HIGHWAY DESIGN MANUAL

REVISION 63

CHAPTER 19: REINFORCED CONCRETE BOX CULVERTS AND SIMILAR STRUCTURES
(Limited Revision)

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19.1 INTRODUCTION

This chapter presents the requirements for designing reinforced concrete culverts. It also provides guidance about the information to include in the contract documents, where to present the information, and details for cast-in-place culverts.

The information in this chapter is intended to be used as guidelines and minimum recommendations. A list of available references needed to complete a culvert design is also provided. As with any structural engineering design, alternate design methods are available. The designer has the ultimate responsibility to provide an efficient, safe design. It is not possible to provide guidance for all conditions so guidance is provided for the typical design.

Engineering judgment will need to be used for most projects. The history of the project site must always be evaluated and must be factored into each design. Each location will usually have some unique character (floods, scour, surroundings, salt water, historic character, etc.). Unique environments need to be thoroughly evaluated and all environmental requirements satisfied.

Definitions (explanations of the terminology used in this chapter) follow:

A culvert is defined in the Standard Specifications as any structure, whether of single- or multiple-span construction, with an interior width of 6.096 m (20 ft.) or less when the measurement is made horizontally along the center line of the roadway from face-to-face of abutments or sidewalls. Structures spanning more than 6.096 m (20 ft.) along the center line of the roadway are considered bridges. The information in this chapter applies to both culvert and bridge size culverts.

While it is recognized that any structure with a span over 6.096 m is technically not a culvert, for simplicity, all structures in this chapter will be referred to as culverts. However, the procedures for designing culverts and bridges are significantly different due to the differing risks associated with the size of the structure. Safety and economic issues and technical complexity can vary significantly with differing site conditions which will dictate the size and type of the most appropriate structural solution. Bridge-size culverts (>6.096 m) warrant more complex hydraulic and foundation treatments which require the expertise of a bridge engineer. Simpler, less complex, culvert-size structures (<6.096 m) may be designed by highway engineers with minimal oversight of a bridge engineer. Any questions on whom should design a specific-size structure should be discussed with the Regional Structures Engineer.
The procedure for the hydraulic analysis of culverts differs based on the span length. It is recommended that for culverts with spans over 3.65 m (12 ft.) a HEC-RAS analysis or an equally sophisticated backwater analysis be used to determine the size and shape of the culvert. For smaller culverts, an approximate analysis such as HY8 may be used with the criteria outlined in Chapter 8 of this manual. Any structure with a span greater than 6.096 m will also require a more detailed analysis. The procedures for structures with a span greater than 6.096 m is outlined in the AASHTO Model Drainage Manual with NYSDOT modifications. The NYSDOT modifications for the AASHTO Model Drainage Manual and assistance in hydraulic design procedures for structures greater than 6.096 m may be obtained from the Structures Design and Construction Division or the Regional Hydraulics Engineer.

There are two types of concrete culverts: four-sided (box) and three-sided.

**Concrete box culverts** (four-sided) typically have rectangular cross sections. An arch or arch-topped culvert is considered a box culvert if the “sidewalls” are built monolithic with a bottom (invert) slab. Concrete box culverts are typically used where the streambed is earth or granular soil and rock is not close enough to the streambed to directly support the structure.

**Three-sided concrete culverts** may be rectangular in nature or a frame with varying wall and/or slab thicknesses or an arch or arch-topped structure. They have separate foundations with footings supported by rock or piles or an invert slab. The largest culverts are typically not boxes; rather they are frames or arches and are discussed in Section 19.8.4.

Use of three-sided concrete culverts where rock is not at or near the streambed require pile support for the footings or some other form of positive scour protection. Three-sided concrete culverts on spread footings may be used for railroads, cattle passes, equestrian/bicycle/pedestrian/golf cart paths, and other uses that do not convey water, i.e., they do not have scour vulnerability.

The **clear span** is the perpendicular distance between the inside face of the sidewalls. The maximum clear span recommended for a concrete box culvert is 7.3 m.

The **design span** for nonskewed culverts is the perpendicular distance between the centerlines of the sidewalls. For culvert units with skewed ends, the design span is the distance between the centerlines of the sidewalls parallel to the skewed end. A design span for a concrete box culvert in excess of 7.5 m may prove to be uneconomical.
19.2 SELECTION CRITERIA

The most appropriate type of short-span structure must be determined by the designer. The basic choices are a corrugated metal structure, concrete box culvert, concrete frame or arch, and a short-span bridge. While the site conditions are the primary deciding factor for structure selection, aesthetics and economics are also very important.

Precast and cast-in-place concrete culverts are usually more expensive in initial cost than corrugated metal structures. However, concrete culverts should not be rejected as an alternative without making an engineering analysis that includes suitability to the site and life-cycle cost estimates. The advantages of concrete culverts are superior durability for most environmental conditions, greater resistance to corrosion and damage due to debris, greater hydraulic efficiency, and typically longer service life (i.e., potentially lower life-cycle costs).

At sites with limited headroom, concrete culverts may be the least expensive option. Corrugated metal structures may not fit the site conditions without appreciable changes to the roadway profile due to minimum height of soil cover requirements. Smaller corrugated metal structures typically require a minimum height of soil cover of 600 mm and for some structures the soil cover increases to 1.2 m or more depending on size and shape. Concrete culverts, frames, and arches can have the least amount of cover by placing a minimum of 100 mm of asphalt pavement directly on the top slab. Corrugated metal structures will also typically require taller structures to provide adequate waterway area below design high water than concrete culverts. If a corrugated metal structure is a viable option, an engineering and cost analysis should be done. Hydraulics may dictate the need for a concrete culvert because of excessive back water, excessive water velocity, or ice and debris.

When a concrete culvert is selected as the appropriate structure for the site, a precast option should be the first choice. Speed of erection, maintenance of traffic, stream diversion problems, and site constraints can be minimized when this option is chosen.

Before a final determination is made to use a large concrete culvert, the use of a short-span bridge with laid-back slopes and integral abutments should be investigated. Possible advantages of a bridge may be minimized work in the stream, speed of erection, minimized interference with the existing structure foundation, and easier stage construction. For procedural steps on planning short-span bridges, see Section 3 of the NYSDOT Bridge Manual.

Information on corrugated metal structures (steel and aluminum) is available in Chapter 8 of this manual. Corrugated metal structures may be more cost efficient and should be considered when there will be no major risk of corrosion such as an arch on pedestal walls where there is infrequent water contact with the metal portion of the structure. Acceptable crossing features are railroad tracks or bicycle and equestrian paths.
19.3 PROJECT DEVELOPMENT PROCEDURES FOR BRIDGE-SIZE CULVERTS

19.3.1 Structure Type Selection

Section 3 and Appendix 3D of the NYSDOT Bridge Manual identify the planning procedures to follow in determining appropriate structure type for short-span structures. Proper selection of the feasible structure alternatives is based on site- and project-specific parameters, including but not limited to:

- Vertical and horizontal clearance requirements.
- Available “beam” (top slab) depth.
- Maintenance and protection of traffic requirements (e.g., stage construction).
- Construction constraints (e.g., water diversion requirements).
- Foundation requirements.
- Environmental concerns (e.g., natural streambed).
- Desired aesthetic treatments (e.g., arch appearance).
- Geometric limitations (e.g., skew angle, R.O.W. restrictions, utilities, etc.).

