PDHonline Course C261 (10 PDH)

Planning and Design Gravity Sewers

Instructor: Jerry D. Morrow, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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TEN STATE STANDARDS

Planning and Design Gravity Sewers

PART I – GENERAL CONCEPTS

Description

Sewers are hydraulic conveyance structures that carry wastewater to a treatment plant or other authorized point of discharge. A typical method of conveyance used in sewer systems is to transport wastewater by gravity along a downward-sloping pipe. These sewers, known as conventional gravity sewers, are designed so that the slope and size of the pipe is adequate to maintain flow towards the discharge point without surcharging manholes or pressurizing the pipe. Velocities of 2.0 feet-per-second (fps) is maintained at least daily to assist in cleaning sewers.

Sewers are commonly referred to according to the type of wastewater that each transports. For example, storm sewers carry storm water; industrial sewers carry industrial wastes; sanitary sewers can carry both domestic sewage and appropriate industrial wastes. Another type of sewer, known as a combined sewer, exists in older communities, but such systems are no longer constructed and are eliminated whenever possible because of the unnecessary loads on wastewater plants. Combined sewers can carry domestic sewage, industrial waste, and storm water. This document will focus on sanitary sewer systems even though much of the data directly relates to storm water sewers.

Applicability

Conventional gravity sewers are typically used in urban areas with consistently sloping ground because excessively hilly or flat areas result in deep excavations and increase construction costs. Conventional gravity sewers remain the most common technology used to collect and transport domestic wastewater in the United States.

Advantages and Disadvantages

Advantages

Conventional gravity sewer systems have been used for many years and procedures for their design are well established. When properly designed and constructed, conventional gravity systems perform reliably and last for many years without excessive maintenance. Properly designed and constructed conventional gravity sewers provide the following advantages:

1. Can handle grit and solids in sanitary sewage (as long as minimal velocities are maintained.)
2. Can maintain a minimum velocity (at design flow), reducing the production of hydrogen sulfide and methane. This in turn reduces odors, blockages, pipe corrosion, and the potential for explosion (Qasim 1994).

Disadvantages

• The slope requirements to maintain gravity flow can require deep excavations in hilly or flat terrain, increasing construction costs or even making continuous gravity systems impossible.

• Sewage pumping or lift stations may be necessary as a result of the slope requirements for conventional gravity sewers, which result in a low spot at the tail of the sewer, where sewage collects and must be pumped or lifted to a new gravity collection system. Pumping and lift stations substantially increase the cost of the collection system and of course require ongoing maintenance.

• Manholes associated with conventional gravity sewers can be a source of inflow and infiltration, increasing the volume of wastewater to be carried, as well as the size of pipes and lift/pumping stations, and, ultimately, increasing costs, not to mention the increased cost of treating excess water.

Design Criteria

The design of conventional gravity sewers is based on the following design criteria:

1. Design flow (average and peak).
2. Minimum pipe diameter.
3. Velocity.
4. Slope.
5. Depth of sewers.
6. Loads on buried conduits.
7. Appurtenances.
8. Site conditions.

Long-Term Serviceability. The design of long-lived sewer infrastructure should consider serviceability factors, such as ease of installation, design period, useful life of the conduit, resistance to infiltration and corrosion, and maintenance requirements. The design period should be based on the ultimate tributary population and usually ranges from 25 to 50 years (Qasim 1994).

Design Flow. Sanitary sewers are designed to carry peak residential, commercial, institutional, and industrial flows, as well as infiltration and inflow. Gravity sewers are designed to flow full at the ultimate design peak flow. Design flows are based on various types of developments. Table 1 provides a list of design flow for various development types.

Minimum Pipe Size. A minimum pipe size is dictated in gravity sewer design to reduce the possibility of clogging. The minimum pipe diameter recommended by the Ten State Standards is 200 mm (8 inches). Though the Ten State Standards are adopted by ten specific states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin) and the Province of Ontario, they often provide the basis for other state standards. A copy of the Ten State Standards has been included with this material, because it is an easy read and works well as a quick reference. Every State has design standards with similar requirements and some are specific to the State. They should be reviewed prior to undertaking specific design problems.

Velocity. The velocity of wastewater is an important parameter in a sewer design. A minimum velocity must be maintained to reduce solids deposition in the sewer, and most states specify a minimum velocity that must be maintained under low flow conditions. The typical design velocity for low flow conditions is 0.3 m/s (1 foot/second). During peak dry weather conditions the sewer lines must attain a velocity greater than 0.6 m/s (2 feet/second) to ensure that the lines will be self cleaning (i.e., they will be flushed out once or twice a day by a higher velocity)(Qasim 1994).

Slope. Sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane. Table 2 presents a list of minimum slopes for various pipe sizes. If a sewer slope of less than the recommended value must be provided, the responsible review agencies may require depth and velocity computations at minimum, average, and peak flow conditions. The size of the pipe may change if the slope of the pipe is increased or decreased to ensure a proper depth below grade. Velocity and flow depth may also be affected if the slope of the pipe changes. This parameter must receive careful consideration when designing a sewer.

Depth of Sewer. Depth of bury affects many aspects of sewer design. Slope requirements may drive the pipe deep into the ground, increasing the amount of excavation required to install the pipe. Sewer depth averages 4 to 10 feet below ground surface. The proper depth of bury depends on the water table, the lowest point to be served (such as a ground floor or basements with sewers), the topography of the ground in the service area, and the depth of the frost line below grade. When errors are made in sewer design, it is commonly the over-sight of making a gravity connection to an adjacent basement that was intended to be sewered. When serving new construction, the contractor building the new structure needs to recognize at what elevation the basement floor should be set to obtain a gravity connection to the gravity line. This information should be shown on the sewer plans for each lot on which new construction will be undertaken. When assigning this elevation, take into consideration the slope of the connection line, clearance to get the connection line beneath the footing and allow room for the “P” trap at the floor drain.

TABLE 1 AVERAGE DESIGN FLOWS FOR DEVELOPMENT TYPES

Type of Development Design	Flow (GPD)
Residential:	general 100/person
Single-family	370/residence
Townhouse unit	300/unit
Apartment unit	300/unit
Commercial: general	2,000/acre
Motel:	130/unit
Office:	20/employe 0.20/net s.f.
Industrial	varies with type of industry, measurement necessary
General	10,000/acre
Warehouse	600/acre
School site (general)	16/ student

Appurtenances. Appurtenances include manholes, building connections, junction chambers or boxes, and terminal cleanouts, among others. Regulations for using appurtenances in sewer systems are well documented in municipal design standards and/or public facility manuals. Manholes for small sewers (610 mm [24 inches] in diameter or less) are typically 1.2 m (4 feet) in diameter. These 4-foot manholes are often designed with “boots” or flexible connectors poured into the side to the manhole to allow a quick and waterproof connection. Larger sewers require larger manhole bases, but the 1.2 m (4 foot) riser may still be used after a flat top is placed on the base with provisions for a 4-foot riser to be belled along one side. When using larger manholes, the criteria for sizing is allowing all piping in and out of the manhole to fit in to “dog house” type openings and still maintain concrete between the openings to give the base the strength to be set without cracking. When the larger sewers are properly laid, the larger base is placed over the pipes and concrete encasement is poured along with the invert to seal the manhole. It is important to cradle each pipe installed in this manner to insure that settling does not crack the manhole. Manhole spacing depends on regulations established by the local municipality.

Manholes are typically required when there is a change of sewer direction, size or slope. However, certain minimum standards are typically required to ensure access to the sewer for maintenance. Typical manhole spacing ranges between 90 to 180 m (300 to 600 feet) depending on the size of the sewer and available sewer cleaning equipment. For example, one municipality requires that the maximum manhole spacing be at intervals not to exceed 120 m (400 feet) on all sewers 380 mm (15 inches) or less, and not exceeding 150 m (500 feet) on all sewers larger than 380 mm (15 inches) in diameter (Fairfax County PFM 1995).

TABLE 2 - MIMIMUM SLOPES TO ACHIEVE 2.0 FEET PER SECOND VELOCITY

SEWER SIZE (ENG)	SEWER SIZE (MET)	SLOPE IN FEET / 100 FEET
8 Inch	20 cm	0.40
9 Inch	23 cm	0.33
10 Inch	25 cm	0.28
12 Inch	30 cm	0.22
14 Inch	36 cm	0.17
15 Inch	38 cm	0.15
16 Inch	41 cm	0.14
18 Inch	46 cm	0.12
21 Inch	53 cm	0.10
24 Inch	61 cm	0.08
27 Inch	69 cm	0.067
30 Inch	76 cm	0.058
36 Inch	91 cm	0.046

Effective operation of a conventional gravity sewer begins with proper design and construction. Serious problems may develop without an effective preventative maintenance program. Occasionally, factors beyond the control of the maintenance crew can cause problems. Potential problems include:

- Explosions or severe corrosion due to discharge of uncontrolled industrial wastes.
- Odors.
- Corrosion of sewer lines and manholes due to generation of hydrogen sulfide gas.
- Collapse of the sewer due to overburden or corrosion.
- Poor construction, workmanship, or earth shifts may cause pipes to break or joints to open up. Excessive infiltration/exfiltration may occur.
- Protruding taps in the sewers caused by improper workmanship (plumber taps or hammer taps) these taps substantially reduce line capacity and contribute to frequent blockages.
- Excessive settling of solids in the manhole and sewer line may lead to obstruction, blockage, or generation of undesired gases.
- The diameter of the sewer line may be reduced by accumulation of slime, grease, and viscous materials on the pipe walls, leading to blockage of the line.
- Faulty, loose, or improperly fit manhole covers can be a source of inflow. Ground shifting may cause cracks in manhole walls or pipe joints at the manhole, which become a source of infiltration or exfiltration.

Source: Anne Arundel County Std. Details, 1997. Source: Concrete Pipes and Products, Inc., 1992.

PART II – PLANNING AND SEWER LAYOUT

Planning for the economical development of a sewer system requires information on current flows and forecasts of future flows. The projection of flow increases should provide 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.

Design Period.
A design period must be chosen and sewer capacity planned that will be adequate. Professional planners are reluctant to predict land use or population changes for more than 20 years into the future. However, when planning, design, financing and construction are considered together with the relatively minor additional cost of providing extra capacity, a 50-year design period is the minimum that should be considered. 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 tunnels and 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 when considering extended design periods.

Drainage Area
A drainage area is the territory being considered within which it is possible to find a continuously downhill surface route from any point to the established outlet. Drainage areas should also include areas that are tributary by gravity that will be served by future sewer construction and areas that are not tributary by gravity, which could be served by pumping or adverse grade construction. It should be noted that natural drainage boundaries do not necessarily coincide with political boundaries.

Design Flows. A sanitary sewer has two main functions: (1) to carry the peak discharge for which it is designed, 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 peak flow and that it functions properly at minimum flows.

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

Population Estimates. The best tool to use for estimating future sewage flow is population data. Forecasts of commercial and industrial flows are also helpful. A long-range population forecast is needed and, if possible, an estimate of future commercial and industrial development. A larger value for gallons/capita/day (gcd) should be used when these estimates are not available.

Population data should be collected for the total drainage area. Population projections for large areas are generally more accurate than for smaller areas because historic records are more readily available and local changes have less influence.

Convert Population Data to Average Flow. Convert population data to quantity of sewage using an average gallons/capita /day (gcd). This per capita flow varies from 50 to 140 and some areas as high as 160 where industrial flows are included. The minimum and maximum average daily quantities for the initial and final years of the design period are necessary for designing siphons and treatment plants.

A value of 100 gcd has been found to be a reasonable average flow. This does not include commercial and industrial flows. An over-all figure of about 125 gcd may be used to convert population to average flow including commercial and industrial flow. The Land Use Coefficients (shown in Table 3) can be used to predict flow from future land use. These coefficients should be adjusted in accordance with flow studies in the local area. These rates make no allowances for flow from foundation drains, roofs or yard drains, none of which should be connected to a sanitary sewer.

Plot a projection of average flow for the drainage area. A factor is applied to account for the variation between average flow and peak flow. This variation is primarily the result of the time of concentration since peak flows do not reach a point in a sewer at the same time. The use of a higher factor for small area flows (mainline sewers) as compared to large area flows (trunk sewers) is justified because small flows are particularly sensitive to changes, where a slight increase in rate of flow represents a large percentage increase. Larger areas and larger flows have a greater time of concentration that reduces the resulting variation.

Design Criteria for Sewer Service Laterals

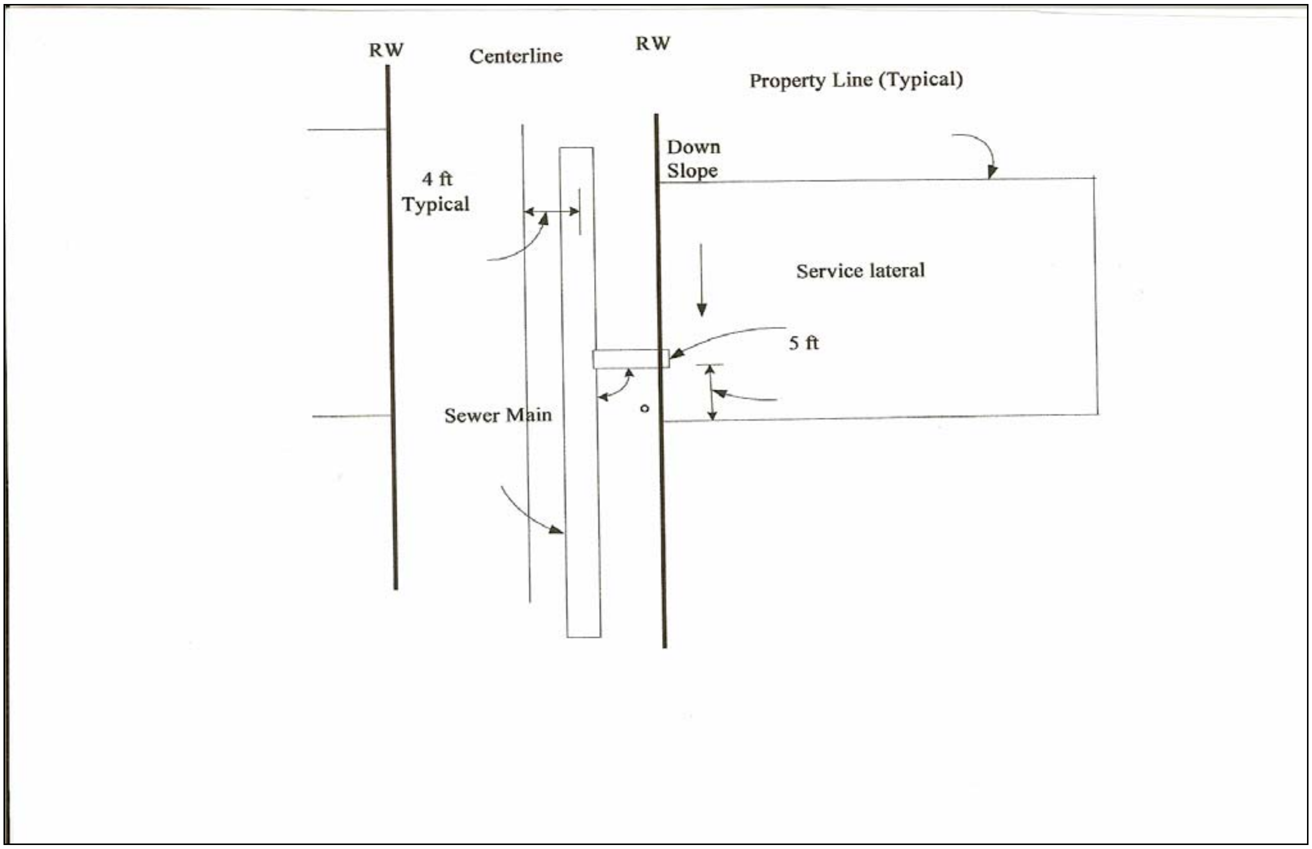
Install a public sewer service lateral (SL) to provide sanitary service to each platted private property. The lateral shall be located within the ROW or an easement as follows:

- For a service lateral from a public sewer main in the ROW, extend the service lateral to the property line.
- For a service lateral from a public sewer main in an easement, provide a tee or wye only.
- For a service lateral through a private easement to a lot, extend the private service lateral in the private easement to the property line of the lot being served.

For a site with more than one building, plumbing regulations typically may allow a separate service lateral to serve multiple buildings on the same platted tax lot. For multiple tax lots with multiple buildings, the designer must obtain approval from the Bureau of Development Services before providing service with one service lateral, regardless if the buildings are individually owned or if they have different owners. There are many external factors that can influence a property owner's decision to construct a common private sewer or multiple building sewers for multifamily, commercial or Industrial property. Give special attention to the service line capacity that drains to a common private sewer and any lateral that serves multi-family residential, commercial and industrial development. Also, give special attention if future possible or planned land divisions may result in separately owned buildings on different tax lots on a common private sewer.

Horizontal Alignment

Service line tees should be perpendicular to the sewer main to avoid excessive exposure of other utilities during excavation for construction or maintenance.



minimum of five-feet from the down slope served property corner. Each proposed building or dwelling should have an individual lateral.

Slope

Two percent or 1/4-inch per foot is the minimum sewer lateral slope for determining a sewer main design elevation. There is no maximum slope defined for a lateral inside a ROW or easement. However, when the slope exceeds 100 percent (45 degrees or one foot per foot) the designer should consider using a Deep Connection Riser (DCR).

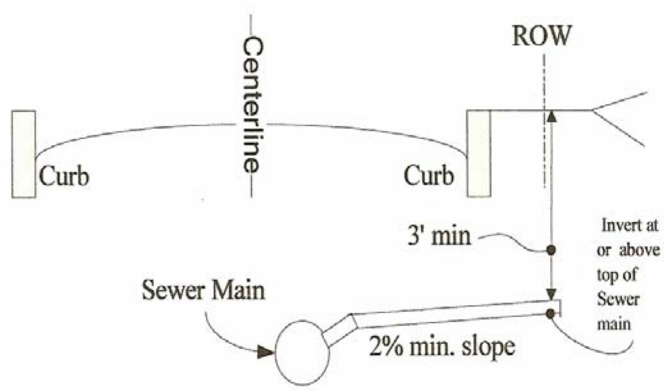
Vertical Alignment

A lateral's vertical alignment is influenced by many factors that include the service elevation, the distance from the main sewer, minimum cover requirements, conflicting utilities and site conditions.

The designer should show on the plan and profile the elevation of the lowest habitable floor of the dwelling or building (e.g. basement or first floor) served. If design constraints prevent service to the lowest floor, a note must be added to the drawings stating what floor elevation can be served with the proposed pipeline.

If the designer has knowledge of any proposed building on a parcel being developed, show the elevations on the plan and profile.

The regulatory agency will normally established minimum cover depths to the top of the service lateral at the property line or the easement line. At a property line, the top of pipe shall be a minimum of 3 feet below the street grade. In an off-street area, the minimum cover is 3 feet.



Minimum Depth of Cover

To avoid surcharge under normal flow conditions a lateral invert at a sewer main must be at or above the pipe springline. This requires the sewer main invert to be lower than that of the lateral invert. For a sewer reconstruction project or when pipes are upsized to control basement flooding, pay attention to establish all existing service lateral inverts. If necessary, design the new pipe at a greater depth to assure that any lateral invert will enter the pipe at or above the new pipeline springline or reconstruct the lateral to avoid an operation problem.

Calculating Service Lateral and Mainline Inverts

Use the equation below to determine the minimum service lateral invert elevation on the mainline sewer.

$$LSE - 2\ feet - \Delta - {}^{1}/_{2}\ Main\ OD = Minimum\ Lateral\ Invert\ Elevation\ on\ Sewer\ Main$$

Where:

LSE	=	Lowest service elevation determined at the site/building
2 feet	=	A standard dimension to provide the minimum clearance needed to construct a building sewer under a basement floor slab and building foundation and to account for other losses.
Δ	=	Elevation change calculated by multiplying 2 percent by either the distance to the point of connection on a building/dwelling or 100 feet, whichever is greater
1/2 Main OD	=	One-half the sewer main diameter

Given: The distance from building sewer at the house to the mainline sewer = 100 feet. The proposed sewer main is a concrete ASTM C14 pipe 8-inches in diameter.

