				
10	Testing				
11	Base Rock, Longt.				
12	Base Rock, Lat.				
13	Paving, Longt. (4)				
14	Paving Lat. (4)				
15	Pipe Cleaning				

(1) Type Soil Exc. ________ , (2) Type Soil B'fl ________

(3) Type of Compaction, Longt. ________ , Lat. ________

(4) Type Paving, Longt. ________ , Lat. ________

Safety Check: Working Conditions ________? Public ________?

Comments on work conduct, personnel, equipment, materials, incidents, final inspection notes, acceptance recommendation, etc: ________

Time this job ________ Signed ________

Note: Use one sheet per job. Submit original to office daily. Retain duplicate copy for inspector's diary.

Figure 2.4 Inspector's Daily Report[8]

- Monthly reports -- The inspector should also maintain monthly reports that are not as detailed as the daily reports. These are used to determine the amount of material that was installed by the contractor to determine the amount the contractor should be paid.

REPORT OF QUANTITIES INSTALLED

As of (Date): ________________

Job: ______________________________

Final Report ☐
Progress Report ☐

Installer ______________________
Engineer ______________________
Contractor ______________________

STREET	4" B.S.	6" Main	8" Main	____" Main	M.H.	F.I.	Extra Wyes	

Instructions to Inspector:
Make report in duplicate
Report progress as of last day of month, when job not complete.
Submit final report when installation has been completed.
Make notes about unusual items.

____
Inspector

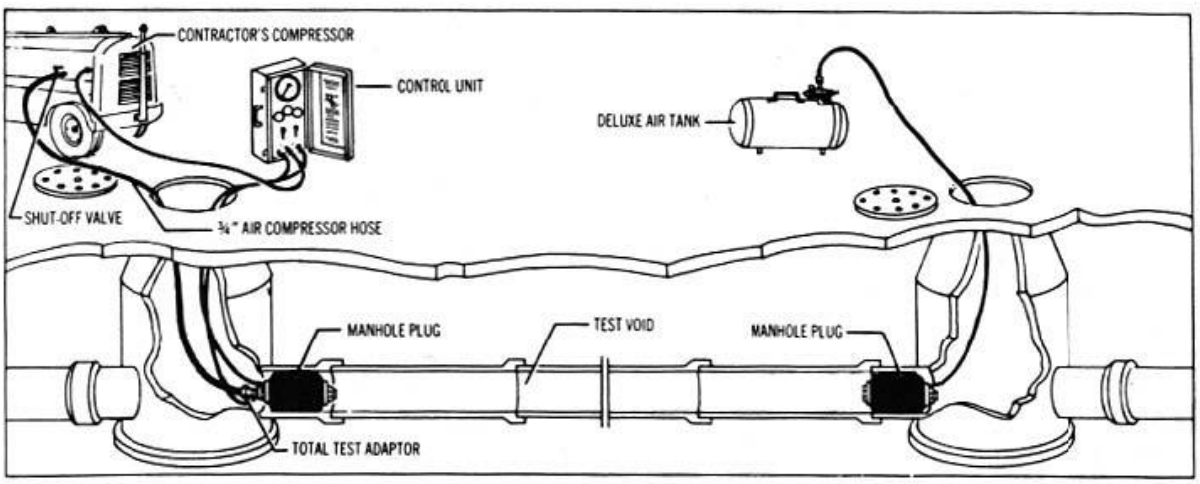
Figure 2.5 Sample Monthly Report[9]

- At the beginning of construction, the inspector should have two copies of the project drawings that can be marked in the field.
  - One set of the drawings should be a working set to ensure that the contractor is following the plans.
  - The second set should be marked as “Record Drawing.” The inspector should mark any constructed changes (i.e., lower manhole invert, longer sewer run) on this set of plans with red pencil. In addition, the inspector should mark the location of laterals on this drawing.
- When the project is completed, the inspector gives the record drawing to a draftsman so that the marked changes can be inserted into the drawing. It is important that the changes are incorporated to have a realistic graphical representation of the underground sewer system. These drawings are known as “as built” drawings.

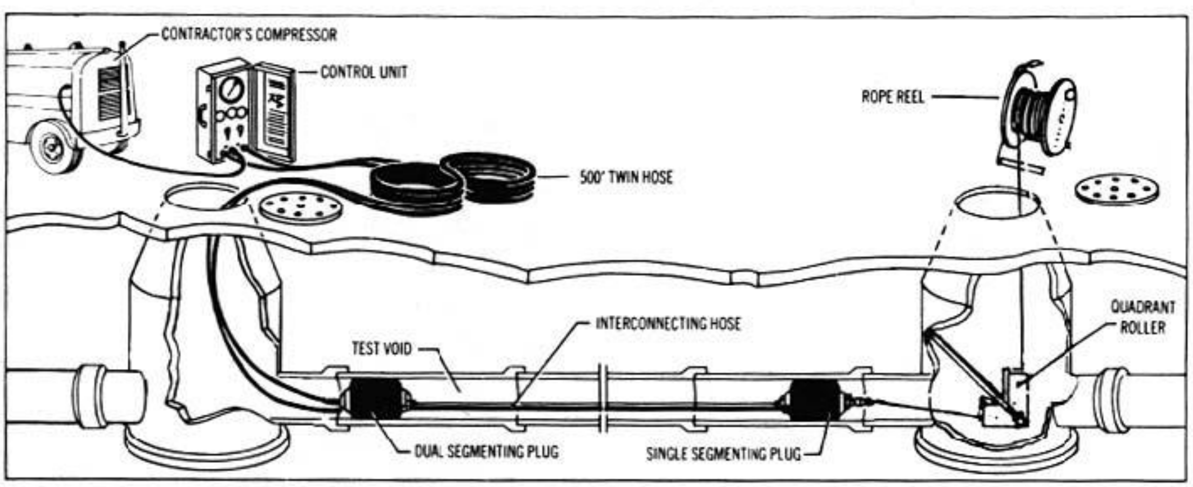
Leakage

- Low pressure air testing or water testing is used to test a sewer system for leakage. The tests are used to determine the amount of exfiltration or infiltration in the pipe.

- Air testing uses an air compressor, pressure gage and plugs to isolate the sewer section being tested. If the line is air tight then, of course, there will be no leakage.



Manhole to manhole air test



Segment of pipe air tests

Figure 2.6 Air Testing[10]

- The air test is conducted by supplying air into the sewer system until the internal pressure of the system reaches a set test pressure.
  - Allow the air pressure to stabilize for 2 minutes.
  - Next, the air supply is disconnected and the amount of time required for the pressure to drop, first by 0.5 psi and then, by an additional 1.0 psi, is recorded.
  - The measured time is then compared to an allowable time for that section of sewer. The allowable time is based on the diameter of sewer, length of sewer and an allowable air loss per square foot of sewer.
  - If the measured time is less than the allowable time, the sewer passes the test. If the measured time is more than the allowable time, the sewer section should be searched for leaks.
- Water testing involves plugging the downstream manhole at the inlet and filling the upstream manhole with water up to 4 foot.
  - The level is marked and a time is recorded.
  - The level is allowed to drop 2 feet and another time is recorded; or wait 120 minutes and measure the distance between the marked level and current water level.
  - The volume of water that was lost is determined by the diameter of the manhole. An acceptable exfiltration or infiltration test in Pennsylvania is 100 gallons per inch of pipe diameter per mile per day for any section of the system.

Calculation Rate of Exfiltration for Water Testing

Calculate the rate of exfiltration in gal/inch/mile from 400 feet of 8-inch pipe when the water level in the upstream 4-foot manhole drops 2 inches in 120 minutes.

Step 1: Calculate volume of water exfiltrated during test.

Note: Interior manhole surface area = (0.785) (Diameter)^2 = ft^2

Volume, gal = Area of water in manhole, sq. ft x Water level drop, in.
= (0.785) (4 ft)^2 (2 in) (ft/12 in) (7.48gal/ft^3) = 15.66 gal.

Step 2: Determine the water exfiltration rate during the test

Rate, gpd = Volume, gal/Test Time, min
= (15.66 gal) (60min/hr) (24hr/day)/(120min)
= 187.92
= 188 gpd

Step 3: Calculate the exfiltration for the section tested.

Exfiltration, gpd/in/mi = Exfiltration rate, gpd / (Diameter, in) (Length, mi)
= (188gpd)/ (8 in) (400 feet) (mi/5,280ft) = 310 gpd/in/mi

This is an example of an unacceptable section because the exfiltration rate was greater than 100 gpd/in/mi. Therefore, the sewer line should be evaluated to determine the location(s) of exfiltration.