Sizes that are common to more than one manufacturer should be selected, whenever possible, in an effort to obtain competitive bidding.

19.3.2 Precast Arch and Arch-Topped Unit Guidelines

- Aesthetics concerns may make the use of arch-shaped units desirable. The use of arch-shaped facade panels is not recommended, especially for hydraulic openings due to ice and debris problems.

- The amount of skew that can be fabricated varies. Some fabricators prefer to produce only 0° skew units. In cases where squaring of the unit ends would create a geometric conflict (proposed R.O.W. problems, utilities, stage construction, or site geometry), it must be clearly indicated on the contract plans as follows:

  DUE TO SITE RESTRICTIONS, ONLY SKewed-END UNITS ARE ACCEPTABLE.

- If site constraints do not eliminate the squaring of the ends, it must be clearly indicated on the contract plans as follows:

  SQUARED-END UNITS MAY BE SUBSTITUTED FOR THE SKewed-END UNITS SHOWN WITH NO CHANGE IN THE PAYMENT LIMITS SHOWN AND AT NO ADDITIONAL COST TO THE STATE.

- When railing or barrier is attached to the skewed headwall and site constraints do not eliminate the squaring of the ends, include the following note on the contract plans:
IF THE CONTRACTOR PROPOSES TO SUBSTITUTE SQUARE ENDS, DETAILS OF HOW THE RAILING/BARRIER ATTACHMENT IS TO BE ADDRESSED MUST BE PROVIDED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER.

- An arch unit is preferable whenever units are to be placed on a pedestal-type wall to create a grade separation for motor vehicles or trains, and a dry environment is mandatory. The arch shape addresses any possible ponding problem of surface drainage that a flat unit cannot address without special fabrication or field adjustment needs.

- Arch units are preferred in cases where fills above the precast units are 3 m (10 ft.) or more.

- Precast arch-topped units are currently available in spans up to 14.6 m (48 ft.).

- Arched units have been used as liners for old masonry or concrete arches. After the construction of a pedestal wall at the base, the unit can be slid into place. The void between the existing arch and the liner is filled with grout installed through fittings cast into the liner units.

- Large arch units may be shipped in 2 or 3 pieces and assembled on site.

19.3.3 Precast Frame Units (Three-Sided Structures) Guidelines

- Many of the precast, frame-type units can be fabricated with skew angles up to 45°. This characteristic is useful when stage construction is proposed.

- When used for staged construction with shallow highway pavements, no temporary spandrel walls are needed at the staging line to support the fill or pavement.

- Frame units provide a simpler bridge rail/headwall connection detail.

- Frame units provide a hydraulic opening greater than arches of equivalent clear span when flowing full.

- Precast frame units can be fabricated by some manufacturers with any increment of span length up to 12.2 m, although typical span length increments are 600 mm.

- Maximum rise of the units is normally limited to 3.1 m due to shipping and handling considerations. If a larger rise is necessary, the designer should investigate the need for a pedestal wall.
19.3.4 Details/Contract Plans

If a precast, three-sided frame, arch or arched-topped structure is determined to be the most appropriate solution, the following procedures should be followed:

• The plan view in the contract plans shall clearly show the orientation of the ends of the structure. The two most typical options for culverts on a skew are ends parallel to the centerline of the roadway (skewed ends) or ends perpendicular to the centerline of the structural units (square ends). The end treatment depends upon the skew, whether it is in a fill section or at grade, the location within the R.O.W., conflicts with utilities, stage construction details, the alignment of the feature crossed, and other site limitations. Skewed ends may require additional reinforcement and can lead to constructability issues. The maximum skew at which a precast unit should be fabricated is 45°. The culvert orientation to the \( \frac{\pi}{2} \) of the highway may be at a skew greater than 45°.

• Include a full elevation view in the contract plans showing the configuration of the most appropriate type unit (e.g., frame or arch). Any limitations on using a larger span must be shown. (Since some manufacturers only fabricate units at fixed increments of span length, showing the limitations would allow the manufacturers to bid using special units or the next larger span length of their standard units).

• Show some of the other acceptable structure types in separate partial elevation views. Limiting spans and heights must be shown for all alternatives.

• Three-sided frames that have a clear span-to-rise ratio greater than 4:1 should have the structure modeled with a pin and roller support if any displacement at the support is anticipated. When a clear span-to-rise ratio greater than 4:1 is required at a specific site, a multicell structure or a conventional bridge should be considered.

• No fabricator shall be eliminated from consideration by NYSDOT for a given project. However, specific project requirements that may exclude some fabricators must be identified (such as fabrication on a skew or a desired arched appearance).

• For four-sided culverts, the payment limits shall be identified as the length of the total structure along a longitudinal centerline of the structural units. For three-sided structures, the payment limits shall be identified as the area of the structure in plan view.

• The applicable details in Section 19.7.1 shall be placed on the plans.

19.3.5 Quality Assurance Reviews

The office of the design engineer responsible for the contract plans is also responsible for the review of the design calculations for the units as well as any revisions to the foundation design. The policies and procedures for assuring quality in Section 20 of the Bridge Manual shall be followed.
See Section 19.8.6 for information on design and shop drawing approvals.

19.4 FOUNDATIONS

All structures discussed in this chapter, regardless of span and height of cover, are considered buried structures in regard to foundation design. Thus, there is no requirement for seismic analysis. This may change in the future as more research is completed.

For culverts with spans greater than 6.096 m, foundation recommendations are provided to the designer in the Foundation Design Report (FDR). The FDR is prepared by the Geotechnical Engineering Bureau in conjunction with Structures Design and Construction Division. Foundation design questions should be directed to the Structures Design and Construction Division. Foundation design parameters for culverts with spans less than 6.096 m are provided by the Geotechnical Engineering Bureau.

Typical foundation treatment types can be found in the current Bridge Detail sheets (BD-CBx). The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper foundation treatment.

19.4.1 Rock

When sound rock is at or near the surface of a streambed, an invert slab is not required. Concrete footings are either keyed or doweled into rock based on a consultation with an Engineering Geologist from the Geotechnical Engineering Bureau.

If the elevation of the rock surface varies by 600 mm or less, the wall height should be constant and the footing height varied. If the variation in rock surface elevation exceeds 600 mm, the height of the culvert wall may be varied at a construction joint or at a precast segment joint. In some cases, it may be required to use walls of unequal heights in the same segment, but this should be avoided.