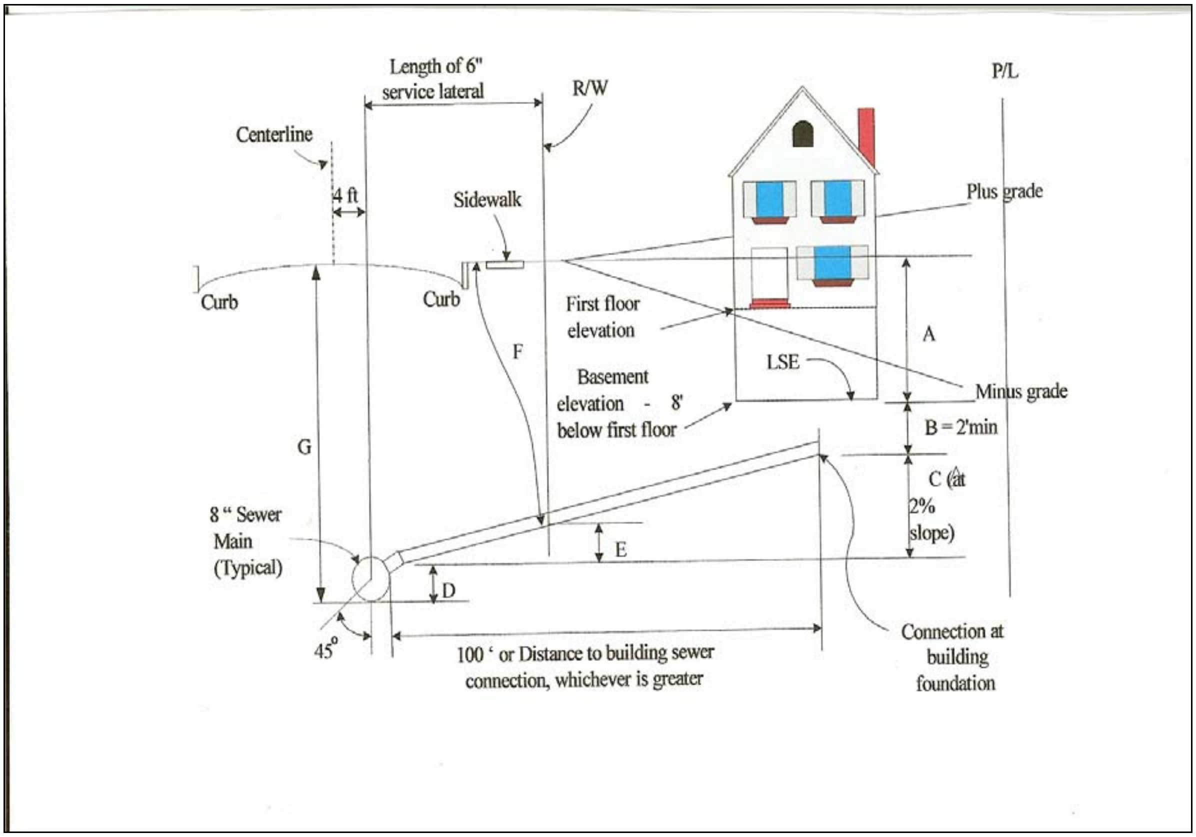
Calculate: the minimum elevation at the mainline sewer to provide gravity sewer service.

$$100.00 - 2\ feet - (100 \times 0.02) - (8/(12 \times 2)) = 96.0\ feet$$

By rearranging the equation it is possible to calculate the minimum building elevation served with gravity service from an existing sewer main. Any living space below this elevation will not realize gravity sewer service without employing a different design. The equation is:

$$Sewer\ main\ invert \pm 1/2\ \ Main\ O\ D. + \Delta + 2\ \ feet = Min.\ gravity\ service\ elevation$$

See the figure below for illustration of the defining reference locations and elevations.



Peak Factors. The "Peak Factor Table 4" may be used to raise average flow to peak flow. "Peak Factors" are the relationship between average daily dry weather flow and the highest dry weather peak of the year and varies from 1.3 to 3.5. This method yields a reasonable estimate of the peak factors. As flows increase, the peak factor decreases. If possible, the peak factors should be adjusted to flow studies in the local area.

Extraneous Flows. Sanitary sewer design quantities should include consideration of the various non-sewage components, which inevitably become a part of the total flow. 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 kept within economically justifiable limits 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 inch per hour on 1,200 sq. ft. 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. 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 inch of water over the cover. Such leakage may contribute amounts of storm water exceeding the average sanitary flow.

Infiltration. Two very prominent sources of excessive infiltration can be poorly constructed manholes and or connections and improperly laid house laterals. Laterals frequently have a total length greater than the collecting system and may contribute as much as 90% of infiltration. House connections should receive the same specifications, construction and inspection as public sewers. In the past, sewer designers allowed higher amounts of infiltration to aid in transporting solids. Infiltration must now be kept to a minimum.

Summations of Flow. Starting at the upper end of the sewer under review, add projected average flows for 50 or more years in the future. As the projected average flows from each drainage area are totaled, multiply by the appropriate peak factor to determine the peak flow for each reach of the line. These values are the design capacities for the proposed sewer.

Flow Monitoring. A sewer flow-monitoring program can be undertaken to determine when existing sewers will reach hydraulic design capacity. Monitoring methods vary from high water markers that record maximum depths to gaging with 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. Check adjacent population, gaugings, water consumption, rainfall and any other available data to determine if the measured quantity of flow is reasonable. If adjacent measurements or the estimate is greatly different from the gaged amount, the cause should be identified and corrected before proceeding with a relief sewer. With a long-range projection of peak flow based on population and a short-range projection based on past gagings, a reasonable estimate utilizing both can be made. As new or more reliable information becomes available, the projection should be updated. Planning for relief sewers must begin with sufficient lead-time before the projection reaches the design capacity of the sewer.

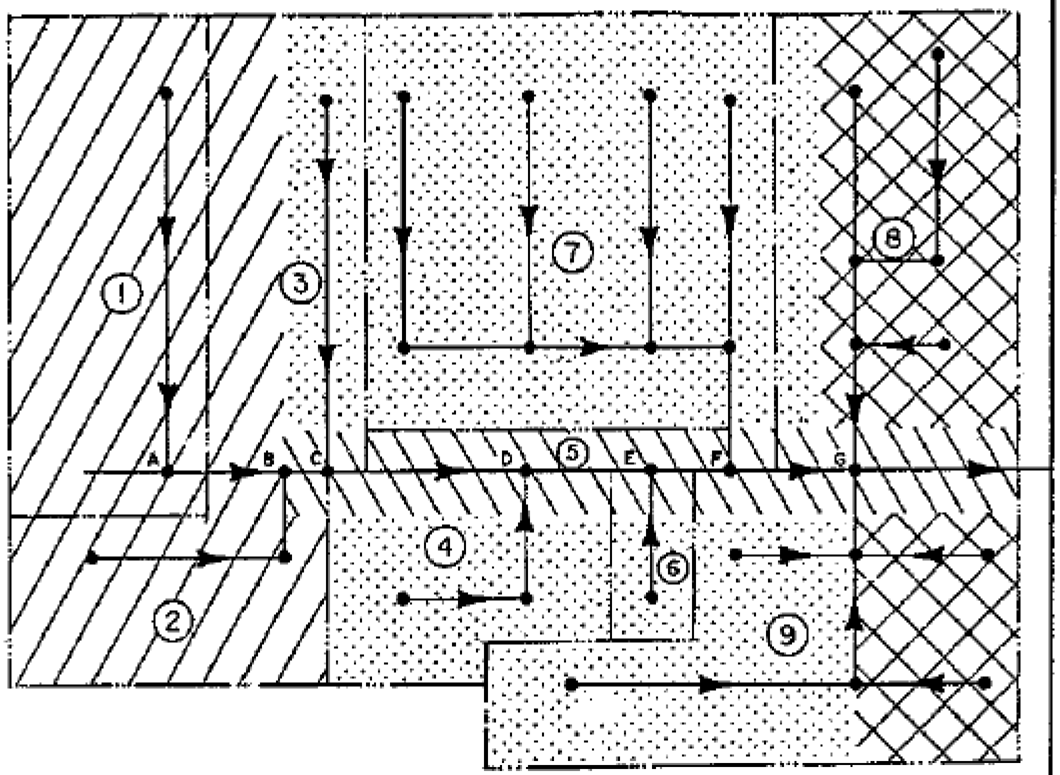
Sewer line modeling computer programs are available to analyze existing systems and establish quantities for the design of relief sewers.

TABLE 3

LAND USE	ABR.	AVERAGE COEFFICIENTS
High Density R4, R5	H.D.	140 people/ acre (100 gpd) .0217 cfs/acre
Medium Density R3	M.D.	75 people/ acre (100 gpd) .0116 cfs/ acre
Low Density RS, R1, R2	L.D.	20 people/ acre (100 gpd) .0031 cfs/ acre
Suburban RA, RE	Sub.	10 people/ acre (100 gpd) .0016
Hillside	H.S.	7 people/ acre (100 gpd) .0011 cfs/ acre
Agriculture A1, A2	Agr.	2.5 people/ acre (100 gpd) .0004 cfs/ acre
Light Industry CM, M1, M2	Lt.	0.008 cfs/ acre
Heavy Industry M3	Hvy	0.008 cfs/ acre
General Commercial 2, 3, 4	Gen.	0.006 cfs/ acre
Limited Commercial CR, 1, 2	Ltd.	0.006 cfs/ acre
Hospital	H	500 gal/day/hosp. Bed
School	S	0.062 cfs/ Student
University or College	U	0.371 cfs/ Univ Student
Civic or Admin. Center	C.C.	0.006 cfs/ acre
Airport	A	0.001 cfs/ acre
Park	P	0.0003 cfs/ Acre
Future Park	F.P.	0.0003 cfs/ Acre
Golf	G	0.0003 cfs/ Acre
Cemetery	C	0
Reservoir	R	0
Public Works	W	0
Open Space	O.S.	0

Values should be verified or adjusted based on flow studies of the area if available.

SAMPLE LAND USE MAP



MH	A	B	C	D	E	F	G
Qav.	.37	.59	1.21	1.98	2.14	4.47	9.19
Qd.	.96	1.53	2.8	4.5	4.8	9.4	18

LEGEND

Exist. or Prop. Sewer

Drainage Area Boundary - Flows generated in each drainage area can be accumulated along the sewer being studied.

A Lettered Manhole = Confluence Manhole

Low Density Res. - L. D.
Medium Density Res. - M. D.
High Density Res. - H. D.
Commercial - Comm.

Future or Ultimate land use information will normally determine the area in acres of each land use within each drainage area.

Qav. Average Quantity
Qpk. Peak Quantity
Qd. Design Quantity = QPK

From flow estimating calculations

1. The coefficients of discharge used in this example are as follows:

Low Density	LD	.0031
Medium Density	MD	.0116
High Density	HD	.0217
Commercial	Comm	.006

2. Peak Factors (Pf) are shown in the Peak Factor Table 4.

3. Qav flows are accumulated as they become tributary to the line. See Sample Land Use Map and Sample of Flow Estimating Calculations. Drainage Area 1 average flow is totaled and converted to Qpk in Manhole (MH) A, Drainage Area 2 is added at MH B, Drainage Area 3 is added at MH C, Drainage Area 4 is added at MH D. Drainage Area 5 is served by a number of house connection sewers directly tributary to the study sewer all along the Drainage Area. To simplify calculations the flow from this area has been lumped together and added at one point. The point arbitrary selected was MH D so Drainage Areas 4 and 5 are both added at that point. As each Qav is added to the sum of upstream Qav's the subtotal is converted to Qpk with the Pf. The Qpk or Qd downstream from MH D in this example is 4.5 cfs.

4. If a larger sewer was being studied, this entire area could be considered one Drainage Area with the same procedures followed to accumulate Qav and then convert to Qpk using the Peak Factors.

5. If a relief sewer were proposed that would intercept a portion of this Study Area the average flow from Drainage Areas or parts of Drainage Areas tributary to the new line would be added to the relief line and subtracted from the existing line. The average flows would be totaled and converted to Peak using Peak Factors.

6. The estimated Qav and Qpk's are shown on the Sample Land Use Map. The Qav's are shown because they can be easily added and subtracted and are useful when studying alternate routes, etc. The Qpk's are the quantities to be used to determine the adequacy of an existing sewer or to design a new one. These Qpk's can also be called Qd.

EXAMPLE PROBLEM

Dr. Area	Land Use	Area	Coef.	Qav.	Pf	Qpk	Sum. Qav	Pf	Qd	Outflow from MH
1	LD	120	.035	.372						
				.37	2.6	.96				
							.37	2.60	.96	A
2	LD	68	.0031	.211						
	CCM		.006	.012						
				.22	.280	.6				
							.59	2.60	1.53	B
3	LD	44	.0031	.136						
	MD	40	.0116	.464						
	COM	4	.006	.024						
				.62	2.5	1.6				
							1.21	2.35	2.8	C
4	MD	50	.0116	.580						
	C0MM	14	.006	.084						
				.66	2.5	1.6				
							1.87			
5	COM	18	.006	.108						
				.11	2.83	.3				
							1.98	2.25	4.5	D
6	MD	12	.0116	.139						
	COMM	4	.006	.024						
				.16	2.80	.4				
							2.14	2.25	4.8	E
7	MD	200	.0116	2.320						
	COM	2	.006	.012						

				2.33	**2.25**	**5.2**				
							4.47	**2.10**	**9.4**	**F**
8	**HD**	**120**	**.0217**	**2.604**						
	COMM	**12**	**.006**	**.072**						
				2.68	**2.2**	**5.9**				
							7.15			
9	**MD**	**78**	**.0116**	**.905**						
	HD	**48**	**.0217**	**1.042**						
	COMM	**16**	**.006**	**.096**						
				2.04	**2.25**	**4.6**				
							9.19	**1.96**	**18**	**G**

FACTOR TABLE 4

Qav	Pf	Qpk		Qav	Pf	Qpk
0 - 0.1	3.50	0 – 0.3		58 – 66	1.82	96 – 108
0.1 – 0.3	2.80	0.3 – 0.8		66 – 78	1.80	108 – 124
.0.3 – 0.6	2.60	0.8 – 1.5		78 – 83	1.58	124 – 131
0.6 – 0.9	2.50	1.5 – 2.2		83 – 87	1.57	131 – 136
0.9 – 1.2	2.40	2.2 – 2.8		87 – 95	1.56	136 – 148
1.2 – 1.5	2.35	2.8 – 3.5		95 – 101	1.55	148 – 156
1.5 – 1.9	2.30	3.5 – 4.3		101 – 108	1.54	156 – 166
1.9 – 2.4	2.25	4.3 – 5.3		108 – 116	1.53	166 – 177
2.4 – 3.0	2.20	5.3 – 6.5		116 – 124	1.52	177 – 188
3.0 – 3.8	2.15	6.5 – 8.1		124 – 133	1.51	188 – 200
3.8 – 4.9	2.10	8.1 – 10.2		133 – 142	1.50	200 – 212
4.9 – 6.3	2.05	10.2 – 12.8		142 – 152	1.49	212 – 226
6.3 – 7.5	2.00	12.8 – 14.9		152 – 163	1.48	226 – 240
7.5 – 8.3	1.98	14.9 – 16.4		163 – 175	1.47	240 – 256
8.3 – 9.2	1.96	16.4 – 17.9		175 – 188	1.46	256 – 274
9.2 – 10.3	1.94	17.9 – 19.9		188 – 202	1.45	274 – 292
10.3 – 11.4	1.92	19.9 – 22.0		202 – 216	1.44	292 – 310

11.4 – 12.7	**1.90**	**22.0 – 24.0**		**216 – 233**	**1.43**	**310 – 332**
12.7 – 14.2	**1.88**	**24.0 – 27.0**		**233 – 250**	**1.42**	**332 – 354**
14.2 – 15.9	**1.86**	**27.0 – 29.0**		**250 – 269**	**1.41**	**354 – 378**
15.9 – 18.0	**1.84**	**29.0 – 33.0**		**269 – 290**	**1.40**	**378 – 405**
18.0 – 20.0	**1.82**	**33.0 – 36.0**		**290 – 312**	**1.39**	**405 – 432**
20.0 – 22.0	**1.80**	**36.0 – 39.0**		**312 – 336**	**1.38**	**432 – 462**
22.0 – 25.0	**1.78**	**39.0 – 44.0**		**336 – 362**	**1.37**	**462 – 494**
25.0 – 28.0	**1.76**	**44.0 – 49.0**		**362 – 391**	**1.36**	**494 – 530**
28.0 – 32.0	**1.74**	**49.0 – 55.0**		**391 – 422**	**1.35**	**530 – 568**
32.0 – 36.0	**1.72**	**55.0 – 62.0**		**422 – 455**	**1.34**	**568 – 607**
36.0 – 40.0	**1.70**	**62.0 – 68.0**		**455 – 492**	**1.33**	**607 – 652**
40.0 – 45.0	**1.68**	**68.0 – 75.0**		**492 – 532**	**1.32**	**652 – 700**
45.0 – 51.0	**1.66**	**75.0 – 84.0**		**532 – 575**	**1.31**	**700 – 750**
51.0 – 58.0	**1.64**	**84.0 – 95.0**		**575 – oo**	**1.30**	**750 - oo**

PART III – HYDRAULIC DESIGN

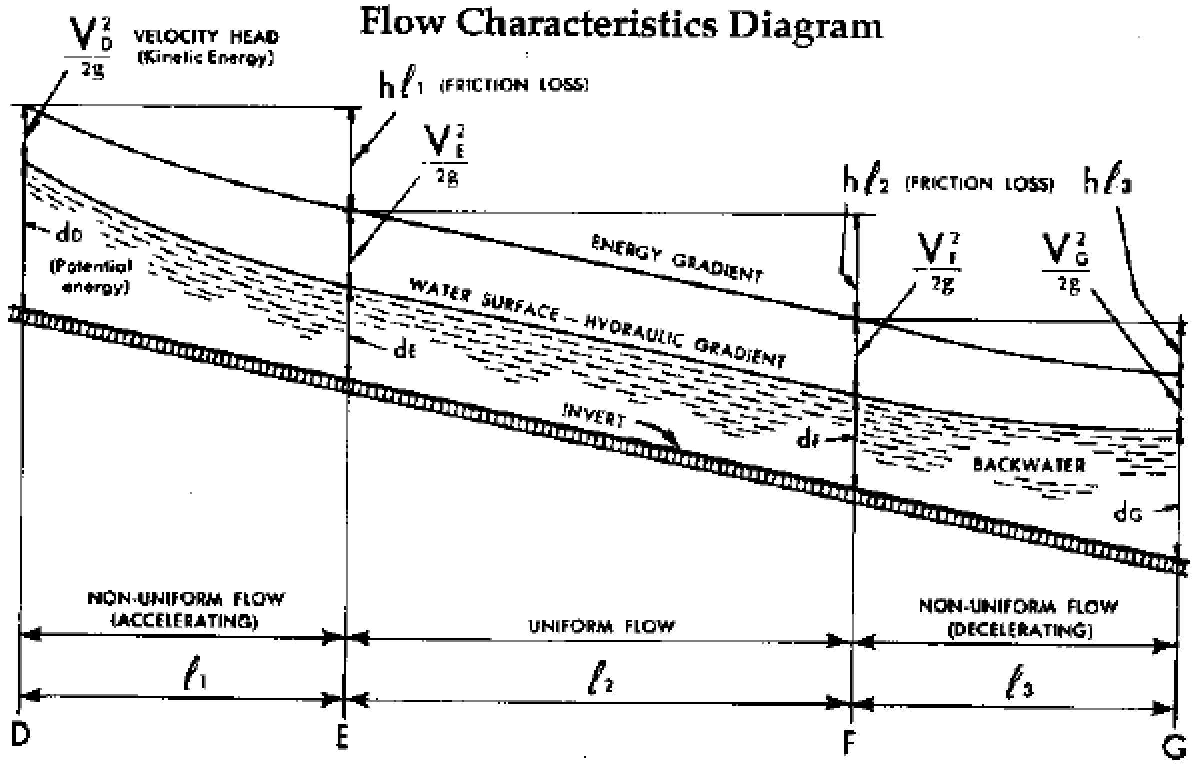
This section on hydraulics of sewers deals only with uniform flow. Standard hydraulic handbooks should be consulted for special conditions. However, in the vast majority of design conditions, uniform flow is the selected flow condition. Since the flow characteristics of sewage and water are similar, 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 or require pumping. Under these conditions the sewer line will flow full and be under head or internal pressure.

The Flow Characteristics Diagram demonstrates the theory and terminology applied to flow in open channels. To simplify the diagram, all slopes are subcritical and it is assumed that 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 causes a decrease in the velocity.

Flow Characteristics Diagram



Note: All Slopes are Sub-critical.

The Hydraulic Profile

Three distinct slope lines are commonly referred to in hydraulic design of sewers.

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.

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 in such a manner that the change in the energy gradient elevation allows for the head loss.

3. Sanitary sewers through 15-inch diameter are normally designed to run half-full at peak flow and larger sewers are designed to run three-quarters full at peak flow.

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. Using the land use map, working profile sheets are prepared. The profile sheets show the surface elevations, subsurface structures and any other control points, such as house connections, buried utilities and other sewer connections. A typical profile for sewer design is shown below.

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, always being mindful of being low enough to serve adjacent structures.

Determination of Pipe Sizes

Knowing the peak flow and the tentative slope, a tentative pipe size can be selected for each reach. Diagrams based on Manning's Equations showing quantity, slope, pipe size and velocity can be used to find pipe sizes. The diagrams show quantities for one-half depth for small pipe up through 15-inch diameter and three-quarters depth for 18-inch and larger sizes. The "n" values range from .010 to .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

Using the flows (Qd) from the Sample Land Use Map, the pipe sizes may be selected after determining the slope of the line and the "n" value to be used. The slope is obtained by drawing a preliminary profile showing control points, such as, sewers to be intercepted, major structures, ground lines, outlet sewer, etc. If the available slope is .005 along this reach and "n" equal to .012, use the "n" = .012 Design Capacity Graph. Locate the intersection of the .005 slope and Qd and read the larger pipe size. In the reach downstream from MH A the Qd is .96 cfs. This Qd intersects the .005 slope between a 10-inch and a 12-inch pipe. The larger pipe is selected. In the reach downstream from MH B, the Qd is 1.53 cfs, indicating that a 15-inch pipe will be required. Further downstream, the outflow from MH F is 9.4 cfs, and a 21-inch pipe is necessary.

As a final check, plot the pipe lines 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. Adjacent connection lines, extended to the elevation that would exist at the centerline of the new sewer should be plotted on the profile and be able to pass over the new line. This allows connections to be made with a 45-degree bend. Note that some regulatory agencies require these connections to be made only at manholes. The designer should be familiar with the requirement. The pipe size will have to be rechecked if the slope has been changed for any reason. 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. The designer is reminded that precise calculations of hydraulic data are not possible except under controlled conditions.

