CHAPTER 20
DESIGN OF CONVENTIONAL GRAVITY SEWERS

21. DESIGN CAPACITY

___ In general, sewer capacities should be designed for the estimated ultimate tributary population, or for the design population identified in the facilities plan, except in considering parts of the systems that can be readily increased in capacity. Similarly, consideration should be given to the maximum anticipated capacity of institutions, industrial parks, etc.

___ Combined wastewater and stormwater sewers shall not be approved.

In determining the required capacities of sanitary sewers consider the following factors:

___ a. Maximum hourly domestic sewage flow;

___ b. Additional maximum sewage or waste flow from industrial plants;

___ c. Inflow and groundwater infiltration;

___ d. Topography of area;

___ e. Location of sewage treatment plant;

___ f. Depth of excavation; and

___ g. Pumping requirements.

22. DESIGN FLOW

22.1 Per Capita Flow

___ New sewer systems shall be designed on the basis of an average daily per capita flow of sewage of 70 to 120 gallons per day. This range is assumed to consist of 70 gpd of domestic sewage plus 0 to 50 gpd of infiltration. The amount of infiltration will depend on the type, size, and length of the sewer system. Different figures for domestic sewage and infiltration may be used if supported by water use records and flow data. Commercial and industrial flows shall be included as necessary.

22.2 Peak Design Flow

Sanitary sewers shall be designed on a peak design flow basis using one of the following methods. Use of other values for peak design flow will be considered if justified on the basis of adequate documentation.

a. The ratio of peak to average daily flow as determined from the following formula:

$$Q_p/Q_a = \frac{18+ (P)^{1/2}}{4+ (P)^{1/2}}$$ where P = the population in thousands, or;

b. Values established from an infiltration/inflow study acceptable to the Department.

23. DETAILS OF DESIGN AND CONSTRUCTION

23.1 Minimum Size

___ No gravity sewer conveying raw sewage shall be less than 8 inches (20 cm) in diameter. House laterals (service lines) shall be no less than 4 inches in diameter. Exceptions are given in Chapter 20A.

23.2 Depth

___ In general, sewer shall be sufficiently deep to be protected from surface loading and to receive sewage from basements and to prevent freezing. The minimum depth shall be 3 feet. Shallower depths may be allowed if structural design or other conditions warrant.

23.3 Slope

23.3.1

___ All sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second (0.61 m/s), based on Manning's formula using an "n" value of 0.013. The following are the minimum slopes that should be provided; however, slopes greater than these are desirable:

Sewer Size (diameter)	Minimum Slope in Feet Per 100 Feet (m/100 m)(%)
8 inch (20 cm)	0.34
9 inch (23 cm)	0.29
10 inch (25 cm)	0.25
12 inch (30 cm)	0.20
14 inch (36 cm)	0.16
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)	0.066
30 inch (76 cm)	0.058
36 inch (91 cm)	0.045

23.3.2

___ Slopes slightly less than those required for the 2.0 fps (0.61 m/s) velocity, when flowing full, may be permitted. Such decreased slopes will only be considered where the depth of flow will be at least 0.3 of the pipe diameter for design average flow. Whenever such decreased slopes are selected, the design engineer must furnish with his report his computations of the anticipated flow velocities of average and daily or weekly peak flow rates. The pipe diameter and slope shall be selected to obtain the greatest practical velocities to minimize settling problems. The operating authority of the sewer system will give written assurance to the Department that any additional sewer maintenance required by reduced slopes will be provided.

___ A decreased slope will also be considered when the sewer is being laid between existing manholes and the depth cannot be changed due to the depth of the collection system downstream.

23.3.3

___ Sewers shall be laid with uniform slope between manholes.

23.3.4

___ Where velocities greater than 15 fps (4.6 m/s) are attained, special provision shall be made to protect against displacement by erosion and shock.

23.3.5

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

a. Not over 36 feet (11 m) center to center on grades 20% and up to 35%;

b. Not over 24 feet (7.3 m) center to center on grades 35% and up to 50%; and

c. Not over 16 feet (4.9 m) center on grades 50% and over.

23.4 Alignment

___ Sewers 24 inches (61 cm) or smaller shall be laid with straight alignment between manholes. The alignment shall be checked by either using a laser beam or lamping.

Curvilinear alignment of sewers larger than 24 inches may be considered on a case by case basis provided that compression joints are specified and ASTM or the specific pipe manufacturer's maximum allowable joint deflection limits are not exceeded. When curvilinear sewers are proposed, minimum slopes indicated in paragraph 23.3.1 must be increased (including manholes) accordingly to provide a recommended minimum velocity of 2.0 fps when flowing full.

23.5 Changes in Pipe Size

___ When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. An approximate method for securing these results is to place the 0.8 depth point of both sewers at the same elevation.

___ Sewer extensions should be designed for projected flows even when the diameter of the receiving sewer is less than the diameter of the proposed extension. The Department may require a schedule for future downstream sewer relief.