19.4.2 Earth or Granular Soil

When a concrete culvert cannot be founded on rock, an invert slab should be the first choice for the foundation treatment. However, in areas of compact soil and low stream velocities, three-sided concrete culverts may be used if they have positive scour protection such as piles, sheeting, articulated concrete mats, rip-rap lined invert, or spread footings founded below the calculated scour depth.

In areas with a significant potential for cobbles and boulders to move with the bed load, a three-sided culvert with a strip footing on piles should be investigated. The movement of cobbles and boulders will damage a concrete invert and reduce its life span.

To avoid differential settlement, concrete box culverts should never be founded partially on rock and partially on earth. If rock is encountered in a limited area, it should be removed to a minimum depth of 300 mm below the bottom of the bottom slab and backfilled with either
select granular material or crushed stone. Concrete culverts are rigid frames and do not perform well when subjected to differential settlement due to a redistribution of moments. If differential settlement cannot be avoided, a concrete culvert should not be used.

All precast concrete box culverts should have a designed undercut and backfill. The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the depth of the undercut and type of backfill material required. The current BD-CBx sheets show recommended foundation treatments.

A concrete box culvert can be considered if settlement is expected and the foundation material is fairly uniform. However, the culvert should be designed to accommodate additional dead load due to subsequent wearing surface(s) which may be needed to accommodate the settlement of the box. The Geotechnical Engineering Bureau can provide an anticipated settlement amount.

If the foundation material is extremely poor and it is desirable to limit settlement, the problem should be referred to the Regional Geotechnical Engineer or the Geotechnical Engineering Bureau to determine the best course of action. A typical remedy might be removal of unsuitable or unstable material and replacement with suitable material.

19.4.3 **Precast Frames, Arch-Topped Units, and Arches**

When a bridge-size, three-sided structure is selected for a site, there are several types that may meet the project specifications. The designer must decide which specific type of unit would best fit that particular application and use those vertical and horizontal reactions for design of the foundations. The designer may contact known fabricators for design reactions. If no specific type of unit is determined as most appropriate, a conservative estimate of the design reactions of all types should be used.

The following note shall be included on the final contract plans:

*THE ASSUMED VERTICAL REACTION IS _____ kN/m. THE ASSUMED HORIZONTAL REACTION IS _____ kN/m. THE CONTRACTOR MUST SUBMIT A REVISED FOUNDATION DESIGN TO THE ENGINEER IN CHARGE IF THE ACTUAL LOADS OF THE SUPPLIED STRUCTURE EXCEED THESE ASSUMED VALUES. THE REVISED DESIGN SHALL BE SUBMITTED AT THE SAME TIME THE DESIGN CALCULATIONS FOR THE THREE-SIDED STRUCTURE ARE SUBMITTED FOR APPROVAL.*

19.4.4 **Wingwalls**

A wingwall is a retaining wall placed adjacent to a culvert to retain fill and to a lesser extent direct water. Wingwalls may be cast-in-place or precast. Wingwall/retaining wall design information is provided in Chapter 9 of this Manual and Section 11.5.3 of the Bridge Manual. Wingwall design is not included in this Chapter. Computer programs available for cast-in-place wall design are BRADD2 and WALLRUN. Computer programs (C-WALL and BINWALL) are in the development stages for precast cantilever and bin type walls. If
design assistance is required, contact the Regional Structures Engineer or the Structures Design and Construction Division. If assistance in the determination of appropriate type of wall is required contact the Geotechnical Engineering Bureau or Regional Geotechnical Engineer.

Wingwall alignment is highly dependent on site conditions and should be evaluated on a case-by-case basis. The angle(s) of the wall(s) on the upstream end should direct the water into the culvert. It is also desirable to have the top of the wall elevation at its end above the design high water elevation to prevent overtopping of the wall.

When precast wingwalls are allowed the designer should be aware of potential conflicts with ROW, M&PT, utilities, etc. The footprint of the footing and excavation, especially for bin type walls, can be extensive. Note(s) should be placed on the plans alerting the Contractor to these requirements when they exist.

Due to the skew and/or grade differences between the precast culvert unit and precast wingwalls it is necessary to do a cast-in-place closure pour between the culvert end unit and the wingwalls. A closure pour is not required if cast-in-place wingwalls are used. See the current BD-CBx sheets for details.

19.5 DESIGN GUIDELINES FOR REINFORCED CONCRETE CULVERTS

Reinforced concrete box culverts (prismatic precast or cast-in-place, four-sided or three-sided) subjected to either earth fill and/or highway vehicle loading shall be designed in accordance with NYSDOT LRFD Bridge Design Specifications and the guidelines in Sections 19.5.1 - 19.5.10.

19.5.1 Design Method

The design and analysis method shall be in accordance with NYSDOT LRFD Bridge Design Specifications.

19.5.2 Dead Load and Earth Pressure

The dead load on the top slab shall consist of the pavement, soil, and the concrete slab. For simplicity, assume the pavement as soil.

The following criteria shall be used in determining dead load and earth pressures for design:

- Soil = 19 kN/m$^3$, (120 pcf)
- Concrete = 24 kN/m$^3$, (150 pcf)
- Lateral earth pressure = 2.9 kPa max., 1.45 kPa min. (60 pcf max., 30 pcf min.)
19.5.3 **Live Load**

Reinforced concrete box culverts shall be designed for HL-93 vehicle live load and the NYSDOT Design Permit Vehicle.

19.5.4 **Wall Thickness Requirements**

Exterior wall thickness requirements for reinforced concrete box culverts shall be controlled by design, except that minimum exterior wall thickness requirements have been established to allow for a better distribution of negative moment, corner reinforcement as follows:

<table>
<thead>
<tr>
<th>CLEAR SPAN</th>
<th>MINIMUM EXTERIOR WALL THICKNESS</th>
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<tbody>
<tr>
<td>&lt;2.44 m</td>
<td>150 mm</td>
</tr>
<tr>
<td>≥2.44 m &amp; &lt; 4.27 m</td>
<td>200 mm</td>
</tr>
<tr>
<td>≥4.27 m &amp; &lt; 6.096 m</td>
<td>250 mm</td>
</tr>
<tr>
<td>≥6.096 m</td>
<td>300 mm</td>
</tr>
</tbody>
</table>

Interior wall thickness, in multicell applications, shall be controlled by design but shall not be less than 150 mm in any instance.

19.5.5 **Concrete Strength**

Reinforced concrete box culverts shall be designed for the following concrete strengths:

- **Precast** \( f'_c = 35 \text{ MPa}, \text{ min. to 50 MPa, max. (increments of 5 MPa)} \)
- **Cast-in-place** \( f'_c = 21 \text{ MPa} \)
19.5.6 Reinforcement Requirements

Reinforcement shall be either bar reinforcement, welded wire fabric (plain), or welded wire fabric (deformed) in accordance with NYSDOT LRFD Bridge Design Specifications.