The Manning Equations

The most commonly used velocity and quantity equations are:

$V=(1.486/n)*R^{2/3}S^{1/2}$ (Velocity)

$Q=(1.486/n)*ar^{2/3}S^{1/2}$ (Quantity)

"V" is 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.

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

"n" is 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" represents the cross-sectional area of the flowing water in square feet.
"r" represents 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" represents 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 DIFFERENT DESIGN DEPTHS

(To convert depth/Diameter to % of velocity)

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

Values for "n"
Based upon current data, it appears that "n" values of .010 - .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, which differ from the design value. These new values can be used for future flow calculations. Factors for determining Q's at different "n" values are shown on the Design Capacity Graphs.

Conveyance Factors

Conveyance Factors equal Q/Qd expressed as a percent. Q is the amount of flow at any depth and Qd is the amount of flow when the depth is at design depth. Design depth for pipe 15-inch and smaller, is one-half full (.5D) and for pipe 18-inch 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 follow.

Examples 1 and 2 demonstrate the use of the .5D Table for pipe 15-inch and less in diameter.

Example No. 1 Determination of Percentage of Design Capacity of an Existing Sewer

The depth of flow measured in a 10-inch sewer is 0.35 feet. The diameter of a 10-inch pipe expressed in feet is 0.83 feet. Use the.5D Table, calculate d/D, 0.35 divided by 0.83, equals 0.42. Enter table with 0.42 (.4 vertical and .02 horizontal) and read 73%. For the size, slope and "n", read Qd from the appropriate Design Capacity Graph. If 1.2 cfs is the Qd then multiply by 0.73 to find Q equal to 0.9 cfs.

Example No. 2 Determination of the Depth of Flow When the Q is known

The same 10-inch sewer has a design capacity of 1.2 cfs. The estimated flow will be 0.7 cfs. To find the depth, divide 0.7 by 1.2 which equals 58%. Enter Table with 58% and read d/D of 0.37. Multiply by the diameter 0.83 feet to find depth of 0.31 feet.

Examples 3 and 4 demonstrate the use of the .75D Table for pipe 18-inch and larger in diameter.

Example No. 3 Determination of Quantity of Flow

The depth of flow in a 21-inch sewer is 1.12 feet. d/D is 1.12 divided by 1.75 or 0.64. Use the .75D Table and read 81%. If the Qd from the Design Capacity Graph for this line is 9.2 cfs, multiply 81% times 9.2 for a Q of 7.5 cfs.

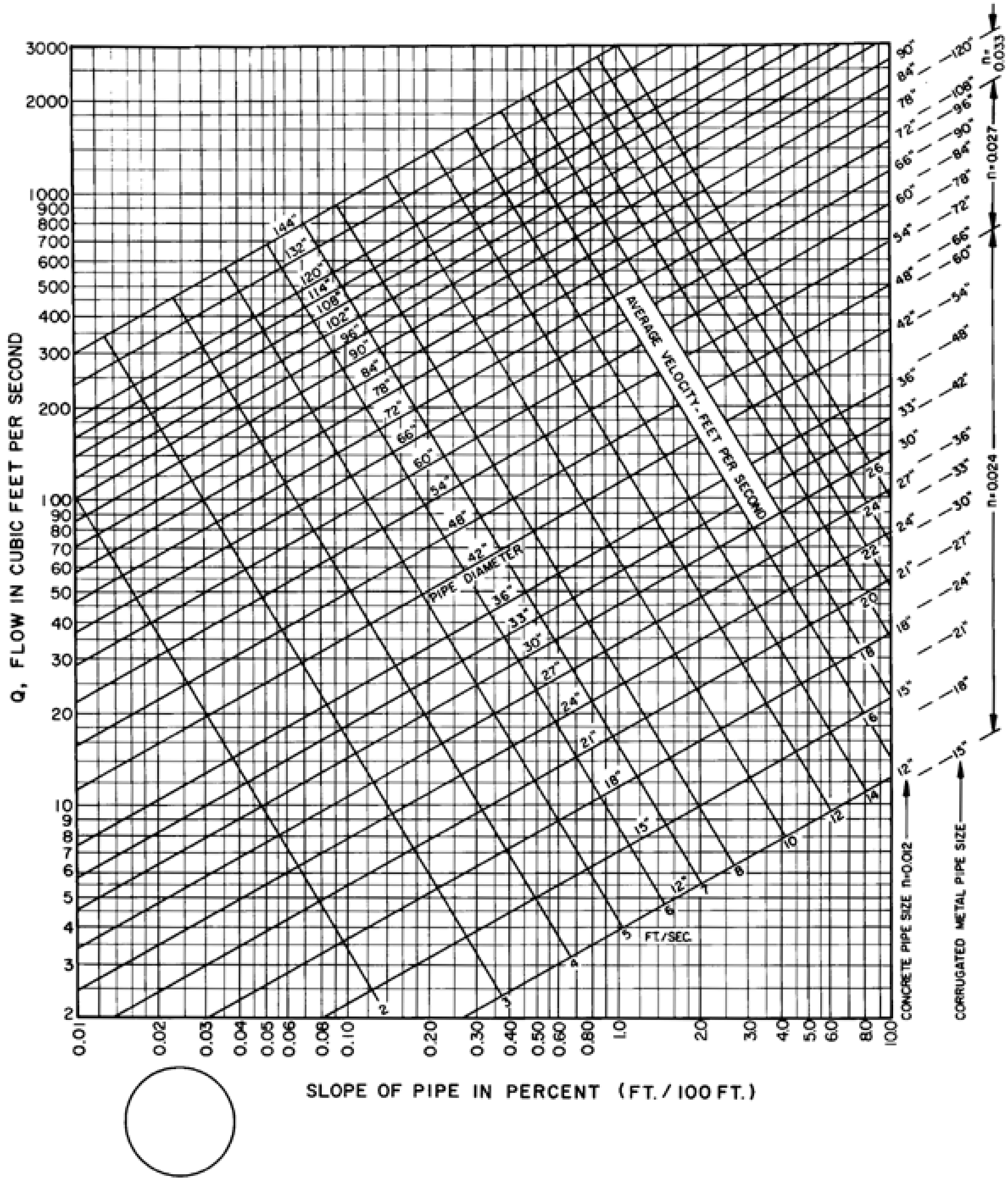
Example No. 4 Determination of Depth of Flow When the Q is known

If the Q is 8 cfs and Qd is 9.2 cfs, divide 8 by 9.2 to find the Conveyance Factor of 87%. Enter the Table with 87% and read d/D of 0.67. The depth for a Q of 8 cfs is 0.67 times the diameter 1.75, which is 1.17 feet.

DESIGN CAPACITY GRAPHS

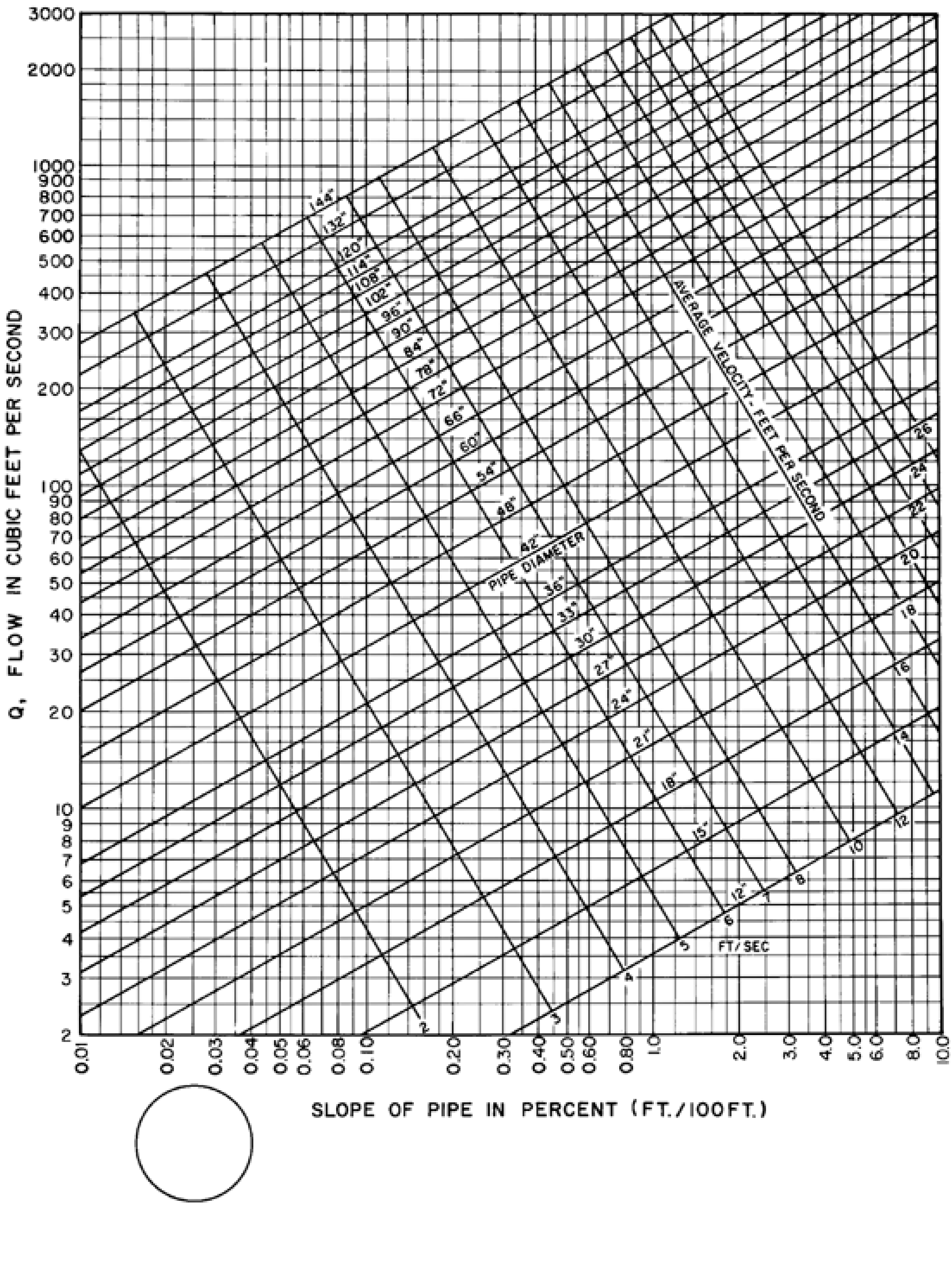
Full Flow Curves

Circular Pipe, $n = 0.012$



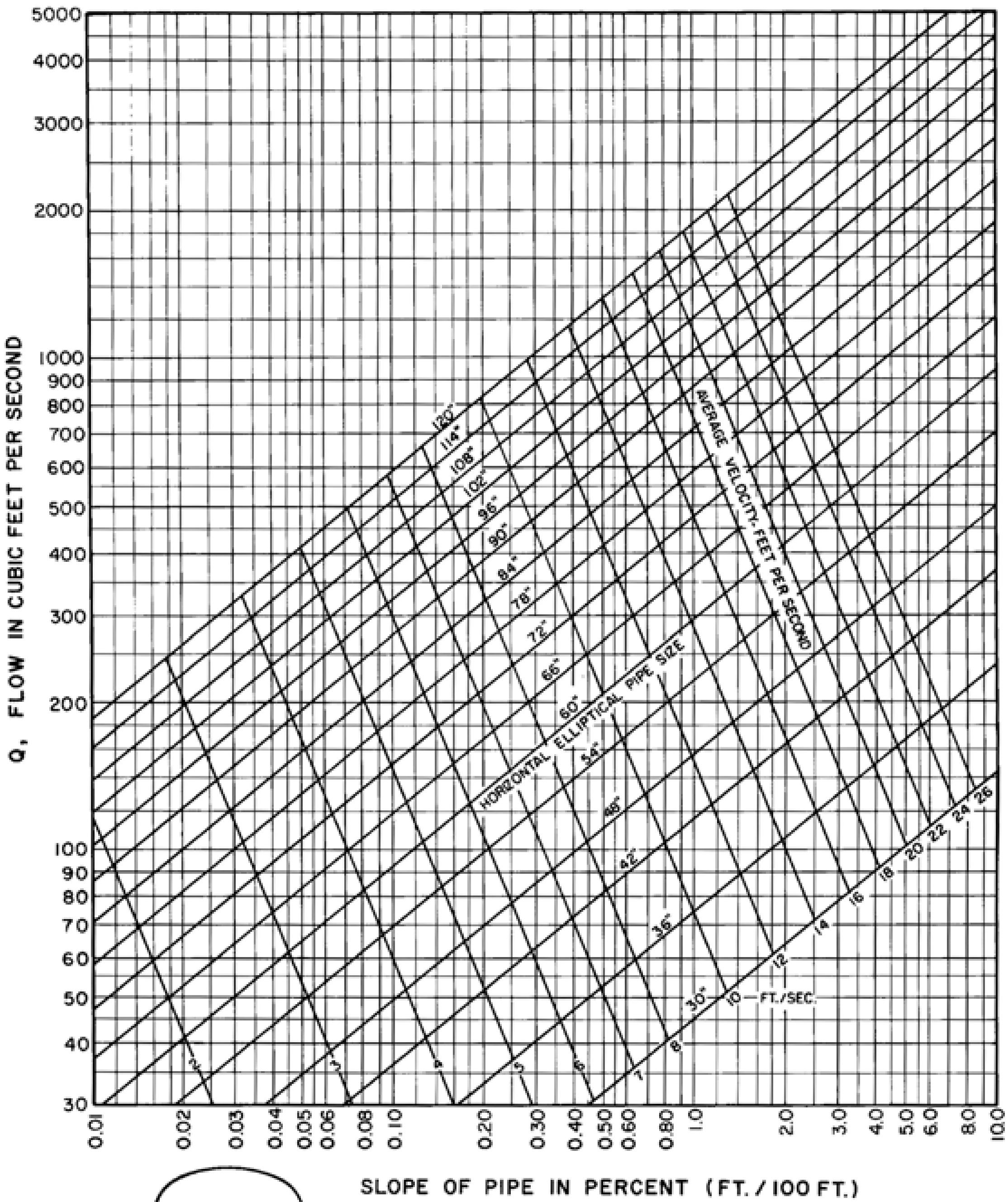
Full Flow Curves

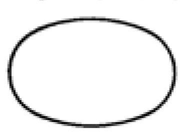
Circular Pipe, $n = 0.013$



Full Flow Curves

Elliptical Pipe, $n = 0.012$





Hydraulic Properties

Circular Concrete and Corrugated Metal Pipe

D PIPE SIZE [IN]	A AREA [SQ. FT.]	R HYDRAULIC RADIUS [FEET]	VALUE OF C					
			CONCRETE PIPE			CORRUGATED METAL PIPE		
			n=0.010	n=0.012	n=0.013	n=0.024	n=0.027	n=0.033
12	0.79	0.25	46	39	36	19		
15	1.23	0.31	84	70	65	35		
18	1.77	0.38	137	114	105	57		
21	2.41	0.44	206	172	158	86		
24	3.14	0.50	294	245	226	23		
27	3.98	0.56	403	336	310	168		
30	4.91	0.63	533	444	410	222		
33	5.94	0.69	688	573	529	286		
36	7.07	0.75	867	723	667	361	321	
42	9.62	0.88	1310	1090	1010	545	484	
48	12.60	1.00	1870	1560	1440	778	692	
54	15.90	1.13	2560	2130	1970	1070	947	
60	19.60	1.25	3390	2820	2600	1410	1250	1030
66	23.80	1.38	4370	3640	3360	1820	1620	1320
72	28.30	1.50	5510	4590	4240	2290	2040	1670
78	33.20	1.63	6820	5680	5240	2840	2520	2070
84	38.50	1.75	8300	6920	6390	3460	3080	2520
90	44.20	1.88	9900	8320	7680		3700	3020
96	50.30	2.00	11900	9880	9120		4400	3590
102	56.70	2.12	13900	11600	10700			4220
108	63.60	2.25	16200	13500	12500			4920
114	70.90	2.38	18700	15600	14400			5680

120	78.00	2.50	21500	17900	16500			6510
132	95.00	2.75	2700	23100	21300			8400
144	113.00	3.00	35000	29100	26900			10600

Hydraulic Properties

Arch Concrete and Corrugated Metal Pipe

EQUIVALENT CIRCULAR SIZE [INCHES]	CONCRETE PIPE				CORRUGATED METAL PIPE			
	SIZE RISE x SPAN [INCHES]	A AREA [SQ. FT.]	R HYDRAULIC RADIUS [FEET]	VALUE OF C n=0.012	SIZE RISE x SPAN [INCHES]	VALUE OF C		
						n=0.024	n=0.027	n=0.033
18	13 1/2 x 22	1.60	0.30	89	13 x 22	48		
24	18 x 28 1/2	2.80	0.45	204	18 x 29	101		
30	22 1/2 x 36	4.40	0.56	370	22 x 36	185		
36	26 1/2 x 44	6.40	0.68	613	27 x 43	306	272	
42	31 1/2 x 51	8.80	0.80	939	31 x 50	461	409	
48	36 x 58 1/2	11.40	0.90	1320	36 x 58	661	588	
54	40 x 65	14.30	1.01	1780	40 x 65	892	793	
60	45 x 73	17.70	1.13	2380	44 x 72	1180	1040	
72	54 x 88	25.60	1.35	3870	59 x 81		1770	1450
84	62 x 102	34.60	1.57	5790	67 x 95		2620	2150
96	77 1/2 x 122	51.70	1.92	9890	75 x 112			3100
108	87 x 138	66.00	2.17	13700	83 x 128			4220
120	97 x 154	81.80	2.42	18300	91 x 142			5510
132	106 1/2 x 169	99.10	2.65	23500				

CONVEYANCE TABLE 5

.5d Table for Pipe 15" and Smaller

For pipe 15" and smaller, Qd = 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	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: The depth of flow in an 8" sewer was measured at 0.21 d/D = .21/.67 = 0.31. Enter the table for small sewers with d/D = .31 and read 42% Q design. Q design is read from Design Capacity Charts.

.75d Table for Pipe 18" and Larger

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

D/d	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	%	0	0	0	0	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	24	26	27	29	30	32	34	35
.4	37	39	40	42	44	45	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: The depth of flow in an 18" sewer was measured at 1.02 d/D = 1.02/1.5 = 0.68. Enter the table with d/D = .68 and read 88% Q design. Q design is read from Design Capacity Charts.

VALUES OF MANNING "n" COEFFICENT FOR VARIOUS MATERIALS

Closed Conduits	
Asbestos-Cement pipe	
Brick	0.011 – 0.015
Cast Iron	0.013 – 0.017
Concrete	
Smooth	0.012 – 0.014
Rough	0.015 – 0.017
Concrete Pipe	0.011 – 0.015
Corrugated Metal Pipe	
Plain	0.022 – 0.026
Paved Invert	0.018 – 0.022
Asphalt Lined	0.011 – 0.015
Plastic Pipe	0.011 – 0.015
Open Channels	
Asphalt	0.013 – 0.017
Brick	0.012 – 0.018
Concrete	0.011 – 0.020
Concrete Rip Rap	0.020 – 0.035

PART IV – STRUCTURAL ANALYSIS

This section deals with the examination and evaluation of all those forces, which affect or influence the structural stability of a rigid conduit. Methods are outlined by which trench loads may be considered and analyzed for the purpose of accomplishing required structural support. The load on a buried pipe is calculated as pounds per linear foot and is call D-Load. Concrete pipe is classified under ASTM C-76 by Class I through V with D-Loan maximums assigned to each. If the calculated D-load exceeds the strength of the pipe, an increase of bedding condition is necessary, such as going to Class A (concrete cradle or encasement). PVC pipe is probably the most commonly used sewer conduit. The manufacturer normally provides a series of charts showing material type and depth of bury within the strength of each Class of pipe. In order to understand and properly use the charts and Classes of pipe, it is necessary to understand how trench loads are calculated.

Importance of Predetermining Loads Accurately

There is a tendency to think of sewer pipe from the hydraulic standpoint only and to neglect the importance of pipe as a structural element. It must, above all else, maintain structural stability.
Nearly all building codes impose legal standards upon designers to insure against the failure of building structures. Standard practice in highway work and railroad work also provides for predetermined structural safety.

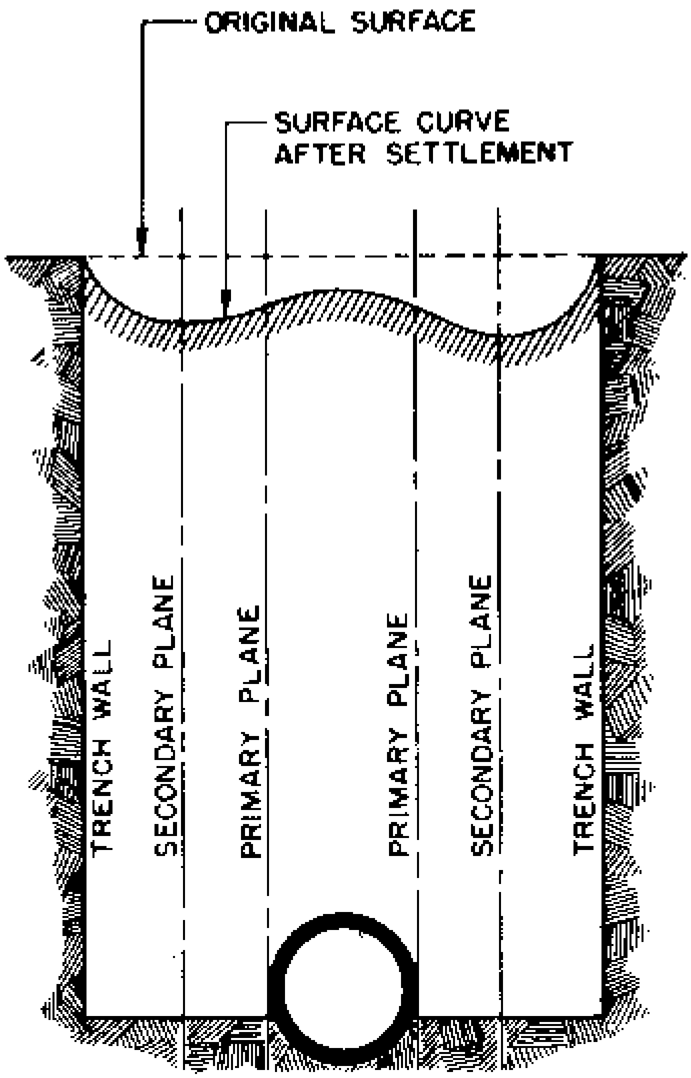
Determined Loads

Just as the safety of ordinary structural members involves the application of "mechanics" to cases of assumed live loadings, the safety in underground pipe work involves application of "soil mechanics" for determining the load on the pipe. The amount of load to be supported by the pipe can be computed and the result will be safe and accurate in the same sense that predetermination of beam strength is safe and accurate.

