9-10.1 GENERAL. Drainage structures are located and designed to adequately handle runoff across improvements and to handle runoff from the improvement. The location of culverts is covered in Chapter IV of this manual. The hydraulic design of culverts and other drainage facilities is discussed in preceding sections. In this section criteria pertaining to the selection of culvert and storm sewer material and appurtenances are presented.

9-10.2 TYPES. Permissible culvert pipe types are separated into groups as listed in Table 9-10.1.

TABLE 9-10.1
PERMISSIBLE PIPE TYPES BY GROUP

Group A (ADT > 3500)	Group B (ADT ≤ 3500)	Group C (Other Applications)
Reinforced Concrete Vitrified Clay	Group A Pipe Polymer Coated Corrugated Metal Corrugated Aluminum Alloy Corrugated Polyethylene Corrugated PVC (Polyvinyl Chloride) Corrugated Aluminum-Coated Steel	Group A Pipe Group B Pipe Corrugated Zinc-Coated Steel Corrugated Bituminous-Coated Steel

In general, there are two methods of specifying the permissible culvert types dependent upon the design ADT. For most applications, a group of culvert types is specified as described in succeeding sections. For special situations, a qualified pipe group may be specified, as described in Subsection 9-10.2(5). The final selection of the structure type is based on requirements in the standard specifications, on good engineering judgment, and economy with consideration of service and maintenance costs.

9-10.2 (1) ROADWAYS WITH ADT > 3500. For roadways with ADT > 3500, reinforced concrete pipe will be specified for crossroad structures, except for the following conditions:

- Reinforced concrete box culverts are specified when it is more economical to build the reinforced box culvert than it is to provide an equivalent pipe culvert.
- Vitrified clay pipe (extra strength) is specified when the purpose of the culvert is a sanitary sewer.
- Group C pipe should be specified for the portion of median outlet pipes outside the edge of pavement where such pipes are located on high fills requiring a break in flowline grade. Details for such installations are illustrated in Figure 9-10.1.
- Group B pipe is specified to drain drop inlets into crossroad drainage structures when such installation necessitates a steep flowline grade and when the pipe will not extend under the pavement or in other non-traffic areas, such as behind guardrail at median piers.

Pipes of 12 in. and 15 in. [300 mm and 375 mm] are not used except as outlets from drop inlets and in storm sewer systems.

The requirements for using reinforced concrete pipe or vitrified clay pipe for structures may be waived if conditions warrant, such as poor structure foundation conditions, high fills, simplification of handling traffic, etc.

9-10.2 (2) ROADWAYS WITH ADT ≤ 3500. For roadways with ADT ≤ 3500, Group B pipe should be specified for crossroad structures. The hydraulic design computations for Group B pipe should be performed for both corrugated and smooth wall pipe. The pay item for the corrugated pipe size should be used. At each pipe location on the plans, both the corrugated and equivalent smooth wall diameters should be shown as in the following examples:

36” Group B Pipe (30”)
36” Group B Pipe (36”)

The equivalent smooth wall diameter must be shown whether the size is equal to or less than the corrugated size. The standard specifications for pipe and end sections describe the nomenclature for this procedure. Some exceptions to specifying Group B on the plans are the following:

- Reinforced concrete box culverts should be considered for pipes larger than 60 in. [1500 mm] in diameter.
- Reinforced concrete pipe, corrugated polyethylene pipe or polyvinyl chloride pipe should be specified for locations where high acidity or alkalinity of soils or waters or other abrasive or corrosive elements are present.
- Corrugated metallic-coated steel pipe-arch structures in sizes B-5 and larger may be specified where necessary because of limited allowable structure height. A battery of round pipes or a single elliptical reinforced concrete pipe may be considered in lieu of B-1 through B-4 corrugated metallic-coated steel pipe-arch structures.
- Elliptical reinforced concrete pipe may be specified in special cases, usually for storm sewers, where necessary because of limited allowable structure height.

Pipes of 12 in. and 15 in. [300 mm and 375 mm] are not used for crossroad culverts, except where the use of an 18 in. [450 mm] pipe will create an unsightly or impracticable drainage condition.