When the fill height over the box culvert is less than 600 mm, all reinforcing steel in the top mat of the top slab shall be epoxy-coated or the concrete shall contain corrosion inhibitor.

All faces of reinforced concrete box culverts not requiring design or distribution reinforcement shall be reinforced with the equivalent of #13 bar reinforcement at 300 mm centers in each direction. Under no circumstances shall any reinforcement be spaced greater than 300 mm.

Shear reinforcement and/or slab and wall thicknesses shall be designed to have adequate shear capacity in accordance with NYSDOT LRFD Bridge Design Specifications.

19.5.7 Skewed Precast Units

Skewed precast culvert sections shall be designed for whichever of the following two conditions controls:

The skewed end clear span analyzed without the skew effect.

The square end clear span analyzed with the skew effect.

19.5.8 Detailing Requirements

The minimum reinforcing bar cover requirements for cast-in-place and precast box culverts shall be as indicated in Section 15 of the Bridge Manual.

Top and bottom slab, outside-face, transverse steel shall be full-length bars, unless spliced to top and bottom corner reinforcing steel.

19.5.9 Load Rating Requirements

Bridge-size culverts, as defined by the *Uniform Code of Bridge Inspection*, shall require the submission of two (2) copies of detailed load rating calculations prepared in accordance with the current *AASHTO Manual for Bridge Evaluation* with all interim provisions in effect. Calculations shall be certified and stamped by a professional engineer currently registered and authorized to practice in New York State and shall specify which method (Allowable Stress or Load Factor) was used in load rating computations. Load ratings will also be computed by the Load and Resistance Factor Rating (LRFR) method.

Bridge-size precast box culverts shall be load rated by the fabricator’s licensed professional engineer and the both load ratings shall be shown on the approved fabrication drawings.
which are to be included in the record plans. Cast-in-place box culverts shall be load rated by the licensed professional engineering designer and the load rating shall be shown on the contract plans. Load rating calculations shall be based on the AASHTO HS or MS live-load vehicle for the Allowable Stress or Load Factor rating and HL-93 live load vehicle for the Load and Resistance Factor Rating. Inventory and operating values shall be reported in either English or metric tons. Level one load ratings shall be maintained in the Regional Office.

19.5.10  **Span-to-Rise Ratios**

Three-sided box culverts and frames with clear span-to-rise ratios that exceed 4-to-1 are not recommended. Designers of these units typically compute moments, shears, and thrusts based on fully pinned support conditions that are able to resist horizontal forces and prevent horizontal displacements. When span-to-rise ratios exceed 4-to-1, frame moment distribution is more sensitive to support conditions, and positive moments at mid-span can significantly exceed computed values even with relatively small horizontal displacement of frame leg supports.

If it is necessary to use a three-sided frame with a span-to-rise ratio in excess of 4-to-1, the structure should be analyzed for mid-span positive moment using pin-roller support conditions. Fully pinned support conditions could be used if site and construction conditions are able to prevent horizontal displacement of frame leg supports. Such a condition may exist if footings are on rock, and frame legs are keyed into footings with adequate details and construction methods.
19.6 COMPUTER DESIGN AND ANALYSIS PROGRAM

This section provides an overview of the software currently used by NYSDOT for design and analysis of reinforced concrete culverts. It should not be construed as an endorsement of any software by NYSDOT. Unless noted by contract, consultants to NYSDOT are not required to use this software. Users should refer to the corresponding manuals for more detailed instructions and limitations.

The current version of ETCulvert by Eriksson Technologies is used by the Office of Structures. It has been distributed to NYSDOT Regional Structures personnel and is also used by the Precast Concrete Association of New York (PCANY). Questions regarding the use of this program or how to obtain a copy and/or a User’s Manual should be addressed to Eriksson Technologies at www.lrfd.com.

ETCulvert will design and/or analyze a one-cell reinforced concrete box culvert with prismatic members (precast or cast-in-place), with or without bottom slab in accordance with the design criteria in NYSDOT LRFD Bridge Design Specifications or AASHTO Standard Specifications for Highway Bridges. The program will design wall and slab thicknesses and required reinforcement for a box culvert and provide the bar schedule and Load Rating.
19.7 DESIGN AND DETAILS OF CONCRETE CULVERTS

Standard details for cast-in-place concrete culverts are shown in Figures 19-1 through 19-6. Standard details for precast concrete culverts are shown in the current Bridge Detail (BD-CBx) sheets. These standard details are available for use by designers in Microstation format.

When a cast-in-place concrete culvert is proposed for a site, the designer is required to provide a complete design for the contract plans. If a precast concrete culvert is proposed, the contractor/fabricator will be required to submit the design and fabrication details to the State for approval. This should be done within 45 days following the contract award date or as indicated in the contract documents.

If alternate designs (i.e., cast-in-place vs. precast) are proposed for a site, the bar list table for the cast-in-place culvert unit may be omitted from the contract plans. Once the contract has been awarded and an alternate is chosen, the designer must provide a complete design if the cast-in-place alternate is selected. This should be done within 45 days following the contract award date, or as indicated in the contract documents.
19.7.1 **Contract Plans**

The contract plans should include these minimum design details, if applicable. Refer to the Bridge Manual for information on plan standards for bridge-size culverts.

- A plan view showing:
  - Grid north arrow.
  - Scale bar.
  - Existing highway boundaries including existing ROW monuments.
  - New right of way line(s) including proposed ROW monuments.
  - Individual ROW parcels, reputed owner, map and parcel numbers, and type of acquisition.
  - Culvert or bridge identification number (BIN).
  - Culvert and highway alignment.
  - Survey baseline: transit stations, ties, azimuths, and relation to new centerline.
  - Stream channel alignment.
  - Stream flow direction.
  - Skew angle of the culvert relative to a line perpendicular to the centerline of roadway.
  - Stationing along the culvert centerline, including beginning and ending station.
  - Equality stations for the intersection stream alignment with the highway centerline.
  - Length of culvert.
  - Subsurface exploration locations (e.g., boring locations).
  - Culvert item number and description.
  - Culvert end treatment (end unit or wing wall orientation).
  - Scour protection.
  - Slope protection.
  - Limit of stream work.
  - Utility facilities (above ground and underground).
  - Railing or barrier type.
  - Limits of pavement work (e.g., resurfacing, reconstruction, shoulder widening).
  - Limits of grading.