Trench Load Equation

The Marston theory is the basis for the Trench Load Tables. An understanding of the Marston Equation, and the factors involved, is helpful when using the trench load tables. Essentially, any structure installed below the surface of the earth supports the weight of all the materials above it, depending upon certain characteristics of the fill. These characteristics, (principally internal soil friction) tend to increase or diminish the weight of the material above the pipe.

This is true for both trench and embankment loads. Considering a structure of circular cross-section such as a sewer pipe, the backfill material directly above the pipe is that material which lies between vertical planes tangent to the outside of the pipe barrel. The net load on the pipe exclusive of live load, is the actual weight of such backfill material plus or minus an amount which depends on whether internal soil friction assists in the support of the mass of backfill over the pipe or not (i.e.: sand or clay).



Cross section of a typical trench showing primary and secondary planes.

Cross-section of a typical trench showing primary and secondary planes.

The drawing above demonstrates the cross-section of a typical sewer trench showing the location of planes tangent to the sides of the pipe. These are called the primary planes. When the backfill in a trench is compacted uniformly, uniform settlement can be expected with the passage of time. The depth of the backfill between the primary tangent planes will be reduced through such settlement by a fairly definite amount, depending upon the nature and compaction of the original backfill. The backfill between the trench walls and the primary planes on either side of the pipe will also settle in time.

Frictional Forces in the Backfill

Since the depth of the backfill between the pipe and the trench sidewalls is greater than the depth of the backfill directly over the pipe, it will settle or compact more than the material directly over the pipe. This movement will be restricted by friction between the back-fill particles on each side of the primary tangent planes. The increased settlement of the backfill on both sides of the pipe tends to pull down the mass of backfill over the pipe, and thereby transmit an additional load to the pipe.

Secondary vertical planes are assumed anywhere between the primary planes and the walls of the trench as shown in the drawing. As mentioned previously, the backfill between the primary and secondary planes is prevented from settling to a maximum amount by the action of a frictional force along the primary vertical planes. This increases the load supported by the pipe.

The remainder of the backfill which lies between the secondary planes and the trench walls is supported in part by friction along the trench walls. This reduces the load on the pipe.

The Effect of Trench Width

It will be seen that, as the secondary plane is moved away from the pipe, the differential settlement on opposite sides of the plane will become less. It is therefore possible to locate a definite position where the differential settlement on opposite sides of the secondary plane is so small that no frictional forces are transmitted across it. When this location is within the cross section of the trench, the weight of backfill between the secondary plane and trench wall can add nothing to the load on the pipe. In other words, the trench width may be increased from this point on without adding to the weight on the pipe. At this point, the pipe is no longer considered to in a trench condition, but it positive projection or embankment condition.

The minimum distance which meets the above qualifications is called the transition width of the trench. It is the trench width at which further widening will have no effect on the load on the pipe. When the actual width is less than the transition width, friction in the plane of the trench wall tends to support part of the load and to lessen the load on the pipe. This phenomenon is graphically illustrated by the curve marked surface curve after settlement in the previously referenced drawing. Wherever this curve deflects downward from its origin directly over the center of the pipe, internal friction in the backfill transmits weight to the pipe. Where the curve deflects upward (as alongside the trench wall) backfill weight is transmitted to the sidewall of the trench.

Marston Equation

The Marston Equation applies the preceding reasoning to the calculation of loads on pipes. Actual tests have been made with many kinds of soil to determine their weights and frictional characteristics and to determine the relative settlement of each. These measurable quantities have been combined into a single expression to produce for each case a computation of the total weight supported by the pipe.

The factors taken into consideration in the following Marston Equation are:

1. Depth of backfill cover over the top of the pipe.
2. Width of trench measured at the level of the top of the pipe.
3. Unit weight of backfill.
4. Values for frictional characteristics of the backfill material.

The Marston Equation for pipe in narrow trenches (trench condition) is:

$$W_c = C_d w B_d^2$$

Where W_c = the vertical external load on a closed conduit due to fill materials (lb/ft of length),

C_d = Load calculation coefficient for conduits completely buried in ditches, abstract number (see Computation Diagram),

w = the unit weight of fill materials, (lb/ft^3) and

B_d = Horizontal width of ditch at top of conduit (ft).

By substitution of available data in the Marston equation, a direct result is obtained for the load on the pipe in terms of pounds per linear foot called D-Load.

The Computation Diagram is based on various types of soil conditions, and may be used to obtain the values of the load calculation coefficient "C_d."

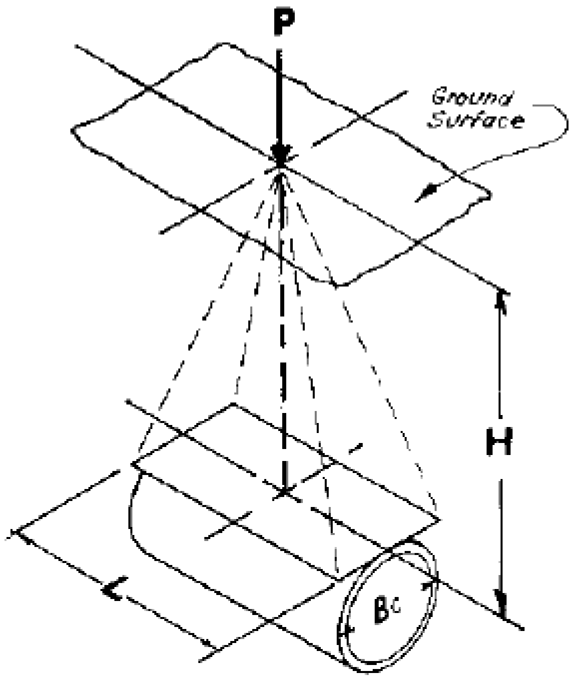


Diagram 1. - Superimposed concentrated load vertically centered over pipe.

The Trench Load Tables have been compiled using the Marston equation described above. The soil weights are based upon an arbitrary value of 100 lbs./cu.ft. The values used in the calculations are as follows:

	k_u' (Dimensionless)
Sand & Gravel	0.165
Saturated Topsoil	0.150
Dry Clay	0.130
Wet Clay	0.110

When the actual soil weight is known to vary from the estimated value, the tabulated loads may be adjusted up or down by direct ratio.

Embankment Loads

Although these Trench Load Tables show loads on pipe in trenches, they are equally applicable for pipe installed under embankment conditions. As the width of the trench increases, other factors remaining constant, the load on the pipe increases until it reaches a limiting value equal to the embankment load on the pipe. This limiting value is called the "transition width". The transition widths shown in the Trench Load Tables have been calculated using the equation for positive projecting conduits in wide trenches.

Superimposed Loads

Concentrated and distributed superimposed loads should be considered in the structural design of sewers, especially where the depth of earth cover is less than 8 ft. Where these loads are anticipated, they are added to the predetermined trench load.

Concentrated Loads

The following equation is used to determining loads due to superimposed concentrated load, such as a truck wheel load:

$$W_{sc} = C_s PF / L$$

In which W_{sc} is the load on the conduit in lb/ft of length; P is the concentrated load in lb; F is the impact factor; C_s is the load coefficient, a function of $B_c/(2H)$ and $L/(2H)$; H is the height of fill from the top of conduit to ground surface in ft; B_c is the width of conduit in ft; and L is the effective length of conduit in feet.

Unless other data are available, it is safe to estimate that truck wheel loads are the greatest loads to be supported. H-20 wheel loadings are standard for highway and bridge design and are equally applicable for estimating loads on sewers. H-20 refers to loading resulting from the passage of trucks having a gross weight of 20 tons, 80% of which is on the rear axle, with axle spacing of 14 ft., center to center, and a wheel gauge of 6 ft., each rear wheel carrying one half this load or 8 tons each without impact.
If the concentrated load is not centered vertically over the pipe, but is displaced laterally and longitudinally, the load on the pipe can be computed by adding the effect of the concentrated load. Dividing the tabular values of C_s by 4 will give the effect for this condition. An alternative method of determining concentrated live or superimposed loads on a buried conduit is to use the Percentages of Wheel Loads shown in the Table below. These percentages have been determined directly from experimental data. Note that an allowance for impact must be added to the percentage figures shown in the table. The table does not apply to distributed superimposed loads.

TABLE OF VALUES OF LOAD COEFFICIENTS, Cg, FOR CONCENTRATED AND DISTRIBUTED SUPERIMPOSED LOADS VERTICALLY CENTERED OVER CONDUIT*

$\frac{D}{2H}$ or $\frac{8}{2H}$	$\frac{M}{2H}$ or $\frac{1}{2H}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	**0.019**	**0.037**	**0.053**	**0.067**	**0.079**	**0.089**	**0.097**	**0.103**	**0.108**	**0.112**	**0.117**	**0.121**	**0.124**	**0.128**
0.2	**0.037**	**0.072**	**0.103**	**0.131**	**0.155**	**0.174**	**0.189**	**0.202**	**0.211**	**0.219**	**0.229**	**0.238**	**0.244**	**0.248**
0.3	**0.053**	**0.103**	**0.149**	**0.190**	**0.224**	**0.252**	**0.274**	**0.292**	**0.306**	**0.318**	**0.333**	**0.345**	**0.355**	**0.360**
0.4	**0.067**	**0.131**	**0.190**	**0.241**	**0.284**	**0.320**	**0.349**	**0.373**	**0.391**	**0.405**	**0.425**	**0.440**	**0.454**	**0.460**
0.5	**0.079**	**0.155**	**0.224**	**0.284**	**0.336**	**0.379**	**0.414**	**0.441**	**0.463**	**0.481**	**0.505**	**0.525**	**0.540**	**0.548**
0.6	**0.089**	**0.174**	**0.252**	**0.320**	**0.379**	**0.428**	**0.467**	**0.499**	**0.524**	**0.544**	**0.572**	**0.596**	**0.613**	**0.624**
0.7	**0.097**	**0.189**	**0.274**	**0.349**	**0.414**	**0.467**	**0.511**	**0.546**	**0.584**	**0.597**	**0.628**	**0.650**	**0.674**	**0.688**
0.8	**0.103**	**0.202**	**0.292**	**0.373**	**0.441**	**0.499**	**0.546**	**0.584**	**0.615**	**0.639**	**0.674**	**0.703**	**0.725**	**0.740**
0.9	**0.106**	**0.211**	**0.306**	**0.391**	**0.463**	**0.524**	**0.574**	**0.615**	**0.647**	**0.673**	**0.711**	**0.742**	**0.766**	**0.784**
1.0	**0.112**	**0.219**	**0.318**	**0.405**	**0.481**	**0.544**	**0.597**	**0.639**	**0.673**	**0.701**	**0.740**	**0.774**	**0.800**	**0.816**
1.2	**0.117**	**0.229**	**0.333**	**0.425**	**0.505**	**0.572**	**0.628**	**0.674**	**0.711**	**0.740**	**0.783**	**0.820**	**0.849**	**0.868**
1.5	**0.121**	**0.238**	**0.345**	**0.440**	**0.525**	**0.596**	**0.650**	**0.703**	**0.742**	**0.774**	**0.820**	**0.861**	**0.894**	**0.916**
2.0	**0.124**	**0.244**	**0.355**	**0.454**	**0.540**	**0.613**	**0.674**	**0.725**	**0.766**	**0.800**	**0.849**	**0.894**	**0.930**	**0.956**

PERCENTAGE OF WHEEL LOADS TRANSMITTED TO UNDERGROUND PIPES*

Tabulated figures show percentage of wheel load applied to one linear foot of pipe

Pipe Size in Inches

Depth of Backfill	6”	8”	10”	12”	15”	18”	21”	24”	27”	30”	33”	36”	39”	42”
	Outside Diameter of Pipe in Feet (Approx.)													
Over Top Of Pipe In Feet	**.64**	**.81**	**1.0**	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3.0**	**3.3**	**3.5**	**3.9**	**4.2**
1	**12.8**	**15.0**	**17.3**	**20.0**	**22.5**	**24.8**	**26.4**	**27.2**	**28.0**	**28.6**	**29.0**	**29.4**	**29.8**	**29.9**
2	**5.7**	**7.0**	**8.3**	**9.6**	**11.5**	**13.2**	**15.0**	**15.6**	**16.8**	**17.8**	**18.7**	**19.5**	**20.0**	**20.5**
3	**2.9**	**3.6**	**4.3**	**5.2**	**6.4**	**7.5**	**8.6**	**9.3**	**10.2**	**11.1**	**11.8**	**12.5**	**12.9**	**13.5**
4	**1.7**	**2.1**	**2.5**	**3.1**	**3.9**	**4.6**	**5.3**	**5.8**	**6.5**	**7.2**	**7.9**	**8.5**	**8.8**	**9.2**
5	**1.2**	**1.4**	**1.7**	**2.1**	**2.6**	**3.1**	**3.6**	**3.9**	**4.4**	**4.9**	**5.3**	**5.8**	**6.1**	**6.4**
6	**0.8**	**1.0**	**1.1**	**1.4**	**1.8**	**2.1**	**2.5**	**2.8**	**3.1**	**3.5**	**3.8**	**4.2**	**4.3**	**4.4**
7	**0.5**	**0.7**	**0.8**	**1.0**	**1.3**	**1.6**	**1.9**	**2.1**	**2.3**	**2.6**	**2.9**	**3.2**	**3.3**	**3.5**
8	**0.4**	**0.5**	**0.6**	**0.8**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.2**	**2.3**	**2.3**	**2.6**

*These figures make no allowance for impact. See table of impact factors

Distributed Loads

For determining loads on pipe due to superimposed loads distributed over a surface area (Diagram 2) the following equation was developed:

$$W_{sd} = C_s p F B_c$$

in which W_{sd} is the load on the conduit in lb/ft of length; p is the intensity of distributed load in psf; F is the impact factor; B_c is the width of the conduit in ft; C_s is the load coefficient, a function of D/(2H) and M/(2H); H is the height from the top of the conduit to the ground surface in ft; and D and M are the width and length, respectively, of the area over which the distributed load acts, in ft. (For values of C_s and F, see below)

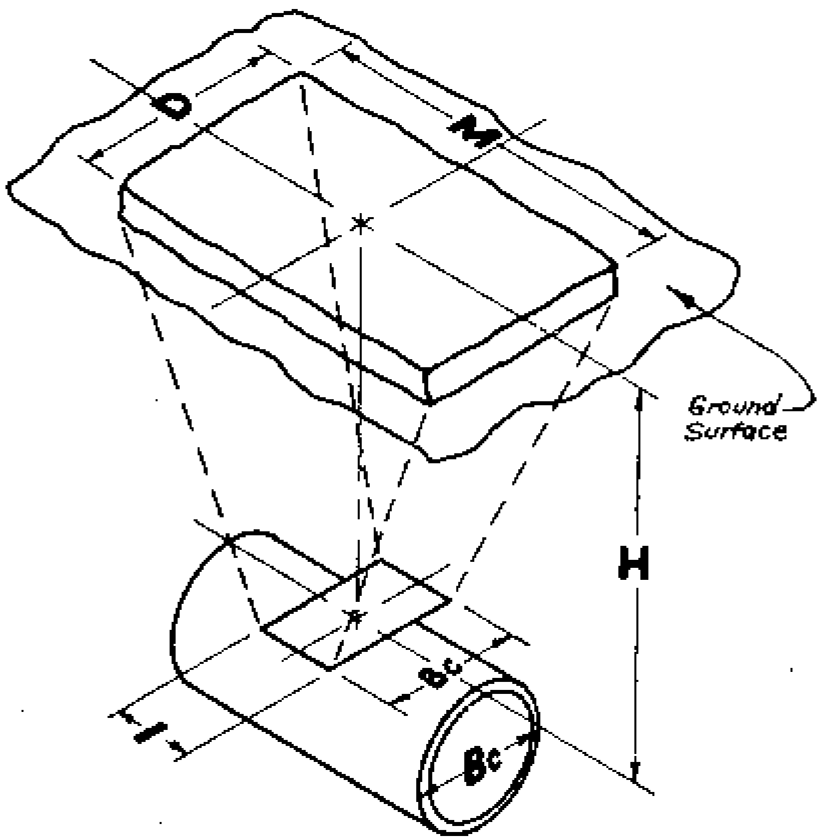


Diagram 2 - Superimposed distributed load vertically centered over pipe.

Diagram 2 - Superimposed distributed load vertically centered over pipe. If the area of the distributed superimposed load is not centered vertically over the pipe, but is displaced laterally and longitudinally, the load on the pipe can be computed by adding algebraically the effect of various rectangles of loaded area. It is more convenient to work in terms of load under one corner of a rectangular loaded area rather than at the center. Dividing the tabular values of C_s by 4 will give the effect for this condition.

Dynamic Loads

Impact factors must be considered to account for the influence of dynamic loading due to traffic. The following table shows suggested values.

IMPACT FACTORS (F)

Traffic	Impact Factor
Highway	1.50
Railway	1.75
Runways/Airfield	1.00
Taxiways, aprons, hardstands	1.50

Trench Width

To properly approach the analysis of loads imposed on the pipe, it is necessary to decide, for each size of pipe, what the minimum practicable design trench width at the top of the pipe is to be and still permit good workmanship. The design trench width, the depth of fill over the pipe, and the soil characteristics of the fill, will produce the load which must be supported by the pipe and its bedding. This load is readily available from either Trench Load Tables or the Pipe Institute trench load computer program when the above factors are known.

Using Trench Load Tables

The correct use of the Trench Load Tables is demonstrated by the following hypothetical case where a designer wants to know the trench load imposed by the following conditions:

A 12-inch sewer is to be installed in an area of sand and gravel with an average weight of 100-lb./cu. ft. The top of the pipe is 8 ft. below ground surface and the trench width is 30 inches.

Pipe size -	12 in.
Backfill -	Sand and Gravel
Trench width -	30 in.
Backfill weight -	100 lb./cu. ft.
Cover depth -	8 ft.

From the Trench Load Tables, the load is 1240 lb./lin. ft.

Typical Load Computation for Highway Work

Suppose that plans call for the installation of a 15-inch sewer line with 5 ft. of cover in a 3 ft. wide trench of wet clay weighing 130-lb/cu. ft. and that construction equipment wheel loads of 16,000 lbs. each will pass over the backfilled trench before the pavement is placed. What is the total load on the pipe? To determine the trench load use the Trench Load Table.

Pipe size -	15 in.
Backfill -	Wet Clay
Trench width -	36 in.
Backfill load (1170 lb./lin. ft. x 130/100) =	1520 lb./lin. ft.
Live load =	624 lb./lin. ft.
Total trench load =	2144 lb./lin. ft.

In computing the load to be supported by the pipeline illustrated above, live load must be added to the backfill load.

Proper Bedding to Develop Design Supporting Strength

To obtain the installed supporting strength in accordance with the class of bedding used, the pipe barrel must be uniformly supported by direct contact with firm bedding. Firm bedding means the pipe barrel must rest on undisturbed native or imported material. The native material in the trench bottom must be capable of excavation to a uniform undisturbed flat bottom in the case of Class D. If the trench is over-excavated, the trench bottom should be brought back to grade with the required bedding material.

Load Factors

The load, which a pipe can support, varies according to the class of bedding selected.

Trench details shown depict the recommended classes of bedding and cradling. Load factors have been determined for each. The load factor is the ratio of the supporting strength of the pipe in the trench to its three-edge bearing test strength. It does not include a factor of safety. The three-edge bearing strength has been established as a base and is considered equivalent to a load factor of 1.0.

Field Supporting Strength

The load factor is used to compute the supporting strength of a pipe with any designated type of bedding or cradling. Thus, the three-edge bearing strength of a pipe is multiplied by the appropriate load factor to obtain the installed field supporting strength of the pipe produced by the specific type of bedding or foundation selected. (Field supporting strength = load factor x pipe three-edge bearing strength.) Therefore, it is possible to provide the necessary field supporting strength to exceed the calculated trench loads. Supporting Strength in Trench

Conditions

Class D Load Factor = 1.1

The pipe may be laid on a flat or unshaped trench bottom of suitable undisturbed native material or, in the case of over excavating, on a restored flat bedding base. In either case the bottom of the entire pipe barrel shall have a continuous and uniform bearing support. The initial backfill shall be of select material.

Class C Load Factor = 1.5

The pipe shall be bedded in granular material carefully placed on a firm trench bottom with a minimum thickness beneath the pipe of 4 inches or one-eighth of the outside diameter of the pipe, whichever is greater, and the bedding filled under the haunches of the pipe with a shovel or other suitable tool to a height of one-sixth of the outside diameter of the pipe. Crushed stone, gravel or other locally available non-cohesive materials may be used. The initial backfill shall be of select material.