Corrugated polyethylene pipe (Type S) and polyvinyl chloride pipe are double walled, full circular cross section pipes, with an outer corrugated wall and a smooth inner liner. Only 12 to 60 in. [300 to 1500 mm] diameter sizes of corrugated polyethylene, or 12 to 48 in. [300 to 1200 mm] diameter sizes of PVC pipe, are approved for use on highway projects. Corrugations may be either annular or helical. Headwall protection is provided by means of a beveled pipe end treatment, safety slope end section, or metal or concrete flared end sections. Section 728 of the Standard Specifications require all PVC pipes to have an end section of one of the other Group B pipe materials to protect from ultraviolet degradation where the end of the pipe is exposed.

9-10.2 (3) ROADWAYS AND ROADSIDE APPLICATIONS WITH ADT < 1700. For roadways, side roads, and entrances with ADT < 1700 Group C pipe should be specified using the same method for corrugated and smooth wall Group B pipe as explained in Subsection 9-10.2(2).

9-10.2 (4) OTHER ROADWAY DRAINAGE STRUCTURES. Outer roadway drainage structures shall be selected by ADT as shown in Subsections 9-10.2 (1), (2) and (3). Continuous drainage structures extending under outer roadways are designed to the same standard as required for the portion of the structure under the main roadway. Since a continuous drainage structure usually increases the standard for the portion under the outer roadway, it is usually more economical to use independent structures. Where continuous structures are used, the runoff between the outer roadway and the main roadway is usually carried into the crossroad structure by drop inlets and pipe. Where the crossroad structure is a relatively small pipe, the drop inlet is constructed in the crossroad structure.

For drainage applications other than crossroad pipes, such as entrances, side roads and median drainage, Group C pipe may be specified.

Flared end sections or beveled pipe end treatment are specified at both ends of pipe structures 66 in. [1650 mm] or less in diameter. In special cases where low clearance exists and the structure is essentially at right angles on roads with less than 400 ADT, pipe arches with flared end sections may be specified.

9-10.2 (5) INSTALLATIONS FOR SPECIAL SITUATIONS. For installations on a project which normally would require a pipe group option, special conditions may exist which would justify the specifying of a qualified pipe group type. Justification for the selection of a qualified group pipe type include, but are not limited to, unstable foundation, high embankments, high erosive forces, highly abrasive or corrosive conditions, high fire hazard or other pertinent reasons. When any one or a combination of these factors exist, the culvert pipe type(s) best suited to resist such destructive forces is selected and specified by excluding pipe types from a specified group with a note on the plans or Job Special Provision. When a qualified pipe group is specified, the reasons for such selection are included in the letter of transmittal of the plans.

9-10.2 (6) STORM SEWERS. The permissible storm sewer type under the paved portion and any planned widening of roadways with ADT greater than 3500 is Group A pipe. All other applications of storm sewer are Group B pipe. The standard specifications require that corrugated metal culvert pipes used for storm sewer be smooth interior pipe types, so that consistent hydraulic characteristics may be assumed during design of the entire interconnected system.

9-10.2 (7) MULTIPLE OPENING INSTALLATIONS. Multiple opening structures, either boxes or pipes, are used only as required where the allowable structure height is restricted. Where multiple pipes are constructed, the pipes are separated by a distance of 1/2 their outside diameter, or a minimum of 1 ft. [300 mm], whichever is greater. Multiple box structures require that the plans be done by GHQ Bridge. Where such plans are required, GHQ Bridge is furnished with the culvert section, grade across the structure, typical section, and any other necessary information. For drainage areas of 1000 acres [400 ha] and under which require a structure designed by GHQ Bridge (multiple cell box, etc.), the district shall also make the necessary analysis and provide to GHQ Bridge the cell sizes, drainage area, the magnitude of the discharge, frequency, and design highwater for placement on the plans for each structure. A summary of responsibilities for multiple opening installations is contained in Table 9-10.2 below.