- A longitudinal section (elevation) along the culvert centerline showing:
  - Culvert or bridge identification number (BIN).
  - Invert elevations.
  - Existing stream bottom or original ground.
  - Culvert stationing including begin and end station.
  - Typical highway section, including rail treatment.
  - Any membrane waterproofing or top slab wash including any protective overlay for membrane protection (see Section 19.13).
  - Earth cover, measured from the top of the top slab to the top of pavement.
  - Foundation treatment (footing on rock or piles, four-sided box with cut-off walls).
  - Scour protection, including any keyways or geotextile lining.
  - Channel work.
  - All pertinent foundation details including bedding material.
REINFORCED CONCRETE BOX CULVERTS AND SIMILAR STRUCTURES

- Culvert end treatments.
- Any utility facilities attached to the fascia, in the embankment, barrier, or sidewalk.
- End units or wing walls, headwalls, and cutoff walls with elevations and dimensions.

- A culvert section showing:
  - Culvert clear span and rise.
  - All pertinent foundation details including bedding material.
  - Chamfers.
  - Membrane waterproofing or top slab wash (see Section 19.13).
  - Excavation and backfill payment limits and items.
  - Low-flow dish.

- Miscellaneous details showing:
  - Maintenance and protection of traffic including provisions for pedestrians
  - Construction staging Information (determines lengths of segments and potential need for skewed segments) including appropriate excavation support and protection systems (e.g., sheeting).
  - Railing details: Locate the railing on the culvert and indicate how it is to be attached. See Section 19.9 and current BD-CBx sheets.
  - End unit treatment: Provide details for square, skewed, beveled, or open end unit.
  - Headwall, cut-off wall, wing wall, apron slab and nosing information: Provide geometry, reinforcement, location on culvert, keyway details, and connection details.
  - Wing wall sections showing excavation and backfill items and pay limits and appropriate excavation protection.
  - Slope and/or stream bank protection.
  - Channel section detail.
  - Culvert-end, safety grate details.
  - Removal of existing culvert(s).
  - Temporary detour location including type, size, and loading requirements for any necessary detour structures.
  - Cofferdams or water diversion.
  - Erosion and sediment control plan and/or stormwater pollution prevention plan.
  - Any other necessary information which cannot be clearly presented in the culvert plans, longitudinal section, or culvert section.

- Notes indicating:
  - Live loading requirements: MS-23 unless another loading is required.
  - Hydraulic data: All culverts should show 50-year design flow (Q50) or the design flow used. A table of hydraulic data and the minimum hydraulic area perpendicular to flow below Design High Water shall be shown for culverts that are categorized by definition as bridges.
  - Erosion and sediment control and stormwater pollution prevention plan requirements
Restrictions for work in streams.

Preface Culvert Requirements: See Designer Notes for Precast Culverts in Section 19.8.5. In addition, if draw connectors are to be left in place, include a note stating: “Draw connectors are to be left in place and shall be galvanized in accordance with §719-01 of the Standard Specifications.”

Electrical safety requirements: See NYSDOT Bridge Manual.

Assumed wall, top slab, and bottom slab thicknesses.

- Culvert Identification Number Plate. Note to designer: If a culvert has an identification number, a plate shall be placed or maintained in a similar fashion to a Bridge Identification Number (BIN) plate. Cost of the plate shall be included in the various items in the contract. Include BIN special note in contract.

Tables
- Tables as shown on current BD-CBx sheets.
- Tables may be helpful for projects which involve multiple culverts. The information in the tables should include:
  - Culvert or bridge identification number (BIN).
  - Mainline stationing.
  - Length.
  - Item number and description.
  - Remarks.

19.7.2 Design Procedure

Determine the clear span and rise of the culvert using proper design procedures for the feature crossed (see Sections 19.2 and 19.3). See Chapter 8 of this manual for information on designing the opening of structures with spans of 6.096 m or less crossing water features.

Determine the minimum and maximum height of the fill, which is the distance from the top of the roadway to the top of the top slab of the culvert. This is based on an assumed top slab thickness.

For a cast-in-place culvert, use the Culvert Program (Section 19.6) or manual calculations to determine the wall and slab thickness and required reinforcement.

If an extreme skew (e.g., 60°) is necessary, squaring the ends should be considered if site conditions will allow. Squaring the ends will reduce the required top slab thickness, the reinforcement, and edge beam requirements. Under certain conditions (e.g., staged construction, ROW issues, utility conflicts, detour conflicts), the units may need to be skewed.

Precast design requirements are in Section 19.8.
Figure 19-1 Typical Cross Sections, Cast-In-Place

NOTE:
The contractor may request the use of transverse construction joints to the O.C.E.S. If approved, the joints shall be parallel to the main reinforcing steel.

Refer to §19.7.1
Figure 19-2 Wing Walls Plan and Elevation, Cast-In-Place
Figure 19-3 Contraction and Construction Joint, Cast-In-Place

SECTION A-A, FIG. 19-2
(THRU CONTRACTION JOINT)

SECTION B-B, FIG. 19-2
(THRU CONTRACTION JOINT)

KEY DETAIL - BARREL CONSTRUCTION JOINT

ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS OTHERWISE NOTED.
Figure 19-4 Wing Wall Plan, Culvert on Skew, Cast-In-Place

Refer to §19.7.1
Figure 19-5 Wingwall Aprons, Cast-In-Place

Refer to §19.7.1 12/16/05
19.7.3 Reinforcement

The main reinforcement in the top and bottom slabs shall be perpendicular to the sidewalls in cast-in-place culverts and nonskewed units of precast culverts. In a cast-in-place concrete culvert with a skewed end unit, the top and bottom slab reinforcement will be "cut" to length to fit the skewed ends. The "cut" transverse bars have the support of only one culvert sidewall and must be supported at the other end by the edge beam or cut-off wall. See Figure 19-6. For reinforcement requirements of skewed precast culverts, see Section 19.8.2.

When the fill height over the culvert is less than 600 mm, all reinforcing steel in the top mat of the top slab shall be epoxy-coated or the concrete shall contain corrosion inhibitor.

All reinforcement contained within the headwall or edge beam including the reinforcement that extends into the top slab of the culvert shall be epoxy-coated and shall meet the requirements of §709-04 of the Standard Specifications or the concrete shall contain corrosion inhibitor. If the headwall or edge beam is a significant distance from the highway where it is not in danger from chlorides, the epoxy coating can be eliminated.