Class B Load Factor = 1.9

The pipe shall be bedded in crushed stone or other suitable material which is non-consolidating and not subject to migration. The bedding shall be carefully placed on a firm trench bottom with a minimum thickness beneath the pipe of one-eighth the outside pipe diameter, but not less than 4 inches and filled under the haunches of the pipe with a shovel or other suitable tool to a height of one-half the outside pipe diameter, or to the horizontal centerline. Shoveling the bedding material under the haunches of the pipe is essential if the total load factor is to be realized. The initial back-fill shall be of select material.

Crushed Stone Encasement Load Factor = 2.2

There are specific sites where a load factor of 2.2 may be desirable. The pipe shall be bedded and encased in crushed stone or other suitable material which is non-consolidating and not subject to migration. The bedding shall be placed on a firm trench bottom with a minimum thickness beneath the pipe of one-eighth the outside pipe diameter, but not less than 4 inches and filled under the haunches of the pipe with a shovel or other suitable tool. Shoveling the bedding material under the haunches of the pipe is essential if the total load factor is to be realized. The encasement material shall extend laterally to the specified trench width and upward to a horizontal plane at the top of the pipe barrel following removal of any trench sheeting or boxes. The initial backfill shall be of select material.

Controlled Density Fill (CDF or Flowable Fill) Load Factor = 2.8

The pipe shall be bedded on crushed stone or other suitable material. The bedding shall have a minimum thickness beneath the pipe of 4 inches or one eighth of the outside diameter of the pipe, whichever is greater. CDF shall be carefully discharged to the top of the pipe and allowed to flow approximately equally to both sides to prevent misalignment. The fill can be made in a single pour to the top of the pipe or it can be made in two or more lifts if desired. It is recommended that the CDF material be continuously agitated in the delivery truck due to rapid segregation of materials. This is particularly important just before pouring. The material shall have a 28-day compressive strength of 100 to 300 psi. A suggested mix for one cubic yard is as follows: 100 lbs. cement, 250 lbs. fly ash, 2700 lbs. sand and approximately 60 gallons of water. The material should flow with near water-like consistency. Other proportions may be approved if satisfactory local experience is available. The initial backfill may be placed when the CDF is capable of supporting the backfill material without intermixing. This will normally be about 20 to 30 minutes or when the penetrometer readings are greater than 62.5-lbs./sq. ft. Further evaluation may be necessary where native soils are expansive.

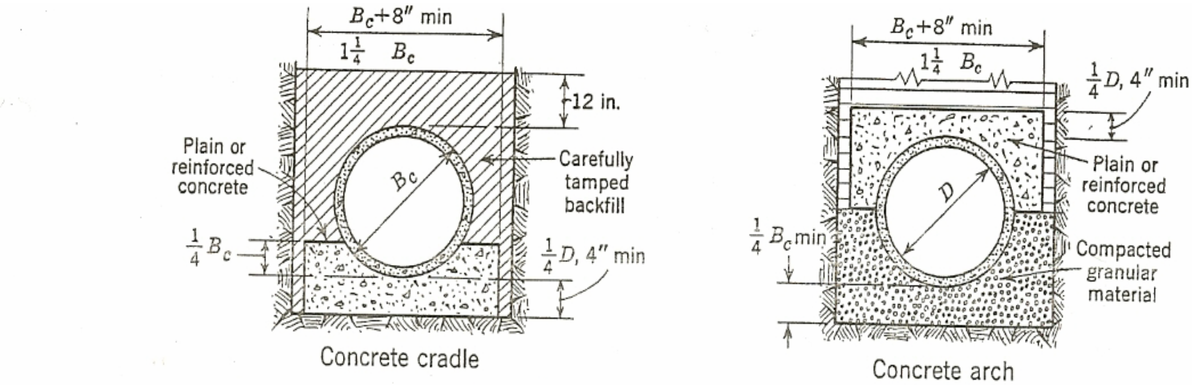
Class A: Concrete Cradle, Arch or Full Encasement

Three types of Class A bedding are illustrated giving the designer a wide selection of load factors. It is therefore possible to select an adequate Class A bedding to meet most design conditions. The angular material shall be crushed stone or other suitable material which is non-consolidating and not subject to migration. The concrete shall be 3000 psi or greater strength.

NOTE 1: Carefully placed material shall mean material that has been spaded or shoveled so that the material fills and supports the haunch area and encases the pipe to the limits shown in the trench diagrams.

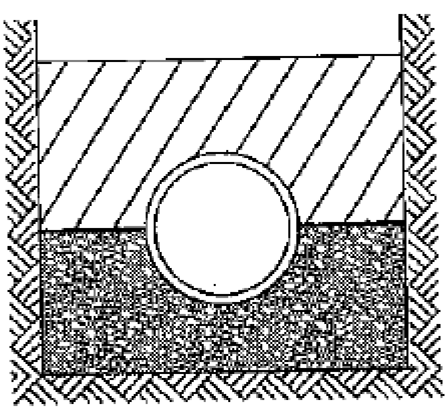
NOTE 2: The initial backfill shall be placed from the bedding to a level of 12 inches over the top of the pipe and shall consist of select, finely divided material free of debris, organic material and large rock and stones.

When making trench load calculations, a safety factor within the range of 1.5 is desirable. This can be accomplished by using the different bedding classes. Bedding design must be both structurally sufficient and cost effective.

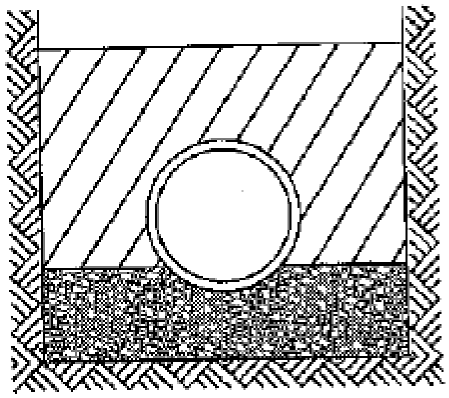


CLASS A

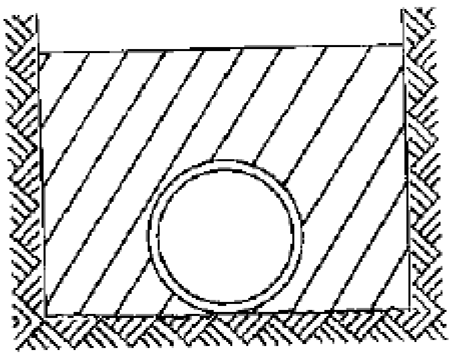
Class A Bedding	
Load Factor	
Load factor for Class "A" bedding =	2.2 to 3.4
Field supporting strength (4400 x) =	
Safety factor () =	



Class B Bedding	
Load Factor 1.9	
Load factor for Class "B" bedding =	1.9
Field supporting strength (4400 x 1.9) =	8360
Safety factor (8360/5090) =	1.64



Class C Bedding	
Load Factor 1.5	
Load factor for Class "C" bedding =	1.5
Field supporting strength (4400 x 1.5) =	6600
Safety factor (6600/5090) =	1.30



Class D Bedding	
Load Factor 1.1	
Load factor for Class "D" bedding =	1.1
Field supporting strength (4400 x 1.1) =	4840
Safety factor (4840/5090) =	0.95

Class A-I Concrete Cradle
The pipe is placed to line and grade on supports under the barrel. Concrete is poured from the bottom of the trench up to a height of one-fourth of the outside diameter of the pipe. The load factor varies with the cross-sectional area of reinforcing steel in the transverse direction.

Class A-II Concrete Arch
This method of increasing the supporting strength of pipe requires the pipe to be bedded in angular material to the springline. Concrete is placed on the bedding and extends over the top of the pipe. The load factor varies with the cross-sectional area of steel reinforcing in the transverse direction. Solid support for the legs of the arch are critical to satisfactory performance.

Class A-IV Full Concrete Encasement

This method of encasement can be used when other systems do not provide the required strength. It is also used to span areas of unstable soils where the pipe-concrete composite system must be designed as a beam. Although this type of installation carries a load factor designation, the plan details should be reviewed by an engineer experienced in structural concrete design.

Special structures and appurtenances are essential to the proper functioning of any complete system of sanitary sewers. These may include manholes, junction boxes, service connections, and other structures or devices of special design. Many states have established criteria through their regulatory agencies governing the design and construction of appurtenances to sanitary sewer systems. In addition, each private and public engineering office usually has its own design standards, which have developed during years of experience. Therefore, many variations will be found in the design of these structures. The following discussion is limited to a general description of each of the various appurtenances, with special emphasis upon the features considered essential to good design.

Manholes

Manholes are the most common appurtenances found in sewer system. Their principal purpose is to permit the inspection and cleaning of the sewers. Most manholes are circular in shape, with the inside dimension sufficient to perform inspecting and cleaning operations without difficulty. A minimum inside diameter of 4 feet for circular manholes has been widely adopted for sanitary sewers and 4-feet is consistent with the *Ten States Standards.*

The manhole is usually constructed directly over the centerline of the sewer. The manhole may be constructed tangent to the side of the sewer for better accessibility. Consideration must be given to the need for introduction of cleaning and test equipment into the sewer. The opening into the manhole must provide accessibility to the interior without difficulty. A minimum clear opening of 24 inches is recommended. The opening may be centered over the manhole, or constructed off-center in such a way as to provide a vertical side for the entire depth.

Precast manholes with precast bases have become the norm for small sewer lines. They have a flat base with a lip to allow plain concrete to be placed around the base to prevent floatation. Flexible "boots" provide a mechanical connection to the sewer pipe. The connections normally enter the manhole several inches above the base to allow a flexible connection at the face of the manhole. The precast base provides a less expensive, waterproof, flexible connection. All very desirable attributes of the structure. With larger sewer pipe, a larger base is required. When sizing the base, be sure to allow room for a change in direction or diameter. Normally, these manholes are plain-end, ASTM C-76 pipe turned on end. When sizing the precast base for large sewer pipe, remember that the manufacturer will likely provide "dog house" shaped
openings, slightly larger than the OD of the pipe, and the remaining leg between openings must be strong enough to support the base during shipping and installation. A base slab of concrete, preferably at least 8-inches thick, should be provided to support the weight of the manhole and to prevent the entrance of ground water. The flow should be carried in smoothly constructed U-shaped channels, which may be formed integrally with the concrete base. The height of the channel should be adequate to contain the flow. Adjacent areas should be sloped to drain to the channel. Where more than one sewer enters the manhole, the channels should be curved smoothly and have sufficient capacity to carry the maximum flow. Where the sewer changes direction or size in a manhole, or a branch sewer enters a manhole, the invert should be sloped to allow for the sewer height increase. Extreme caution should be exercised in the placement of manholes to assure an unyielding foundation. Settlement of the manhole may cause shearing of the pipe adjacent to the manhole. Short stubs (24 inch length maximum) with flexible joints and or flexible boots should be used at the manhole walls to help absorb minor movement. If a concrete cradle is utilized, the flexible joint is moved away from the manhole.

Manhole Frames, Covers and Steps

Manhole frames and covers are normally made of cast or ductile iron. All metal-bearing surfaces with waterproof gaskets between the frame and cover should be used. This inhibits the infiltration of storm water and reduces the need for extra line capacity and reduces the volume of waste that is treated. Where the manhole cover is subject to traffic, it should be fabricated to insure good seating. Solid covers are preferable to the perforated type on sanitary sewers to restrict objectionable odors and to limit the entrance of surface waters. Adequate ventilation can usually be obtained through the house connections. Locked or special bolted down covers may be used to prevent theft, vandalism or unauthorized entrance.

Steps and ladder rungs are provided in some manholes as a means of access. To the greatest possible extent, steps should be made of corrosion resistant materials. Firm anchorage in the wall and provision in the design to prevent slipping are desirable objectives. Since there have been many serious failures of manhole steps, some engineers omit all steps, preferring the use of other confined space entry equipment.

Drop Manholes

Differences in elevation of incoming and outgoing sewers, which would result in deposition of solids or nuisance to maintenance personnel, should be avoided. When it is necessary to drop the elevation of the sewer at a manhole, the drop should be made by means of an outside connection. Fitting dimensions govern the minimum vertical outside drop that can be made. The designer's judgment will determine, where the difference in elevation warrants using an outside drop instead of lowering the upstream or branch sewer. Concrete encasement of the entire out-side drop is necessary to protect it against damage during backfilling of the trench or separation from the manhole.

Measuring and Sampling Flow in Sewers

Flows in sewers may be estimated by a number of available methods. Approximate flows may be computed using the Manning open-channel flow equation if the slope of the sewer is known. Flows may be roughly determined from measurement of the wetted cross-sectional area of the sewer, supplemented with velocity measurements.

Most flow measurement in sewers makes use of Palmer-Bowlus flumes, weirs, or velocity. The latter is obtained by the use of meters capable of measuring velocity by magnetic or doppler sensors. Velocity measurements in combination with head measurements make it possible to calculate flows by $Q = V \times H$. This replaces the Manning Equation both in accuracy and convenience. The Parshall Flume, unlike the Palmer-Bowlus Flume, requires a positive head loss at the downstream end and is not utilized in in-line systems.

No one method of measuring flows applies to all situations. Accurate open channel flow measurement depends on existing line conditions and the composition of the sewage. Even in optimal conditions, plus or minus 10% accuracy system wide is all that can be expected. Flows approximating 40,000 gallons per day and below are measured by means of weirs as better resolution can be obtained. Flows above these levels can usually be measured satisfactorily by Palmer-Bowlus flumes or velocity.

The weir, as generally used for sewage flow measurement (gaging) is simply a vertical, watertight bulkhead placed at right angles to the sewage flow with a sharp-edged opening cut in the bulk-head. The shape of the opening varies, but rectangular, triangular and trapezoidal patterns are most frequently used.

The depth of the flow over a weir (head) varies as the rate of flow (discharge) over the weir. Continuous head-recording devices provide a means for ascertaining instantaneous flow rates and total flows through sewers over an extended period of time.

All the planning and design goes without merit if the presentation of the final design in the form of plans and specifications is not clear and concise. A set of plans must be easily read and understood by contractors who by necessity must evaluate and bid from plans from a number of engineers, prepared for many different owners. The vast majority of properly prepared plans have a similar appearance, even though most municipalities have standards from which the design is presented.

The following guide for the presentation of sanitary sewer plans has been taken from the Los Angles County Department of Public Works, Bureau of Design. It has been modified slightly to omit references to sample plan sheets and details not included for the purpose of clarity.

While the document sets a standard that makes all of its plans appear similar and be easily read by County employees, it is not dissimilar to many other standards used by municipalities across the country.

Bureau of Engineering

SEWER DESIGN

PREPARATION OF PLANS

INTRODUCTION

A construction plan shows in detail the type, extent, location and materials of construction. To prepare a good construction plan, the Designer must plan the layout, clearly delineate all construction, and thoroughly check for accuracy and eliminate conflicting instructions. A well-prepared, neat and highly legible construction plan reflects credit upon the Engineer and the City and minimizes construction problems in the field.

The purpose of this Section is to standardize and establish parameters for the preparation of sewer plans in all design offices of the Bureau. In this pursuit, standards are established, their applications are explained and examples are, where practical, shown. The examples covered apply to the most common types of City sewer construction.

In preparing sewer plans, the Engineer shall endeavor to provide the contractor with concise and simple instructions. It is essential that the Engineer understands that the plan view is the sewer's horizontal alignment (construction plan) and the profile is the sewer's vertical alignment. Construction notes shall not be placed on the profile. Notes on the plan view should be minimized. If these do not suffice, the Engineer may use general notes on the title sheet or specific construction notes on the plan sheets.

Excessive delineation, dimensions and labels add nothing to the clarity of the plan. On the contrary, they detract from it by obscuring essential construction details. Unnecessary detail on the plans is time consuming, costly and inefficient for both the draftsman and the checker.

Preliminary plans will be necessary for most sewer projects. Regardless of the size of the sewer project, the Engineer shall submit two sets of plans to all affected agencies, including substructure owners, requesting review and return of one set with comments.

PLAN LAYOUT FOR SEWER PROJECTS

The plan layout formats for all City projects are shown on Standard Plans. The formats are applicable to all City plans and shall be used as guides for sewer plans prepared by the City and other agencies for the City Engineer. In all cases, City standard symbols shall be used. The general sequence of sheets shall be as follows:

- a. Title Sheet
- b. Plan and Profile Sheets
- c. Intersections and Enlargements
- d. Maintenance Hole Details
- e. Structural Details
- f. Storm drain and Street Reconstruction Details
- g. Excavation and Fill Cross-sections
- h. Log of Test Borings

Only large projects normally require the use of most of these types of sheets. For most City projects, only the first two types are usually required.

SINGLE SHEET PLAN LAYOUT

The Single Sheet Plan Layout is shown in Standard Plan. This format is useful for short length sewers and other smaller projects. The most frequent uses of this Standard Plan format for sewer plans are Class "B" Permit projects. The Engineer shall check the permittee's sewer plan submittal for conformance with the prescribed format.

TITLE SHEET PLAN LAYOUT AND SECONDARY SHEET PLAN LAYOUT

See standards which apply to all types of projects for the City. The format and instructions apply to sewer plans +prepared by other agencies for the City Engineer, except that, their standard sheets shall be used.

TITLE SHEET PLAN LAYOUT

The Title Sheet Plan Layout as shown in Standard Plan may be modified to suit the sewer plan requirements, at the Engineers discretion.

KEY MAP

A small scale map showing the streets in which sewers are to be constructed shall be shown on the title sheet. The area shown shall be extensive enough to locate major streets along/adjacent to the sewer.

Sewers to be constructed shall be shown on the map along with the sewer line numbers. The plan sheets on which the sewer line is shown shall also be indicated. If applicable, an Assessment District boundary or Class B Permit Participation boundary shall be shown on the Key Map if practical. The Key Map shall also show the following:

a. Street limit lines
b. Street names
c. Delineation of the proposed sewer, with maintenance holes shown in their correct locations relative to the streets
d. The sewer line numbers and sheet numbers
e. North arrow, and scale
f. Railroads
g. Important channels and flood control systems.
h. City boundary

On large projects it may be desirable to reproduce a "Vicinity Map" on the title sheet in addition to the Key Map. The Vicinity Map should be of smaller scale than the Key Map and should show the location of the project in relation to streets, boundaries and important features. The "Vicinity Map" should cover a more extensive area than the "Key Map". Maintenance holes and similar details should be shown on the Key Map, and not on the Vicinity Map.

The Key Map may be used to indicate the street resurfacing required. The Engineer shall use consistent hachures and symbols to identify the class of pavement and a specific thickness if this technique is utilized.

INDEX OF SHEETS

An index, in tabular form and numerical sequence, of the sheets comprising the construction plans for the project, or for the sanitary sewer portion of the project, shall be shown in the upper right corner of the title sheet.

NOTICE TO CONTRACTORS

Under the "Notice to Contractors" on the Title Sheet Plan Layout, all general requirements and special notices shall be called out to the Contractor's attention. Some notes supplement or supersede the SSPWC or the Standard Plans and others provide general data.

All general notes on the title sheet shall be of general application. Construction notes of specific work shall be placed on the sheet where the construction is shown. General structural notes shall be located on the structural detail sheet.

INSPECTOR'S/SURVEYOR'S FIELD OFFICE

The Engineer shall check with the Inspector of Public Works, Bureau of Contract Administration, and Survey Division (SURV) for field office requirements. A note shall be added to the "Notice to Contractor" list if field offices are requested.

PERMITS

All permit information shall be shown on the "Notice to Contractors." CALTRANS and LACDPW encroachment permits, State DIS excavation and tunnel classifications and the NPDES discharge permits are examples which shall be listed, if applicable to the proposed sewer project.

EXISTING SEWER FLOW HYDROGRAPH

If the sewer project involves an existing sewer, the Engineer shall provide a diurnal flow hydrograph on the Title Sheet or elsewhere on the plans when the following conditions are met:

a. Sewers 15 inch and smaller, when the velocity exceeds 10 fps.

b. Sewers 18 inch and greater, when d/D exceeds 0.5 at PDWF.

c. Other unusual circumstances, when approved by the District/Division Engineer.

A note shall be placed with the flow hydrograph to advise the contractor that during the storm season, the peak flow could be significantly greater.

The flow hydrograph shall be based on recent field data. The field data shall consist of depth of flow readings at 1/2 hour intervals for not less than 24 hours. When such data is unavailable, or is more than a few years old, the Engineer shall prepare a request to the Survey Division to measure the flow. Prior to making the request, the Engineer shall make a field check to ascertain that the maintenance holes selected for gauging are accessible, and not paved over. The sewer MHs shall be checked to ascertain the flow characteristics are suitable for accurate gaugings. The following information shall be shown in the request:

a. The locations of the MHs to be gauged for diurnal flow.

b. Date or dates and at what frequency.

c. Special gaugings or measurements.

d. Whether the request is top priority, priority or routine.

e. The correct project title and work order number to which the work is to be charged.

f. The name and telephone number of the Project Engineer.

Because accurate gaugings can seldom be obtained at junction structures and at Type "B" MHs having different sized inlets and outlets or with appreciably curved channels, the MHs selected for gauging should, if possible, be Type "B". The MHs should also have straight channels and inlets and outlets of the same size and on the same grade. When sewers in residential areas are to be gauged during night hours, the Police Department shall be advised.

SEWER LEGEND AND ABBREVIATIONS

A list standard abbreviations is provided. While these are usually adequate, the Engineer may determine additional abbreviations to be incorporated in the plans and specifications for a specific project. If such additional abbreviations are found necessary, they shall be placed on the Title Sheet.

