CHAPTER 2: GRAVITY SEWER DESIGN

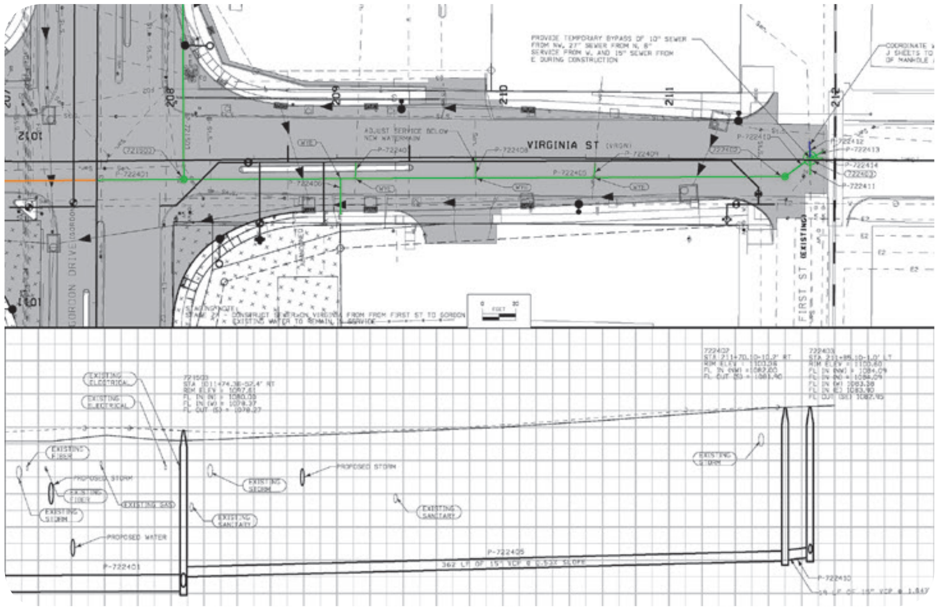

Figure 2-1: Sample plan and profile illustration

Planning and Layout

Sewer Planning

Sufficient lead time to formulate economic proposals, secure approvals, arrange financing, design, construct and place in operation the necessary sewers to carry domestic, commercial and industrial wastewater from a community to a point of treatment is required for projects. Most agencies have Sewer System Master Plans in place to be used in the design of pipe sizing and locations.

Design Period

A design period must be chosen and sewer capacity planned that will be adequate. Population and land use changes for more than 20 years into the future are sometimes difficult to predict and plan. However, when planning, designing, financing and construction are compared to the relatively minor additional cost of providing extra capacity, a minimum design life of 50-years should be considered and when possible, a design life of 100-years or more is recommended. Planners should design for ultimate development where special conditions exist such as remote areas near the boundary of a drainage area. Also to be considered are areas where special construction, such as pump stations and inverted siphons may be required. The cost of additional capacity is minimal compared to the cost of relief lines installed at a later date.

Mainline sewers should be designed for the population density expected in the areas served, since the quantity of domestic sewage is a function of the population and of water consumption. Trunk and interceptor sewers should be designed for the tributary areas, land use and the projected population. For these larger sewers, past and future trends in population, water use and sewage flows must be considered. The life expectancy of the pipe is critical. Clay pipe has a demonstrated life expectancy in excess of 200 years.

Design Flows

A sanitary sewer has two main functions:

1. to carry the maximum design flow, and
2. to transport suspended solids so that deposits in the sewer are kept to a minimum.

It is essential therefore that the sewer has adequate capacity for the maximum design flow and that it function properly at minimum flow as well.

Maximum design flow determines the hydraulic capacity of sewers, pump stations, and treatment plants. Minimum flows must be considered in design of sewers and inverted siphons to insure reasonable cleansing velocities.

Extraneous Flows

Sanitary sewer design quantities should include consideration of the various non-sewage components, which can become a part of the total flow. These non-sewage components have been greatly reduced as sanitary sewers have been separated from storm sewers, but a consideration factor for these flows is still seen as advisable.

The cost of transporting, pumping and treating sewage obviously increases as the quantity of flow delivered to the pumps or treatment facility increases. Thus, extraneous flow should be eliminated to the extent possible by proper design and construction practices and adequately enforced connection regulations.

Inflow

A very few illicit roof drains connected to the sanitary sewer can result in a surcharge of smaller sewers. For example, a rainfall of 1 in. per hour on 1,200 ft^2 of roof area, would contribute more than 12 gpm.

Connection of roof, yard and foundation drains to sanitary sewers should be legally prohibited and steps taken to eliminate them. Most municipalities have now enacted, or are in the process of enacting laws to accomplish this. Water from these sources and surface run off should be directed to a storm drainage system.

Tests indicate that leakage through manhole covers may be from 20 to 70 gpm with a depth of 1 in. of water over the cover. Such leakage may contribute amounts of storm water exceeding the average sanitary flow.

Infiltration

Prominent sources of excessive infiltration can be poorly constructed manholes and/or connections and improperly laid house laterals. In a given system, laterals frequently have a total length greater than the collecting system. House connections should receive the same specifications, construction and inspection as public sewers.

