

APPENDIX B

PRINCIPLE SPILLWAY

VERSION 1.0

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SECTION B-1: DESCRIPTION OF PRACTICE

A principal spillway is the primary outlet device for a stormwater impoundment. It usually consists of either a *riser structure in combination with an outlet conduit*, which extends through the embankment, or a *weir control section* cut through the embankment. The purpose of a principal spillway is to provide a primary outlet for storm flows, usually up to the 10- or 25-year frequency storm event. The principal spillway is designed and sized to regulate the allowable discharge from the impoundment facility.

SECTION B-2: PERFORMANCE CRITERIA

Not applicable.

SECTION B-3: PRACTICE APPLICATIONS AND FEASIBILITY

A principal spillway is used on any impoundment BMP, including retention, extended-detention, and detention facilities. It may also be used with constructed wetlands and infiltration measures.

SECTION B-4: ENVIRONMENTAL AND COMMUNITY CONSIDERATIONS

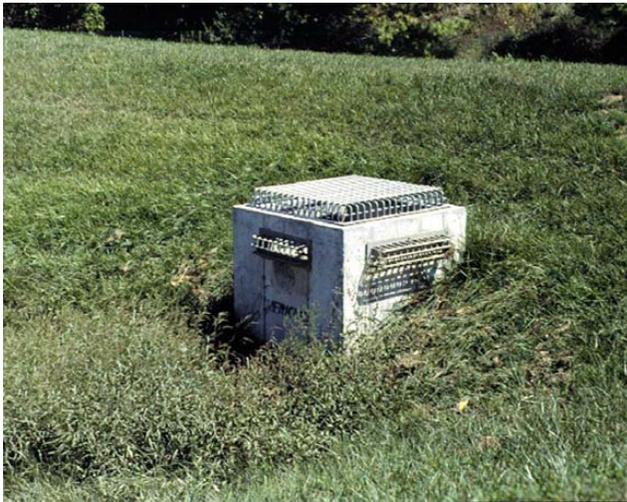
Not applicable.

SECTION B-5: DESIGN APPLICATIONS AND VARIATIONS

A principal spillway typically consists of a *multistage riser structure* and an outlet conduit or a *weir* that allows flow to pass over a *control section* of the embankment. The shape and geometry of the weir as well as that of the riser structure can be manipulated to meet the needs of the specific facility. The use of a weir as the principal spillway eliminates the barrel projecting through the embankment. The barrel through the embankment and the associated piping and seepage control represent not only significant material and construction costs, but also the potential trouble spots for long-term maintenance and possible repair.

The most common type of riser structure is a drop *inlet spillway*. A drop inlet spillway usually consists of a rectangular or other shaped riser structure containing one or several openings sized to control one or more discharge rates. For aesthetic or safety concerns, the drop inlet riser structure may be installed in the embankment with only its top showing. The discharge openings may be extended to the design water surface elevations with pipe. See **Figures B-1(a-f)** for typical riser structures and locations.

The barrel shape or geometry and size through the embankment is based upon the required flow capacities and availability of materials.



*Principal Spillway Multi-Stage Riser:
Bird Cage Trash Rack*



*Principal Spillway Multi-Stage Riser
for a Temporary Sediment Basin*



*Principal Spillway Multi-Stage Riser
with a V-Shaped Wei*

SECTION B-6: SIZING AND TESTING GUIDELINES

Not applicable.

SECTION B-7: DESIGN CRITERIA

The purpose of this section is to provide minimum design recommendations and guidelines for principal spillway systems (riser structure and barrel). The designer is responsible for determining those aspects that are applicable to the particular facility being designed, and for

determining if any additional design elements are required to insure the long-term functioning of the system.

One very important requirement is that the crest elevation of the principal spillway must be at least 1.0 ft. below the crest of the emergency spillway.

Drop Inlet Spillways

Drop inlet spillways (riser and barrel system) should be designed such that a) *full flow is established in the outlet conduit and riser at the lowest head over the riser crest as is practical,* and b) *the facility operates without excessive surging, noise, vibration, or vortex action at any stage.* To meet these two requirements, the riser must have a larger cross-sectional area than the outlet conduit. **Chapter 13** of the *Virginia Stormwater Management Handbook* (2009) provides the basic hydraulic calculation procedures needed to design the spillway riser and barrel system.

Headwall/Conduit Spillways

Headwall spillways consist of a pipe extending through an embankment with a headwall at the upstream end. The headwall is typically oversized to provide an adequate surface against which to compact the embankment fill.

Weir Spillways

A weir spillway, when used as a principal spillway, should be armored with concrete or other non-erosive material, since it usually carries water during every storm event. At the spillway, armoring should extend from the upstream face of the embankment to a point downstream of the spillway toe.

In general, all principal spillways should be constructed of a nonerosive material. The selected material should have an anticipated life expectancy similar to that of the stormwater management facility. Precast riser structures cannot be substituted if plans call for a cast in place structure, unless approved by the design engineer and the plan approving authority. Sections of precast structures must be anchored together for stability and flotation requirements. A structural engineer should evaluate shop drawings for pipe, precast structures, or other fabricated appurtenances before fabrication or installation. **Cinder block and masonry block structures should not be used.**

Vegetated spillways designed to carry flow during the 100-year frequency storm or greater are discussed in **Appendix C, Vegetated Emergency Spillway.**

Combined Principal and Emergency Spillways

An *emergency spillway*, separated from the principal spillway, is generally recommended. However, using an overland emergency spillway at the embankment abutments may not be practical due to site limitations, such as the following:

- Topographic conditions (e.g., abutments are too steep)
- Land use conditions (e.g., existing or proposed development imposes constraints)
- Other factors (e.g., roadway embankments are used as a dam, basins are excavated, etc.).

In these instances, a *combined principal/emergency spillway* may be considered. A combined principal/emergency spillway is simply a single spillway structure that conveys both low flows and extreme flows (such as the 100-year frequency flow). The combined spillway may take the form of a drop inlet spillway, a weir spillway, a headwall/conduit spillway or any other spillway type.

A primary design consideration for a combined principal/emergency spillway, particularly if it is a drop inlet spillway, is protection against clogging.

Conduits/Structures through Embankments

The *contact point* between the embankment soil, the foundation material, and the conduit is the most likely location for *piping* to occur due to the discontinuity in materials and the difficulty in compacting the soil around the pipe. Therefore, special attention must be given to the design of any conduit that penetrates an embankment.

It is highly recommended that the designer limit the number of conduits that penetrate through an embankment. Whenever possible, utility or other secondary conduits should be located outside of and away from the embankment. When additional conduits cannot be avoided, they should meet the requirements for spillways i.e., water tight joints, no gravel bedding, encasement in concrete or flowable fill, restrained to prevent joint separation due to settlement, etc.

Many embankment failures occur along the principal spillway because of the difficulty in compacting soil along a pipe. To help alleviate this concern, designers should consider the use of a weir as a control structure.

An additional cause of embankment failure is the separation of pipe joints due to differential settlement and pipe deflection. Corrugated metal pipe (CMP) must meet or exceed the minimum required thickness specified in **Table B-1**. The contractor and project inspector should verify the metal thickness (compare manufacturer's certification which accompanies the pipe shipment with the plan specifications), corrugation size, proper connecting bands, and gasket type. Maximum allowable deflection of CMP conduits is 5% of the pipe diameter. However, with larger pipe sizes, it may be difficult to get watertight joints even if the deflection is less than that which is allowed. For increased design life, the engineer may choose to specify a heavier gage than indicated in **Table B-1**.