SURVEY DATA

Survey data references shall be located in the spaces provided on the Title Sheet. This information includes a listing of all applicable bench marks and their most recently determined elevations. Sufficient bench marks shall be listed on the plans to enable the surveyors, engineers and contractors to accurately establish horizontal and vertical alignments. In general, bench marks shall be provided at the beginning and end of the project and at least one bench mark shall be provided for each 700feet length of sewer. If more bench marks are available, it is advisable to show them. When showing bench marks to be used, care shall be taken so that bench marks that have been removed, or are considered "unstable" are not shown.

SECONDARY SHEET PLAN LAYOUT

The Secondary Sheet Plan Layout may be plain or it may have a profile grid at the top one-half of the sheet. Plain sheets shall be used for miscellaneous details, plans and elevation sections. An example would be structural details with sections.

TITLE BLOCK

The work order title and number and the sheet description title shall be shown in the Title Block. The scales shall be shown on the plan and profile sheet.

SCALE

Standard scales used for City sewer plans are usually 1 inch = 40 feet or 1 inch = 20 feet horizontal and 1 inch = 4 feet vertical. These are shown on the margin block provided at the bottom of each Secondary Sheet. In hillside areas, at the discretion of the Engineer, the vertical scale is often 1 inch= 8 feet. When used, it shall be clearly indicated in the profile with large block letters (**DOUBLE VERTICAL SCALE**) enclosed in a box.

STRUCTURAL DETAILS

The SED shall use architectural scales (i.e., 1/4 inch = 1'-0". These shall be shown below the detail or section title. When the entire sheet is to the same scale, it may be noted in the marginal block. (See Part H of the Manual).

PLANS FOR OTHERS

All City sewer plans drawn for freeway projects shall be 1 inch = 50 feet horizontal and 1 inch = 10 feet vertical.

DRAFTING AND MATERIAL

The sewer plan shall be drawn onto standard City transparency sheets. Pencils the preferred line work. However, ink may be used at the discretion of the Engineer. All work shall be neat, with clear and concise lettering and in conformance with City Engineer standards. The City Engineer Drafting and Cartography policy and procedure shall be per Part I of the Bureau Manual. Engineers shall refer to Part I for preparation of the sewer plans.

LETTERING

The draftsperson shall execute satisfactory Reinhardt freehand lettering or, when available, Compute raided Drafting (CAD). For title blocks, sheet numbers, major headings and profile grid elevations and stations, CAD or Leroy lettering shall be used. The use of transfer letters, or words preprinted on transparent adhesive shall not be used for record drawings. Central Records Section will not process for signature those drawings which have paste-ons, adhesive tapes, or decals on them. The drawings shall be duplicated onto an archival medium and the replacement mylar processed. The minimum height for lettering shall be per Standard Plan. The placement of lettering in relation to the bottom edge of the sheet.

Note that it is permissible to overlap the lettering by 9 degrees in the vicinity of the perpendicular line to the bottom edge of the sheet. However, this should be done uniformly, either to the left or to the right. In general, avoid the overlap.

LINEWORK

The conventional drafting line work is shown on standard drawings. This line work shall be used on all sewer plans. It is essential that all drawings be consistent in contrasts and symbols.

DRAFTING MATERIAL

City Engineer standard transparencies shall be made from synthetic material. Plastic sheet pencils shall be used in delineation work. Excessively hard or soft and graphite pencils shall be avoided.

REPROGRAPHIC TRANSPARENCIES

Existing plans, maps and aerial photographs can be reproduced on standard City transparency sheets by Reprographics, Administrative Division. The Engineer shall consider the cost effectiveness of reprographic transparencies.

AERIAL TOPOGRAPHIC MAP

The Survey Division has aerial topographic maps of the hillside areas. Topographic maps show existing culture, such as, trees, roadways, walks, buildings and contours. These maps are reasonably accurate but will have to be adjusted to scale through the reprographic work. By "ghost image production" the existing culture and contours can be shown in light contrast in relation to the proposed sewer. The Engineer shall check for changes in current conditions such as trees which may have grown larger since the photograph was taken.

EXISTING SEWER OR STREET PLANS

If a sewer is proposed parallel to an existing sewer or in an existing improved street, the Designer shall consider "ghost image production" of the required limits from existing plans. Any new data for surface culture should be transferred onto the print used prior to reprographics so that the contrast of existing culture is consistent. Since both street and sewer plans should be standard scale (1 inch = 40 feet), the reproduction should be adequate.

Where the scale of the other agency differs from that used on the available plan, the Reprographics Section of the Administration Division can photographically reduce the scale to the appropriate scale.(e.g. changing from a 40 scale to a 50 scale). It is also possible to increase the scale (i.e. changing from a 40 scale to a 20 scale). However, this practice should be discouraged because increasing an mage by photographic methods usually produces poor quality. Where "ghost images" are desired, the loss of quality is not as apparent and may be permissible provided the increase in scale does not exceed 25 percent.

THE PLAN VIEW

The Plan View shows the proposed sewer and all appurtenant work required as well as all other structures in close proximity to the project. Specific construction notes or symbols pertinent to work shall be concise and placed on the plan view. All proposed construction shall be indicated by bolder line work in contrast to existing culture, surface improvements and construction proposed under separate contracts or future extensions.

PLAN SHEET ORIENTATION

The plan shall be oriented so that the North Arrow generally points to the top or to the right of the sheet for the major portion of the alignment. Assuming the top of the sheet as due north, the range within which the north arrow may point is from 45o westerly of north to 135o easterly of north.

Where a sewer is to be constructed in a North-South direction, it is usually not feasible to orient the plan sheet so that North is at the top of the sheet. In this case, it is preferable to orient the plan sheet so that the downstream end of the sewer is at the left, and the upstream end is at the right. In combined projects where sewer plans are part of another plan, the alignment of the originating design office should be followed, if practical, to maintain the same orientation.

CENTER LINE ALIGNMENT

The proposed horizontal sewer center line alignment shall be delineated on the plan view as a fine alternating short and long dashed line. All ties and stationing shall be referenced to the center line or other survey line. The horizontal center line alignment will be used by the construction surveyors to provide a stake line from which the sewer pipe is constructed.

CENTER LINE STATIONING

Sewers shall be stationed with stations increasing in an upstream direction. The fractional stationing shall be shown to 0.01 foot. The Engineer shall maintain continuous stationing for principal sewers from the terminal station of the existing sewer to the terminal of the proposed sewer with a provision for future extension and continuous stationing. Stationing of sewer laterals shall commence at the intersection of the center lines of the main line and the lateral. All full stations shall be identified with a transverse hash on the sewer center line. Each fifth station shall show the station numeral. Negative stationing referred to as "back stationing" should be avoided. A common practice is to commence stationing at 1+00 to preclude the possibility of a "negative" stationing, however, station 0+00 is proper.

HORIZONTAL CURVES

The Plan View shall indicate the sewer horizontal curve data and the BC and EC stationing. The PI, BC or EC shall be tied to street center line intersection(s) or other references. State Grid coordinates (computer checked) shall also be provided. The PI, BC and EC shall also be indicated on the profile. Information for the horizontal curve shall include the following:

a. Δ = Central angle or angle between tangents
b. R = Radius of curvature
c. L = Length of curve
d. T = Tangent length
e. Radial point State Grid coordinates (computer)

ANGLE POINTS

An angle point is a minor change in alignment not having a curve to provide a smooth or gradual transition. It should be limited to those cases where a curve is not feasible. The standard pipe bevel The plans shall indicate the station and State Grid coordinates with the deflection angle point to the nearest second. Ties shall be provided to intersection or street center lines or other references.
The plans shall indicate all grade changes (GC) and the BVC, EVC, PI, and where applicable, the R for all VCs. A beginning of VC (BVC) and end of VC (EVC) shall be shown with transverse leaders on the plans. The Engineer shall check the contractor's pipe layout shop drawings for the pipe selected and upon approval and construction of the VC, shall include all VC data shown on the plan as part of "As-Built" records.

SURVEY TIES

Sewers located in streets or alleys shall be tied at right angles to the applicable survey or centerlines. Sewer MHs and terminal cleanout structures adjacent to street or alley survey or centerline intersections, BC's, or EC's shall be tied by right angle ties. Street or alley survey or center line PI's may be used as points to which ties may be made. Ties to structures shall be shown to the nearest0.01 foot.

In a right-of-way extending between two streets or alleys, the maintenance hole closest to the street or alley shall be tied to the nearest centerline intersection or other known point. Intermediate maintenance holes may be tied to one another by angles and distances or may be tied to a random survey line. Where there is a discrepancy between the measured and the calculated or recorded angle, the measured angle shall be used.

Where sewers are to be constructed on curved or irregular width streets, and the center line of the sewers or structures are not concentric or parallel to the existing survey control lines, a separate sketch showing survey control and the center line of the proposed sewer shall be detailed on the plan. It shall show all angles and distances of the survey control line with ties to the sewer structures, angle points, curve data and sewer stationing.

EXISTING SURFACE CULTURE

If current aerial topographic maps are not available or used for the base transparency, the existing surface culture along the sewer alignment will have to be determined by a field inspection survey. This data shall be gathered by the Survey Division. All existing surface culture affected by the proposed sewer shall be shown on the plan using the appropriate existing culture symbols.

PAVEMENT

The class and thickness of the existing pavement over the proposed sewer shall be shown on the plans. A good practice is to indicate the existing pavement on the Key Map and Resurfacing Plan on the first sheet. Where this is not practical, the plan sheets shall be utilized to indicate this information. The Engineer shall determine from existing street plans and field surveys the class of pavements and the specific limits, also the joints in the case of PCC. PCC pavement may be broken to the point where it may be necessary to remove or saw cut for trench work. Pavement removals to the nearest joints or cracks shall be per SSPWC.

CURB, GUTTER, SIDEWALK AND DRIVEWAYS

Existing improvements which might be affected or might require removal and reconstruction in conjunction with sewer HC work shall be shown on the plans. It is important to show driveways and sidewalks since continuous access may be required. Replacement requirements may be placed directly on the plan.

OVERHEAD CULTURE

The plans shall indicate all culture projecting overhead, such as, large trees, power or telephone poles, traffic signal masts and street electrofliers. Any overhead culture that will affect construction operations shall be trimmed, modified or removed. A note shall be placed on the plans directing the contractor to perform such tasks or shall indicate that the conflict will be relocated or otherwise managed by another agency.

WATER METERS, FIRE HYDRANTS AND HANDHOLES

The plans shall show all surface appurtenances to the water systems. Access to appurtenances shall be maintained by the contractor per the SSPWC. All relocations shall be coordinated through the Construction Division at the construction substructure meeting. (See F 321.33).

PUBLIC SERVICE FACILITIES

Public service facilities, especially those providing emergency services and other similar facilities should be shown on the plans. Facilities that shall be shown are fire stations, police stations, hospitals, schools and universities, public auditoriums of significant size and/or importance, major public buildings and facilities, public transportation facilities (bus stations, bus stops, railroad terminals, airports, etc.) among others. Criteria in determining whether to indicate such a facility or not is whether public safety and/or convenience may be affected by the proximity of the facility to the construction operations. In general, it would be prudent to indicate such a facility rather than to omit it.

SUBSTRUCTURES ON THE PLAN VIEW

All substructures within the public right-of-way in which the proposed sewer is aligned shall be shown on the plans. Figures F 533A and F 533B show the substructure legend for conduits, structures and other appurtenances. The term "substructure", shall include conduits, cables, MHs, vaults, and all other similar appurtenances. The size, shape, dimension and other identifying data shall be indicated.

The Engineer shall be responsible for the accuracy of the information shown on the plans. (See F 321.3, et seq.) Potholing shall be performed for possible interferences encountered which cannot be resolved by records or the substructure owner. Substructures containing or conveying unstable substances or those which are hazardous shall be clearly located and described.

SUBSTRUCTURE CONVENTIONAL LINEWORK AND IDENTIFICATION

See Figures F 522A, F 522B, F 533A and F 533B for substructure line work. The plan shall be reviewed for consistency of substructure line work as well as accuracy. Each substructure shall be tied to the nearest property line, street centerline or other appropriate reference. The size or dimension of the substructure shall be indicated, followed by the owner acronym and a tie distance in feet. If potholed the substructure's measured location and dimensions, shall be shown on the plan. (See F 512.15, F 522 and F 533).

ABANDONED SUBSTRUCTURES

The abbreviation for abandoned shall be ABAND per Standard Plan. Abandoned substructures are those which have been relinquished by the owner. The contractor shall be responsible for removal of interfering sections, sealing of structures and appurtenant work.

SUBSTRUCTURES TO BE ABANDONED-IN-PLACE

Substructures to be abandoned-in-place indicate that the owner will abandon the substructure and will install new substructures clear of the proposed sewer. The substructure owner and the contractor shall coordinate the abandonment necessary in conjunction with the sewer work. The utility substructure owner shall submit "As-Built" substructure records to the Permit Processing Section One-Stop Counter or the public counter of the appropriate district office.

SEWER ABANDONMENTS

Sewers which will be abandoned with the project shall be delineated as "Aband". All maintenance holes on the portion of the sewer to be abandoned and the nearest maintenance holes on the same line shall be stationed. The limits of the abandonment shall be indicated by a leader. The notation" Abandon Ex.__________" Sewer" (show size of sewer) shall be shown on the leader.

6/92 F 533holes in the portion of sewer being abandoned shall not be separately indicated to be abandoned. The contractor shall abandon an existing sewer between the limits, as well as, all structures and appurtenances between said limits.

Sewers shall be shown to be abandoned only once. Where the same sewer to be abandoned is shown on more than one sheet, it shall be cross referenced to the abandonment sheet.

SUPPORTS, REINFORCEMENT AND PROTECTION OF SUBSTRUCTURES

The plans shall indicate precisely the type and length of protection to be provided by the contractor. Requirements for temporary supports shall be listed or otherwise covered in the Special Provisions and/or detailed on the plans.

UTILITY SERVICE CONNECTIONS

Power and telephone service connections shall be shown on the plan and checked by the DWPPS and Pac Bell or telephone company. Other services shall be marked in the field ahead of construction.

SEWER PIPELINE DATA

The sewer includes the pipe, MHs and appurtenant structures to be constructed or placed on the alignment per F 531. (See F 400, et seq. for pipe, MHs and structures).

The sewer to be constructed shall be shown only once on the plans, as a solid, unbroken line. If the delineation of a portion of the sewer or its appurtenant structures is repeated on the same sheet or on other sheets, it shall be shown as dashed lines and reference made to the location or sheet on which the sewer and its appurtenant structures were originally shown; for example, "12 inch Sewer shown elsewhere hereon," or "8 inch Sewer shown on Sheet No. 4".

SEWER PIPE

The Engineer shall show the length, size, type, class of pipe and the pipe bedding if other than Case1, "Pipe Laying in Trenches", for each reach between MHs and/or structures.

LENGTH OF PIPE

The pipe length shown shall be the true length along the pipe horizontal projection between inside walls of MHs or structures as shown on the Standard Plan or details for structures. The length shall be to the nearest whole foot.

TYPE AND CLASS OF PIPE

The type and class of pipe shall be indicated on the plans and in the Special Provisions. Whenever possible, a single specification or a single note indicating the type and class of pipe should be utilized.

For allowable types of sewer pipes, see F 410, et seq. Whenever possible, the greatest number of alternatives in pipe materials should be allowed in order obtain the most competitive bid prices from contractors and suppliers.

ALTERNATIVE TYPES AND CLASSES OF PIPE

Materials for pipes other than those listed previously in F 410, et seq, may be considered and specified. However, prior to specifying any alternative, the Engineer shall consult with the WSED for recommendations. Only City Engineer approved pipe may be specified on City sewer plans.

PIPE BEDDING

"Pipe Laying in Trenches" shows the different classes of allowable bedding.
Unless otherwise specified, Case 1 bedding shall be required. Special bedding requirements shall be reviewed by and designed by the SED and approved by WSED.

PIPE JOINTS

Pipe Joints shall conform to F 430, et seq. Other joints shall be subject to District Engineer approval.

MAINTENANCE HOLES AND SIMILAR STRUCTURES

Sewer MHs shall conform to F 440, et seq. Other MHs may be specified for particular problems or circumstances. However, prior to specifying any other MH, the WSED and the Bureau of Sanitation shall be consulted. In general, the use of special MHs should be avoided due to potentially higher construction and maintenance costs. Safety shall be paramount.
If necessary, special MHs or details of modifications shall be drawn directly on the sheet with the plan and profile of the location of the MH involved. When this is not possible, the details shall be drawn on a separate detail sheet. If a note will suffice to indicate the required modification, a detail delineating the modification will not be necessary.

Station MHs to the nearest foot since the contractor may adjust the location up to two feet to meet pipe ends. Where the MH stationing on one line equals some other station on a confluent line, show both stations and the sewer line numbers; for example, 12+62.87̰̃ = 0+00 □. When there is an equation on the same line, indicate which station applies to downstream stationing and which applies to upstream stationing; for example, 6+72.24 back = 6+74.63 ahead. Where the 0+00 of the proposed sewer equals some other station on the sewer into which it outlets, indicate the stations, for example: 0+00 □= 45+23.72 on Ex. 18 inch Sewer. If an existing sewer is intercepted by a proposed sewer, indicate the stations, thus: 12+24.42 □̣= 8+67.73 on Ex. 8 inch Sewer. Indicate the maintenance hole type immediately beneath the leader to the maintenance hole on which the maintenance hole station is shown. (See F 531.1)

If the proposed maintenance hole differs in any respect from the standard plan for the type of maintenance hole specified, the maintenance hole shall be labeled "Special". State in what respect the specified maintenance hole differs from the Standard Plan: "Special MH B-5, Const. W. Wall Vertical," or show differences on a detail and refer to said detail on the plan: "Special MH B-5 per Detail "C" on Sheet 6". When the detail may be shown on the same sheet and in close proximity to the maintenance hole the detail may be joined to the maintenance hole with a leader marked "Identical," in which instance no reference will be required. The detail shall indicate the location of the MH or structure by a station reference.

HOUSE CONNECTIONS ON THE PLANS

House Connections (HCs) shall conform to standard drawings. Dimensions and data required by the Standard Plan shall be delineated on the plans. Lengths of HCs do not have tube shown on the plan when the street dimension suffices for transverse connection to the sewer. Lengths given at each HC at the ends of the reach of sewer shown on the sheet will suffice. A guide for showing HCs are sewer Wye Maps available at district offices. (See F 321.1).

LOT LINES AND NUMBERS

A short line perpendicular to the street property line shall be shown to indicate the lot line or lot cut line. The cadastral map provides data such as lot numbers, tract numbers and front footage. (See F 321.1). If an Assessment Act sewer is proposed, the entire lot may be delineated on the plan, otherwise, the lot area shall be calculated and shown. If a postal card substantiation of the proposed HC location is filed, the letter "C", in parenthesis, shall be placed after the sewer wye station on the plan.

HOUSE CONNECTION DATA

HCs shall be 6 inches in size and 4 feet below the existing or projected top of curb at the property line. The following information is required to be shown on the plans for all HCs:

a. Station opposite the location of the upper end of the HC, and the "Wye" station where the sewer is laid on a curve.

b. "Wye" or saddle tap stations which are at some location other than 2 feet downstream from the station of the upper end of the HC.

c. "Tee" stations which are other than the station of the upper end of the HCs sewer.

d. Type of HC if other than Type "A".

e. Pipe size and the letters HC if the HC is other than 6 inch.

f. Length "A" (when the HC sewer length is not apparent from the street dimensions and the sewer ties).

g. Length "B" on all Type "C" and "D" HC sewers.

h. Standard Specifications require the following: Unless otherwise shown on the plans, HCs shall be 6 inches in diameter, and shall be Type "A" as detailed on the Standard Plan titled "Standard House Connection Type 'A'". The figure in a circle on the plans adjacent to an HC station indicates the depth in feet below the existing curb to which the invert of the upper end of the HC shall be constructed. If no depth is indicated, the invert of the upper end of each HC shall be built to the elevation shown on the profile, or if no elevation is shown, to a depth 4 feet below the top of existing or future curb.

Where curbs exist, (unless the depth of the upper end of each Type "A" HC sewer is 4 feet below the top of the curb), the depth shall be shown on the plan to the nearest half foot, enclosed in a circle adjacent to the HC station.

i. Connections to an existing building sewer or HC. (Building plumbing/sewer is defined as sewer pipe extending 2 feet beyond the building.)

j. Locations approved by post card from the owner.

k. Construction in a tunnel.

TYPES OF HOUSE CONNECTIONS

The Engineer shall specify the HC type on the plan when other than Type "A" is required. If all HCs are other than Type "A", but one specific type, a general note is preferable to indicating the type at each HC. An HC schedule on the plan listing variable HC data, in a tabular format may be used (See F 481).

HOUSE CONNECTION WYE

The wye station shall be shown on the plan at the end of the HC at the property line. A second station shall be shown if the end of HC is other than 2 feet greater than the wye.

HOUSE CONNECTION DEPTH

If other than 4 feet, the difference between the HC invert and the existing or proposed curb finished grade shall be shown to the nearest 0.1 foot. It shall be encircled on the plan at the HC station. A minimum depth of 4.0 feet shall be required at curb grade at the upper end of HCs at the property line. A minimum depth of 3.5 feet may be shown on the high side of streets in hillside areas.

HOUSE CONNECTION SLOPE

Normally, the minimum slope for a HC shall be 2 percent. Slopes not less than 1 percent may be used in exceptional cases. (See F 535.23)

HOUSE CONNECTION LENGTH

The HC length shall be shown along the HC delineated on the plan and/or may also be inserted in a HC schedule. The HC length shall be given to the nearest whole foot. (See F 535 and F 535.21).