Deflection

- Deflection tests need to be performed on the constructed sewer within 30 days after final backfill has been placed.
- The tests consist of using a rigid ball or mandrel to measure the deflection and joint offsets.
  - The mandrel test is performed by pulling the device through the sewer from manhole to manhole.
  - The mandrel device will not pass through the sewer if the flexible type pipe has been deflected beyond five percent of the pipe diameter, if the rigid pipe has been crushed or if a building lateral is protruding into the sewer line.
  - If there is a problem, the pipe must be excavated and corrected.

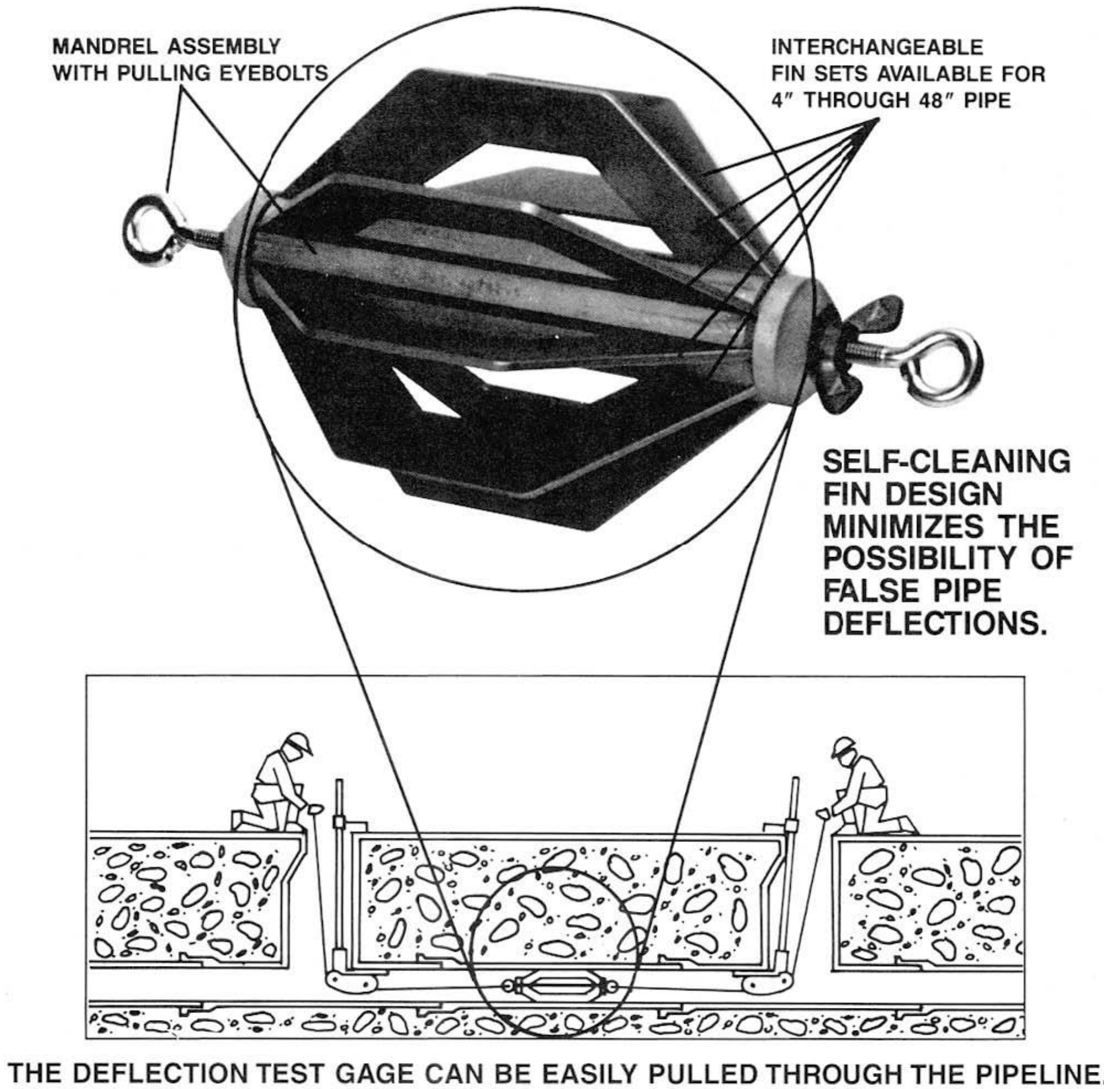


Figure 2.7 Deflection Test Gage[11]

Key Points for Unit 2 – 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 wastewater collection systems.
- 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.

Exercise for Unit 2 – Installation, Construction Inspection & Testing.

1. The two major types of pipes used in collection systems today are __________ pipe and ______________ pipe.

2. Pipe __________________ is when the pipe has changed direction, either up, down, right or left from the direction it was originally laid.

3. When using rigid pipe, which class of bedding is typically not permissible?

   a. Class A b. Class B c. Class C d. Class D

4. An 8-inch diameter Vitrified Clay Pipe (VCP) has a standard strength of 2,000 pounds per foot, and is laid in a Class B trench. What is the total supporting strength?

5. The contract drawings provide a _________________ representation of the work to be done.

6. The qualitative requirements for a project covering topics like the material and workmanship involved in the manufacturing and installation of equipment can be found in the:
   a. Legend b. Index c. Specifications d. PA One Call

7. Name the two types of reports that an inspector would normally write to keep track of progress and problems at a work site.
   a. ___________________________ b. __________________________

8. Liquid leaking out of a collection pipe is called _______________________.

9. Liquid leaking into a collection pipe from the surrounding bedding material is called _____________________________ .

10. A deflection test gage ball or mandrel can not be pulled through a sewer pipe if the pipe is deflected more than five percent of the pipe diameter.
    a. True
    b. False

[1] George Tchobanoglous and Frank Burton, *Wastewater Engineering: Treatment, Disposal, Reuse*, 3rd Edition, (New York, NY: Irwin/McGraw-Hill, 1991), p.27.

[2] Tchobanoglous, p. 28.

[3] Tchobanoglous, p. 29.

[4] Steve Goodman, "Wastewater Collection Systems (Purpose, Components and Design)," in *Operation and Maintenance of Wastewater Collection Systems: A Field Study Training Program*, Vol I, (Sacramento California: California State University, Sacramento Foundation, 1999), p. 99.

[5] "Gravity Sanitary Sewer Design and Construction," from *ASCE-Manuals and Reports on Engineering Practice-NO- 60 WPCF-Manual of Practice-NO, FD-5*, (New York, NY: American Society of Civil Engineers, 1982), p. 193.

[6] "Gravity Sanitary Sewer Design and Construction," p. 195.

[7] "Gravity Sanitary Sewer Design and Construction," p. 195.

[8] Goodman, p. 120.

[9] Goodman, p. 121.

[10] Goodman, p. 110.

[11] Goodman, p. 118.

Additional Resources Used

Link to DEP Domestic Wastewater Facilities Manual: www.dep.state.pa.us/eps/docs.

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Unit 3 – Management and Operations

Learning Objectives

- List and describe the policies and requirements associated with the management and operations of a collection system.
- List and explain three cleaning methods and five inspection methods.
- Define infiltration and inflow and explain how to determine their sources.
- List and explain three rehabilitation methods.
- Describe how manholes and appurtenances are rehabilitated.

Permit Requirements

- Currently, there are no permitting requirements for a community that only has a collection system.
- A National Pollutant Discharge Elimination System (NPDES) permit may be required in the future.
- Currently, only communities with a treatment facility must have a NPDES permit. The permit must be renewed every five years.

Annual Reporting – Chapter 94

Annual reporting requirements are described in the Pennsylvania Code Title 25 Environmental Protection § 94.12 Annual Report.

- The treatment plant permittee needs to submit a complete and accurate wasteload management report to the Pennsylvania Department of Environmental Protection by March 31 of each year.
- The report requires:
  - Information about the sewer system, such as a map showing all sewer extensions constructed and all extensions approved or exempted in the last year, and all known proposed projects that will require public sewers.
  - A list that summarizes each extension and the population to be served by the extension.
  - Discussion on the inspection, maintenance and repair of the sewer system and the condition of the sewer system.
  - A proposed plan for reducing the overload conditions if any part of the sewer system is overloaded or is projected to be overloaded in the next 5 years.

Capacity, Maintenance, Operations and Management (CMOM)

Combined Sewer Overflows Policy

The United States Environmental Protection Agency's Combined Sewer Overflows (CSO) Policy provides guidance for the control of CSO under the NPDES permitting program. The CSO Policy includes nine minimum controls to reduce the prevalence and impacts of CSO.

The nine minimum controls are as follows:

- ❑ Proper operation and regular maintenance programs for the sewer system and the CSO outfalls to include I/I reduction.
- ❑ Maximum use of the collection system for storage.
- ❑ Review and modification of pretreatment requirements to ensure that CSO impacts are minimized.
- ❑ Maximization of flow to the POTW for treatment.
- ❑ Elimination of CSO during dry weather.
- ❑ Control of solid and floatable materials in CSO.
- ❑ Pollution prevention programs to reduce contaminants in CSO.
- ❑ Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts.
- ❑ Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

For additional information of the nine minimum controls, see EPA's "Combined Sewer Overflows Guidance for Nine Minimum Controls" document, which can be found at EPA's website. The EPA document number is EPA 832-B-95-003, and the web address is: www.epa.gov/npdes/pubs.