TABLE 9-10.2
RESPONSIBILITIES FOR MULTIPLE OPENING INSTALLATIONS

Drainage Area (Acres)	Number of Cells	Design Fill in Standard Plans	Responsible Entity		Bridge Number	Pay Items, Job Specials, Estimate
			Hydraulics	Final Plans		
<1000	1	Yes	District	District	No	Roadway
<1000	1	No	District	GHQ Bridge*	No	Roadway
<1000	2 or 3	N/A	District	GHQ Bridge	Yes	Bridge
>1000	1, 2 or 3	N/A	GHQ Bridge	GHQ Bridge	Yes	Bridge

*GHQ Bridge will produce a typical section for the District to use in roadway plans (including quantities per foot)

9-10.2 (8) TEMPORARY INSTALLATIONS. For bypasses, crossovers or other temporary installations, regardless of design ADT, Group C pipe should be specified using the same method as for corrugated and smooth wall Group B pipe as explained in Subsection 9-10.2(2).

9-10.3 BOX CULVERTS.

9-10.3 (1) STANDARD PLANS. Box culvert standard plans for all roadways are tabulated in the "Table of General Design Data" in Chapter IV.

9-10.3 (2) SHAPE. The most economical box culvert shape is approximately square, or a span slightly less than the height. Hydraulic factors will control the required shape of the box culvert. Box culvert sizes are indicated on the plans as "(span) x (height)".

9-10.4 PIPE HEADWALLS. Type S pipe headwalls may be used in lieu of drop inlets for median pipes for medians 60 ft. [18 m] wide or wider. Details for Type S pipe headwalls are shown on Standard Plan 604.05.

9-10.5 FLARED END SECTIONS. Flared end sections are required for crossroad pipe structures where the design traffic exceeds 750 vpd as tabulated in Section 4-04. Standard Plan 732.00 shows details for flared end sections. Where flared end sections are used on skewed pipe, the section is placed on the same line as the pipe, and the fill slope is warped to fit.

9-10.6 BEVELED PIPE END TREATMENT. Beveled pipe end treatment should be used on either corrugated metallic-coated steel pipes or corrugated polyethylene pipes 21 in. [525 mm] or less within the clear zone, as shown on Standard Plan 732.05. All beveled pipes use encasement. Corrugated metallic-coated steel pipe-arches are not beveled. In general, the bevel should not be flatter than 6:1 nor should the skew exceed 15 degrees. If these controls are exceeded, special consideration is given to the use of headwalls, riprap, or slope pavement to stiffen the structure against uneven loading from the embankment and the dynamic forces of the water. Proposed designs for

these conditions are submitted to the Support Center for approval.

9-10.7 FLOODGATES. Floodgates are specified for the outlet ends of pipes where required to prevent floodwater from backing through the pipe. Type 1 floodgates are specified for concrete pipes. Floodgates for concrete box structures will require a special item number and special provision. Type 2 floodgates are specified on corrugated metal pipes. The hydraulic head should be specified on the plans. If the hydraulic head is not specified on the plans, the height of fill above the pipe will be considered the hydraulic head. The number of floodgates is listed on the plans in accordance with pipe sizes.

9-10.8 SAFETY SLOPE END SECTIONS. All drainage pipes greater than 21 in. [525 mm] that fall within the clear zone are required to have safety slope end sections to eliminate the potential for vehicle snagging. End sections with two types of safety treatment for 4:1, 6:1 and 10:1 [1:4, 1:6 and 1:10] slopes are shown in Standard Plan 732.10. The 2B sheet should be used to indicate the slope of the end section and whether the end section is for a crossroad or parallel drainage structure.

9-10.9 REINFORCED CONCRETE PIPES.

9-10.9 (1) CLASSES OF STRENGTH. Reinforced concrete pipe is available and is specified on the plans as any one of five classes designated as Class I, II, III, IV or V. Class V pipe is the strongest design.

9-10.9 (2) USE OF VARIOUS CLASSES. Class I and Class II reinforced concrete pipe is used only for sewers in trenches outside roadbed and street limits. Class I pipe is provided in 60 to 108 in. [1500 to 2700 mm] diameters, inclusive, and is used in trenches 14 ft. [4.2 m] or less in depth. Class II pipe is provided in sizes from 12 to 108 in. [300 to 2700 mm] diameters, inclusive, and is used in trenches 18 ft. [5.4 m] or less in depth. Deeper trenches require Class III, IV or V pipe. Class III, IV or V pipe is used for all other drainage structures and are provided in sizes from 12 to 108 in. [300 to 2700 mm] diameters, inclusive.