Watertight joints are necessary to prevent infiltration of embankment soils into the conduit. All joints must be constructed as specified by the pipe manufacturer. "Field joints" where the ends of the pipes are cut off in the field should not be accepted. In addition, six inch hugger bands and "dimple bands" should not be accepted for CMP conduits. The construction specifications (found later in this Standard) specify 12-inch bands with 12-inch O-ring or flat neoprene gaskets

for pipes 24 inches or less in diameter. Larger pipes require 24-inch wide bands with 24-inch wide flat gaskets and four “rod and lug” type connectors. Flanged pipe with gaskets is also permitted. Refer to the Construction Specifications in this standard for more information.

All pipe gaskets should be properly lubricated with the material provided by the pipe manufacturer. Use of an incorrect lubricant may cause deterioration of gasket material.

Conduit Piping and Seepage Control – *Seepage* or *piping* along a pipe conduit, which extends through an embankment, should be controlled by use of one of the following: (1) *anti-seep collars*, as shown in **Figure B-2**, or (2) *filter or drainage diaphragms* as shown in **Figure B-3**. Concrete cradles, as discussed in item 3 below, may also be used.

Seepage control will not be required on pipes less than 6 inches in diameter.

1. *Anti-Seep Collars*: These collars lengthen the percolation path along the conduit, subsequently reducing the *exit gradient*, which helps to reduce the potential for piping. While this works well in theory, the required quality of compaction around the collars is very difficult to achieve in the field.

The Bureau of Reclamation, the U.S. Army Corps of Engineers, and the USDA-Natural Resource Conservation Service no longer recommend the use of anti-seep collars. The U.S. Department of the Interior-Bureau of Reclamation issued *Technical Memorandum No. 9* in 1987 that states:

“When a conduit is selected for a waterway through an earth or rockfill embankment, cutoff collars will not be selected as the seepage control measure.”

Alternative measures have been developed and used in the designs of major structures. These measures include *graded filters* or *filter diaphragms*, and *drainage blankets*. These devices are not only less complicated and more cost-effective to construct than the cutoff collars, but also allow for easier placement of the embankment fill.

Designers and engineers, however, continue to use anti-seep collars as the sole method of seepage control for small dams. This may be due to the complexity of the design procedure for graded filters. It may also be due to the designer’s concern that little engineering supervision and/or inspection will occur during construction, which is generally necessary for the successful installation of graded filters.

Anti-seep collars, when used, should be installed around all conduits through earth fills according to the following criteria:

- a. Enough collars should be placed to increase the seepage length along the conduit by a minimum of 15%. This percentage is based on the length of pipe in the saturation zone.
- b. The assumed normal saturation zone should be determined by projecting a line through the embankment, with a 4H:1V slope, from the point where the normal water elevation meets the upstream slope to a point where it intersects the invert of the conduit. This line, referred to as

the *phreatic line*, represents the upper surface of the zone of saturation within the embankment. For stormwater management basins, the phreatic line starting elevation should be the 10-year storm pool elevation. (See **Appendix A, Earthen Embankment.**)

- c. Maximum collar spacing should be 14 times the minimum projection above the pipe. The minimum collar spacing should be 5 times the minimum projection.
- d. Anti-seep collars should be placed within the saturation zone. In cases where the spacing limit will not allow this, at least one collar should be in the saturation zone.
- e. All anti-seep collars and their connections to the conduit should be watertight and made of material compatible with the conduit.
- f. Collar dimensions should extend a minimum of 2 feet in all directions around the pipe.
- g. Anti-seep collars should be placed a minimum of 2 feet from pipe joints unless flanged joints are used.

The calculation procedure for sizing anti-seep collars is presented in **Chapter 13** of the *Virginia Stormwater Management Handbook* (2009): Multi-Stage Riser Design, STEP 15.

2. *Filter and Drainage Diaphragms:* Anti-seep collars extend the flow path along the conduit and, therefore, discourage piping. In contrast, filter and drainage diaphragms do not eliminate or discourage piping, rather they control the transport of embankment fines, which is the major concern in piping and seepage. Rather than trying to prevent seepage or increase its flow length, these devices channel the flow through a filter of fine graded material, such as sand, which traps any embankment material being transported. The flow is then conveyed out of the embankment through a perforated toe drain or other acceptable technique.

While filter and drainage diaphragms require careful design, the procedure is straightforward. The *grain size distribution* of the embankment fill and foundation material must be determined so that the filter material grain size distribution can be specified. If the specified filter material is not available on the site, it must be imported. The design procedure for filter and drainage diaphragms can be found in the following references:

- USDA-NRCS *TR-60*
- USDA-NRCS *Technical Note No. 709*
- USDA-NRCS *Soil Mechanics Notes 1 and 3* (Available upon request from DEQ or NRCS)

There are some distinct advantages to using filter diaphragms over anti-seep collars:

- By eliminating the obstructions created by anti-seep collars, heavy compaction equipment can more thoroughly compact the embankment fill material adjacent to the conduit.
- The labor intensive formwork associated with anti-seep collar construction is eliminated.

- Cracks that form in the fill along the conduit will be terminated by the filter and will not propagate completely through the dam.

A geotechnical engineer should supervise the design of filter and drainage diaphragms. The critical design element is the grain size distribution of the filter material compared with that of the embankment fill and foundation material.

Overall, the following criteria apply to the use of filter and drainage diaphragms:

- a. The diaphragm should consist of sand, meeting fine concrete aggregate requirements (at least 15% passing the No. 40 sieve but no more than 10% passing the No. 100 sieve). If unusual soil conditions exist, a special analysis should be completed.
- b. The diaphragm should be a minimum of 3 feet thick and should extend vertically **upward** and **horizontally** at least 3 times the pipe diameter and vertically **downward** at least 24 inches beneath the barrel invert, or to rock, whichever is encountered first (SCS Tech. Note 709).
- c. The diaphragm should be placed immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.
- d. In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

Up to four feet of embankment material may be placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12-inch lifts of filter material, flooded and vibrated as described above, until the top of adjacent fill is reached.

- e. The diaphragm should be discharged at the downstream toe of the embankment. The opening sizes for slotted and perforated pipes in drains must be designed using the filter criteria. A second filter layer may be required around the drain pipe in order to alleviate the need for many very small openings. Fabric should *not* be used around the perforated pipe as it may clog rendering the perforations impenetrable by water.

The construction specifications for a filter diaphragm should include provisions to prevent settlement of the filter material upon saturation. This is usually accomplished by flooding the filter upon installation and compacting with vibratory equipment as soon as the water drops below the surface (Van Aller, 1990).

Whatever measures are taken to control seepage, proper construction techniques and inspection are critical to a successful project. The contractor should ensure that backfill material meets the specifications for *quality, lift thickness, placement, moisture content, and dry unit weight*. In addition, special care should be taken in the placement and compaction of the embankment material beside the barrel. Compaction along this conduit must extend away from the pipe

enough to overlap with the compaction of the embankment. The use of filter and drainage diaphragms will ease this effort while providing greater protection against the damaging effects of piping and seepage.

During construction, it is recommended that a qualified professional inspect filter and drainage diaphragms. Inspection logs should be submitted along with any as-built plans.