Long Term Control Plan

The CSO Control Policy also lists nine elements that should be addressed in a municipality's Long Term Control Plan (LTCP). The LTCP is the plan that a municipality will follow to ultimately obtain full compliance with the Clean Water Act.

The nine elements of the LTCP are as follows:

- ❑ Characterization, monitoring, and modeling activities as the basis for selection and design of effective CSO controls.
- ❑ A public participation process that actively involves the affected public in the decision-making to select long-term CSO controls.
- ❑ Consideration of sensitive areas as the highest priority for controlling overflows.
- ❑ Evaluation of alternatives that will enable the permittee, in consultation with the NPDES permitting authority, WQS authority, and the public, to select CSO controls that will meet CWA requirements.
- ❑ Cost/performance considerations to demonstrate the relationships among a comprehensive set of reasonable control alternatives.
- ❑ Operational plan revisions to include agreed-upon long-term CSO controls.
- ❑ Maximization of treatment at the existing POTW treatment plant for wet weather flows.
- ❑ An implementation schedule for CSO controls.
- ❑ A post-construction compliance monitoring program adequate to verify compliance with water quality-based CWA requirements and ascertain the effectiveness of CSO controls.

For additional information of the nine minimum controls see EPA's "Guidance for Long-Term Control Plan" document, which can be found at EPA's website. The EPA document number is EPA 832-B-95-002, and the web address is: www.epa.gov/npdes/pubs.

Cleaning Methods

Mechanical

- Power bucket machines are used to remove large amounts of debris in larger sewer lines. The bucket machine is either truck- or trailer-mounted, and two machines are required to clean a sewer line. One machine is used to thread a "bucket" type cleaning device into the sewer line, and the other machine is used to remove the collected material.

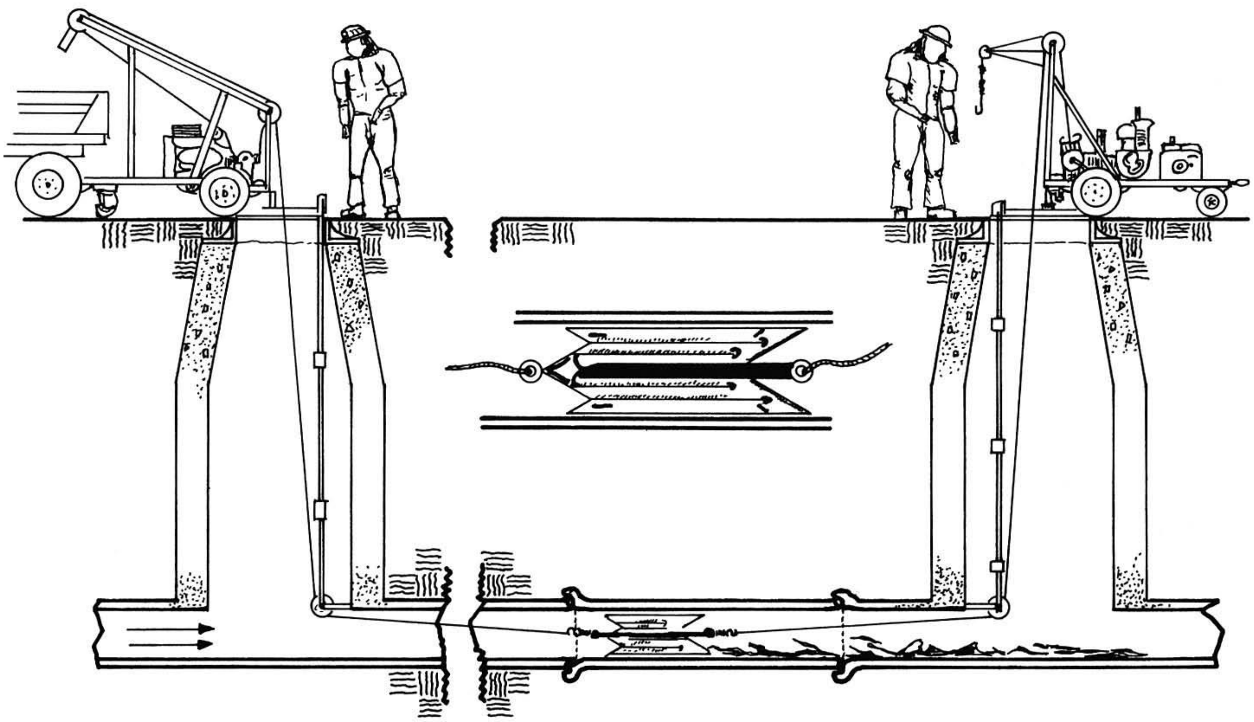


Figure 3.1 Power Bucket Cleaning[1]

- Power rodders are used to handle stubborn stoppages of roots, grease and debris. The power rodding machine consists of a steel rod to push or pull clearing tools through the sewer. The machines are either truck- or trailer-mounted, and they use either gas or a diesel engine and a hydraulic system for power. The machine is effective on stubborn stoppages in lines up to 15-inches in diameter.