The following bar label criteria shall be used for box culverts:

Bar Identification Schedule
(see Figure 19-1)

A1  Top Corner Bars (design steel)
A2  Bottom Corner Bars (design steel)
A100  Top Slab, inside face transverse bars (design steel)
A200  Bottom Slab, inside face transverse bars (design steel)
A300  Top Slab, outside face transverse bars (design steel for multiple cells)
A400  Bottom Slab, outside face transverse bars (design steel for multiple cells)
B1  Exterior wall, inside face vertical bars (design steel)
B2  Exterior wall, outside face vertical bars (design steel)
B3  Interior wall, vertical bars both faces (design steel)
C1  Top Slab, bottom slab and wall longitudinal bars (temperature reinforcement)
C100  Top Slab, inside face longitudinal bars (design distribution steel)
C200  Bottom Slab, inside face longitudinal bars (design distribution steel)

See the Culvert Program User’s Manual for bars used less frequently. This bar schedule is valid for cast-in-place and precast culverts.
Figure 19-6 Reinforcement Diagram, Cast-in-Place
19.7.4 **Headwalls/Edge Beams**

Headwalls are normally used on all culverts. In deep fills a headwall helps retain the embankment. In shallow fills the headwall may retain the subbase and/or highway pavement and provide the anchorage area for the railing system.

Headwalls that are over 300 mm in height or have a railing attachment should be cast-in-place. Headwalls 300 mm or less in height with no railing attachment may be either precast or cast-in-place. If a curb must be placed on a culvert without a sidewalk, the headwall must be cast-in-place to allow for the tie-in of the curb's anchor bar, unless the curb is also placed at the precast plant.

The typical maximum height of headwalls is 900 mm. Greater heights are attainable but are only used in special cases. Design and analysis of the headwall is required for heights above 1.8 m. See the current BD-CBx sheets for the minimum required reinforcement for heights up to 1.8 m.

Cast-in-place culverts with skewed ends may require additional stiffening of the top and bottom slabs by what is most commonly called an "edge beam" in the top slab and a "cut-off wall" in the bottom slab. An edge beam is very similar to a headwall in that it may be used to anchor guide railing posts or retain earth fill. Its main purpose, however, is to stiffen the top slab of cast-in-place culverts that lose their rigid frame action as a result of having a skewed end. A cut-off wall will stiffen the bottom slab as well as prevent water from undermining the culvert (see Section 19.10).

When additional strength is required in the concrete edge beam, the following criteria shall be used:

- If there is a 1-on-2 slope to the edge beam, it will be more economical to increase the depth of the edge beam in order to meet the required design.

- When the edge beam is at shoulder elevation (anchoring guide rail), the edge beam height should be maintained and the width of the edge beam should be increased.

Assistance in edge beam and cut-off wall design may be obtained from the Structures Design and Construction Division.

19.8 **PRECAST CONCRETE CULVERTS**

Precast concrete culverts are fabricated in a plant where the ability to control placement and curing conditions typically results in higher strength and more durable concrete. Precasting permits efficient mass production of concrete units. The advantages usually more than offset the cost of handling and transporting the units to the site. The majority of concrete culverts installed are precast.
Precast units are limited to certain sizes and skews due to transportation and handling concerns. Skewed units may need more reinforcement and thicker slabs and/or sidewalls. The use of skewed units will increase the cost of the culvert due to increased fabrication costs.

In culvert installations with square end units, each interior unit will routinely be square unless the designer has included special requirements in the contract documents. Staged construction is an example of a special requirement which may require skewed interior units. The units that meet at the division of the stages may need to be skewed to provide adequate width for travel lane(s).

Skewed precast culvert units should be avoided, if practical. Precast concrete culverts should have square ends, whenever possible. Skewed units are sometimes required to satisfy right-of-way constraints and/or staged construction requirements for skewed alignments. In the event they are necessary, skewed precast culvert units shall be designed for the skewed-end design span. Large skews may lead to units that require additional reinforcement and/or greater wall and slab thickness than typical square units with the same clear opening. Fabricators should be contacted for information on maximum skews available.

In culvert installations with skewed end units, the interior units will routinely be square and the end unit skewed at each fascia. However, this will usually be determined by the manufacturer of the precast units unless the designer has included special requirements in the contract documents.

Precast culverts may regularly need to be placed on moderate or steep grades. No maximum slope is recommended for box culverts because of the need to match the slope of the streambed. When the slope of the culvert exceeds 5%, the top of the cut-off wall should be beveled to match the slope. However, larger three-sided box culverts and the frames and arches discussed in Section 19.8.4 should be limited to a maximum slope of 2%. Precast fabricators should be contacted for the maximum grade that can be fabricated if the designer is proposing a grade larger than 2%. If matching a steep streambed slope is necessary for a three-sided culvert, the footings can be stepped and/or the length of the sidewall varied.

When two or more single-cell, precast concrete culverts are placed side-by-side, it is usually not possible to place the walls of adjacent cells tightly together. It is reasonable to detail a 50 mm to 100 mm gap between the walls of adjacent cells. This gap should be filled with any concrete item in the project or Class D concrete if no other concrete item is available.

19.8.1 Contract Plans

Dimensions of the sidewalls and top and bottom slab, and reinforcement size and spacing should not be shown on the plans, unless necessary. If sidewall or top slab dimensions are dictated by site conditions, show only affected dimensions and indicate if they are minimums, maximums, or specifically required dimensions. The assumed top slab dimension used to determine fill limits should be shown in the table as indicated in the current BD-CBx sheets.

A note in the contract plans shall require the manufacturer, through the contractor, to provide all design details not included in the contract plans. This method should result in the most economical culvert design.
19.8.2 Reinforcement

The main reinforcement in the top and bottom slabs shall be perpendicular to the sidewalls except in skewed units. Precast concrete culverts with skewed ends cannot use edge beams as stiffening members because of forming restrictions. For this reason, transverse reinforcement cannot be "cut," as in cast-in-place culverts, to fit the skewed end unit.

When a precast end unit is skewed, the transverse reinforcement must be splayed to fit the geometry of the skew. This splaying of the reinforcement will increase the length of the transverse bars and, more importantly, the design span of the end unit. For small skews, the splayed reinforcement is usually more than adequate. However, large skews may require more reinforcement and can increase the design span to the point where increased slab thickness may be necessary.

If the sidewalls of a three-sided culvert are rotated to accommodate the skew angle, thereby leaving main reinforcement parallel to the centerline of the over roadway, the three-sided culvert shall be designed for the design span parallel to the main reinforcement.

See Section 19.7.3 for bar identification schedule.

19.8.3 Design and Fabrication

When contract plans do not contain complete design details for the precast concrete culvert, the Contractor shall be responsible for providing them. All design submissions from the Contractor shall include a complete set of working drawings and a complete set of design calculations. The drawings and the design calculations shall be stamped by a professional engineer licensed to practice in New York State. If the Culvert Program (Section 19.6) is used to design the culvert, the program input and output sheets shall be submitted for the design calculations.

Fabrication requirements of precast concrete box culverts are contained in §706-17 of the Standard Specifications.

19.8.4 Precast Frames, Arch-Topped Units, and Arches

In addition to box units, there are various types of proprietary, precast concrete frames, arch-topped units, and arches available. These units are typically used when larger culverts (spans ≥ 6 m ±) are required. They can be considered when hydraulics can be adequately provided and/or aesthetics are a consideration. Where appropriate, they may be placed on a combined invert footing/slab, footings on rock, or pile-supported footings.