3. *Concrete Pipe Bedding*: If the embankment fill material under the spring line of the conduit is **inadequately** compacted, *piping* may result. This problem is magnified if the conduit is not designed with flexible watertight joints; differential settlement of the embankment and foundation materials may pull the conduit joints apart, allowing the stormwater to escape into the surrounding soil, greatly adding to the piping condition. Installation of a concrete cradle will help to reduce the risk of piping under the barrel and the subsequent failure of the embankment, resulting from differential settlement.

Cradles not only provide conduit support, but also provide a better condition for the placement and compaction of backfill.

Concrete cradles serve two distinctly different, yet related functions: 1) they help to prevent piping along conduit, and 2) they provide a 90° bedding angle for the loading support of the conduit.. See Figure B-4.

The concrete cradle may not be necessary along the entire length of the conduit to prevent piping, but it is recommended. This will eliminate a sudden change in the support provided under the conduit. The load distribution of the conduit is assumed to be the same as the typical load distribution characteristics of reinforced concrete pipe (*RCP*). The external loading capacity of *RCP* depends upon a bedding condition that provides equal support around the base of the pipe. General pipe culvert installation specifications call for the placement of gravel under the pipe to distribute the load evenly. However, **gravel bedding under an embankment conduit is *never* appropriate unless it is designed as a filter or drainage diaphragm.** Therefore, if the external load on the barrel is enough to warrant provision for its maximum *supporting strength*, then a concrete cradle should be installed along the conduit's entire length. Note that external loads on the barrel may be due to the height of the embankment fill, the anticipated construction traffic, or the weight of the compaction equipment.

Single Conduits: All conduits penetrating dam embankments should be designed using the following criteria:

- a. Conduits and structures penetrating an embankment should have a smooth surface without protrusions or indentations that will hinder compaction of embankment materials.
- b. All conduits should be circular in cross-section except cast-in-place reinforced concrete box culverts.
- c. Conduits should be designed to withstand the external loading from the proposed embankment without yielding, buckling or cracking, all of which will result in joint

separation.

- d. Conduit strength should not be less than the values shown in **Tables B-1** and **B-2** for corrugated steel, aluminum, and PVC pipes, and the applicable ASTM standards for other materials. The manufacturer should submit certification that the pipe meets plan requirements for design load, pipe thickness, joint design, etc.
- e. Inlet and outlet flared-end sections should be made from materials that are compatible with the pipe.
- f. All pipe joints should be made watertight by using flanges with gaskets, coupling bands with gaskets, bell and spigot ends with gaskets, or by welding. See **Section B-11, Construction Specifications and Inspections** later in this Appendix.

Multiple Conduits: Where multiple conduits are used, each conduit should conform to the requirements in item (b), above. In addition, sufficient space between the conduits and the installed anti-seep collars should be provided to allow for backfill material to be placed between the conduits with earth moving equipment and to allow for easy access by hand-operated compaction equipment. The distance between conduits should be equal to or greater than one-half of the pipe diameter, but not less than 2 feet.

Cathodic Protection

In some areas of Virginia, sedimentary layers may be very acidic. This is particularly common in the coastal and piedmont regions east of the fall line, or roughly east of Interstate 95. Cathodic protection should be provided for *coated welded steel* and *galvanized corrugated metal* pipe when soil and resistivity studies indicate the need for a protective coating. Cathodic protection may also be provided when additional protection and longevity are warranted.

Outlet Protection

Outlet protection should be used on the downstream toe of a spillway structure to help dissipate the high-energy flow through the spillway and to prevent excessive erosion in the receiving channel. Various types of outlet protection can be used including: *riprap at the endwall or end-section of an outlet conduit* or a *designed hydraulic jump with impact blocks*. The type of outlet protection depends on the flow velocities associated with the spillway design flood and energy dissipation required. Riprap is the preferred form of outlet protection when designed according to **Chapter 13** of the *Virginia Stormwater Management Handbook* (2009) and the *Virginia Erosion and Sediment Control Handbook* (VESCH, 1992). Gabion baskets are also an acceptable outlet protection material. Other references for designing outlet protection include publications by the Federal Highway Administration, the USDA-Natural Resource Conservation Service, the U.S. Department of the Interior-Bureau of Reclamation and the U.S. Army Corps of Engineers.

The following general criteria are recommended for the placement of riprap at the outfall of a stormwater impoundment:

1. The bottom of the riprap apron should be constructed at 0% slope along its length. The end of the apron should match the grade and alignment of the receiving channel.
2. If the receiving channel is well defined, the riprap should be placed on the channel bottom and side slopes (no steeper than 2:1) for the entire length, L_a , required per **Chapter 13** of the *Virginia Stormwater Management Handbook* (2009) and the *Virginia Erosion and Sediment Control Handbook* (VESCH, 1992). Riprap placement should not alter the channel's geometry. Excavation of the channel bed and banks may be required to construct the full thickness of the apron.
3. If the barrel discharges into the receiving channel at an angle, the opposite bank must be protected up to the 10-year storm elevation. In no instance should the total length of outlet protection be shortened. If a permit requires that no work may be performed in the stream or channel, then the outlet structure should be moved back to allow for adequate protection.
4. The horizontal alignment of the apron should have no bends within the design length; L_a . Additional riprap should be placed if a significant change in grade occurs at the downstream end of the outfall apron.
5. Filter fabric should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap.

Trash Racks and Debris Control Devices

Most basins will collect a certain amount of trash and debris from incoming flows. Floating debris such as grass clippings, tree limbs, leaves, trash, construction debris, and sediment bed load from upstream watersheds are common. Therefore, all control structures, including detention; extended-detention and retention basin low-flow weirs and orifices should have a trash rack or debris control device. The following are recommended design criteria for trash racks and debris control devices:

1. Openings for trash racks should be no larger than one-half of the minimum conduit dimension, and to discourage child access, bar spacing should be no greater than 1 foot apart. The clear distance between the bars on large storm discharge openings should generally be no less than 6 inches.
2. **Flat grates for trash racks are not acceptable.** Inlet structures that have flow over the top should have a non-clogging trash rack such as a hood-type inlet that allows passage of water from underneath the trash rack into the riser, or a vertical or sloped grate. The designer should verify that the surface area of the vertical perimeter of a raised grate equals the area of the horizontal top opening. This will allow adequate flow passage should the top horizontal surface become clogged. Examples are shown in **Figure B-5**.
3. Metal trash racks and monitoring hardware should be constructed of galvanized or stainless steel metal.

4. Methods to prevent clogging of extended detention orifices in dry extended detention basins should be carefully designed since these orifices are usually very small and located at the invert or bottom of the basin (refer to **Design Specification No. 15, Extended Detention**).

Anti-vortex Device

All drop inlet spillways designed for pressure flow should have adequate anti-vortex devices. An anti-vortex device is not required if weir control is maintained in the riser through all flow stages, including the maximum design storm or safety storm.

An anti-vortex device may be a baffle or plate installed on top of the riser, or a headwall set on one side of the riser. Examples of anti-vortex devices are shown in **Figure B-6**.