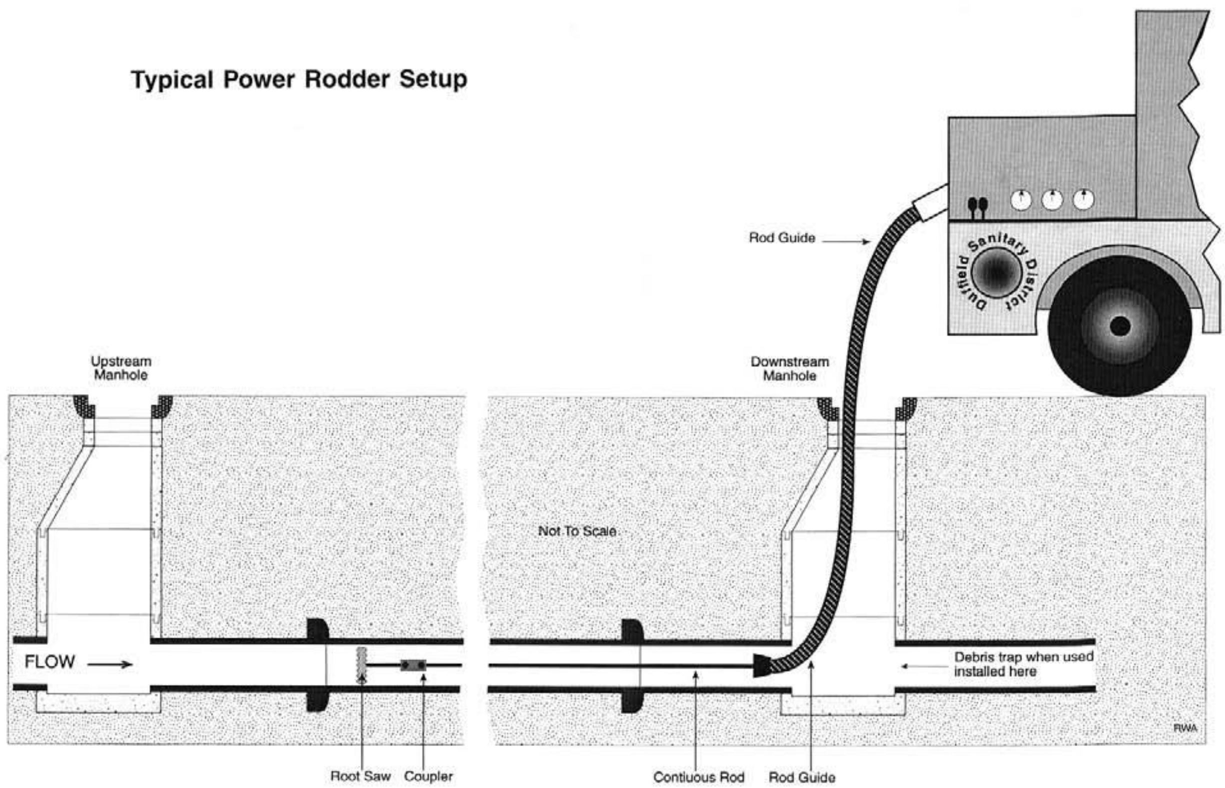


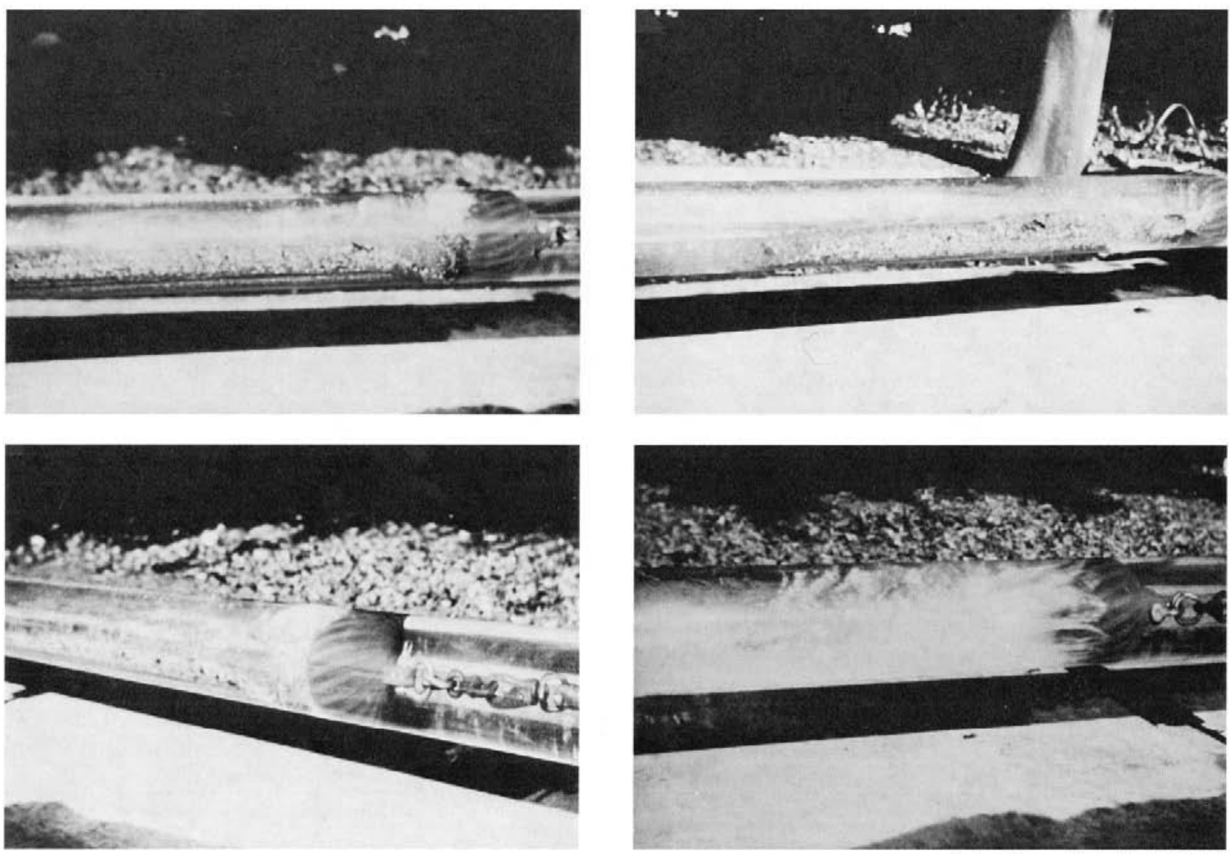
Figure 3.2 Power Rodder[2]

- Hand rods are typically used for emergency stoppages. Hand rods are sectional rods that are typically 36 inches in length and stored on a shallow reel that is equipped with a removable tripod. When the reel is set up on the tripod, the rod can be manually pulled off or on to the reel, allowing the reel to turn freely.

Hydraulic

This type of cleaning uses high velocity water to clean the sewers. Hydraulic cleaning consists of the following methods: balling, high-velocity cleaners, flushing, sewer scooters, and the use of kites, bags and poly pigs.

- Balling is an economical method for cleaning debris from sewers. This method consists of using a ball, which ranges in size from 6 inches up to 48 inches and water. The ball is designed with diagonal grooves and ridges. As water builds up behind the ball, the water will flow through the grooves and the ball will rotate. Based on the use of the ball and water pressure, this method typically removes only grit material on the bottom of the line and grease buildup inside the line.



(Courtesy of Sacramento County, Water Quality Division)

Figure 3.3 Sewer Cleaning with a Ball[3]

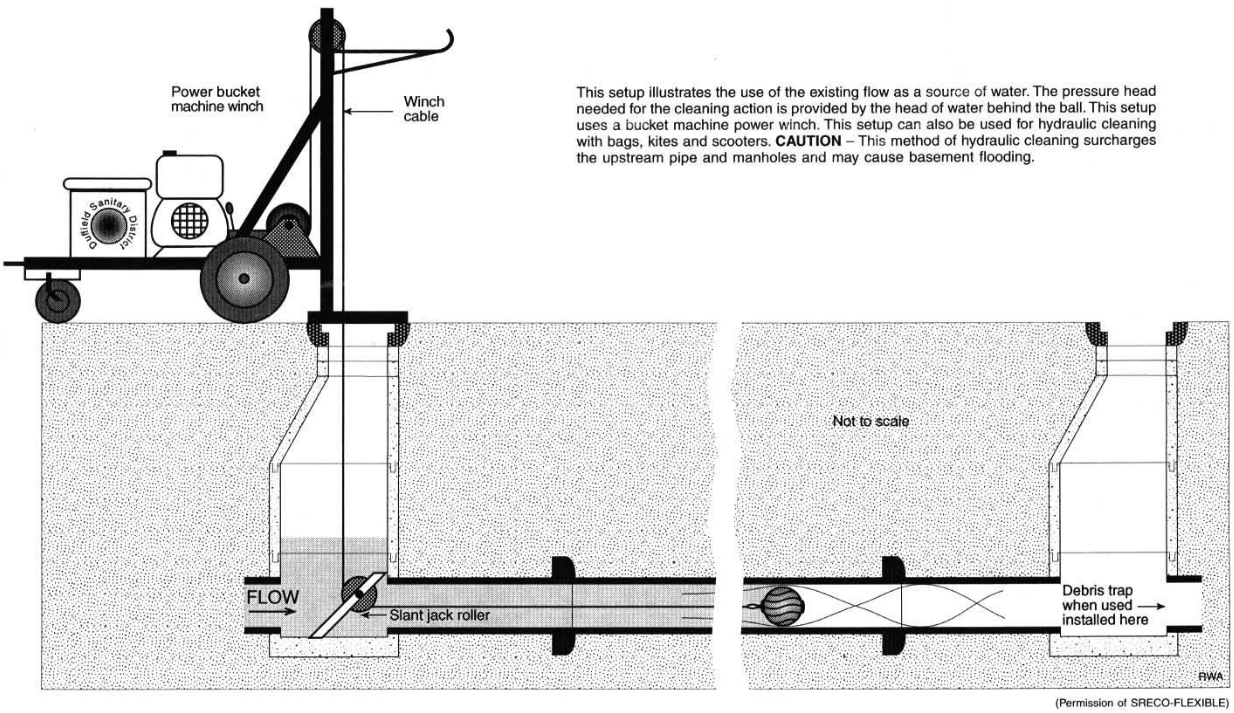


Figure 3.4 Set Up for Hydraulic Cleaning[4]

- High velocity cleaners are effective at removing loose debris in sewers. High velocity cleaning equipment comes in a variety of sizes and can be mounted on a truck or trailer. The main components of high-velocity water cleaners are the water supply tank, high-pressure water pump, and 500 or more feet of hose attached to a hose reel.