The advantages of the precast concrete arches and frames are the same as for the precast concrete box culverts, except that longer spans (up to 14.6 m) are possible.
19.8.5 Designer Notes for Precast Culverts

1. For headwalls where $H > 1.8$ m, specific design information must be provided in the contract documents. $H$ is the height of the headwall above the top of the top slab. See current BD-CBx sheets.

2. Headwalls where $0.3 \leq H \leq 1.8$ m are to be attached to the box culvert by use of mechanical connectors for reinforcing bar splices meeting the requirements of §709-10 (epoxy-coated) of the Standard Specifications. The female-threaded portion of the connector is cast into the box culvert.

3. Threaded inserts, where detailed, shall be designed for use with #16 and #19 reinforcing bars. Inserts shall be noncorrosive and, when used in 35 MPa concrete, able to resist minimum pull out loads of 49 kN for #16 reinforcing bars and 71 kN for #19 reinforcing bars.

19.8.6 Design and Shop Drawing Approvals

The Materials Bureau has design and shop drawing approval authority for precast concrete box culverts. Precast concrete box culvert designs are delegated to Contractors who are required to provide designs by a New York State licensed professional engineer as part of the box culvert pay item. The Structures Design and Construction Division will assist the Materials Bureau in this function by providing quality assurance reviews of the culvert designs. Design calculations for all box culverts shall be submitted to the Department and retained in the project design folder.

All shop drawings require a quality assurance review for general compliance of contract requirements and for suitability of the design for the given design conditions.

Fabrication requirements of precast concrete arches and frames are contained in §562 of the Standard Specifications. The Contractor shall be responsible for providing all design computations and details for these units. The drawings and the design calculations shall be stamped by a professional engineer licensed to practice in New York State. The Deputy Chief Engineer Structures has design and shop drawing approval authority for precast concrete arches and frames.

19.9 GUIDE RAILING

The Department has set policy that requires highway rail to meet NCHRP 350 Test Level-3 (TL-3) and requires bridge rail to meet AASHTO LRFD TL-4 in most situations. See the NYSDOT Bridge Manual, Section 6, for more information. Concrete culverts may be “highway size” or “bridge size” by definition, and therefore, the guide rail requirements can theoretically vary by span of structure.

The use of culvert rail is no longer acceptable because it is not an approved, crash-tested system. Any roadside protection placed at a culvert should be provided as highway guide rail or as bridge rail or barrier.
The anchorage/support of the guide railing is determined by the amount of fill over the top of the unit. If there is more than a minimum of 900 mm of fill and the standard 700 mm shoulder break area and a 1 on 2 or flatter slope, use of common highway guide rail with standard length posts is recommended. Highway guide rail should be used whenever it meets applicable safety standards since it is the most cost-efficient railing/barrier type.

When the recommended offsets from the back of the posts to the shoulder break cannot be achieved or the embankment slopes away from the normal shoulder break steeper than a 1-on-2 slope, extra-long posts are required. In these situations, the 900 mm criteria is no longer valid. See Chapter 10 of this manual for guidance on the required length of posts.

When there is less than 900 mm of fill, the preferred option for guide rail depends upon the amount of fill and the size of the culvert as described below.

- Culverts with less than 1.5 m outside widths (rail length) and less than 900 mm of fill should have the posts straddle the outside of the culvert. This assumes the use of standard post spacing of 1.830 m and box beam guide rail. If post spacings are less than the standard post spacing of 1.830 m, the 1.5 m outside culvert width requirement should be adjusted accordingly.

- Culverts between 1.5 m and 3.0 m outside width (rail length) and less than 900 mm of fill may have posts attached to the top of the box or posts shortened. See EI 04-002 for guidance on the appropriate option.

- Culverts with more than 3.0 m outside widths (rail length) and less than 900 mm of fill should have guide railing anchored into a headwall, edge beam, or individual concrete pedestals. When the guide rail is anchored to a headwall, edge beam, or pedestal, either bridge rail (2-rail with curb, 3-, 4-, or 5-rail) or concrete barrier shall be used.

Concrete barrier is generally not recommended due to the short length of culverts unless it is being connected to barrier along the highway. The transition of the concrete barrier shape to the transition rail will use up most of the length of barrier on the culvert. For example, single-slope barrier has a 4.8 m transition from the end of barrier to the full, single-slope shape.

Designers should note that the location of the first and last posts is critical on culverts with headwalls < 300 mm high. The anchor plate that goes under the top slab must be located so it does not encroach into the haunch. In some special circumstances (e.g., large skews and/or large sidewall thickness) maintaining the required 600 mm between the first/last transition post and the first/last culvert post may require special details beyond those in the BD-CBx sheets. Placement of anchor plates and bolts in the top slab should be avoided because it creates significant forming problems. If assistance is required contact the Regional Structures Engineer or the Structures Design and Construction Division.

For bridge rail details, see the current BD-RSx sheets. For railing anchorage to headwall details, see the current BD-CBx sheets.
19.10 CUT-OFF WALL

A minimum 450 mm wide cut-off wall is required in all culverts with invert slabs to prevent undermining. The cutoff wall should be a minimum of 1.2 m below the invert elevation or to the top of sound rock if the rock is closer. For cast-in-place culverts with skewed ends, the cut-off wall also provides stiffening of the bottom slab. See Figures 19-2 or 19-5 or current BD-CBx sheets.

When cut-off walls are required, they shall always be specified at each end of the barrel. When a concrete apron (Section 19.12) is specified, an additional cut-off wall shall also be specified at the end of the apron. If the apron is continuous with the barrel the cut-off wall is only required at the end of the apron. The bottom of all wingwall footings should be at or below the bottom of the cut-off wall to prevent scour around the edges of the cut-off wall.

When a precast culvert is specified, the cut-off wall may be precast or cast-in-place. When precast concrete cut-off walls are specified, their cost should be included in the cost of the culvert barrel or invert slab. No separate item is required. When a cast-in-place culvert is specified, the cut-off wall should be cast-in-place.

19.11 LOW-FLOW DISH

Box culverts shall have a low-flow dish whenever the stream is classified as a fishing stream by the Department of Environmental Conservation (DEC) and a low-flow dish is requested. The depth of the dish may be as small as 150 mm or as large as 300 mm. The depth of the dish depends on the quantity of flow. Lower flows may require a deeper dish to provide adequate depth of flow. A typical dish is shown in the current BD-CBx sheets.

The dish is usually in the center of the invert slab, but there may be times when the dish will be at or near the sidewall. This may happen when the stream is on a curved alignment and the low flow of the stream is on the outside of the curve.