LOCATION OF HOUSE CONNECTIONS ON CURVED SEWERS

To assist in locating "Wyes", "Tees", chimneys and the upper ends of HCs after the sewer is constructed, the Engineer shall place on the plan a table of distances and offsets to each of the above. A sketch similar to that shown in Figure 535.26 shall be placed in close proximity to the table of distances and offsets on the plan. The table of distances and offsets shall show each offset, either right or left.

HOUSE CONNECTIONS ON STREET WIDENING PROJECTS

When HCs are constructed or remodeled in conjunction with a street widening project the HC may be shown to encroach a short distance onto private property beyond the street property line if it is necessary to attain minimum requirements. If Standard Plans do not adequately indicate the work to be done, special detail(s) shall be shown on the plans.

SPECIAL STRUCTURES AND DETAILS

Except for blanket protection or pipe supports, special structures and details shall be shown on the plans. Applicable cross references to such details including those provided by other agencies shall be noted on the plans.

BYPASSING STRUCTURES

Major sewage bypass construction shall be shown on the plan sheets in light contrast with a cross-referenced any Bypass Construction Plan. (See F 471). Whenever a Bypass Plan is required, an accurate diurnal hydrograph of the sewage flow shall be shown on the plans. The contractor shall provide shop drawings and any bypass structures remaining in-place with the sewers shall be shown on the "As-Builds."

JUNCTION AND DIVERSION STRUCTURES

Junction Structures (JSs) shall be constructed at sewers junctions if a MH is inappropriate (See F 472). Diversion structures resemble JSs in reverse and shall conform to F 473. Flow control devices, such as, stop logs or sluice gates may be necessary. They also require access ports usually in the form of box-shaped shafts. The structures shall be shown on the plans with cross references to structural and other details. JSs and diversion structures shall be reinforced concrete with a plastic protective liner.

TUNNELS AND JACKED CASINGS

The plans shall station the limits of proposed tunneling or jacking. Cross references shall be made to structural and other details. Remnants of a tunnel or jacking operations left in-place shall be shown on the "As-Builts." The SED shall review the contractor's shop drawings submittals, including all provisions intended to fulfill State DIS requirements

SOIL BORING LOCATIONS

The plans shall locate soil borings and numbers referenced to the sewer main line. The plan shall indicate the boring by means of a symbol defined in the legend.

PLAN WORK BY OTHERS

Sewer projects frequently require plans prepared by other agencies. Examples include signal remodeling, street light remodeling, street pavement reconstruction, storm drain reconstruction, and other work affected by the proposed sewer. The requirements for any other plan sheets shall be determined during preliminary design. A request for special plans shall be transmitted to the responsible agency(s) as soon as possible after the pre-design conference.

TRAFFIC CONTROL PLANS

The LADOT will prepare any Traffic Control Plan (TCP) for the project. Street design shall be coordinated with TCP as necessary. (See F 491.3 et. seq).

STREET REMODELING PLANS

Some sewer projects will require street remodeling. The appropriate District Engineer shall prepare any street remodeling or reconstruction plans as well as the resurfacing schedule.

STREET LIGHTING WORK

Street lighting locations for a sewer project may involve street lighting conduit (ELC) remodeling. This work may be placed directly on the sewer plan view without resorting to extra plan sheets. Any plan sheet for ELC relocations shall be requested from the Bureau of Street Lighting.

STORM DRAIN PROTECTION AND/OR RECONSTRUCTION

Sewer projects may require protection and support of existing storm drains. The District Engineer shall review the plans to ensure they are properly protected and supported. Some sewer projects require the relocation and/or reconstruction of storm drains. The District Engineer shall prepare the necessary plans for inclusion in the project plans. Where the relocation and/or reconstruction work will be minor, the details may be placed directly on the sewer plans. (See F 322.3).

STRUCTURAL DETAILS

The Structural Engineer shall prepare all structural details required. Where feasible, the modifications and details may be shown on the sewer plan sheets. Otherwise, structural detail sheet(s) shall be prepared by the Structural Engineer. Unusual structural work involves plastic-lined RCP and RC Band special-designed structures for which Standard plans do not suffice. (See F 410, F 420 and F 490 et seq., and F 512.221). Part H of the Bureau Manual enumerates policy and procedures for structural design.

THE PROFILE VIEW

Sewer profiles show the vertical alignment. The profile view shows the depth of the sewer in relation to the surface over the sewer or the curbs or other official grade lines of the street or alley in which the sewer is located. The profile shall show as accurately as known, the elevations of the existing and proposed substructure crossings in proximity to the sewer. In addition, surface improvements which will affect the structural requirements of the sewer, such as footings, railroad tracks, etc., shall be shown. The profile shall not show construction notes. See Figure 512B for typical information shown on a plan and profile sheet.

THE PROFILE GRID

The standard sewer profile grid shall be 2-1/2-inches by 2-1/2-inches. It shall have the National Geodetic Vertical Datum (NGVD) of 1929 elevations at 10 foot intervals at a scale of 1 inch = 4 feet. In hillside areas, a scale of 1 inch = 8 feet may be used and shall be clearly labeled "DOUBLE VERTICAL SCALE". The horizontal grid shall be a scale of 1 inch = 40 feet. The scale used shall be shown on each sheet when other than standard scales are used (See F 512.22).

THE VERTICAL GRID

The Engineer shall include the NGVD (Equivalent North American Datum) elevations at each end of the profile view. See J 211.5 of the Bureau Manual.

THE HORIZONTAL GRID

The Engineer shall place a full station (100 feet) at each primary vertical grid line along the profile grid base. (See F 531.1). Each station shall be given a numeral representing a full even station (e.g.4 for station 4 + 00). The Engineer shall show only stations pertinent to the sewer grade, along with an elevation to 0.01 feet. These locations shall include each end of the profile view which shall be identical with the plan view limits and at any location where there is a GC. As a matter of policy, GCs shall be located at a MH location.

THE SEWER PIPE IN PROFILE

All sewers shall be shown with two lines to indicate the invert and the soffit. The lines should be as shown in Figure F 533A.

PROFILE ORIENTATION

The profile view of the sewer shall be oriented to the plan view. The pipe shall be stationed commencing at the downstream end and increase in stationing in an upstream direction.

DATA FOR PIPE PROFILE

The pipe or conduit size and the term "sewer" shall be shown on the profile. (e.g., 8 inch SEWER). It shall be shown only once on each sheet unless there is a change-in-size. Where there is a transition, the size on both sides of the transition shall be indicated.

PIPE SLOPE

The pipe construction slope shall be indicated just above the line which identifies the pipe invert. The slope shall be indicated once between GCs in units of ft./ft. Four decimal places shall suffice unless the sewer is large and lengthy or the slope is very flat, less than 0.0020. (e.g., S = 0.0044).

SEWERS 18 INCH AND LARGER

The Engineer shall show sewage flow data for all sewers 18 inch and larger. The following data shall be placed on the profile, tabulated in vertical sequence for each pipe size, slope and design flow:

a. Design flow (cfs)

b. Design flow Velocity (ft/sec)

c. d/D, Depth/Diameter or Height Ratio of Flow

d. n = 0.014, Manning's' Coefficient of Roughness.

MAINTENANCE HOLES AND STRUCTURES

The MHs and structures shall be shown with two bold lines to scale. The MH/structure shall be indicated by delineating vertical leader(s) representing the station point(s) of the MH or structure.

The station and the inlet elevation points at junction MHs or structures shall be shown. The side inlet size and direction of entry shall be shown with the elevation(s). See the appropriate MH or structure Standard plan(s).

HOUSE CONNECTIONS ON PROFILE

A new sewer shall have HCs shown on the profile as an ellipse with stations and elevations. (See F 535.2 et. seq.)

EXISTING HOUSE CONNECTIONS

Where HCs cross the proposed sewer, a dashed ellipse shall be used to identify the crossings. Any support or blanketing requirements shall be noted on the plan view. The terms "existing", "ex." or "exist." are redundant to sewer symbols and line work on the profile and should not be utilized.

PROPOSED HOUSE CONNECTIONS

For Type A HCs where no curb exists, and for Types B, C, and D show the following on the profile, except as noted:

a The station of the upper end of the HC sewer.

b. The letter R or L to indicate the HC sewer is on the right or left side of the public sewer (looking upstream).

c. Invert elevation on HC Types B, C, and D.

d. Invert elevation of the upper end of the HC when a curb exists. The depth of the upper end of the HC shall be shown on the plan only. If only certain types of joints will be allowable, the types shall be shown between reaches of the sewer profile, unless a general note will suffice on the title sheet or applicable plan.

When an existing HC or building sewer is to be joined by a new HC sewer, the precise station on the new public sewer, opposite the connection is seldom known. Because the station, although carefully scaled, is not calculated, the station on the new sewer opposite the connection shall be shown to the nearest scaled foot as a plus or minus station, for example, 132+61? .
With the possible exception of the inverts at the upper ends of some HC sewers, the invert elevations on an existing HC or building sewer are seldom accurately known. For this reason any reference to elevations on an existing HC or building sewer shall be followed by the plus or minus sign, for example, "F"=246.5? , CONNECT EX. 6 inch HC.

HOUSE CONNECTION REMODELING

Construction requirements for HC remodeling shall be noted on the plan view at the HC delineated or in an appropriate table. A solid line ellipse for a new vertical location of a HC crossing the proposed sewer shall be delineated on the profile at the appropriate location. Any HC size larger than6 inch shall also have the size shown.

SUBSTRUCTURES ON THE PROFILE VIEW

All substructures crossing the proposed sewer shall be shown as a dashed ellipse, rectangle, or other appropriate geometric shape along with the size and the identifying service, such as; gas, water, power, telephone, ELC, TSC, etc.

ABANDONMENTS

ABAND to indicate abandoned may be used on the profile view when they are also indicated on the plan view. Consistency in the use of the term **abandoned**, shall be maintained. The ABAN shall not be used on the profile. ABAN indicates a construction execution (plan only).

UTILITY RELOCATIONS

If the substructure owner proposed relocation for a substructure, the vertical location on the profile shall be shown as a solid ellipse, rectangle, or other appropriate geometric figure with the word "proposed" and the size and type of service. The owner acronym shall be indicated on the plan view.

SURFACE LINE OVER SEWER

The existing and/or proposed ground or finished surface over the center line sewer shall be shown on the profile. Current elevations and conditions can be obtained by requesting the Survey Division to prepare a preliminary sewer survey for a calculated centerline alignment. This procedure is appropriate for major sewers, such as, outfalls, relief or interceptor sewers which traverse longer alignments with greater exposure to surface culture.

CUT AND FILL AREAS

Proposed or existing cut and fill zones along the proposed sewer alignment shall be determined. If the former ground line was substantially below the finished surface, the original ground line shall be shown in dashed line and labeled as the former ground line. If the existing pavement was left intact or broken and filled over, a leader with a note shall indicate the type and thickness. All existing substructures at old street levels shall be located (e.g., old street sumps).

RAILROAD OR STREET CAR RAILS

Existing railroad (RR) tracks shall be shown on the profile surface line at crossing points and identified as RR rails. Sewer construction in a jacked casing or tunnel will be required across active RR crossings. Abandoned RR/street car tracks (rails and cross ties) exist in many streets which have been resurfaced with asphalt concrete pavement. Existing trackage shall be indicated on the profile. They shall be shown on the profile in section at its crossing or double-dashed lines if they are located longitudinally over the excavation limits.

EXISTING OR PROPOSED CURB GRADES OVER SEWER

Curb grades have been used in the past to indicate sufficient HC depth at the property lines. The Standard Plans for HC construction and HC remodeling, together with the required plan view data for HCs, should provide sufficient design detail to construct the sewer. The delineation of curb grades in addition to the ground or finished grade line over the center line sewer may be included at the discretion of the Engineer. The function of the profile is to show the contractor the required vertical alignment. It should not have redundant information.

F 546 LOG OF SOIL BORING(S)

Soil boring log(s), when included in the plans, shall be shown on the profile.

Where several borings will be made, a separate Log of Soil Borings Sheet should be made. The Log shall be per the United Soil Classification System.

Soil boring(s) for short length sewer projects can be placed on the profile at or near the corresponding location (station) indicated on the plan by the soil boring symbol. On larger sewer projects where many soil borings will be taken, separate sheets shall show all soil borings. In addition to the log, the soil boring identification number and station, the groundwater level on the date the soil boring was taken and any other significant data shall be included according to the Unified Soil Classification System (USCS).

THE CROSS SECTION VIEW

One cross sectional view shall be included on each plan sheet to indicate substructures in relation to the sewer line. It is policy to include it. Sewers larger than 15 inch shall have a cross sectional viewing the upper right of the profile grid for each plan and profile sheet. The location of the section taken should be representative of the limits of work or at critical substructure situations.

SUBSTRUCTURES WITH UNSTABLE SUBSTANCES

If a substructure containing or conveying an unstable substance lies within 6 feet of the proposed construction, a cross sectional view shall be shown on each plan and profile sheet affected. (See F 321.32).

CROSS SECTION STATION

The cross section shall be taken at a full station unless there is a critical substructure conflict at a specific fractional station.

CROSS SECTION DATA

GRID ELEVATIONS

Cross section grid elevations should be identical to the profile grid elevations. (See F 541).

HORIZONTAL SCALE

The cross section horizontal scale should be 1 inch = 10 feet.

VERTICAL SCALE

The cross section vertical scale shall be the same as that used for the profile. (See F 512.22).

LEADERS AND DIMENSIONS

The leaders to identify substructures should be vertical with the size, shape and identity of the substructure noted and an arrowed leader to the substructure. (See F 521 for lettering). All substructures shall be dimensioned horizontally to the closest street or right-of-way limit line. The proposed sewer shall be tied with horizontal dimensioning to the street center line.

GROUND LINE OR FINISHED SURFACE

The existing or proposed surface over the proposed sewer shall be shown and identified on the cross-section. Since the vertical scale is, usually, 1 inch = 4 feet, the pavement thickness can be shown to scale. Thickened Portland Cement Concrete pavement shall be shown on the cross section.

MISCELLANEOUS DETAILS

Details, such as street reconstruction, modifications of structures, etc., shall be drawn on the sheet(s) titled MISCELLANEOUS DETAILS. Each detail shall be titled and cross referenced to a plan and profile sheet. The structural details shall be drawn by the Structural Engineer on sheet(s) entitled STRUCTURAL DETAILS.

PREPARATION OF SEWER PLANS FOR OTHER AGENCIES

The policies and procedures for preparing sewer plans for agencies other than the City shall be, essentially, the same as the BE projects except the standard sheets, scales and required approvals shall be as requested by the owner/agency. See F 121.21 and F 121.22 for liaison responsibilities with CALTRANS and LACDPW projects. (See F 512 et.seq. and F 524.4).

CHECKING SEWER PLANS

Checking should be limited to those features of the design that require numerical accuracy, textural clarity, and sufficiency of data. It is not the function of the checker to review the entire design and to duplicate the work of the Engineer, provided the development of the design has had proper supervision. The fundamental requirements should have already been determined during the design.

Checking should be accomplished as follows:

a. Check the final plan set against the reviewed preliminary plan sets for accuracy.

b. Check the final plan set against the check list for compliance with requirements (See Figures F 570A & F 570B).

Deficiencies shall be noted by the checker, for the attention of the Engineer. The final plan should be submitted for check within the design schedule.

The title sheet should be checked against the SAMPLE TITLE SHEET. The preliminary, as well as, the final plans shall be checked, using the check lists shown in Figures F 570A and F 570B.

Plan sets shall be ordered/transmitted to all affected agencies, in particular to all owners whose existing substructures might be affected by the proposed sewer construction. The orders/ transmittals shall be followed/accompanied with an Interdepartmental Communication or City Engineer letter requesting review and comment relative to their facilities. This procedure should be executed as soon as possible after preliminary plans are completed.

The final plans shall be reviewed to ensure they conform to the provisions of recent special orders and memoranda, as well as, the SSPWC.

LIST OF AFFECTED AGENCIES AND SUBSTRUCTURE OWNERS

A list of all agencies and substructure owners whose facilities might be affected by the proposed sewer shall be provided with two sets of prints for review and comment. One set should be kept by the reviewer and one set with notations and comments should be returned to the Engineer. In order to avoid unnecessary work and expense, each agency or owner should be contacted to determine the precise number of prints to be produced for their review.

REVIEW AND EVALUATION OF AFFECTED AGENCY COMMENTS

The Engineer shall review all plans and comments returned by the affected agencies to determine any changes or revisions. Comments shall be evaluated carefully prior to making any corrections, notes, details, and modifications to the plans and/or adding any Special Provisions to the project specifications. Any requested correction, modification or notation that need further work shall be investigated and resolved. Additional print sets may be transmitted for further review.

FINAL PLAN REVIEW

After all revisions have been made on the sewer plans, the final plan review shall commence. All BE divisions/districts offices affected by or involved in the project shall receive two sets of prints for their review, prior to plan circulation for approval signatures.

SUBSTRUCTURE REVIEW IN CONJUNCTION WITH PREADVERTISEMENT

Prior to advertisement for bids, a substructure review shall be made by the Engineer to determine whether recent or proposed installations along the proposed sewer alignment will affect the construction. New substructures unaccounted for on the plans require immediate investigation. The investigation shall include:

a. The initiation of a "pothole" investigation to determine the substructure location in both plan and elevation. The plans shall reflect the investigation's findings. If the plans have been signed, a plan revision shall be prepared.

b. In the event of marginal clearances, a request to the Construction Division to include in the Special Provisions or Notice to Bidders that the contractor perform the "potholing." In the case of substructures containing or conveying unstable substances the use of power tools and equipment shall be limited to pavement breaking (See F 321.32).

PLAN REVISIONS

If the sewer plans have been circulated and approval signatures secured, any additions or changes on the plans shall be made as a plan revision. See Part C of the Bureau Manual for plan circulation policy and procedures. Check the current Special Orders.

PLAN PROCESSING AND APPROVALS

The Project Management Division Engineer shall be responsible for final plan processing and distribution of the plans. (See Part C of the Manual). PMD will ensure that each agency or party affected by the proposed project receives a set of the approved plans.

PROCESSING SEWER PLANS FOR OTHER AGENCY PROJECTS

The District Engineers or WSED shall be responsible for sewer plans prepared in conjunction with other agency projects, such as, CALTRANS, LACDPW and agencies other than the DPW. Plans shall be processed for approval by the specified liaison office within the BE.

CALTRANS PROJECTS WITH SEWER WORK

The Central District Engineer (CED) shall be the project liaison to CALTRANS. All sewer plans in conjunction with CALTRANS projects shall be processed and coordinated by the Central District. This includes encroachment and excavation permits for streets that are State Highway routes. See Part E of the Bureau Manual for further information.

LACDPW AND FEDERAL DISTRICT ENGINEER

The CED Engineer shall coordinate with LACDPW and other flood control and drainage agencies. All plans in conjunction with the LACDPW and any other flood control or drainage agency shall be processed and coordinated by the CED. See Part G of the Bureau Manual for detailed information.

UNINCORPORATED TERRITORY AND MUNICIPALITIES

Unincorporated areas adjacent to LA City boundaries are usually under the jurisdiction of the LACDPW. An approval block for that agency's approval shall be provided on City sewer plans affecting unincorporated areas. If any adjacent municipal or other Special District is involved, an approval signature block shall be provided as requested by the individual City or district involved. The Engineer shall secure the agency's requirements for inclusion in an approval block. All plans pertaining to existing or proposed sewage flows into or from adjacent areas of other agencies shall be submitted to the WPMD prior to transmittal of such plans for approval. The WSED is responsible for maintaining sewage service contract records for treatment plant obligations.

THE ENGINEER'S CHECKLIST

The "Engineer's Check List" which follows is intended to minimize omissions and delays to the project.

ITEMS TO BE CHECKED WHEN A PROJECT IS AUTHORIZED

a. Prepare and submit a "Preliminary Engineering Report" for the project.

b. Determine right-of-way required.

c. Arrange a joint field trip with the Real Estate Division and other interested representatives.

d. Pothole substructures which may cause a conflict.

e. Consult with the Engineer of Surveys concerning the necessity of a survey field office.

f. Consult with the Division or District Engineer about the following:

1. Deviation from standards
2. Approval of preliminary plan
3. Criteria for major business or industrial districts
4. Design flows for outfall, interceptor and relief sewers
5. Sewers in potential slide areas, subsidence areas, fills, peat, diatomaceous earth
6. Measuring devices
7. Necessity for inspector's or surveyor's offices
8. Portions of lots to be served
9. Relocation of existing substructures
10. Work in or through other municipalities

g. Write memorandum to the Structural Engineer requesting design or structural check of the following:

1. Sewers specified to be constructed in a tunnel
2. Reinforced concrete structures
3. D-Loads
4. Special pipe bedding per "Table B" of standard plan titled "Pipe Laying in Trenches"
5. Surcharges over existing sewers,
6. Support or reinforcement of sewers located in areas having an unstable sub base

h. Send two sets of prints of preliminary plans to the District Engineer for storm drainage review.

i. Send two sets of prints to LADOT Traffic.

j. Send two sets of prints to the Bureau of Street Lighting.

k. Send print sets of preliminary plans to affected agencies and utility owners if the project is to be expedited.