23.6 Materials

___ Any generally accepted material for sewers will be given consideration, but the material selected should 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. For new pipe materials for which ASTM or other generally acceptable industry standards have not been established, the design engineer shall provide complete pipe 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.

___ All sewers shall be designed to prevent damage from superimposed live and dead 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 to withstand extraordinary superimposed loading, special bedding, concrete cradle or special construction may be used. See ASTM D2321 or C12 when appropriate.

23.7 Installation

23.7.1 Standards

___ Installation specifications shall contain appropriate requirements based on the criteria, standards and requirements established by industry in its technical publications. Requirements shall be set forth in the 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 or ovalation of the pipe, nor seriously impair flow capacity.

23.7.2 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, haunching, and backfill to be placed and compacted as needed. The trench sides shall be kept as nearly vertical as possible. When wider trenches are dug, appropriate bedding class and pipe strength shall be used.

___ b. Ledge rock, boulders, and large stones shall be removed to provide a minimum clearance of 4 inches (10 cm) below and on each side of all pipe(s).

23.7.3 Bedding

___ a. Bedding equal to Classes A, B, or C, or crushed stone as described in ASTM C12 shall be used for all rigid pipe provided the proper strength pipe is used with the specified bedding to support the anticipated load.

___ b. Material equal to Classes I, II, or III, as described in ASTM D2321 shall be used for all flexible pipe bedding, haunching and initial backfill provided the proper strength pipe is used with the specified bedding to support the anticipated load.

___ c. All water entering the excavation 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 such water.

23.7.4 Backfill

___ a. Backfill shall be of a suitable material removed from excavation except where other suitable material is specified. Debris, frozen material, large clods or stone, organic matter, or other unstable materials shall not be used for backfill within 2 feet (0.61 m) of the top of the pipe.

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

23.7.5 Deflection Test

___ a. Deflection tests shall be performed on all flexible pipe. The test shall be conducted after the final backfill has been in place at least 30 days.

___ b. No pipe shall exceed a deflection of 5%.

___ c. If the deflection test is to be run using a rigid ball or mandrel, it shall have a diameter equal to 95% of the inside diameter of the pipe. The test shall be performed without mechanical pulling devices.

23.8 Joints and Infiltration

23.8.1 Joints

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

23.8.2 Leakage Tests

___ Leakage tests shall be specified. These may include appropriate water or low pressure air testing. The leakage outward or inward (exfiltration or infiltration) shall not exceed 200 gallons per inch of pipe diameter per mile per day (0.19 m^3/cm of pipe dia./km/day) for any section of the system between consecutive manholes. An exfiltration or infiltration test shall be performed with a minimum positive head of 2 feet (0.61 m). The air test, if used, shall, as a minimum, conform to the test procedure described in an appropriate ASTM or equivalent standard. The testing methods selected should also take into consideration the range in groundwater elevations projected (if more than the minimum positive head of two feet), and the situation during the test.

24. MANHOLES

24.1 Location

___ 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 400 feet (120 m) for sewer 15 inches (38 cm) and smaller, and 500 feet (150 m) for sewer 18 inches (46 cm) to 30 inches (76 cm), except that distances up to 600 feet (180 m) may be approved in cases where adequate modern cleaning equipment for such spacing is provided. Greater spacing may be permitted in larger sewers. Cleanouts may be used only for special conditions and shall not be substituted for manholes nor installed at the end of the laterals greater than 150 feet (46 m) in length.

24.2 Drop Type

___ A drop pipe should be provided for a sewer entering a manhole at elevations of 24 inches (61 cm) or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches (61 cm), the invert should be filleted to prevent solids deposition.

___ 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 provide access for cleaning.

___ The entire outside drop connection shall be encased in concrete, or other reasonable stabilization methods such as ductile iron pipe and granular backfill shall be used.

24.3 Diameter

___ The minimum diameter of manholes shall be 48 inches (1.22 m); larger diameters are preferable for large diameter sewers. 40 inch diameter is acceptable for rehabilitated manholes. A minimum access diameter of 22 inches (56 cm) shall be provided.

24.4 Flow Channel

___ The flow channel through manholes should be made to conform in shape and slope to that of the sewers.

24.5 Watertightness

___ Manholes shall be of the pre-cast concrete or poured-in-place concrete type and shall be waterproofed. Plastic, fiberglass, or similar manholes are also acceptable, if properly installed. Brick, masonry, or other similar types shall not be used.

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

___ Watertight manhole covers shall be used wherever the manhole tops may be flooded by street runoff or high water up to the 100 year flood elevation. Watertight covers may also be necessary in certain cases where sudden surcharging occurs and where such use would not cause an overflow elsewhere. Locked manhole covers may be desirable in isolated easement locations or where vandalism may be a problem.

___ The specifications shall include a requirement for inspection of manholes for watertightness prior to placing into service.

