NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

Minimum Design Criteria for the permitting of Gravity Sewers

Adopted by the Division of Water Quality on February 12, 1996

Updated to 15A NCAC 2T Regulations on March 2008

1,400 copies of this document were printed at a cost of $281.96, or $0.201 per copy.

Gravity Sewer Minimum Design Criteria

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, a site specific permit must be requested by the applicant. 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 2T .0114.

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
= cross-sectional area of flow (ft^2) or diameter (in.)
wetted perimeter 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 can not 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. Alignment

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

F. Changes In Pipe Size

1. 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 and ovalation of 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. Joints and Infiltration

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. Watertightness

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 24 inches (2 foot) above the 100-year flood elevation or,

   b. Manholes shall be watertight and vented 24 inches (2 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 watertightness 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 stream bed 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 (unless subject to B.2 of this section) or sufficiently removed therefrom 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 for water classified WS (except WS-I or WS-V), B, SA, ORW, HQW, or SB from normal high water (or tide elevation) and wetlands.

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 flood waters 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 can not be maintained, ferrous sewer pipe with joints equivalent to public water supply design standards and pressure tested to 150 psi to assure watertightness, 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, DWQ 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 watertightness before backfilling.

c. A 24 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.