9-10.9 (3) SELECTION OF PIPE CLASS AND INSTALLATION TYPE. In order to select the most economical class of reinforced concrete pipe, the existing soil conditions and fill height must be known. As shown on Standard Plan 726.30, a range of installation types can be used for each soil category; however, the proper installation type will correspond to the most economical, lowest class of pipe for a given fill height.

9-10.9 (4) SPECIFYING PIPE CLASS AND INSTALLATION TYPE ON PLANS. When the culvert pipe is shown on the plans as Group B or Group C, neither the class of reinforced concrete pipe nor the installation type is specified. When reinforced concrete pipe is specified directly on the plans, the class of reinforced concrete pipe and installation type is specified. For fill heights greater than 50 ft [15 m], reinforced concrete pipe is specified on the plans and the contractor is responsible for acquiring a special design. The Job Special Provision (JSP) "Special Design Reinforced Concrete Pipes and Flared End Sections" should be used. Contact the Bridge Liaison Engineer to obtain the D-load for insertion into the JSP. Approval of this special design is required from the Construction and Materials and the Bridge Divisions.

9-10.9 (5) PAYMENT FOR BEDDING. There is no direct payment or bid item for any bedding category; however, when an unsuitable bedding material exists, such as rock, payment for a specific bedding material needed for the installation type specified will be included in the Class 3 excavation.

9-10.10 FILL SETTLEMENTS. Fill settlements can seriously affect concrete box structures by opening joints and cracks sufficiently to allow the fill around the culvert to infiltrate into the culvert, thereby creating voids which can cause the roadbed to fail. In areas subject to large settlements, other structure types are considered or the box culvert is designed to withstand the settlement. This requires special box culvert designs and where box culverts are to be so designed, GHQ Bridge is furnished with full information, including culvert sections, grades, and anticipated settlement. Box culverts with special collars around joints have been successfully designed and used in areas subject to large fill settlements. Since such structures are expensive, it is sometimes more economical to use other structure types, such as flexible pipe.

9-10.11 CAMBER IN CULVERTS. Camber, as used in culvert design, is defined as the distance the central portion of crossroad structures is constructed above final flowline grade to compensate for anticipated settlement. Typical

details for cambering culverts are shown on Standard Plan 726.30. A structure designed with proper camber will settle to near flowline grade and elevation when it reaches final settlement. All culverts, except those on non-yielding foundations, are cambered at a minimum rate of 0.01 ft/ft [0.01 m/m] of overfill. Cambers of 0.1 ft. [30 mm] or less are not shown on plans. Where the fill settlement is known, culverts are designed with a camber equal to the anticipated settlement. The camber is shown on the culvert section at the roadbed shoulders by amount and flowline elevation as illustrated in Chapter IV.

9-10.12 CULVERT EXTENSIONS. All culvert extensions, both boxes and pipes, are extended with structures meeting current design requirements and standards, regardless of the type of standard of the existing structure. Pipe collars, as detailed on Standard Plan 604.40, are used to connect different types of pipe, and concrete pipe to concrete pipe. Box culverts are extended in accordance with details shown on Standard Plan 703.38 and Figure 9-10.2. Additional fills on existing box culverts may require a structural analysis of the existing structure by GHQ Bridge. If so, GHQ Bridge is furnished a print of the completed culvert section and the standard to which the existing structure was designed, if known, for their use in making the analysis.

9-10.13 OVERFILL HEIGHTS.