Drain Pipes and Valves

Stormwater management facilities having permanent impoundments may be designed so that the permanent pool can be drained to simplify maintenance and sediment removal. The draining mechanism will usually consist of a valve or gate attached to the spillway structure and an inlet pipe projecting into the reservoir area with a trash rack or debris control device. The typical configuration of a drainpipe will place the valve inside the riser structure with the pipe extending out to the pool area. This configuration results in the drainpipe being pressurized by the hydraulic head associated with the permanent pool. Pressurized drainpipes should consist of mechanical joints in order to avoid possible leaks and seepage resulting from this condition. In all cases, valves should be secured to prevent unauthorized draining of the facility.

Basin drains should be designed with sufficient capacity to pass the 1-year frequency design storm with limited ponding in the reservoir area, such that sediment removal or other maintenance functions are not hampered.

An uncontrolled or rapid drawdown of a stormwater basin could cause a slide in the saturated upstream slope of the dam embankment or shoreline area. Therefore, the design of a basin drain system should include specific operating instructions for the owner. **Generally, drawdown rates should not exceed 6 inches per day.** For embankments or shoreline slopes of clay or silt, drawdown rates as low as *1 inch per week* may be required to ensure slope stability. (FPFM, 1994).

Antiflotation

The design of a principal spillway riser structure should include a *flotation* or *buoyancy* calculation.

When the ground around the riser is saturated and the water surface elevation in the basin is higher than the riser footing, then the riser structure behaves like a “vessel” floating in water. Such flotation forces on the riser can lead to failure of the connection between the riser and barrel, and any other rigid connections.

The downward force of the riser and footing (assuming the riser is attached firmly to the footing) is the *structure weight*. To maintain adequate stability, this weight must be at least 1.25 times greater than the upward force, or buoyant force, acting on the riser.

An *anti-flotation* calculation procedure is presented in Chapter 13 of the Virginia Stormwater Management Handbook (2009).

Maintenance and Safety

As mentioned previously, trash racks and debris control structures should be sized to prevent entry by children. Fencing or other barriers should be considered around spillway structures having open or accessible drops more than 3 feet. A locking manhole cover on the riser may also be prudent to prevent unauthorized access.

SECTION B-8: REGIONAL AND CLIMATE DESIGN VARIATIONS

Not applicable.