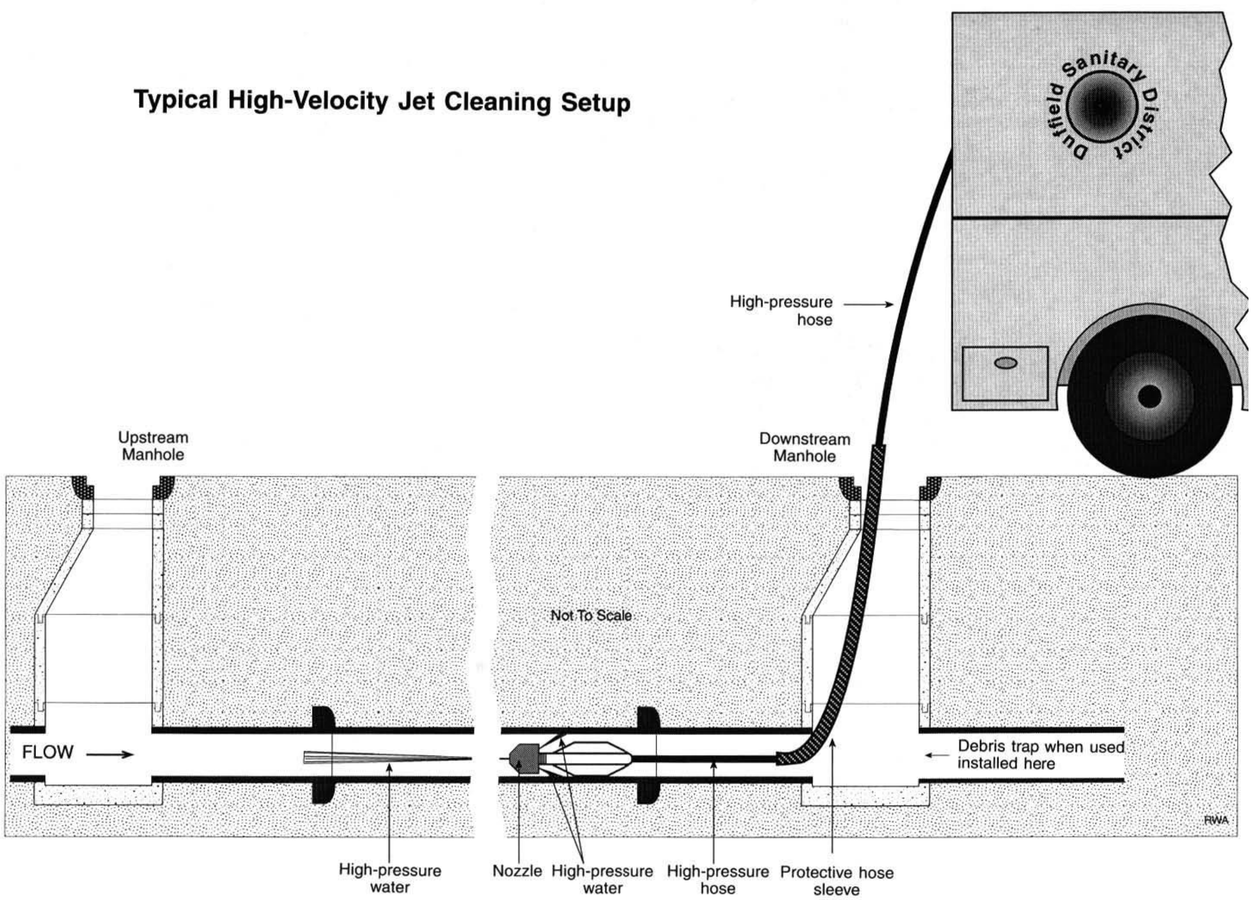


Figure 3.5 High-Velocity Cleaner[5]

- ☐ Flushing is an effective method of removing floatable solids. This method uses either a tanker truck or hydrant to provide sufficient water pressure to flush the line clean. During flushing operations, the downstream manholes must be observed for flow. If flow is lower than expected, this indicates that the upstream sewer requires additional cleaning.

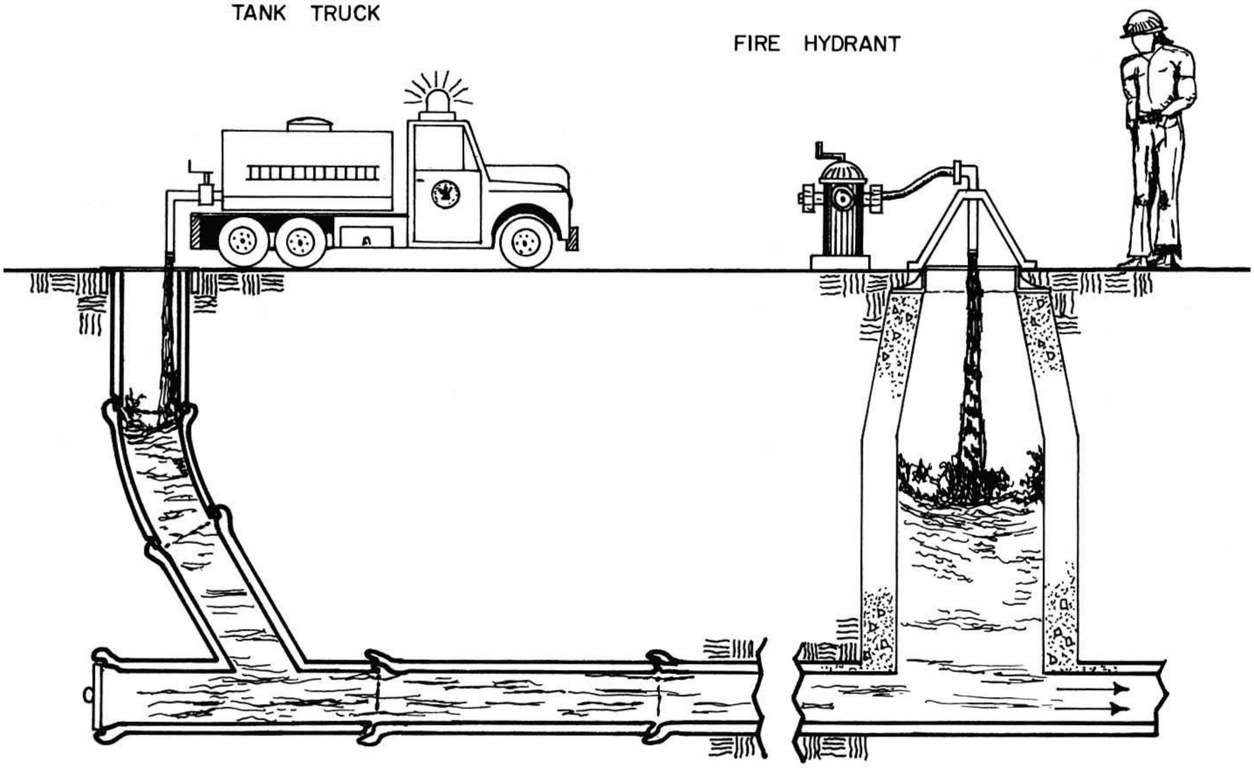


Figure 3.6 Flushing Operation[6]

- The sewer scooter is an effective method of removing large objects from the sewer. The scooter consists of a carriage frame attached to wheels. The frame consists of a circular metal shield that is hinged at the top half and attached to the frame by the lower half. The scooter is propelled through the sewer by water pressure. Scooters range in size from 6 to 96 inches, and can, therefore, be used in a wide variety of sewers.

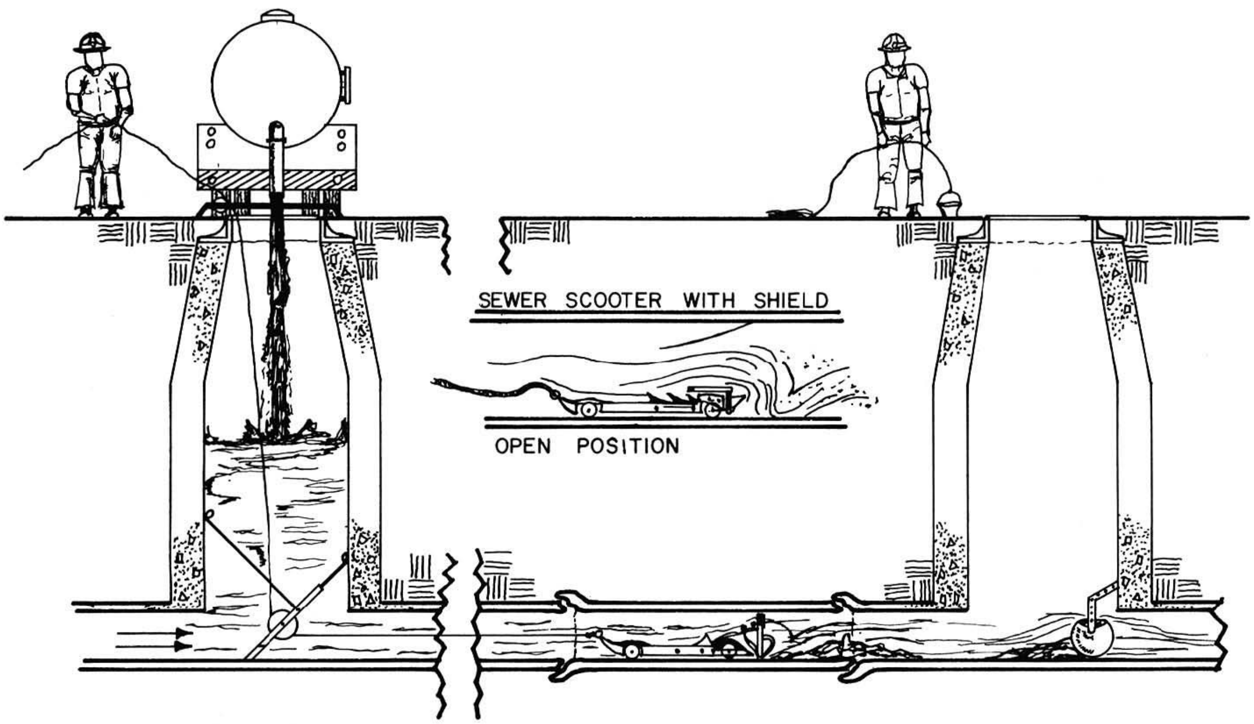
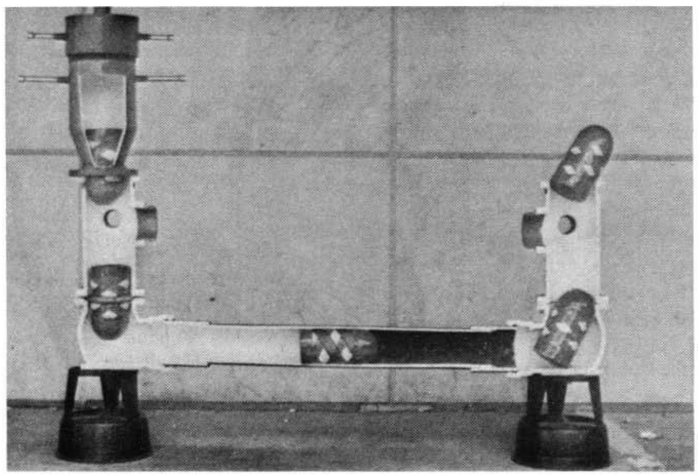