Prior to 1972 and the passage of the Clean Water Grant Act, sewer designers allowed higher amounts of infiltration to aid in transporting solids. "Dilution is the Solution to Pollution" was the phrase used to illustrate the design theory of the time. The cost involved in treating infiltration in modern systems means that it must now be prevented.

Advantages of Flexible Compression Joints

Probably the largest misconception about VCP surrounds the jointing system. VCP is the most widely used pipe material for gravity sanitary sewer pipe over the last few centuries. As a result, many people think of the early field-made joints from the 1900's and not the factory-made flexible compression joints that were first introduced in the late 1950s. The problems with the old jointing system were twofold. The first issue was a leaky joint and the resultant root intrusion and material loss outside the pipe both affecting structural integrity of a pipeline. The second was created by having a joint incapable of adjusting to minor movement after installation. While cement mortar, oakum, and asphaltic joints are a thing of the past there are many miles of pipelines with this antiquated joint system still in service.

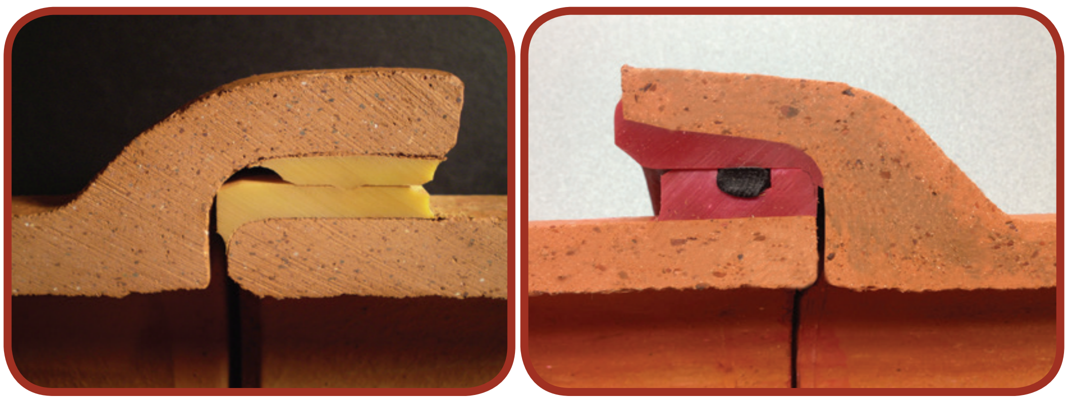

Figure 2-2: *Polyurethane (left) and O-ring and polyester (right) flexible compression joints.*

Flexible compression joints conforming to ASTM C425 provide a tight and flexible joint whether the sewer is above or below ground water. Modern, flexible compression joints use polyester or polyurethane materials and are factory applied to both the bell and spigot of every pipe (see Figure 2-2). Another jointing system option is plain end pipe barrels joined with rubber compression couplings with stainless steel tightening bands (see Figure 2-3). All of these jointing systems allow the clay pipe to shift or move with any minor changes in earth conditions without damaging the pipe. This provides a measure of forgiveness during installation and for the life of the line.

Figure 2-3: *Rubber compression couplings with stainless steel tightening bands.*

Curvilinear Sewers

The factory applied joints of modern VCP pipe are designed to allow some angular deflection while retaining joint integrity. ASTM C425 prescribes the limits of joint deflection as shown in Table 2-1. A smaller curve radius can be created using shorter lengths of pipe.

Radius of Curvature & Angle of Deflection							
Pipe Diameter (inches)	**Maximum Deflection**		**Equation for r***	**Minimum Radius of Curvature (r*)**			
	In./LF	**Angle Θ**		**Pipe Length L (feet)**			
				4	**6**	**8**	**10**
3 – 12	1/2	(2.4°)	r = 24(L)	96	144	192	----
15 – 24	3/8	(1.8°)	r = 32(L)	128	192	256	320
27 – 36	1/4	(1.2°)	r = 48(L)	192	288	384	480
39 – 42	3/16	(0.9°)	r = 64(L)	256	384	512	640
48	1/8	(0.6°)	r = 96(L)	384	576	768	960
* r = Minimum radius in feet							

Table 2-1: *Radius of Curvature & Angle of Deflection*

The equation for use in determining radius, deflection angle per joint or the length of pipe in feet can be stated as follows:

$$r = (360°/\theta)(L/2\pi)$$

The equation for determining the distance each pipe section needs to be deflected from a straight line (measured in inches) can be stated as:

$$\Delta d = \tan\theta\,(L)(12)$$

Where:

r = Radius of the curved sewer in feet

θ = Deflection angle per joint

L = Length of pipe in feet

Δd = Deflection measured in inches per joint

Example 2-1: Finding the Maximum Pipe Length

The planned curve of a street and location of other utilities has tentatively been planned to call for a 125 foot radius. The service demand in this area will require an 8-inch pipe. Referring to Table 2-1, the maximum allowable angular deflection for 8-inch pipe is 2.4°.

$$\mathbf{r = (360^\circ/\theta)(L/2\pi)}$$

$$125 = (360^\circ/2.4^\circ)\ (L/2\pi)$$

$$L = (125)(2.4)(2\pi)/360$$

$$L = 5.24'$$

A standard 5 foot pipe length should be used.

Example 2-2: Finding Angle of Deflection for Each Pipe

If the design radius of the proposed 15-inch diameter sewer will be 220 feet, determine the deflection angle of each piece of pipe.