9-10.13 (1) MINIMUM FILL HEIGHTS. The minimum allowable fill or cover for all structures is 1 ft. [300 mm] at the shoulder line, with the following exceptions:

- The minimum fill for structural-plate pipe structures is tabulated in Figure 9-10.7.
- The minimum clearance from the top of structures to the bottom of bases is 6 in. [150 mm]. Exceptions are special box culverts designed to carry traffic on the top slab.
- For roadways with an ADT ≤ 1700, the minimum fill at the shoulder on the inside of superelevated curves is 18 in. [450 mm]
- Minimum fill heights for vitrified clay pipe (extra strength) are 4 ft. [1.2 m] for the 8 to 21 in. [200 to 525 mm] diameters and 3 ft. [0.9 m] for the 24 to 36 in. [600 to 900 mm] diameters.

Overfill heights which are less than those indicated as allowable for any one pipe type are not considered as justification for the elimination of specifying pipe types by "Group" provided other criteria are satisfactory.

9-10.13 (2) DESIGN FILL HEIGHTS. If any question develops regarding the fill heights to be used, and where the fill height is between values tabulated for design, the design fill height is taken to the next increment requiring the higher design. Pipe culverts are designed throughout their length for the maximum design condition except in the case of structural plate pipe.

A single fill height, representing the maximum height of fill over the culvert, can be used for most box culverts. Additional fill heights may be used for longer culverts, as shown in Figure 9-10.2. Generally, no more than two or three fill heights should be required. When multiple fill heights are used, consideration should be given to the potential for future widening of the roadbed.

Design fill heights for all pipe culverts specified by "Group" are shown on the "B" sheets. The allowable overfill heights for corrugated metal pipe-arches and structural plate pipes are tabulated in Figures 9-10.6 and 9-10.7, respectively. These overfill heights indicate both a minimum and a maximum, neither of which should be exceeded. The column headed "Standard" under gage for pipe-arches in Figure 9-10.6 refers to the gage required for the particular structure by the standard specifications. If overfill heights exceed the range shown, a different gage may be necessary and a special design is requested from the Support Center. A special design is also requested for pipe-arches of a size not listed in Figure 9-10.6. If a different gage is necessary, the plans specify the gage required. Where overfill heights are greater than shown in the figure, consideration should be given to round pipe. The gage for structural plate pipe is specified on the plans and may be changed throughout the length of the structure, where economically feasible, dependent on the fill heights in accordance with Figure 9-10.7.

9-10.13 (3) MAXIMUM FILL HEIGHTS.

9-10.13 (3) (a) BOX CULVERTS. If the fill height exceeds the values tabulated on the standard plans, special designs are required. In such cases, the district furnishes GHQ Bridge with a D-8 form and a print showing the

completed culvert section. A D-8 form is submitted for each section of the culvert requiring special design. GHQ Bridge adds the design data to the form and returns it to the district for their use in computing quantities. An example of a completed D-8 form is shown on Figure 9-10.3 (see also Chapter IV).

9-10.13 (3) (b) PIPES. Design overfill heights which are in excess of those indicated as allowable for any one pipe type are not considered as justification for the elimination of specifying pipe types by "Group" provided other criteria are satisfactory.

9-10.14 CULVERT GRADES. Crossroad drainage structures are usually placed on a grade equal to the natural ditch grade or the ditch grade in which the culvert is being placed. Controlling grades for storm and sanitary sewers are given in preceding sections. Erosion may be a problem at the outlet end of culverts on steep grades, which sometimes can be reduced by breaking the grade through the culvert. Grade breaks can be used to reduce structure excavation. Drop structures can be used at the inlet end of culverts to reduce the grade through the culvert. Drop structures are used with discretion because of the ponding upstream, and because of the unstable condition that may be created by the ponding. The grade for pipes for median drop inlets is broken in accordance with the requirements and details illustrated on Figure 9-10.1.

9-10.15 CULVERT LENGTHS. Culvert lengths are determined graphically by scaling from the culvert sections. The lengths are obtained by intersection of the structure with slope lines as shown on the culvert standard plans, and as described in the following sections. Precise lengths are not computed. In questionable cases a longer length is used. Skewed slopes used for culvert sections are shown on Figure 9-10.4. Intermediate values are interpolated.