SECTION B-9: TYPICAL GRAPHICAL DETAILS

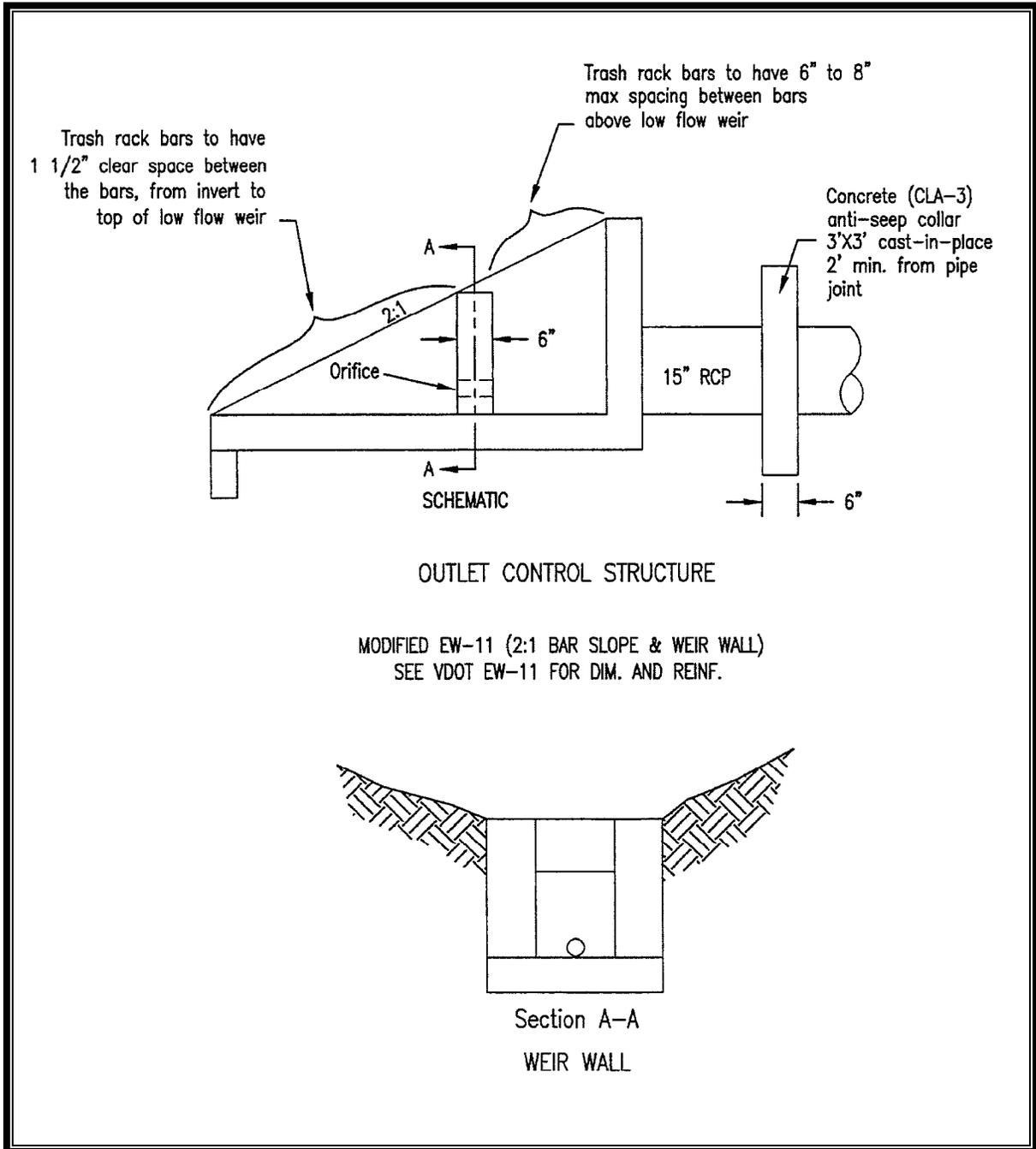


Figure B-1a. Typical Principal Spillway Structures

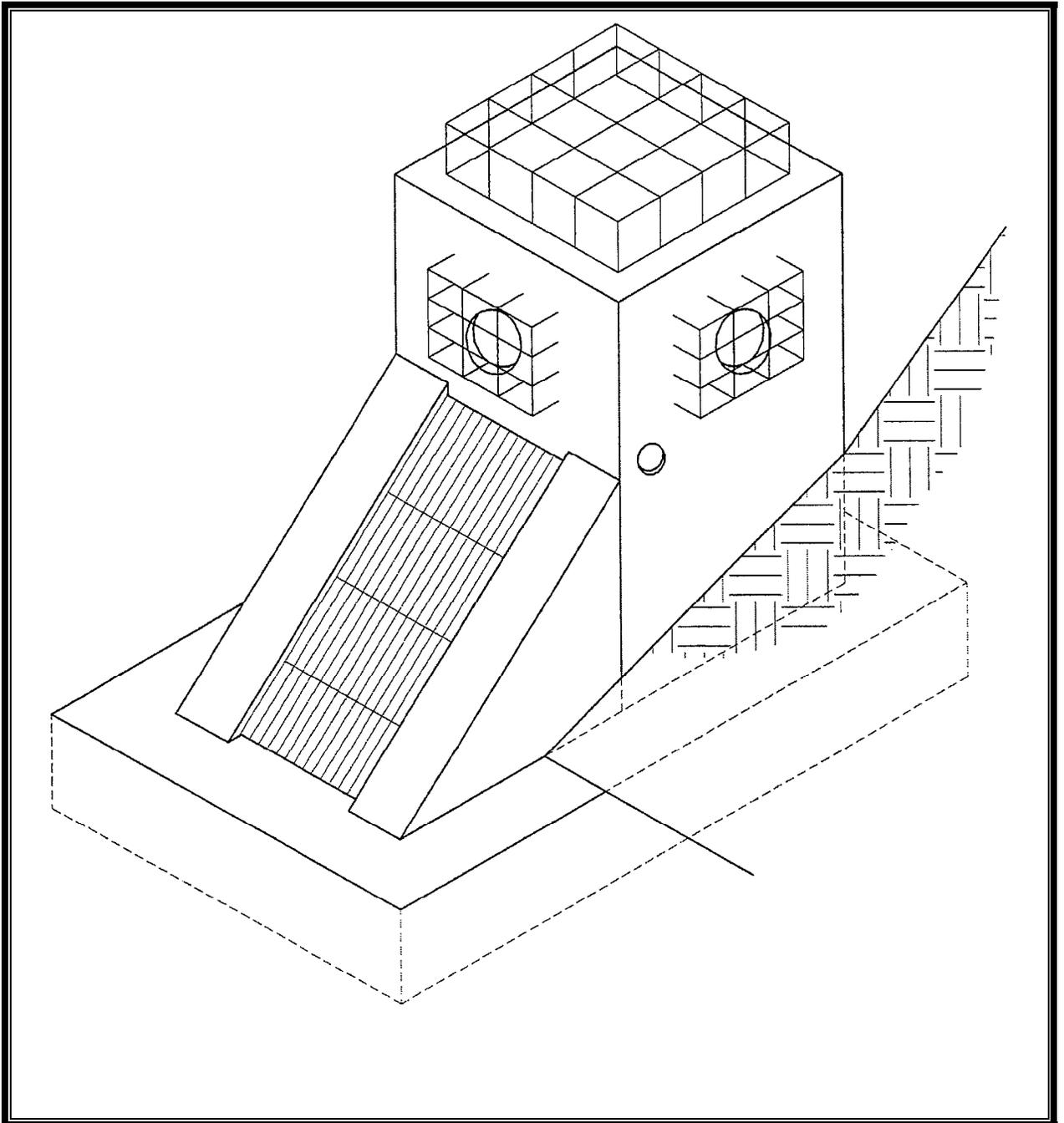


Figure B – 1b. Typical Principal Spillway Structures

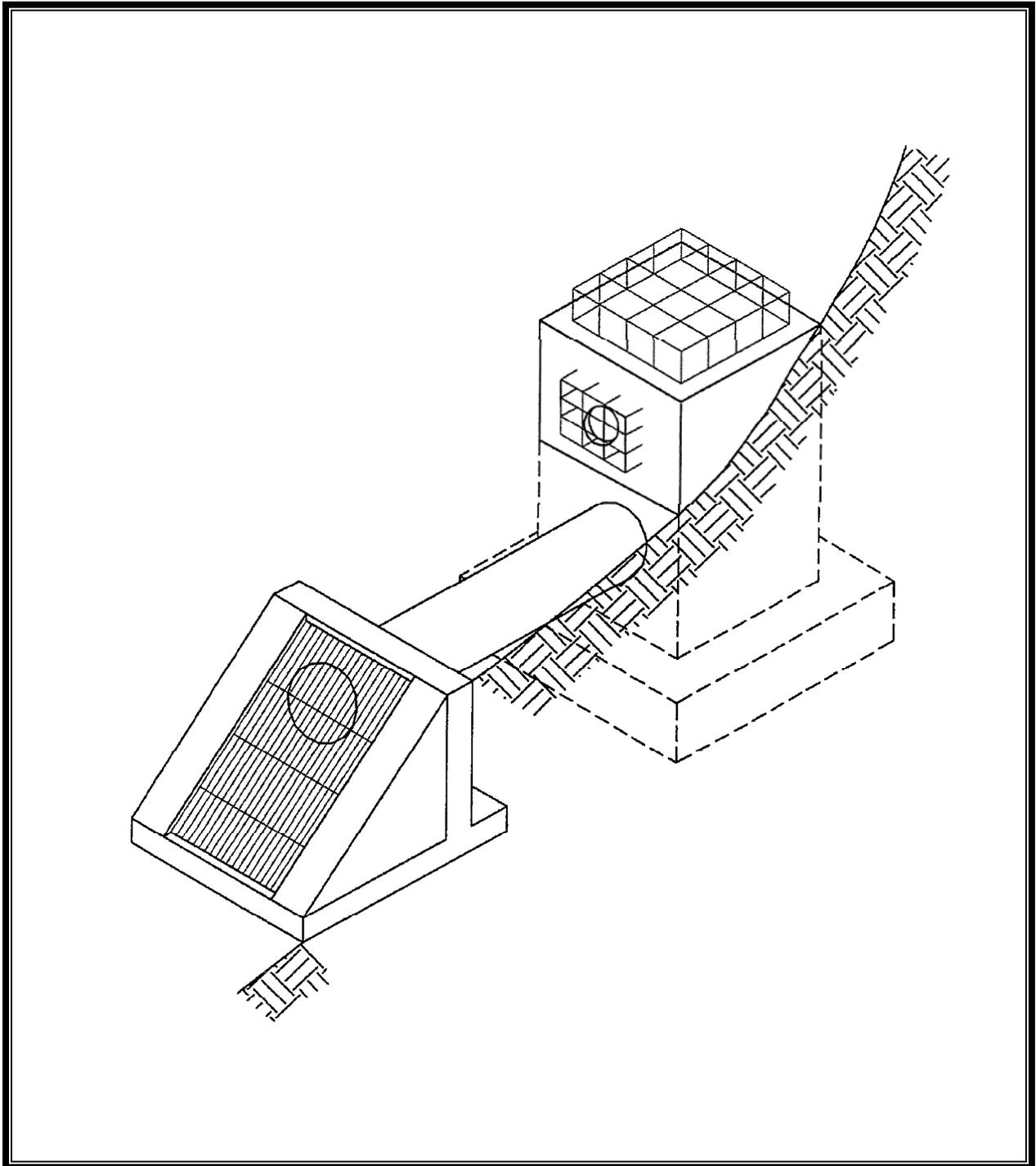


Figure B-1c. Typical Principal Spillway Structures

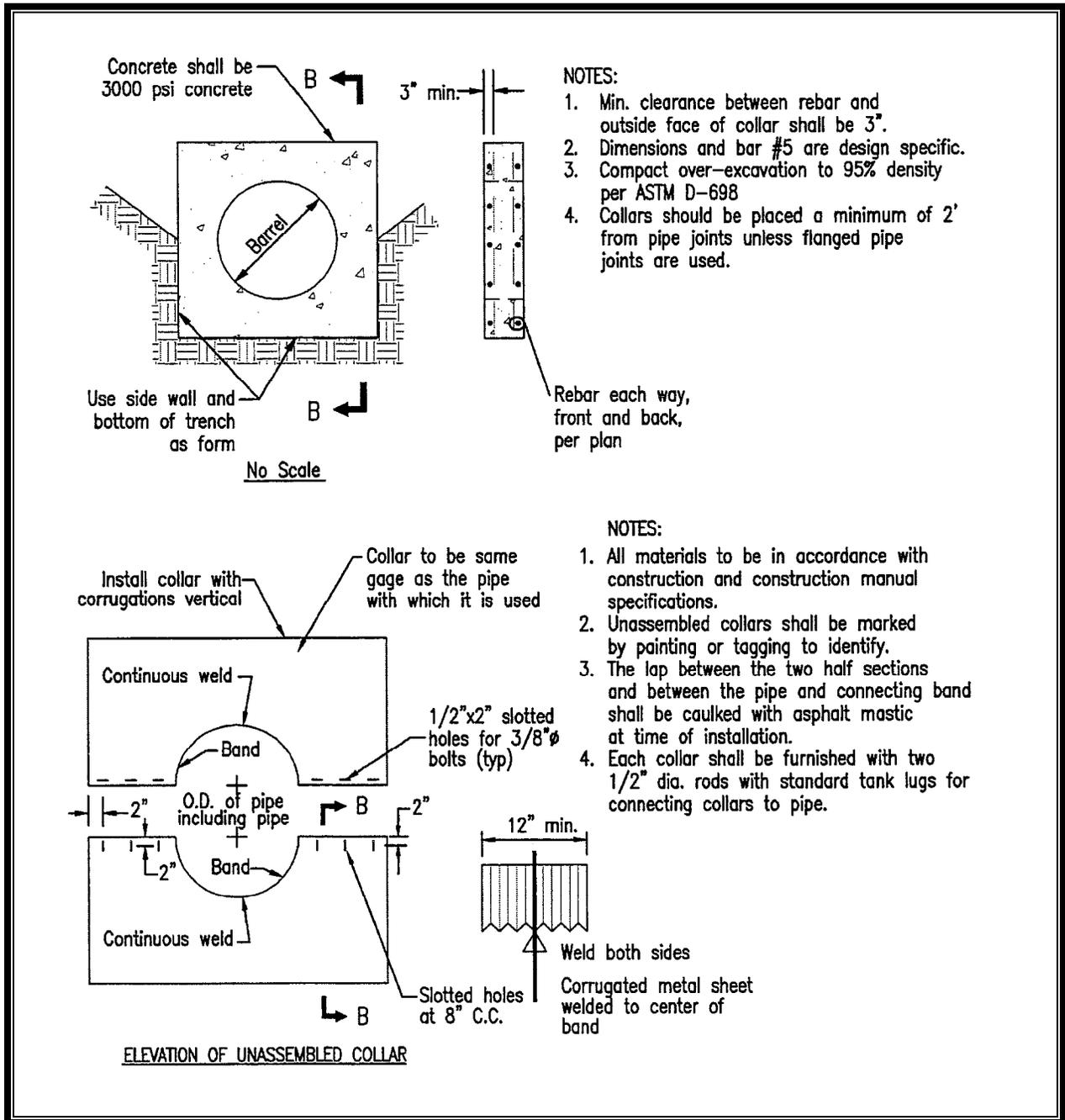