Determine that the design radius of 220 feet is larger than the minimum prescribed in Table 2-1: r = 32(6) = 192.

$$\mathbf{r = (360^\circ/\theta)(L/2\pi)}$$

$$220 = (360^\circ/\theta)(6/2\pi)$$

$$\Theta = (360)(6)/(220)(2\pi)$$

$$\Theta = 1.56^\circ$$

For ease of installation, determine the distance each 6-foot length of pipe needs to be deflected from a straight line in inches.

$$\mathbf{\Delta d = \tan\theta\ (L)(12)}$$

$$\Delta d = \tan 1.56^\circ\ (6)\ (12)$$

$$\Delta d = 1.96''$$

Flow Monitoring

A sewer flow-monitoring program is necessary to determine when existing sewers will reach hydraulic design capacity. Monitoring methods vary from high water markers that record maximum depths to hand held mechanical tools or electronic devices. With a history of flow data, projections can forecast the year the peak flow will reach the design capacity of the sewer.

Sewer line modeling computer programs are available to analyze existing systems and establish quantities for the design of relief sewers.

Basic Premises for Calculating Flow in Sewers

This section on hydraulics of sewers deals only with uniform flow. Standard hydraulic handbooks should be consulted for special conditions.

Since the flow characteristics of sewage and water are similar, the surface of the sewage will seek to level itself when introduced into a channel with a sloping invert. This physical phenomenon induces movement known as gravity flow. Most sewers are of this type.

The flow in a pipe with a free water surface is defined as open channel flow. Steady flow means a constant quantity of flow and uniform flow means a steady flow in the same size conduit with the same depth and velocity. Although these conditions seldom occur in practice, it is necessary to assume uniform flow conditions in order to simplify the hydraulic design.

There are times when sewers become surcharged, encounter obstacles requiring an inverted siphon or require pumping. Under these conditions the sewer line will flow full and be under head or internal pressure.

The Flow Characteristics Diagram (Figure 2-4) demonstrates the theory and terminology applied to flow in open channels. To simplify the diagram, all slopes are subcritical and it is assumed that

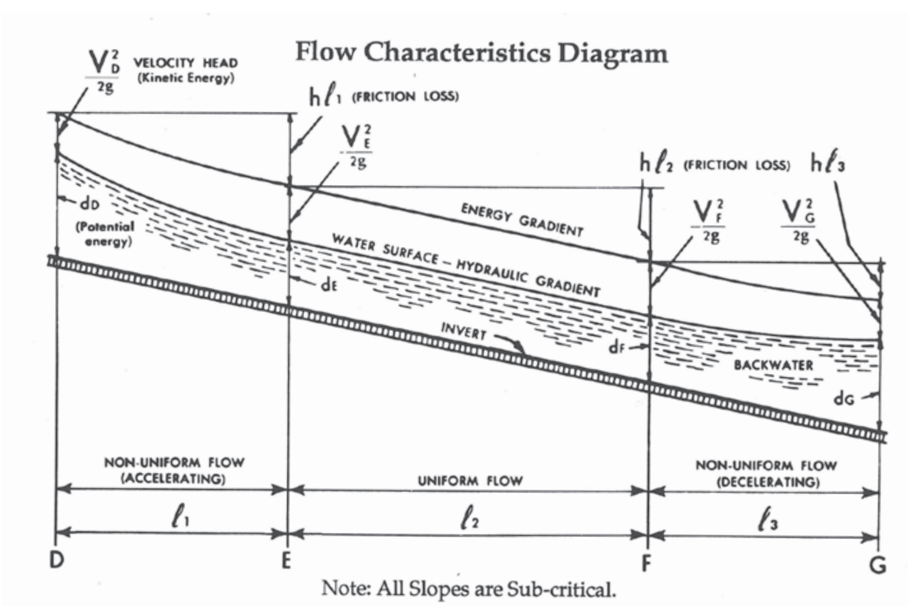

Figure 2-4: Flow Characteristics theory and terminology illustrated

at point D a constant supply of water or sewage is being supplied. Between D and E the slope of the conduit is greater than is required to carry the water at its initial velocity, and is greater than the retarding effect of friction, which causes acceleration to occur. At any point between E and F, the potential energy of the water equals the loss of head due to friction and the velocity remains constant. This is uniform flow. Between F and G the effect of downstream conditions are causing a decrease in the velocity.

The Hydraulic Profile

Three distinct slope lines are commonly referred to in hydraulic design of sewers as shown in Figure 2-4.

1. The Slope of the Invert of the Sewer. This is fixed in location and elevation by construction. Except in rare cases, the invert slopes downstream in the direction of flow.
2. The Slope of the Hydraulic Gradient (H.G.). This is sometimes referred to as the water surface. In open channel flow, this is the top surface of the liquid flowing in the sewer. Except for a few cases, the hydraulic gradient slopes downstream in the direction of flow.
3. The Energy Gradient (E.G.). This is located above the hydraulic gradient, a distance equal to the velocity head, which is the velocity squared divided by two times the acceleration due to gravity ($v^2/2g$). This slope is always downstream in the direction of flow. For uniform flow, the slope of the energy gradient, the slope of the hydraulic surface and the slope of the invert are parallel to one another but at different elevations.