24.6 Electrical

___ Electrical equipment installed or used in manholes shall conform to paragraph 32.3.5.

25. INVERTED SIPHONS

___ Inverted siphons should have not fewer than 2 barrels, with a minimum pipe diameter of 6 inches (15 cm) and shall be provided with necessary appurtenances for convenient flushing and maintenance. The inlet and discharge structures shall have adequate clearances for rodding; and in general, sufficient head shall be provided and pipe sizes selected to secure velocities of at least 3.0 fps (0.92 m/s) for average flows. The inlet and outlet details shall be so arranged that the normal flow is diverted to 1 barrel, and that either barrel may be taken out of service for cleaning. The vertical alignment should permit cleaning and maintenance.

26. SEWERS IN RELATION TO STREAMS

26.1 Location of Sewers on Streams

26.1.1 Cover Depth

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

a. One foot (0.3 m) of cover is required where the sewer is located in rock;

b. Three feet (0.9 m) of cover is required in other material. In major streams, more than three feet (0.9m) of cover may be required, and;

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

Less cover will be approved only if the pipe is properly protected and the proposed sewer crossing will not interfere with any anticipated future modifications to the stream channel. Reasons for specifying less cover should be given.

26.1.2 Horizontal Location

___ Sewers located along streams shall be located outside of the stream bed and sufficiently removed therefrom (minimum 30 feet recommended) to provide for future possible stream widening and to prevent pollution by siltation during construction. Department approved BMPs shall be used where needed.

26.1.3 Structures

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

26.1.4 Alignment

___ Sewers crossing streams should be designed to cross the stream as nearly perpendicular to the stream flow as possible. Sewer systems shall be designed to minimize the number of stream crossings.

26.2 Construction

26.2.1 Materials

___ Sewers entering or crossing streams shall be constructed of cast or ductile iron pipe with mechanical joints; otherwise they shall be encased and constructed so they will remain watertight and free from changes in alignment under flood/high flow conditions.

Material used to backfill the trench shall be stone, coarse aggregate, washed gravel, or other materials that will not cause siltation.

26.2.2 Siltation and Erosion

___ Construction methods that will minimize siltation and erosion in accordance with the Department's list of approved BMPs shall be employed. The design engineer shall include in the project specifications the method(s) to be employed in the construction of sewers in or near streams to provide adequate control of siltation and erosion. Specifications shall require that cleanup, grading, seeding, and planting or restoration of all work areas shall begin immediately. Exposed areas shall not remain unprotected. Excavated material shall be properly stockpiled (on the uphill side of the trench) so as to minimize environmental impacts. All such work shall be specified to meet the regulatory requirements.

27. AERIAL CROSSINGS

___ Support shall be provided for all joints in pipes utilized for aerial crossings. The supports shall be designed to prevent frost heave, overturning and settlement.

___ Precautions against freezing, such as insulation and increased slope, shall be provided. Expansion jointing shall be provided between above-ground and below-ground sewers.

___ For aerial stream crossings, the impact of flood waters and debris shall be considered. The bottom of the pipe should be placed no lower than the elevation of the 50-year flood, or no less than 3 feet from the stream bottom.

28. PROTECTION OF WATER SUPPLIES (refer also to Recommended Standards for Water Works)

28.1 Water Supply Interconnections

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

28.2 Relation to Water Works Structures

___ While no general statement can be made to cover all conditions, it is generally recognized that sewers shall meet the requirements of the appropriate water works reviewing agency with respect to minimum distances from public water supply wells or other water supply sources and structures.

28.3 Relation to Water Mains

___ **Sections 28.3.1, 28.3.2, 28.3.3, and 37.9 herein shall be included in the specifications.**

28.3.1 Horizontal Separation

__ Sewers shall be laid at least 10 feet (3.0 m) 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 ten foot separation, the Department 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 (46 cm) above the top of the sewer.

28.3.2 Crossings

___ Sewers crossing water mains shall be laid to provide a minimum vertical distance of 18 inches (46 cm) 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.

Where a water main crosses under a sewer, adequate structural support shall be provided for the sewer to prevent damage to the water main. Where a water main crosses under a sewer, either the water main or the sewer shall be ductile iron or shall be encased in ductile iron or concrete for a minimum of one full joint length on each side of the crossing, **and** the requirements of Section 28.3.3 shall be met, regardless of the clearance distances.

28.3.3 Special Conditions

___ When it is impossible to obtain proper horizontal and vertical separation as stipulated above, the sewer shall be designed and constructed equal to water pipe, and shall be pressure tested at 150 p.s.i. to assure watertightness prior to backfilling.

29. Sewer Rehabilitation

Sewer rehabilitation should be done in accordance with Existing Sewer Evaluation and Rehabilitation (1983; Water Environment Federation Manual of Practice No. FD-6), Sewer System Infrastructure Analysis and Rehabilitation (1991; EPA/625/6-91/030), other appropriate references, standards, or accepted practices. Replacement shall be done in accordance with the appropriate chapter for new sewers, with exceptions being made as necessary to conform to existing facilities.