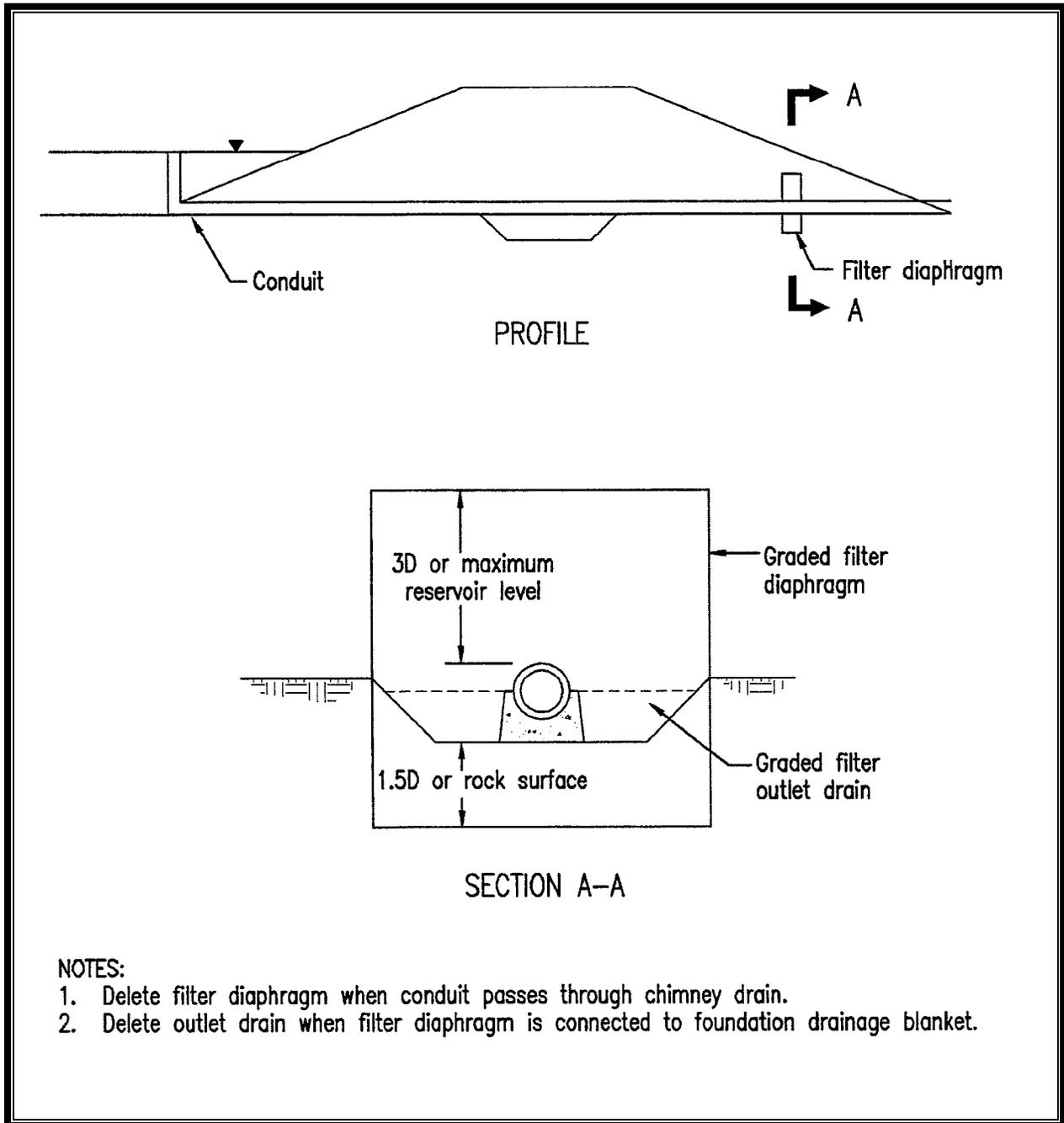


Figure B-2. Concrete Anti-Seep Collar



NOTES:

1. Delete filter diaphragm when conduit passes through chimney drain.
2. Delete outlet drain when filter diaphragm is connected to foundation drainage blanket.

Source: *Seepage Control Along Conduits Penetrating Embankment Dams*, Ray E. Martin, Ph.D., P.E.