Design Requirements

In sewer system design the following hydraulic requirements must be met:

1. The velocity must be sufficiently high to prevent the deposition of solids in the pipe but not high enough to induce excessive turbulence. The minimum scouring velocity is 2 feet per second. Clay pipe is being used successfully where velocities exceed 20 feet per second.
2. Where changes are made in the horizontal direction of the sewer line, in the pipe diameter, or in the quantity of flow, invert elevations must be adjusted so that the change in the energy gradient elevation allows for the head loss.
3. Sanitary sewers up to 15-inches in diameter should be designed to run half-full at peak flow and larger sewers designed to run three-quarters full at peak flow. This also provides necessary air space to transfer sewer gases.

After flow estimates have been prepared, including all allowances for future increases and the layout of the system has been determined, the next step is to establish the slope for each line. Profile sheets show the surface elevations, subsurface structures and any other control points, such as house connections and other sewer connections. A typical profile for sewer design is shown on page 2-1.

Using the profile sheet, a tentative slope of the sewer is determined beginning at the lower end and working upstream between street intersections or control points. The slope is located as shallow as possible to serve the adjacent area and tributary areas with consideration to street grade and any control points or obstructions.

Determination of Pipe Sizes

Knowing the peak flow and the tentative slope, a tentative pipe size can be selected for each reach using the Design Capacity Graph shown on page 2-12. A diagram based on Manning's Equations showing quantity, slope, pipe size and velocity can be used to find pipe sizes. The diagram shows quantities for one-half depth for small pipe through 15-in. diameter and three-quarters depth for 18-in. and larger sizes. The "n" values can range from 0.006 to 0.013. Enter the diagram with Q and slope and read the larger pipe size. Except for cases where there are large head losses, the tentative pipe size will be the final pipe size.

Selecting the Sizes for the New Sewer Line

Once design flows (Q_d), the slope of the line and the "n" value to be used are determined, the required pipe sizes may be selected.

The slope is obtained by drawing a preliminary profile showing control points, such as, sewers to be intercepted, major substructures, ground lines, outlet sewer, etc. The "n" value is selected by the specifying agency or is defined by regional standards.

Example 2-3: Determination of the Required Pipe Size Using a Design Capacity Graph

For a given project, flow estimating calculations resulted in the values below.

Estimated Average & Maximum Flows (cfs) for Project Reaches A - G							
MH	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Q_{av}	0.37	0.59	1.21	1.98	2.14	4.47	9.19
Q_d	0.96	1.53	2.80	4.50	4.80	9.40	18.00

If the available slope is 0.4 ft. per 100 ft. along this reach and the coefficient of friction (n) is 0.013, determine the required pipe size for the reach downstream from MH A, using the Design Capacity Graph shown on page 2-12.

- Locate the intersection of the 0.004 slope and Q_d of 0.96 cfs
- Read the larger pipe size. This Q_d intersects the 0.004 slope between a 10-in. and a 12-in. pipe.

The larger pipe is usually selected.

In the reach downstream from MH B, the Q_d is 1.53 cfs, indicating that a 15-in. pipe will be required.

Further downstream, the outflow from MH F is 9.4 cfs, and a 21-in. pipe is necessary.

As a final check, plot the pipelines on the profile, set the outlet elevation and work upstream through each confluence, making sure there is adequate clearance for substructures and that the line meets all other controls. The pipe size will have to be rechecked if the slope has been changed for any reason.

Knowing the quantity of flow and the pipe size, the velocity can be calculated using the Manning Equation, the Velocity Variation Table (page 2-10) or the Design Capacity Graph (page 2-12). The velocity head can be calculated to give the energy gradient.

In many cases, especially with large diameter sewers, it is necessary to carefully plot the energy gradient of the sewer to determine that the hydraulic design requirements are met.

In these cases, start at the downstream end of the profile and mark the energy gradient at that point. Where the flow enters another sewer it will be the energy gradient of that sewer.

A line to represent a tentative location for the energy gradient for the first section of sewer being designed is then drawn upstream following the available surface slope to the next control point on the profile. As discussed earlier, this could be a point where flow is added, a street intersection, an abrupt change in surface slope or other control points. Care must be taken to see that the final design of the sewer provides adequate cover and that the sewer clears all subsurface obstructions. The profile can now be finalized.

Quantity and Velocity Equations

The following equations are provided to show the basis for flow diagrams and to supply equations for more accurate hydraulic calculations. Precise calculations of hydraulic data are not possible except under controlled conditions.

The Manning Equations

The most commonly used velocity and quantity equations are:

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

$$Q = \frac{1.486}{n} ar^{2/3} s^{1/2}$$

Where:

"*V*" = the velocity of flow (averaged over the cross-section of the flow) measured in feet per second. For sewers flowing at design depth, "V" should exceed 2 feet per second to prevent settlement of solids in the pipe. Conversely, velocities exceeding 20 feet per second should be avoided where possible. Clay Pipe can handle high velocities without damage, however, manholes, structures and angle points must be designed carefully to avoid problems.

"***Q***" = the quantity of flow measured in cubic feet per second.

"***n***" = a coefficient of roughness which is used in Manning's Equation to calculate flow in a pipe. (See the following discussion of "n" values.)

"***a***" = the cross-sectional area of the flowing water in square feet.