Figure 3.7 Sewer Scooter[7]

- Kites, bags and poly pigs are used to clean larger diameter sewers such as force mains. The most common method is with the use of poly pig, which is a type of polyurethane swab. The poly pig is inserted and then the force main is pressurized behind the poly pig. The poly pig travels by the pressure and scours the inside of the force main.



Use of poly pig in force main

AQUA SWAB **2 LBS./CU. FT. DENSITY** Can Be Hand Launched.		**AS** (Aqua Swab) — Proving direction of flow, sealing behind undersized cleaning units, sweeping loose debris **ACCS** (Aqua Criss-Cross Swab) — Light cleaning
AQUA COAT **5 LBS./CU. FT. DENSITY**		**AB** (Aqua Bare) — Gauging, light cleaning **ACC** (Aqua Criss-Cross) — Cleaning **ACCWB** (Aqua Criss-Cross Wire Brush) — Scraping

Figure 3.8 Poly Pigs and Swabs[8]

Chemical

Chemicals may be added to a sewer line to control roots, grease and odor.

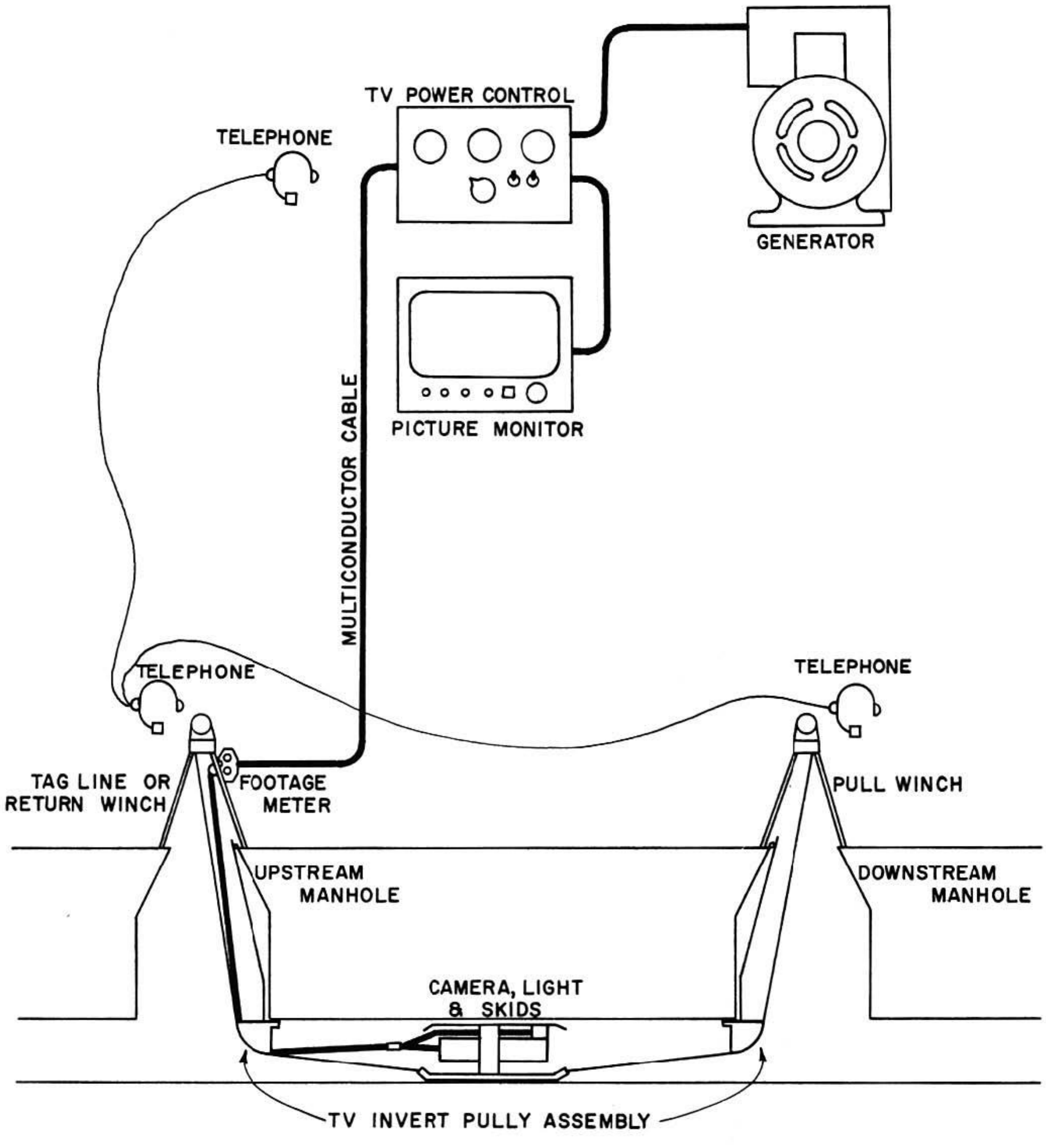
- ❑ No type of chemical should be added to the sewer line before reviewing favorable chemical analysis results from a respectable lab. The chemical needs to be tested to prove that it produces appropriate actual results, rather than relying on expected (or advertised) results.
- ❑ Government agencies and private laboratories conduct impartial testing of new chemicals before they are sold. If assistance is required to determine if a chemical should be used, the Environmental Protection Agency or DEP should be contacted for recommendations.
- ❑ Material Safety Data Sheets (MSDS) should be reviewed to determine the type of chemical, reactions that will occur, safety equipment that should be worn when handling the chemical, first aid that treatment to be given should the chemical get spilled or splashed, and proper clean-up of the chemical.
- ❑ The effect the chemical might have on the treatment plant should be evaluated.

Inspection

Inspection techniques are used to gather information about the condition of the sewer system. The inspection can be used to identify potential or existing problems, and can provide insight into selecting the most appropriate method of avoiding or correcting the problem.

Closed Circuit Television (CCTV)

- ❑ Television inspections are the most effective method of determining the internal condition of a sewer.
- ❑ A CCTV consists of a television capable of traveling through sewer pipe and sending the signal to a monitor to observe the picture. In addition, video recording equipment is also used to maintain a record of the televising and televising report logs are filled out.



NOTE: There are three ways to control the far manhole winch pull:

1. Worker/sound-powered telephone,
2. Worker/walkie-talkie, or
3. No worker/remote control power winch.

NOTE: If a camera-carrying crawler tractor unit is used, no equipment is needed in the downstream manhole.

Figure 3.9 Closed Circuit Television[9]

Smoke Testing

- Smoke testing is used to determine sources of extraneous flow into the sewer system.
- The extraneous flow can be from illegal connection from homes including sump pumps and roof leaders, cracks in piping and surface water entering from holes in manhole lids and from storm sewers connected to the sanitary sewer system.
- Smoke testing a segment of sewer requires the use of a smoke blower unit, pipe plugs and smoke bombs. Prior to conducting smoke testing, residents in the area and local police and the fire department should be notified. During smoke testing pictures, should be taken showing the locations of the smoke and a smoke test report should be completed.