Figure B-3. Graded Filter Diaphragm for Seepage Control Around Conduit

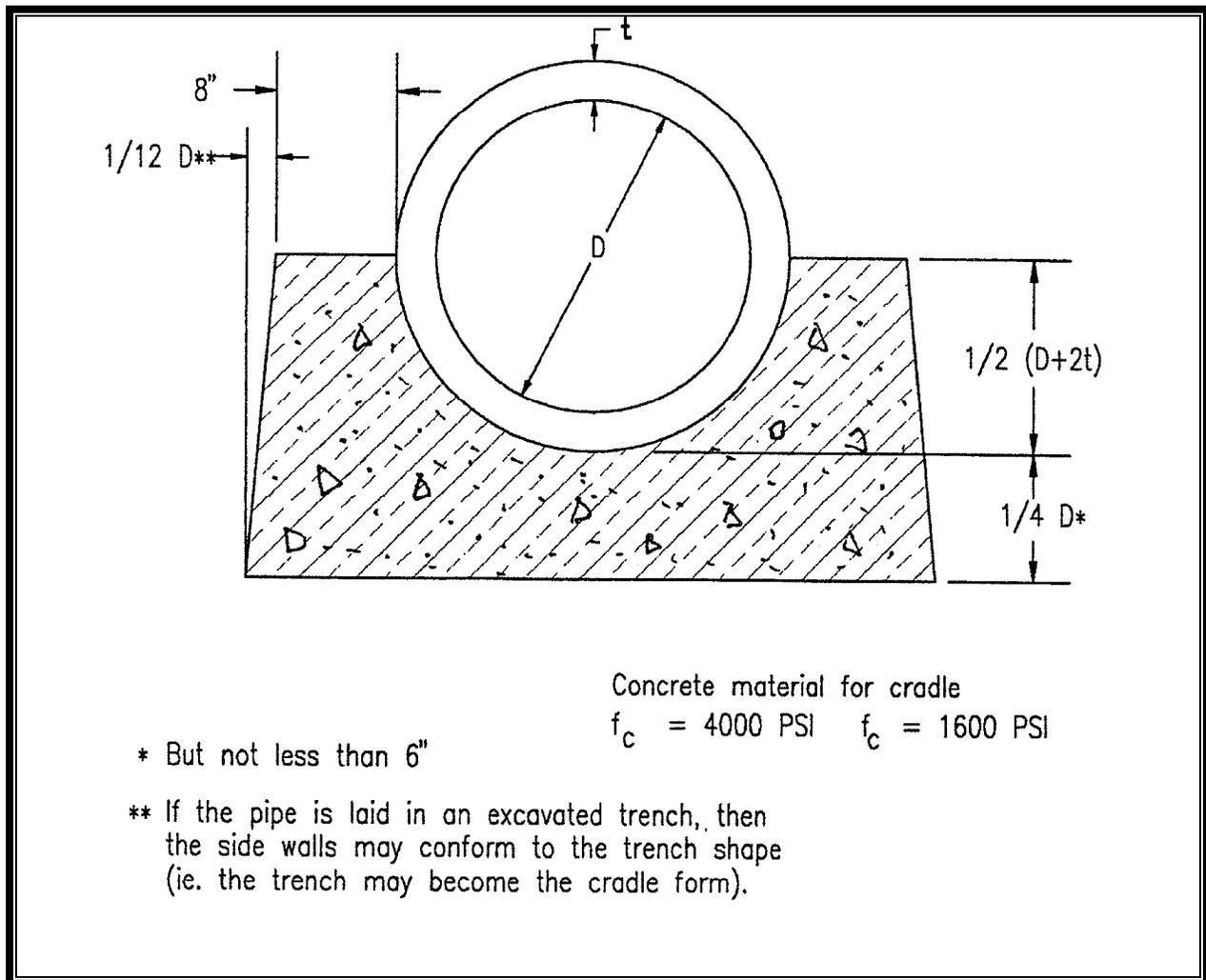


Figure B-4. Concrete Cradle

SECTION B-10: MATERIAL SPECIFICATIONS

Not applicable.

SECTION B-11: CONSTRUCTION SEQUENCE AND INSPECTION

The construction specifications for principal spillways outlined below should be considered as minimum guidelines. More stringent requirements may be needed depending upon individual site conditions. Overall, widely accepted construction standards and specifications, such as those developed by the USDA Natural Resource Conservation Service or the U.S. Army Corps of Engineers, should be followed.

Further guidance can be found in the USDA-NRCS *Engineering Field Manual*. Specifications for the work should conform to the methods and procedures specified for installing earthwork, concrete, reinforcing steel, pipe water gates, metal work, woodwork, and masonry, as they apply

to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government. Final construction specifications should be included on the construction plans.

Corrugated Metal Pipe

The following criteria apply:

1. **Materials:** Corrugated metal pipe may be steel, aluminum coated steel or aluminum.
 - a. *Steel Pipe:* This pipe and its appurtenances should be galvanized and fully bituminous coated and should conform to the requirements of AASHTO Specification M-190 Type A with watertight coupling bands. Any bituminous coating damaged or otherwise removed should be replaced with cold applied bituminous coating compound. Steel pipes with polymeric coatings should have a minimum coating thickness of 0.01 inches (10 mils) on both sides of the pipe. The following coatings or an approved equal may be used: Nexon, Plasti-Cote, Blac-Clad, and Beth-Cu-Loy. Coated corrugated steel pipe should meet the requirements of AASHTO M-245 and M-246.
 - b. *Aluminum Coated Steel Pipe:* This pipe and its appurtenances should conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Any aluminum coating damaged or otherwise removed should be replaced with cold applied bituminous coating compound.
 - c. *Aluminum Pipe:* This pipe and its appurtenances should conform to the requirements of AASHTO Specification M-196 or M-211 with watertight coupling bands or flanges. Aluminum surfaces that are to be in contact with concrete should be painted with one coat of zinc chromate primer. Hot dipped galvanized bolts may be used for connections. The pH of the surrounding soils should be between 4 and 9.
2. **Coupling bands, anti-seep collars, end-sections, etc.:** All connectors must be composed of the same material as the pipe. Metals must be shielded from dissimilar materials with rubber or plastic insulation at least 24 mils thick.
3. **Connections:** All connections to pipes must be completely watertight. The drain-pipe (or barrel) connection to the riser should be welded all around when both are metal. Anti-seep collars should be connected to the pipe so that they are completely watertight. **Dimple bands are not considered watertight.**

A rubber or neoprene gasket should be used when joining pipe sections. The end of each pipe should be re-rolled by enough corrugations to fit the bandwidth. The following connection types are acceptable for pipes less than 24 inches in diameter: flanges with gaskets on both ends of the pipe, a 12-inch wide standard lap type band with a 12-inch wide by 1/2-inch thick closed cell circular neoprene gaskets, and a 12-inch wide hugger type band with O-ring gaskets having a minimum diameter of 3/8 inches greater than the corrugation depth. Pipes 24 inches in diameter and larger should be connected by a 24-inch long annular

corrugated band using rods and lugs and a 24 inch wide by 3/8 inch thick closed cell circular neoprene gasket. Helically corrugated pipe should have either continuous welded seams or lock seams with internal caulking or a neoprene bead.

All pipe gaskets must be properly lubricated with the material provided by the pipe manufacturer, and tensioned. Flat gaskets must be factory welded or solvent glued into a circular ring, with no overlaps or gaps.