"***r***" = the hydraulic radius of the wetted cross-section of the pipe measured in feet. It is obtained by dividing "a" by the length of the wetted perimeter.

"***s***" = the slope of the energy gradient. It is numerically equal to the slope of the invert and the hydraulic surface in uniform flow.

Velocity Variations From Design Depths
(To Convert Depth/Diameter to % of Velocity)

d/D	% V.5D	% V.75D	d/D	% V.5D	% V.75D	d/D	% V.5D	% V.75D	d/D	% V.5D	% V.75D
.05	26	23	.30	78	69	.55	104	92	.80	114	101
.10	40	35	.35	84	74	.60	107	95	.85	114	100
.15	52	46	.40	90	80	.65	110	97	.90	112	99
.20	62	54	.45	95	84	.70	112	99	.95	110	97
.25	70	62	.50	100	88	.75	113	100	1.00	100	88

Table 2-2: *Velocity Variations*

Discussion of Values for "n"

The value of "n" for smooth bore pipe is affected by depth of flow, velocity of flow and quality of construction. In controlled experiments, using clean water, values of "n" under 0.009 have consistently been obtained for vitrified clay pipe and some other sewer materials. Many design engineers recommend that a more conservative value of "n" be used in design because of:

1. the variations in "n" due to variable flow conditions,
2. the deposition of debris, grit and other foreign materials which find their way into a sewer system,
3. the build-up of slime and grease on all pipe surfaces, see Figure 2-5 on page 2-11,
4. the loss of hydraulic capacity of flexible pipe due to ring deflection and
5. misalignment due to construction or settlement.

Based upon current data, "n" values of 0.009 - 0.013 can be applied to all types of smooth bore pipe. After pipelines have been in place for several years, measurements may indicate "n" values that differ from the design value. These new values can be used for future flow calculations. Field-testing of lines in service for 10-years have reported values as low as 0.006, validating the use of 0.013 as a conservative value for Manning's "n". Factors for determining Q's when using the conservative "n" value of 0.013 are shown on the Design Capacity Graph on page 2-12.