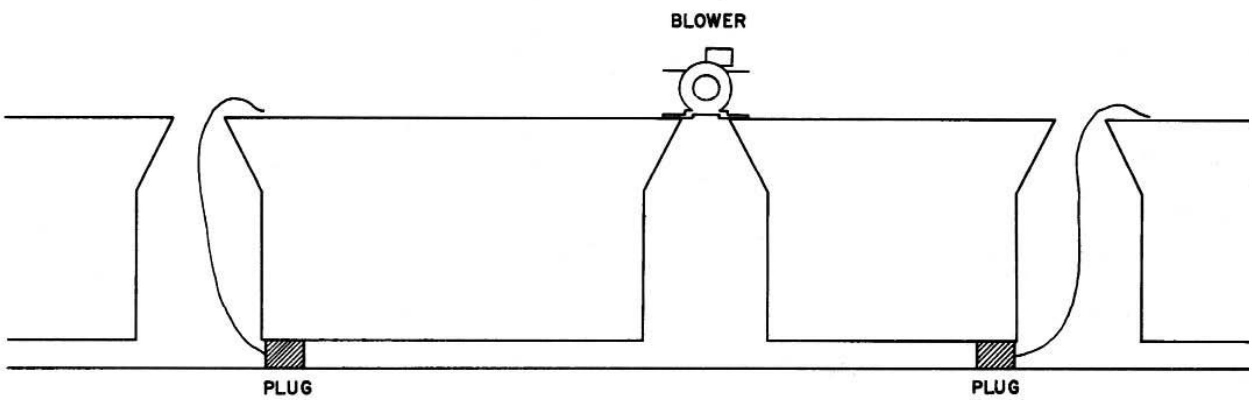


Figure 3.10 Smoke Testing[10]

SEWAGE COLLECTION DIVISION
I/E/I/ SUPPORT UNIT
SMOKE TEST REPORT

M.H. ________ M.H. ________

DATE ________ TIME ________ P.S. ________ SEWER LENGTH ________ DIA. ______

ATLAS PAGE ______ TEST# ________

WEATHER ________ BY ________

NAME ________________

SMOKE INTENSITY

LIGHT ☐ MEDIUM ☐ HEAVY ☐

RESULTS

☐ 01: POS. CATCH BASIN CONN.

☐ 02: REPLACED C.O. CAP

☐ 03: DEFECTIVE C.O. RISER

☐ 04: DEFECTIVE SANITARY

☐ 05: DEFECTIVE HOUSE PIPING

ADDRESS ________________

COMMENTS ________________

Figure 3.11 Smoke Testing Report[11]

Dye Testing

- Can be used to determine connections of extraneous flow to the sanitary sewer, and to determine if wastewater is overflowing into a water body.
- Is performed by one person applying dye at the suspect location and another person watching for the dye at the downstream manhole. The person watching for the dye should record the results of the test. Prior to dye testing, residents in the area should be notified. The notification is very important if the dye is going to be applied at private properties.

Lamping

- Is used on sewers to determine if a section of pipe is open.
- Involves a bright source of light and a mirror. One person goes into a manhole and reflects sunlight or shines a bright lamp beam down the sewer line. A second person goes into the next manhole to see if the light can be seen. If the light can be seen, the line is straight and open. If not, the line is either not straight or it is obstructed.

Manholes

Manholes should be physically inspected to determine their condition and the general condition of the sewer lines based on the amount of flow entering the manhole.

Manhole inspection generally consists of the following five steps:

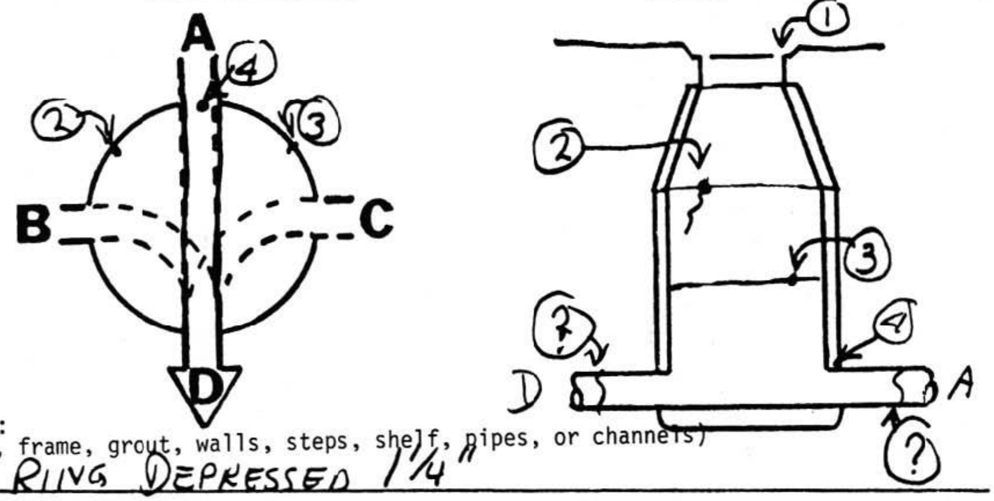
- Locate the manhole.
- Insert gas detection probe through opening in manhole cover to determine the conditions in the manhole. Personal gas detectors are most typically used to measure hydrogen sulfide gas since it can naturally occur in sewers and is explosive, corrosive and poisonous.
- Remove the manhole lid, inspect all surfaces and joints inside manhole and record findings. The following defects should be recorded: cracks or breaks in the walls or bottom; infiltration into the manhole; offsets or misalignment; roots or debris accumulation in the invert, on shelf, steps or rungs; grease accumulation; concrete or grout in the invert resulting in flow turbulence, deterioration of the grout of frame, condition of the steps or rungs; wastewater backing up into manhole; and corrosion.
- Use wire brush to clean ledge of manhole ring and record and cracks.
- Replace manhole lid and check to ensure lid fits properly. This is important because an improperly seated manhole lid could be flipped off by a vehicle driving over it.

MANHOLE INSPECTION REPORT

MH NO. 6822 DATE 7-20-98 TIME 10:15 AM INSPECTOR J.S.

ELEVATION ________ DEPTH TO INVERT 9'7" CLEANLINESS OK

TYPE CONSTRUCTION CONC-CAST STREET REFERENCES 34 AVE & AITKIN



DEFECTS:
(Cover, frame, grout, walls, steps, shelf, pipes, or channels)

1. MH RING DEPRESSED 1 1/4"
2. DIAGONAL CRACK IN BARREL
3. SEAL FAILURE AT JOINT - 1-GPM LEAK
4. SEAL FAILURE & PIPE CRACK - 2-GPM LEAK
5.
6.
7.
8.

(USE REVERSE SIDE FOR ADDITIONAL DEFECTS TO BE NOTED.)

	PIPE SIZE	LENGTH	TO MH#	EST. FLOW	TYPE FLOW
A-	8	275	6823	2"	SOAPY
B-					
C-					
D-	8	320	6821	2"	

REMARKS:
(Include need for repairs)

AUDIBLE LEAK(S) IN PIPES NEAR MANHOLE. DEPRESSED RING MAY INDICATE DROP JOINTS OR BREAKS IN LINE.

Figure 3.12 Manhole Inspection Form[12]

Definitions

Infiltration is groundwater entering the sewer system through faults in the sewer line, lateral or manhole. Typical sources of infiltration are cracks in pipes, leaks around pipe joints, leaks at the connection of the lateral to the sewer and leaks in the manhole walls.

Inflow is the direct discharge of non-sanitary water into the sewer system. Sources of inflow include cross connections from storm sewers, illegal connections from private residences including roof leaders, sump pumps, yard area drains and foundation drains, cooling water discharges from industry and drains from springs. The highest rates of inflow will occur during storm events.

Infiltration and Inflow (I/I) is the total quantity of flow from both infiltration and inflow sources. Large quantities will typically cause the temperature of the raw wastewater to drop sharply.

Sources

What are some of the typical sources of infiltration?

What are some of the typical sources of inflow?

Investigations
Investigations should be performed to determine the sources of the infiltration and/or inflow.

- Physical investigations are often performed at night. Nighttime weirings of residential collection system are done to estimate the quantity of I/I present in the sewer system. Nighttime flows should be minimal because the water usage should be negligible since most residents are asleep.

- Flow estimates are made at the manholes.

- Once the lines that have excessive flow (and, therefore, may have infiltration) have been determined, additional work is needed to identify the source.

Inspections
Visual Inspection

- Visual inspection televising equipment is used to identify sources of infiltration and inflow.

- The defects in the line where groundwater is entering can be seen, and clear water entering the system from direct discharges can be noted for further inflow investigations.

Smoke Testing

- Smoke testing is typically used to determine sources of inflow. This is a good investigative tool, because smoke testing can pinpoint the exact location(s) of the inflow source.

- Following smoke testing, dye testing can be used to verify the source location.

Building Inspections

- Building inspections may also be used to determine sources of inflow. The inspection would include inspecting every structure that may be connected to the sewer system such as roof leaders, foundation drains, area drains or sump pumps.

- If there appears to be nowhere for the water to go, the sewer line can be smoke tested and/or the structure dye tested.

Reduction of Inflow and Infiltration

- Collection system operators should take appropriate action to reduce I/I. This may include disconnecting sump pumps, storm inlets, downspouts, etc… Grouting or cementing of failed pipe joints, adjustment of manhole seating rings and so on.

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.

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, such as parshall flumes, V-notch weirs and H-weirs, 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.