9-10.15 (1) BOX CULVERTS. The length of box culverts is the distance between headwalls, and is scaled to the next higher 1.0 ft. [0.5 m]. Headwalls are designed sloped along the flowline grade. Box culverts over 75 ft. [22.5 m] long, and extensions, are built in sections, and the sections are designed to meet the requirements shown on Figure 9-10.2. The minimum length for box culverts is 2 ft. [0.5 m] greater than the roadbed width measured normal to the centerline of the roadbed.

9-10.15 (2) PIPES. The length of pipe culverts with headwalls is 2 ft. [0.5 m] longer than the distance between headwalls. Pipe headwalls are designed on a flat grade, regardless of the grade of the pipe. The length of pipe culverts not beveled and without headwalls is the distance between the slope lines at the flowline. Corrugated metallic-coated steel pipe lengths are scaled to the next higher even foot [0.5 m]. Other pipe lengths are scaled to the next higher 1.0 ft. [0.5 m]. The length of corrugated metallic-coated steel pipes with beveled ends is 2 ft. [0.5 m] longer than the distance between the intersection of the slope lines and the centerline of the pipe scaled to the next higher even foot [0.5 m]. Pipe bends and special connections are not listed as a pay item on the plans. The plans should include notes to the effect that such items are required and that their costs are included in other items. The plans include, usually on the culvert sections, sufficient dimensions and detail to fabricate pipe with bends or special connections.

9-10.16 EXCAVATION FOR STRUCTURES. Excavation quantities for structures, when measured, are calculated in accordance with details shown in Figure 9-10.5, supplemented by Figure 9-10.1 and applicable standard plans.

9-10.16 (1) CLASS 3 EXCAVATION. Class 3 Excavation applies to excavation for pipe installations such as sewers, utilities, pipe culverts, drop inlets, and manholes. According to Standard Specification Sections 725, 726, 728 and 730, no direct payment is made for trench excavation and backfilling for crossroad pipe culvert installation. When trenching is required for storm sewer, utility, sanitary sewer, or retrofit crossroad culvert installation, Class 3 Excavation quantities are calculated and included with the pay item (see Standard Specification Sec 206).

9-10.16 (2) CLASS 4 EXCAVATION. Class 4 Excavation applies to excavation for box culverts, small retaining walls and other miscellaneous structures. Standard Specification Sec 206 provides for the payment of plan quantities of Class 4 Excavation for box culverts not classified as bridges, so care is exercised in computing the quantities. Field quantities are measured for box culverts classified as bridges. Each structure is checked carefully on the field checks, and appropriate notes are made to ensure that the quantities are as accurate as possible. A common error is to compute only the quantities below the ditch flowline where the structure approaches or exceeds the width of the natural ditch. Class 4 Excavation does not include removal of existing headwalls or

portions of the existing box culvert. These items should be handled as removal of improvements for roadway culverts or partial removal of culvert concrete for bridge culverts. Care is exercised to avoid duplicate payment for the same excavation, such as computing Class 4 Excavation where channel change quantities or roadway excavation has been computed.

9-10.17 CONNECTIONS. The plans provide for connecting new structures to existing structures, and connecting different types of new structures. The plans do not include an item for the connection of pipes to existing manholes, box culverts, drop inlets or sewer pipes. The plans do include the pipe collar item for connecting different types of pipe or different sizes of pipes. Details for pipe collars are shown on Standard Plan 604.40.

9-10.18 CULVERT CLEANOUT. Information needed to properly estimate culvert cleanout items are:

- Location of culvert by station
- Type of culvert, i.e. corrugated metal or concrete
- Length of culvert
- Size of culvert

This information should be listed for each culvert to be cleaned out on the 2B sheets under the heading "Culvert Cleanout, Estimated." This information should be obtained from existing plans; no field measurement is required.

9-10.19 SLOTTED DRAINS. Slotted drains may be used to assist in drainage across entrances or very short sections of the roadway edge. Consistent hydraulic characteristics are not available, so slotted drains should not be expected to completely drain a pavement area. Chapter 4 of the FHWA Hydraulic Engineering Circular 22, “HEC-22 Urban Drainage Design” provides guidance for the design of slotted drains. The plans provide for the contractor to select among different styles of slotted drains (See Standard Plan 604.70). The diameter of pipe and length of slotted drain are specified in the plans.