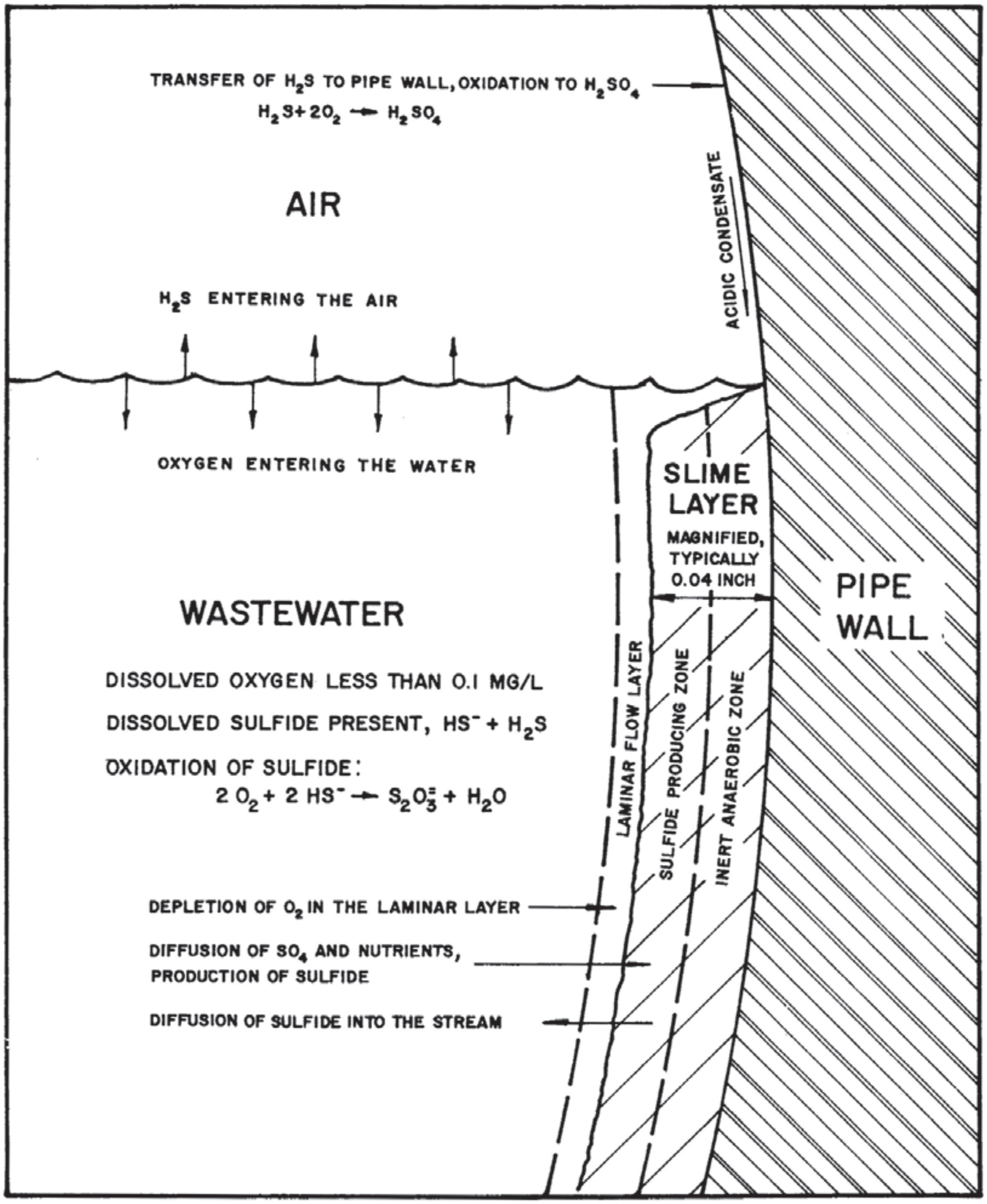

Figure 2-5: *Processes occurring in sewer under sulfide buildup conditions.*
Source: *Environmental Protection Agency, Process Design Manual for Sulfide Control in Sanitary Sewers, Richard D. Pomeroy, October, 1974.*

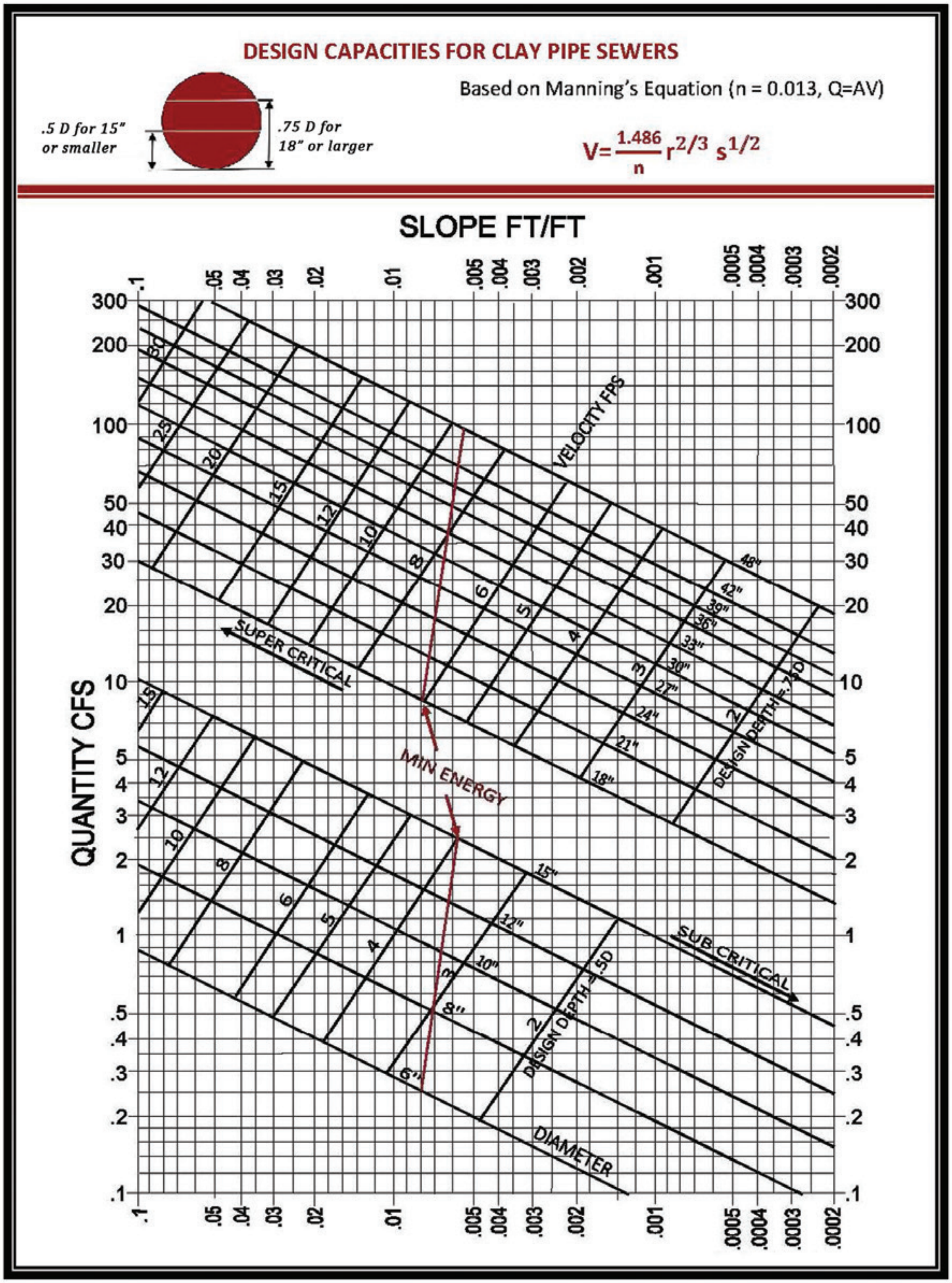

Figure 2-6: *Design Capacities for Clay Pipe Sewers using a friction coefficient of n = 0.013.*

Computer Aided Design

The National Clay Pipe Institute offers a hydraulic design program, Hyflow, which uses Manning's Equations to assist engineers in selecting pipe size, flow quantities or velocity in gravity flow sanitary sewers. It is available online at ncpi.org/toolbox/hyflow.

Examples 2-4 and 2-5 demonstrate two uses of the Hyflow program.