4. **Bedding:** The pipe should be firmly and uniformly bedded throughout its length. Where rock or soft, spongy or other unstable soil is encountered, it should be removed and replaced with suitable earth that is subsequently compacted to provide adequate support. Under no conditions should gravel bedding be placed under a conduit through the embankment.
5. **Backfill:** All backfill material and placement should conform to Structure Backfill specifications in **Appendix A, Earthen Embankment**.

Reinforced Concrete Pipe

The following criteria apply:

1. **Materials:** Reinforced concrete pipe should have bell and singular spigot joints with rubber gaskets and should equal or exceed ASTM Designation C-361.
2. **Bedding:** All reinforced concrete pipe conduits should be laid in a **concrete** bedding for their entire length. This bedding should consist of high slump concrete placed under the pipe and up the sides of the pipe at least 25% of its outside diameter, and preferably to the spring line, with a minimum thickness of 3 inches, or as shown on the drawings.
3. **Laying pipe:** Bell and spigot pipe should be placed with the bell end upstream. Joints should be made per recommendations from the manufacturer. After the joints are sealed for the entire run of pipe, the bedding should be placed so that all spaces under the pipe are filled. Care should be taken to prevent any deviation from the original line and grade of the pipe.
4. **Backfill:** All backfill material and placement should conform to Structure Backfill specifications in **Appendix A, Earthen Embankment**.

Polyvinyl Chloride (PVC) Pipe

The following criteria apply:

1. **Materials:** PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241.
2. **Connections:** Joints and connections to anti-seep collars should be completely watertight.

3. **Bedding:** The pipe should be firmly and uniformly bedded throughout its length. Where rock or soft, spongy or other unstable soil is encountered, it should be removed and replaced with suitable earth that is subsequently compacted to provide adequate support.
4. **Backfill:** All backfill material and placement should conform to Structure Backfill specifications in **Appendix A, Earthen Embankment.**

Filters and Drainage Layers

In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

Up to four feet of embankment material may be placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12-inch lifts of filter material, flooded, and vibrated as described above, until the top of adjacent fill is reached.

Filter fabrics should not be used in lieu of sands and gravel layers within the embankment.

Table B-1. Minimum Gages for Metal Pipes											
CORRUGATED STEEL PIPE 2-2/3" x 1/2" Corrugations ¹							CORRUGATED ALUMINUM PIPE 2-2/3" x 1/2" Corrugations ¹				
Fill Height Over Pipe (ft.)	Pipe Diameter (inches)						Fill Height Over Pipe (ft.)	Pipe Diameter (inches)			
	≤21	24	30	36	42	48		≤21	24	30	36
1 – 15	16	16	16	14	12	10	1 – 15	16	16	14	14
16 – 20	16	16	16	14	12	10	16 – 20	16	14	12	12
21 – 25	16	16	14	12	10	10	21 – 25	16	12	10	*
CORRUGATED STEEL PIPE 3" x 1" or 5" x 1" Corrugations							CORRUGATED ALUMINUM PIPE ² 3" x 1" or 5" x 1" Corrugations				
Fill Height Over Pipe (ft.)	Pipe Diameter (inches)						Fill Height Over Pipe (ft.)	Pipe Diameter (inches)			
	≤24	30	36	42	48	–		30	36	42	48
0 – 20	16	16	16	16	16	–	1 – 15	16	16	16	16
20 – 25	16	16	16	16	14	–	16 – 20	16	14	8	8
¹ Pipe with 6, 8 and 10 inch diameters has 1-1/2 in. x 1/4 in. corrugations							* Not permitted				
² Riveted or helical fabrication											
* Not permitted											
NOTE: Coatings for corrugated steel should be as specified in this specification, or equivalent											

Source: USDA-NRCS Standards and Specifications for Ponds – Code 378

Table B-2. Acceptable PVC Pipe for Use in Earthen Dams¹		
Nominal Pipe Size (inches)	Schedule or Standard Dimension Ratio (SDR)	Maximum Depth of Fill Over Pipe (feet)
≤ 4	Schedule 40	15
	Schedule 80	20
	SDR 26	10
6, 8, 10, 12	Schedule 40	10
	Schedule 80	15
	SDR 26	10
¹ Polyvinyl chloride pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241		

Source: USDA-NRCS Standards and Specifications for Ponds – Code 378

Concrete

Concrete should meet the requirements of the Virginia Department of Transportation (VDOT) *Road and Bridge Specifications*, latest edition.

Outlet Protection

Outlet protection should meet the requirements and construction specifications of the VESCH, 1992 edition, Std. & Spec. 3.18, Outlet Protection, and 3.19, Riprap, latest edition. Materials should conform to the following:

1. Filter fabric should meet or exceed the requirements in Standard & Specification 3.18 and 3.19 in the VESCH, 1992 edition.
2. Riprap should meet or exceed the requirements in Standard & Specification 3.18 and 3.19 in the VESCH, 1992 edition.
3. Gabion baskets should be made of hexagonal triple-twist mesh, PVC coated, heavily galvanized steel wire. The maximum linear dimension of the mesh opening should not exceed 4 1/2 inches and the area of the mesh opening should not exceed 10 square inches.

Stone or riprap for the baskets should be sized according to the following criteria:

Table B-3. Gabion Basket Criteria		
BASKET THICKNESS		STONE SIZE
(inches)	(millimeters)	(i)nches
6	150	3 - 5
9	225	4 - 7
12	300	4 - 7
18	460	4 - 7
36	910	4 - 12

The stone or riprap should consist of fieldstone or rough, unhewn quarry stone. The stone should be hard and angular and of a quality that will not disintegrate from exposure to water or weather. The specific gravity of the individual stones should be at least 2.5.

Recycled concrete may be used and will be considered equivalent if it has a density of at least 150 pounds per cubic foot and no exposed steel or reinforcing bars.

Trash Rack and Debris Control Devices

All trash rack and debris control components should be stainless steel or galvanized metal per the Virginia Department of Transportation (VDOT) specifications. Trash racks attached to a concrete spillway structure should be secured with stainless steel anchor bolts.

SECTION B-12: OPERATION AND MAINTENANCE

This section presents general operation, maintenance and inspection guidelines for principal spillways and components. However, these guidelines are not intended to be all-inclusive. Specific structures may require special measures not discussed here. The engineer is responsible for determining what, if any, additional items are necessary.

1. Spillway structures should be cleared of debris periodically and after any significant rainfall event where inspection reveals a significant blockage.
2. During low water conditions, concrete spillway structures should be inspected to decide if water is passing through any joints or other structure contacts and to identify any cracks, spalling, broken or loose sections. Any cracked, spalled, broken or loose sections should be cleaned and refilled with an appropriate concrete patching material. A professional engineer should be consulted to repair extensive leakage, spalls or fractures.
3. Outlet protection (stilling basins) and discharge channels should be cleared of brush at least once per year.
4. Trash racks and locking mechanisms should be inspected and tested periodically to make sure they are intact and operative.
5. All sluice gates (or other types of gates or valves used to drain an impoundment) should be operated periodically to insure proper function. The gate and stem should be periodically lubricated and all exposed metal should be painted to protect it from corrosion.
6. Any repairs made to the principal spillway (riser or barrel) should be reviewed by a professional engineer. Vertical trenching to expose the barrel should not be allowed under any circumstances. The trench side slopes should be stepped back at a 2:1 slope, minimum.

SECTION B-13: REFERENCES

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