ITEMS TO BE COMPLETED PRIOR TO PREPARATION OF CONSTRUCTION PLANS

a. Check old street profiles for fill areas.

b. Search index for previous plans covering same areas.

c. Consult with others that planned the project.

d. Make preliminary field investigation of the following:

1. Area to be served
2. Topography
3. Locations and elevations of possible outlet sewers
4. Possible obstructions
5. Existing buildings
6. Existing basements and low ground
7. Zoning
8. Vacant property and probable future development
9. Present population
10. Location of existing storm drains and appurtenances
11. Geological and soils conditions

e. Make necessary field survey requests.

f. Request necessary soil borings.

g. Request Geology and Soils Report.

h. Secure street grades.

i. Check for future storm drains.

j. Check capacity in outlet sewers.

k. Request flow measurements where needed.

l. Check predicted future population and land use.

m. Determine location of large industrial waste producers and determine type and quantity of wastes produced.

n. Furnish post card notices to property owners (For Assessment Act Projects, only).

ITEMS TO BE COMPLETED AFTER DISTRICT/ENGINEER'S SIGNATURE BUT PRIOR TO CITY ENGINEER'S APPROVAL

Secure encroachment, excavation and construction permits, as well as, approvals of other agencies or owners. This is in addition to approvals by other Division or District Engineers secured by the PMD.

ITEMS TO BE COMPLETED AFTER CITY ENGINEER'S APPROVAL

Send print sets to agencies or owners approving plans and any District Engineer on projects extending beyond the Design District boundary.

REFERENCES

Other Related Fact Sheets Sewer Cleaning and Inspection EPA 832-F-99-031 September 1999 Sewers, Pressure EPA 832-F-02-006 September 2002

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

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4. Clay Pipe Engineering Manual, 1989. National Clay Pipe Institute.
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7. Fairfax County, Virginia, 1995. Public Facilities Manual.
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9. Means Mechanical Cost Data, 1991. Construction Consultants and Publishers. Kingston, Massachusetts.
10. Qasim, S. R., 1994. Wastewater Treatment Plants. Technomic Publishing Company, Inc. Lancaster, Pennsylvania.
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12. U. S. EPA, 1986. Design Manual: Municipal Wastewater Disinfection. EPA Office of Research and Development. Cincinnati, Ohio. EPA/625/1-86/021.

TEN STATES STANDARDS

Gravity Sewer Minimum Design Criteria

Adopted February 12, 1996

I. APPROVAL OF SEWERS

A. The Division of Environmental Management shall approve new construction, extensions into new areas, and replacement sewers. The County Health Departments will review and approve all collection systems, which connect to a subsurface treatment and disposal facility. Design submittals shall not include flow from rainwater, storm sewers, streets or groundwater.

B. Operations that involve routine maintenance or the rehabilitation of existing sewer lines may not require a permit. In situations where existing sewer lines are undergoing routine maintenance, the existing sewer lines are being rehabilitated by constructing or installing replacement sewers, or the existing sewer lines are being refurbished by the installation of some type of sealant or sleeve inside the existing sewer line, a specific non-discharge permit is not required. The appropriate Regional Office must be notified prior to beginning rehabilitation work. These operations will be deemed permitted as long as; 1) all construction and installation conforms to the design criteria in the regulations and this manual, 2) new sources of wastewater flow are not being connected to the rehabilitated sewers, and 3) all replacements or newly constructed sewers are located in the same proximity (same general horizontal and vertical alignment) and are the same diameter as the existing sewers. If any of the criteria in this Paragraph are not being adhered to, the applicant must request a site-specific permit. Once the maintenance or rehabilitation activities are completed, a North Carolina Professional Engineer's certification (form provided by the Division) must be submitted to the appropriate Regional Supervisor for the completed work.

C. Gravity sewer collection systems which are greater than three miles in length and have a design flow greater than or equal to one MGD shall require an Environmental Assessment be completed and approved prior to submittal of the collection system for a permit.

II. DESIGN CAPACITY AND DESIGN FLOW

Sewer capacities shall be designed for the estimated ultimate tributary population including consideration given to the maximum anticipated capacity of institutions, industrial parks, etc. The capability of downstream sewers to accept future flow made tributary to the collection system shall be evaluated by the engineer. Where future relief sewers are planned, analysis of alternatives should accompany initial permit applications. Wastewater flow rates shall be determined in accordance with 15A NCAC 2H .0219.

III. DETAILS OF DESIGN AND CONSTRUCTION

A. Minimum Size

No public gravity sewer conveying wastewater shall be less than 8 inches in diameter. No private gravity sewer conveying wastewater shall be less than 6 inches in diameter.

B. Depth

Three (3) feet minimum cover shall be provided for all sewers unless ferrous material pipe is specified. Ferrous material pipe, or other pipe with proper bedding to develop design-supporting strength, shall be provided where sewers are subject to traffic bearing loads. Additional protection shall be provided for sewers that cannot be placed at a depth sufficient to prevent damage.

C. Buoyancy

Buoyancy of sewers shall be considered and flotation of the pipe shall be prevented with appropriate construction where high groundwater conditions are anticipated.

D. Slope

1. Minimum Slope

a. All sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second, based on Manning's formula using an "n" value of 0.013. The following are the minimum slopes, which shall be provided; however, slopes greater than these are recommended.

b. Minimum Slopes:

Diameter of Pipe (Inches)	Minimum Slope (Feet per 100 feet)
6	0.60
8	0.40
10	0.28
12	0.22
14	0.17
15	0.15
16	0.14
18	0.12
21	0.10
24	0.08
27	0.07
30	0.06
36	0.05

c. Minimum Flow Depths

Sewers shall be designed flowing half full at the average daily flow.

2. Velocity Calculations for Gravity Sewers

Manning's Equation (Gravity):

$$V = \frac{1.486}{n} \times (R_H)^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

Where: V = velocity in feet/second

n = coefficient of roughness (Manning), n = 0.013

S = slope of energy grade line, ft/ft

R_H = hydraulic radius, ft

= $\frac{\text{cross-sectional area of flow } (ft^2)}{\text{wetted perimeter}}$ or $\frac{\text{diameter (in.)}}{48}$

3. Minimize Solids Deposition

The pipe diameter and slope shall be selected to obtain the greatest practical velocities to minimize settling problems. Designs must include a minimum scouring velocity of 2 feet per second. Sewers shall not be oversized to justify using flatter slopes. If the minimum scouring velocity cannot be maintained during initial operation prior to the design flow capacities being reached, the ability to periodically flush the system shall be required.

4. Slope Between Manholes

Sewers shall be laid with uniform slope between manholes.

5. High Velocity Protection

Where design velocities are projected to be greater than 15 feet per second, the sewers and manholes shall be protected against displacement by erosion and impact. For velocities greater than 20 feet per second, erosion control measures shall be documented on the "Record Drawings" and in the Engineer's Certification.

6. Steep Slope Protection

Sewers on 20 percent slopes or greater shall be anchored securely with concrete, or equal, with the anchors spaced as follows:

a. Not greater than 36 feet center to center on grades 21% to 35%;

b. Not greater than 24 feet center to center on grades 35% to 50 %; and

c. Not greater than 16 feet center to center on grades 50% and over.

E. <u>Alignment</u>

1. All sewers shall have straight alignment between manholes. Straight alignment shall be checked by either using a laser or lamping.

F. <u>Changes in Pipe Size</u>

c. When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient.

2. Sewer extensions shall be designed for projected flows even when the diameter of the receiving sewer is less than the diameter of the proposed extension at a manhole, with special consideration of an appropriate flow channel to minimize turbulence when there is a change in sewer size. Justification shall be provided with the certification of completion and as constructed plans indicating that the capacity of the downstream sewer will not be overloaded by the proposed upstream installation. The Division may require a schedule for construction of future downstream sewer relief.

G. Materials

1. The pipe material selected shall be adapted to local conditions, such as: character of industrial wastes, possibility of septicity, soil characteristics, exceptionally heavy external loadings, abrasion, corrosion, and similar problems. Consideration shall also be given to pipes and compression joint materials subjected to corrosive or solvent wastes.

The specifications shall stipulate: the pipe interior, sealing surfaces, fittings and other accessories shall be kept clean; pipe bundles be stored on flat surfaces with uniform support; stored pipe shall be protected from prolonged exposure (six months or more) to sunlight with a suitable covering (canvas or other opaque material); air circulation shall be provided under any covering; gaskets shall not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight; consultation with the manufacturers shall be undertaken for specific storage and handling recommendations.

2. Suitable couplings complying with ASTM specifications shall be used for joining dissimilar materials which take into account the leakage limitations on these joints.

3. All sewers shall be designed to prevent damage from superimposed live, dead, and frost induced loads. Proper allowance for loads on the sewer shall be made because of soil and potential groundwater conditions, as well as the width and depth of trench. Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability. See ASTM D 2321 OR ASTM C 12 when appropriate.

4. For new pipe materials for which ASTM standards have not been established, the design engineer shall provide complete pipe specifications and installation specifications developed on the basis of criteria adequately documented and certified in writing by the pipe manufacturer to be satisfactory for the specific detailed plans.

H. Installation

1. Standards

Installation specifications shall contain appropriate requirements based on the criteria, standards, and requirements established by the construction industry in its technical publications. Requirements shall be set forth in the construction specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations and future tapping, nor create excessive side fill pressures on the pipe, nor seriously impair flow capacity.

2. Trenching

a. The width of the trench shall be ample to allow the pipe to be laid and jointed properly and to allow the bedding and haunching to be placed and compacted to adequately support the pipe. The trench sides shall be kept as nearly vertical as possible. When wider trenches are specified, appropriate bedding class and pipe strength shall be used.

b. In unsupported, unstable soil the size and stiffness of the pipe, stiffness of the embedment and insitu soil and depth of cover shall be considered in determining the minimum trench width necessary to adequately support the pipe.

c. Ledge rock, boulders, and large stones shall be removed to provide a minimum clearance of 4 inches below and on each side of all pipe(s).

3. Siltation and Erosion

Construction methods that will minimize siltation and erosion shall be employed. The design engineer shall include in the project specifications the method(s) to be employed in the construction of sewers. Such methods shall provide adequate control of siltation and erosion by limiting unnecessary excavation, disturbing or uprooting trees and vegetation, dumping of soil or debris, or pumping silt-laden water into streams. Specifications shall require that cleanup, grading, seeding, and planting or restoration of all work areas shall begin immediately. Exposed areas shall not remain unprotected for more than seven days unless a sedimentation and erosion control plan is submitted to, and approved by, the Division of Land Resources.

4. Bedding, Haunching, and Initial Backfill

a. Bedding Classes A, B, C or crushed stone as described in ASTM C 12 shall be used and carefully compacted for all rigid pipe provided the proper strength pipe is used with the specified bedding to support the anticipated load, based on the type soil encountered and potential ground water conditions.

b. Embedment materials, Classes I, II, or III, as described in ASTM D 2321, for bedding, haunching and initial backfill, shall be used and carefully compacted for all flexible pipe provided the proper strength pipe is used with the specified bedding to support the anticipated load, based on the type soil encountered and potential groundwater conditions.

c. All water entering the excavations or other parts of the work shall be removed until all the work has been completed. No sanitary sewer shall be used for the disposal of trench water, unless specifically approved by the engineer, and then only if the trench water does not ultimately arrive at existing pumping or wastewater treatment facilities.

5. Final Backfill

a. Final backfill shall be of a suitable material removed from excavation except where other material is specified. Debris, frozen material, large clods or stones, organic matter, or other unstable materials shall not be used for final backfill within 2 feet of the top of the pipe. Stones used in backfills shall not be greater than 6 inches along any axis.

b. Final backfill shall be placed in such a manner as not to disturb the alignment of the pipe.

6. Deflection Test

a. Deflection tests shall be performed on all pipe installations. The test shall be conducted after the final backfill has been in place at least 30 days to permit stabilization of the soil-pipe system. As an alternative to waiting 30 days to permit stabilization of the soil-pipe system, the Division will accept certification from a soil-testing firm verifying that the backfill of the trench has been compacted to at least 95% maximum density.

b. No pipe shall exceed a deflection of 5 percent. If deflection exceeds 5 percent, replacement or correction shall be accomplished in accordance with requirements in the approved specifications.

c. The rigid ball or mandrel used for the deflection test shall have a diameter not less than 95 percent of the base inside diameter or average inside diameter of the pipe depending on which is specified in the ASTM Specification, to which the pipe is manufactured. The pipe shall be measured in compliance with ASTM D 2122 Standard Test Method of Determining Dimensions of Thermoplastic Pipe and Fittings. The test shall be performed without mechanical pulling devices.

I. <u>Joints and Infiltration</u>

1. Joints

The installation of joints and the materials used shall be included in the specifications. Sewer joints shall be designed to minimize infiltration and to inhibit the entrance of roots throughout the life of the system.

2. Leakage Tests

Leakage tests shall be specified. This may include appropriate water or low pressure air testing. The testing methods selected should take into consideration the range in groundwater elevations during the test and anticipated during the design life of the sewer.

3. Water (Hydrostatic) Test

The leakage exfiltration or infiltration shall not exceed 100 gallons per inch of pipe diameter per mile per day for any section of the system. An exfiltration or infiltration test shall be performed with a minimum positive head of 2 feet.

4. Air Test

The air test shall, as a minimum, conform to the test procedure described in ASTM C-828-86 for clay pipe, ASTM C 924 for concrete pipe, and for other materials, test procedures approved by the Division of Environmental Management.

IV. MANHOLES

A. Location

1. Manholes shall be installed: at the end of each line, at all changes in grade, size, or alignment, at all intersections, and at distances not greater than 425 feet for all sewers unless documentation and specifications can be provided by the owner/authority stating they have the capability to perform routine cleaning and maintenance on the sewer at distances greater than 425 feet.

2. Cleanouts may be used in lieu of manholes for 6-inch private sewer lines with distances between cleanouts not to exceed 100 feet.

B. Drop Type

1. A drop pipe shall be provided for a sewer entering a manhole at an elevation greater than 2.5 feet (30 inches) above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 2.5 feet (30 inches), the invert shall be filleted to prevent solids deposition.

2. Drop manholes should be constructed with an outside drop connection. Inside drop connections (when necessary) shall be secured to the interior wall of the manhole and access shall be provided for cleaning.

3. Due to the unequal earth pressures that would result from the backfilling operation in the vicinity of the manhole, the entire outside drop connection shall be encased in concrete or ferrous pipe specified with necessary blocking for drop connection.

C. Diameter

1. The minimum diameter of manholes shall be 4 feet (48 inches). Larger diameters are preferable for large diameter sewers. A minimum access diameter of 22 inches shall be provided.

2. The minimum diameter for inside drop manholes shall be 5 feet (60 inches).

D. Flow Channel

1. The flow channel straight through a manhole shall be made to conform as closely as possible in shape, and slope to that of the connecting sewers. The channel walls shall be formed or shaped to three quarters (3/4) of the height of the crown of the outlet sewer in such a manner to not obstruct maintenance, inspection or flow in the sewers.

2. When curved flow channels are specified in manholes, including branch inlets, minimum slopes should be increased to maintain acceptable velocities.

E. Bench

A bench shall be provided on each side of any manhole channel when the pipe diameter(s) are less than the manhole diameter. The bench shall be sloped no less than 1/2 inch per foot (4 percent). The invert elevation of any lateral sewer, service connection, or drop manhole pipe shall be above the bench surface elevation. No invert shall be located directly on the surface of the bench.

F. Water tightness

1. Manholes shall be pre-cast concrete or poured-in-place concrete. Manhole lift holes and grade adjustment rings shall be sealed with non-shrinking mortar or other material approved by the Division.

2. Inlet and outlet pipes shall be joined to the manhole with a gasketed flexible watertight connection or any watertight connection arrangement that allows differential settlement of the pipe and manhole wall to take place.

3. Watertight manhole covers are to be used wherever the manhole tops may be flooded by street runoff or high water. Locked manhole covers may be desirable in isolated easement locations or where vandalism may be a problem.

4. Manholes shall be designed for protection from the 100-year flood by either:

a. Manhole rims shall be 12 inches (1 foot) above the 100-year flood elevation or,

b. Manholes shall be watertight and vented 12 inches (1 foot) above the 100-year flood elevation. Manholes shall be vented every 1,000 feet or every other manhole, whichever is greater.

G. Buoyancy

Buoyancy shall be considered and flotation of the manholes shall be prevented with appropriate construction where high groundwater conditions are anticipated.

H. Inspection and Testing

The specifications shall include a requirement for inspection and testing for water tightness or damage prior to placing into service.

I. Corrosion Protection for Manholes

1. Where corrosive conditions due to septicity or other causes are anticipated, consideration shall be given to providing corrosion protection on the interior of the manholes.

2. Where high flow velocities are anticipated, the manholes shall be protected against displacement by erosion and impact.

V. SEWERS IN RELATION TO STREAMS AND OTHER WATER BODIES

A. Cover Depth

The top of all sewers entering or crossing streams shall be at a sufficient depth below the natural bottom of the streambed to protect the sewer line. The following cover requirements shall be met:

1. One foot of cover where the sewer is located in rock:

2. Three feet of cover in other material unless ferrous pipe is specified. In major streams, more than three feet of cover may be required; and

3. In paved stream channels, the top of the sewer line should be placed below the bottom of the channel pavement.

B. Horizontal Location

1. Sewers located along streams, lakes or impoundments, shall be located at least 10 feet outside of the stream bank or sufficiently removed there from to provide for future possible stream widening and to prevent siltation of the stream during construction.

2. A distance of 50 feet shall be maintained between sewers and water classified as WS-II, WS-III, B, SA, ORW, HQW, or SB (from normal high water [or tide elevation]).

C. Structures

The sewer outfalls, headwalls, manholes, gate boxes, or other structures shall be located so they do not interfere with the free discharge of flood flows of the stream.

D. Alignment

Sewers crossing streams shall be designed to cross the stream as nearly perpendicular to the stream flow as possible and shall be free from change in grade. Sewer systems shall be designed to minimize the number of stream crossings.

E. Materials

Sewers entering or crossing streams shall be constructed of ferrous material pipe with mechanical joints; otherwise they shall be constructed so they will remain watertight and free from changes in alignment or grade and tested to 150 psi. PVC pipe may be used where a minimum of three feet of cover can be maintained. Material used to backfill the trench shall be stone, coarse aggregate, washed gravel, or other materials which will not readily erode, cause siltation, damage pipe during placement, or corrode the pipe.

F. Aerial Crossings

1. Proper joint technology, such as flanged or restrained, adequate supports to prevent excessive flexion, or a combination of both shall be provided for all aerial pipe crossings. Supports shall be designed to prevent frost heave, overturning, and settlement.

2. Precautions against freezing, such as insulation and increased slope, shall be provided. Expansion jointing shall be provided between above ground and below ground sewers. Where buried sewers change to aerial sewers, special construction techniques shall be used to minimize heaving.

3. For aerial stream crossings, the impact of floodwaters and debris shall be considered. The bottom of the pipe should be placed no lower than the elevation of the 25-year flood. Ductile iron pipe with mechanical joints shall be required. In the event that the 25 year flood elevation can not be determined or the proposed gravity sewer must be placed below the 25 year flood elevation, a letter shall be provided by the applicant upon certification stating: "Regular and proper inspection and maintenance of the aerial crossing shall be provided to insure that the creek/stream flow is not impeded and that no damage will be caused to upstream or adjacent properties."

G. Anti-Seepage Collars

In areas where the sewer trench has the potential to drain wetlands, anti-seepage collars shall be installed. Please be advised, in these areas, a 401/404 permit may be required.

VI. PROTECTION OF POTABLE WATER SUPPLIES AND STORM SEWERS

A. Cross Connections Prohibited

There shall be no physical connections between a public or private potable water supply system and a sewer, or appurtenance thereto which would permit the passage of any wastewater or polluted water into the potable supply. No water pipe shall pass through or come into contact with any part of a sewer manhole.

B. Relation to Water Supply Sources

1. A distance of 100 feet shall be maintained between any private or public water supply source, including any WS-I waters or Class I or Class II impounded reservoirs used as a source of drinking water. If this minimum separation cannot be maintained, ferrous sewer pipe with joints equivalent to public water supply design standards and pressure tested to 150 psi to assure water tightness shall be used. The minimum separation shall however not be less than 25 feet from a private well or 50 feet from a public water supply well.

2. All existing waterworks units, such as basins, wells, or other treatment units, within 200 feet of the proposed sewer shall be shown on the engineering plans.

C. Relation to Water Mains and Storm Sewers

1. Horizontal and Vertical Separation

a. Sewers shall be laid at least 10 feet horizontally from any existing or proposed water main. The distance shall be measured edge to edge. In cases where it is not practical to maintain a 10 foot separation, the appropriate reviewing agency (DEM or DEH) may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the sewer closer to a water main, provided that the water main is in a separate trench or on an undisturbed earth shelf located on one side of the sewer and at an elevation so the bottom of the water main is at least 18 inches above the top of the sewer.

b. If it is impossible to obtain proper horizontal and vertical separation as described above or anytime the sewer is over the water main, both the water main and sewer must be constructed of ferrous pipe complying with public water supply design standards and be pressure tested to 150 psi to assure water tightness before backfilling.

c. A 12-inch vertical separation shall be provided between storm sewer and sanitary sewer lines or ferrous pipe specified.

2. Crossings

a. Sewers crossing water mains shall be laid to provide a minimum vertical distance of 18 inches between the outside of the water main and the outside of the sewer. The crossing shall be arranged so that the sewer joints will be equidistant and as far as possible from the water main joints.

b. When it is impossible to obtain proper horizontal and vertical separation as stipulated above, one of the following methods must be specified:

i. The sewer shall be designed and constructed of ferrous pipe and shall be pressure tested at 150 psi to assure water tightness prior to backfilling, or

ii. Either the water main or the sewer line may be encased in a watertight carrier pipe, which extends 10 feet on both sides of the crossing, measured perpendicular to the water main. The carrier pipe shall be of materials approved by the regulatory agency for use in water main construction.