Example 2-4: Determination of the Required Pipe Size and Velocity Using Hyflow

Determine the required pipe size and velocity when flowing full, given:

Coefficient of Friction (n):	0.013
Flow Rate:	11.0 cfs
Slope:	0.28 ft. per 100 ft.

- Enter the Hyflow program from the Toolbox page of the NCPI website.
- On the Flow Data tab, enter the Manning's n of 0.013 and select an alternate "Design Depth of Flow."
- On the Pipe Diameter Solutions tab, enter 100 in the Liq. Depth (%) box.
- Enter 11.0 in the Flow Quantity box (make sure that cfs is selected for the units of measure).
- Enter the drop of 0.28 and run of 100.
- Click the "Get Pipe Diameter Results" button.

Pipe Slope:	0.0028
Coefficient of Friction (n):	0.013
Design Quantity:	11 cfs
Liquid Depth:	100.0%

Pipe Dia. (in.)	Velocity (fps)	Quantity (cfs)
15	2.81	3.44
18	3.17	5.59
21	3.51	8.43
24	**3.83**	**12.03**
27	4.14	16.45
30	4.44	21.77
33	4.72	28.05

From the Hyflow results above, read a **24-inch** pipe size is needed to achieve a flow rate of 11 cfs or more (or 12.03 cfs). Read the velocity of **3.83 fps** when flowing full.

Example 2-5: Determination of the Required Pipe Size and Velocity Using Hyflow

Determine the required pipe size and velocity flowing at a liquid depth to pipe diameter ratio of 0.50, given:

Coefficient of Friction (n):	0.013
Flow Rate:	1.0 cfs
Slope:	1.2 ft. per 100 ft.

- Enter the Hyflow program from the Toolbox page of the NCPI website.
- On the Flow Data tab, enter the Manning's n of 0.013 and select an alternate "Design Depth of Flow."
- On the Pipe Diameter Solutions tab, enter 50 in the Liq. Depth (%) box and 1.0 in the Flow Quantity box (make sure that cfs is selected for the units of measure).
- Enter the drop of 1.2 and run of 100.
- Click the "Get Pipe Diameter Results" button.

Pipe Slope:	0.012
Coefficient of Friction (n):	0.013
Design Quantity:	1 cfs
Liquid Depth:	50.0%

Pipe Dia. (in.)	Velocity (fps)	Quantity (cfs)
6	3.17	0.31
8	3.84	0.67
10	**4.45**	**1.21**
12	5.02	1.97
15	5.81	3.57
18	6.55	5.79

From the Hyflow results above, read a **10-inch** pipe size is needed to achieve a flow rate above the minimum of 1.0 cfs required (1.21 cfs). Read the velocity of **4.45 fps** when flowing at a liquid depth to pipe diameter ratio of 0.50.

Conveyance Factors

Conveyance Factors equal Q/Q_d expressed as a percent. Q is the amount of flow at any depth and Q_d is the amount of flow when the depth is at design depth. Design depth for pipe 15-in. and smaller, is one-half full (.5D) and for pipe 18-in. and larger, three-quarters full (.75D). Depths are expressed in terms of d/D, where "d" is the depth and "D" is the diameter. The Conveyance Factor Tables are shown on page 2-19.

Example 2-6 demonstrates the use of the .5D Table for pipe 15-in. and less in diameter. Example 2-7 demonstrates the use of the .75D Table for pipe 18-in. and larger in diameter.

Example 2-6: Determination of Percentage of Design Capacity and Flow of an Existing Sewer

Compute the percentage of design capacity ($\%Q_d$) and flow (Q), given:

Pipe Size:	10 in. = .83 ft.
Coefficient of Friction (n):	0.013
Measured Depth of Flow:	.35 ft.
Slope:	1.2 ft. per 100 ft.

d/D = Depth of flow/pipe diameter (ft)

d/D = 0.35/0.83

d/D = 0.42

- Use the .5D Table to find $\%Q_d$ (Table 2-3 on page 2-19.)
- Enter table with 0.42 (0.40 on the vertical axis and 0.02 horizontal axis) and read 73%.

This pipe is flowing at 73% of its design capacity (Q_d).

Use the Hyflow Calculator to determine the actual design capacity:
- Enter the Hyflow program from the Toolbox page of the NCPI website.
- On the Flow Data tab, enter the Manning's n of 0.013.
- On the Flow Solutions tab, select 10-in. from the drop down menu.
- Enter drop of 1.2 and run of 100 (make sure cfs is selected for the units of measure).
- Click the "Get Flow Results" button.

The results appear on page 2-16.