Native streambed material is sometimes required by the DEC over the top of the bottom slab. The typical depth requirement is 300 mm. One problem that may occur is the movement of the native material during high flows. Typically, material washed out during high flows will be replaced with new material as the water recedes. Sometimes it may take several lesser flows for the material to be replaced. This periodic movement of material may abrade the surface of the concrete culvert. The depth of the concrete covering the reinforcing bars should be increased if this situation is anticipated. Note that covering the bottom slab with native material will make it very difficult, if not impossible, to inspect the bottom slab.

The Culvert Program (Section 19.6) will design the bottom slab of a culvert with a low-flow dish. The program will evaluate the additional shear capacity provided by the dish when requested by the designer. Midspan and end moments of the bottom slab are calculated assuming a prismatic section using the slab thickness at the thinnest location.
19.12 APRONS

Box culverts can significantly increase the stream flow velocity because the concrete has a roughness coefficient significantly lower (i.e., smoother) than the streambed and banks. The longer the culvert and the steeper the slope, the more the velocity will be increased. To dissipate this increase in energy and to prevent scour, a stone apron shall be placed at the outlet of all culverts. In addition, a stone apron should be specified at the inlet of all culverts to prevent scour caused by the constriction of flow.

The recommended minimum length of the stone apron is 7.5 m. The stone apron should cover the full width of the streambed. In addition, stone filling should be placed on the side slopes to a minimum elevation of 300 mm above Design High Water. A 1.5 m wide by 1.2 m deep key of stone filling should be placed in the streambed at the end of the apron away from the culvert. Stone filling should also be used to stabilize all disturbed slopes to a minimum elevation of 300 mm above Design High Water. Stone apron and slope protection details can be found on BD-EE7.

The Regional Hydraulics Engineer or the Structures Design and Construction Division Hydraulic Engineering Unit should be consulted to determine an appropriate length of apron for special situations such as locations where excessive scour has occurred.

The stone apron will begin at the end of the barrel if no concrete apron is specified. If a concrete apron is specified, the stone apron will begin at the end of the concrete apron. The size of the stone filling shall be determined by the design velocity or Regional preference, whichever is larger. For design velocities of 3 m/s or higher, heavy stone filling or larger should be specified. For design velocities less than 3 m/s, medium stone filling may be used. Some Regions prefer to use heavy stone filling for all structures and other Regions prefer to use heavy stone filling when lower velocities are reached. This is acceptable practice since the integrity of the structure is not compromised.

When stream velocities are very high (>5 m/s), where special site conditions exist, or where the existing soils are very poor, a concrete apron may be used. It should extend to the end of the wing walls (see Figure 19-5). A cut-off wall (Section 19.10) is required at the end of the concrete apron and at the end of the culvert barrel. The cut-off wall at the end of the culvert barrel is added protection if the apron fails or separates from the barrel. Concrete aprons may fail from frost heaves, bed load material abrading the apron, or other unique situations. If the apron is continuous with the barrel the cut-off wall is only required at the end of the apron.

Where there is significant movement of cobbles and boulders in the bed load, a three-sided culvert on a strip footing on piles should be investigated. The movement of cobbles and boulders may damage a concrete invert.

For some unique situations with very high-water velocities, steep profiles, or special circumstances, energy dissipators (baffles) may be required to reduce the velocity. Baffles are concrete sections that extend 300 mm to 750 mm above the bottom slab. The Regional Hydraulics Engineer or the Structures Design and Construction Division Hydraulic Engineering Unit should be consulted to determine the need for and the design of energy dissipators.
When a precast box culvert is specified, the concrete apron and wing walls may be precast or cast-in-place. When precast concrete aprons and/or wing walls are specified, their costs should be paid by separate item. In some instances, if necessary, they may be included in the cost of the culvert barrel. When a cast-in-place culvert is specified, the concrete apron and wing walls should be cast-in-place.

19.13 SUBBASE DRAINAGE

Draining surface and ground water away from the culvert through the subbase is just as important as the conveyance of water through the culvert. All flat-topped or nonarched culverts should have a minimum longitudinal slope of approximately 1%, if possible, to drain the water that permeates through the pavement and subbase, away from the top of the culvert. The slope is very important, in situations where there is low fill (0.3 m±) or asphalt directly on the culvert, to limit the likelihood that water will pond, freeze, cause potholes, and become a continuous maintenance problem.

If a longitudinal slope is not possible, a 1% slope (wash), perpendicular to the centerline of the culvert, can be used. The wash can be from the centerline to each side or all in one direction. The wash can be formed into a cast-in-place culvert but is difficult to form on precast culverts. On precast culverts, the wash can be added after the culvert is in place by placing a shim course of asphalt or concrete.

An acceptable option in low fill conditions is to place a concrete pavement on top of the culvert. The minimum depth of concrete required is 150 mm. The concrete pavement is less susceptible to potholes than asphalt but is more costly and should have a longer service life. Contact the Materials Bureau or the Regional Materials Engineer for guidance when considering the use of a concrete pavement section. If there is concern about movement of the units cracking the concrete pavement, the precast units may be post-tensioned together.

Culverts will occasionally be used to allow the passage of things other than water, including but not limited to pedestrians, bicycles, trains, golf carts, or farm animals. In cases where it is desirable to have a dry environment, a waterproof membrane should be used to cover the joints between precast culvert units or to cover the construction joints in cast-in-place culverts. Even though a joint sealer is always placed between individual precast concrete culvert units and the units are pulled tightly together, water may seep through the joint. The minimum requirement for waterproofing these joints is to provide a membrane strip having a minimum width of 600 mm, centered on the joints, covering the top slab, and then extending down the sidewalls to the footing.

A waterproof membrane may be used to cover the joints of precast concrete culverts that convey water through the culvert. The designer must understand that the purpose of the waterproofing membrane is to restrict seepage of water or migration of backfill material through the joints in the culverts and it is not intended to protect the concrete.
If the waterproof membrane is extended down the sidewall to the footing, weep holes may be necessary. See the Bridge Manual, Section 11, for location and spacing requirements.

The joints between culvert segments can have inconsistencies that may, over time, cause damage to a waterproofing membrane. An asphalt wash/shim course can protect the membrane by providing a smoother surface on which to place the membrane. In these instances a sheet membrane should be used on top of the culvert.

When watertight joints are required, contact the Materials Bureau for the proper waterproof membrane item to be included in the contract. This item contains all the material and construction details necessary for the application of the system.
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<td>19.5.7, 19.7.3, 19.7.4, 19.8, 19.8.2</td>
</tr>
<tr>
<td>Stone Filling</td>
<td>19.12</td>
</tr>
<tr>
<td>Two-Cell Culvert</td>
<td>19.8</td>
</tr>
<tr>
<td>Waterproof Membrane</td>
<td>19.13</td>
</tr>
<tr>
<td>Wingwalls</td>
<td>19.4.4, 19.10</td>
</tr>
</tbody>
</table>