- To have a realistic evaluation of what is occurring, precipitation events (aka. Rainfall derived inflow/infiltration or RDII) and groundwater levels should be measured during the metering period. This data will help in evaluating the causes of high flow.

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.

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. These factors should be considered when prioritizing rehabilitation.

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.

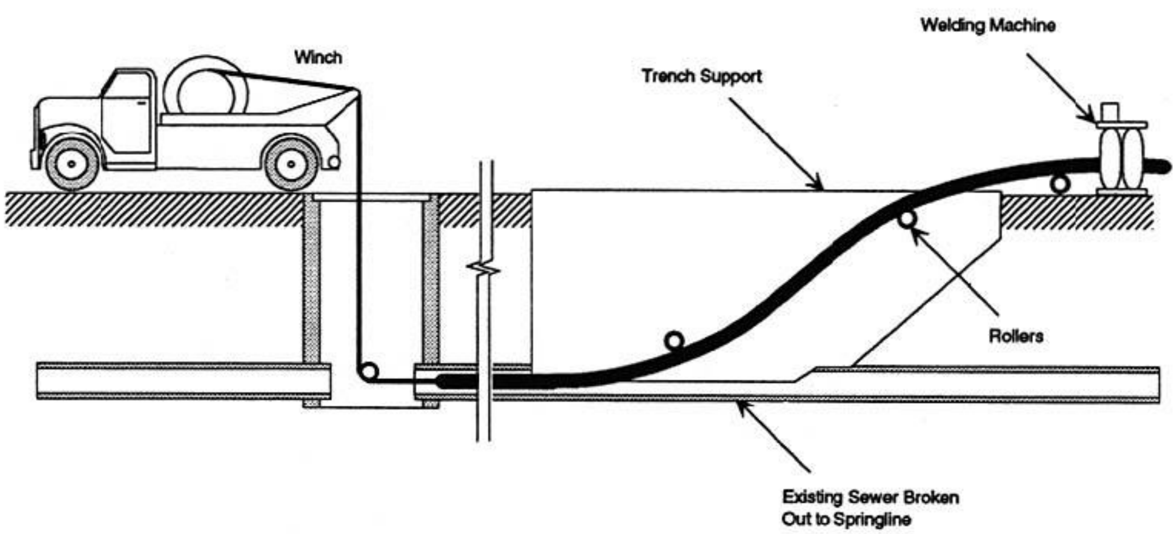


Figure 3.13 Sliplining[13]

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.

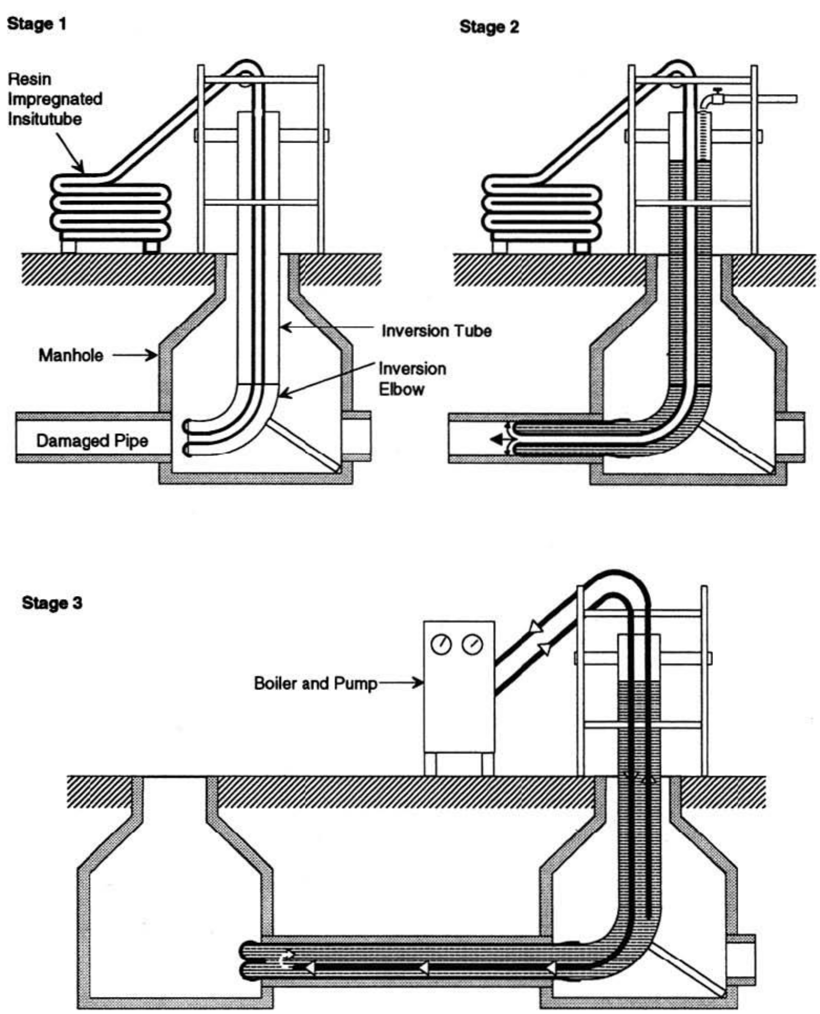


Figure 3.14 Cured-in-Place[14]

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.

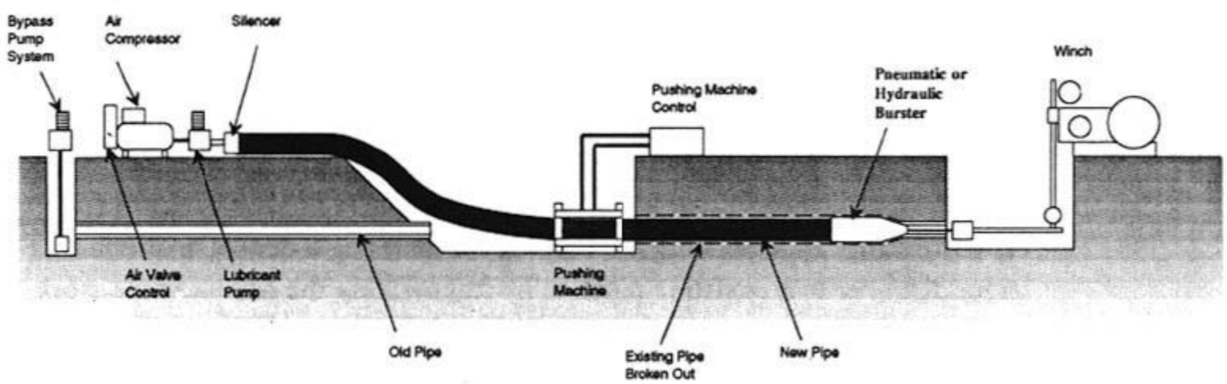


Figure 3.15 Pipe Bursting[15]

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.

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.

Key Points for Unit 3 – 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 DEP.
- 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.

Exercise

1. List the three types of collection system cleaning methods.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. What are the three methods of mechanical cleaning?

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. List three of the six types of hydraulic cleaning and explain when each method is appropriate for use.

   a. ______________________________

   b. ______________________________

   c. ______________________________

4. List three rehabilitation methods.

   a. ______________________________

   b. ______________________________

   c. ______________________________

5. Smoke testing can be useful in detecting:
   a. illegal sump pump connections b. cracks in sewer piping
   c. storm sewers connected to sanitary sewers d. all the above

6. Lamping can be used to determine if a sewer is not straight or blocked.
   a. True b. False

7. Grouting is an excellent way to repair the structural integrity of a deteriorated manhole.
   a. True b. False

[1] Dallas Hughes, “Pipeline Cleaning and Maintenance Methods” in *Operation and Maintenance of Wastewater Collection Systems: A Field Study Training Program*, Vol I, (Sacramento California: California State University, Sacramento Foundation, 1999), p. 370.

[2] Hughes, p. 377.

[3] Hughes, p. 339.

[4] Hughes, p. 340.

[5] Hughes, p. 347.

[6] Hughes, p. 355.

[7] Hughes, p. 358.

[8] Hughes, p. 363.

[9] George Freeland, “Inspecting and Testing Collection Systems” in *Operation and Maintenance of Wastewater Collection Systems: A Field Study Training Program*, Vol I, (Sacramento California: California State University, Sacramento Foundation, 1999), p. 244.

[10] Freeland, p. 274.

[11] Freeland, p. 282

[12] Freeland, p. 240.

[13] Joint Task Force of the Water Environment Federation and the American Society of Civil Engineers, “Pipeline Rehabilitation Methods” in *Existing Sewer Evaluation and Rehabilitation WEF Manual of Practice FD-6 ASCE Manuals and Reports on Engineering Practice*, No. 62, 2nd Edition, (NY, NY: Water Environment Federation, American Society of Civil Engineers, 1994), p. 153.

[14] Joint Task Force, p. 157.

[15] Joint Task Force, p. 166.