Example 2-6 (Continued): Determination of Percentage of Design Capacity and Flow of an Existing Sewer

From the results below; for flowing 50% full, read the design capacity Q_d = 1.21 cfs. Since the pipe is flowing at 73% of its design capacity; multiply Q_d by 0.73 to find Q.

$$Q = Q_d \times \%Q_d$$

$$Q = 1.21 \times .73$$

$$Q = 0.88 \text{ cfs}$$

Pipe Diameter:	10 in.
Pipe Slope:	0.012
Coefficient of Friction (n):	.013
Selected Output Unit:	cfs

Percent of Pipe Dia.	Depth Liq (in)	Velocity (fps)	Quantity (cfs)
5	0.5	1.16	0.01
10	1.0	1.80	0.05
15	1.5	2.31	0.12
20	2.0	2.75	0.21
25	2.5	3.13	0.33
30	3.0	3.46	0.48
35	3.5	3.75	0.64
40	4.0	4.02	0.82
45	4.5	4.25	1.01
50	**5.0**	**4.45**	**1.21**
55	5.5	4.62	1.42
60	6.0	4.77	1.63
65	6.5	4.88	1.83
70	7.0	4.97	2.03
75	7.5	5.03	2.21
80	8.0	5.06	2.37
85	8.5	5.05	2.50
90	9.0	4.99	2.58
95	9.5	4.86	2.60
100	10.0	4.45	2.43

Example 2-7: Determination of Percentage of Design Capacity and Flow of an Existing Sewer

Compute the percentage of design capacity (%Q_d) and flow (Q), given:

Pipe Size:	21 in. = 1.75 ft.
Coefficient of Friction (n):	0.013
Measured Depth of Flow:	1.12 ft.
Slope:	.4 ft. per 100 ft.

d/D = Depth of flow/pipe diameter (ft)

d/D = 1.12/1.75

d/D = 0.64

- Use the .75D Table to find %Q_d (Table 2-4 on page 2-19).
- Enter table with 0.64 (.6 on the vertical axis and 0.04 horizontal axis) and read 81%.

This pipe is flowing at 81% of its design capacity (Q_d).

Use the Hyflow Calculator to determine the actual design capacity:
- Enter the Hyflow program from the Toolbox page of the NCPI website.
- On the Flow Data tab, enter the Manning's n of 0.013.
- On the Flow Solutions tab, select 21-in. from the drop down menu.
- Enter drop of .4 and run of 100 (make sure that cfs is selected for the units of measure).
- Click the "Get Flow Results" button.

Pipe Diameter:	21 in.
Pipe Slope:	0.004
Coefficient of Friction (n):	0.013
Selected Output Unit:	cfs

Example 2-7 (Continued): Determination of Percentage of Design Capacity and Flow of an Existing Sewer

Percent of Pipe Dia.	Depth Liq (in)	Velocity (fps)	Quantity (cfs)
5	1.1	1.09	0.05
10	2.1	1.70	0.21
15	3.2	2.18	0.49
20	4.2	2.59	0.89
25	5.3	2.95	1.39
30	6.3	3.26	1.98
35	7.4	3.54	2.65
40	8.4	3.78	3.40
45	9.5	4.00	4.20
50	10.5	4.19	5.04
55	11.6	4.35	5.90
60	12.6	4.49	6.77
65	13.7	4.60	7.61
70	14.7	4.69	8.43
75	**15.8**	**4.74**	**9.18**
80	16.8	4.77	9.84
85	17.8	4.76	10.37
90	18.9	4.70	10.73
95	20.0	4.58	10.82
100	21.0	4.19	10.08

From the results shown above; for flowing 75% full, read the design capacity Q_d = 9.18 cfs.

Since the pipe is flowing at 81% of its design capacity; multiply Q_d = 9.18 cfs. by 0.81 to find **Q = 7.44 cfs.**

CONVEYANCE FACTOR TABLES

.5D TABLE FOR PIPE 15" AND SMALLER

For pipe 15" and smaller, Q_d = Q at a depth of .5 Diameter

d/D	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	%	0	0	0	1	1	1	2	3	3
.1	4	5	6	7	8	10	11	13	14	16
.2	18	19	21	23	25	27	30	32	34	37
.3	39	42	44	47	50	52	55	58	61	64
.4	67	70	73	77	80	83	86	90	93	96
.5	100	103	106	110	113	117	120	124	127	131
.6	134	138	141	144	148	151	154	158	161	164
.7	167	170	173	176	179	182	185	188	190	193
.8	195	197	200	202	204	206	207	209	210	212
.9	213	214	214	215	215	215	214	213	211	208
1.0	200									

Example: If the depth of flow in a 8" sewer is measured at .21' d/D = .21/.67 = .31. Enter table for smaller sewers with d/D = .31 and read 42% Q design. Q design is read from Design Capacity Charts.

Table 2-3: *Conveyance Factors for Pipe up to 15 inches in diameter*

CONVEYANCE FACTOR TABLES

.75D TABLE FOR PIPE 18" AND LARGER

For pipe 18" and larger, Q_d = Q at a depth of .75 Diameter

d/D	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	%	0	0	0	1	1	1	1	1	2
.1	2	3	3	4	5	5	6	7	8	9
.2	10	11	12	13	14	15	16	17	19	20
.3	21	23	2	26	27	29	30	32	34	35
.4	37	39	40	42	44	46	48	49	51	53
.5	55	57	59	60	62	64	66	68	70	72
.6	74	76	77	79	81	83	85	87	88	90
.7	92	94	95	97	99	100	102	103	105	106
.8	107	109	110	111	112	113	114	115	116	116
.9	117	118	118	118	118	118	118	117	116	114
1.0	110									

Example: If the depth of flow in a 18" sewer is measured at 1.02' d/D = 1.02/1.5 = .68. Enter table with d/D = .68 and read 88% Q design. Q design is read from Design Capacity Charts.

Table 2-4: *Conveyance Factors for Pipe 18 inches in diameter and larger*