Maryland
Department of
the Environment

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DAM SAFETY

POLICY MEMORANDUM #12

TO: Dam Owners, Operators, and Engineers

FROM: Stormwater, Dam Safety, and Flood Management Program
Water and Science Administration

DATE: December 21, 2022

SUBJECT: Design Considerations for Spillway Risers and Trash Racks

Policy Statement

It is the policy of the Maryland Department of the Environment (the Department) that the design of dam embankments must consider potential failure modes and incorporate defensive design measures as appropriate. This policy seeks to clarify the structural design requirements for spillway risers and trash racks constructed for small ponds and most earthen dams and supplements all other design requirements for construction of dams and impoundments. The criteria provided herein are minimums, and it remains the responsibility of the designer to determine if and where more conservative approaches are warranted.

Background

Spillway risers are subjected to relatively severe environments. This includes not only hydraulic flows, wave action, and submergence, but also associated combinations of wet/dry and freeze/thaw cycles, and general exposure to the elements. These conditions vary considerably from, and are more severe than, those encountered in normal building construction. Accordingly, risers must exhibit adequate stability and strength in addition to enhanced durability, adequate crack control, and generally good serviceability characteristics.

General

- Spillways must be designed to operate safely at the discharges and pressures that would be experienced under all normal or flood flow conditions up to and including the design storm. Safe operation of a spillway begins with designing such structures to ensure structural integrity, structural stability, and the ability to pass normal and flood flows without damaging the dam embankment. Risers must be structurally designed to withstand all anticipated water, earth, ice, and earthquake loads.

- Dam owners and operators must be aware of the expected lifespan of the structure and plan for continued maintenance and eventual replacement.

- All man-made elements of dams deteriorate with age. It is important that elements of the spillway and appurtenances be constructed in such a manner that will allow for easy maintenance and inspection. For example, a riser that requires access by boat creates an additional burden that hinders normal maintenance and inspection. Additionally, the useful life of most dams far exceeds the life expectancy of many dam components (e.g., drains, valves, trash racks). Consideration must be given during design to provide features that allow for rehabilitation and replacement at some future time.

- Risers must have an inlet cross-sectional area (total area of riser openings) at least 1.5 times that of the conduit (spillway pipe).

- The designer should specify that the riser and barrel be constructed of the same materials. Where that is impractical (e.g., HDPE barrel) the designer must consider any special details that are necessary to ensure the connection between the riser and barrel is watertight, and that the materials used generally have similar anticipated useful design life.

- The design must include articulation at the first pipe joint downstream of the riser to allow movement of the riser with respect to the conduit (i.e., the first pipe joint must be located within four (4) feet of the riser).

- The riser must be designed in a manner such that flow **out** of the riser through the pipe spillway controls the total discharge before any opening **into** the riser transitions to orifice flow. Flow through the riser when a riser opening is in orifice flow must be limited by the pipe spillway. The objective is for flow control to go from the weir flow in riser to pipe flow in the barrel without allowing the riser to be controlled by orifice flow, which could cause cavitation. This is achieved by adequate sizing of riser weir crest lengths and/or raising the elevation of the top of the riser.

- For risers with solid covered tops, the bottom of the cover slab must be set at an elevation to prevent orifice flow control before pipe flow control governs.

- Ultimate bearing capacity of foundation soils under risers must be calculated, and the report must show that a minimum factor of safety of three (3.0) must be met under normal loading conditions. Risers may not be founded on gravel/aggregate subgrades.

- The flotation analysis for the riser must assume all openings are plugged. The factor of safety against flotation must be 1.2 or greater if the soil backfill (and any water and connected structures) is not included in the computations. Where the buoyant unit weight of soil backfill is included in the computations, the factor of safety must be 1.5 or greater. The flotation analysis must assume the entire riser and riser base as submerged.

- Risers with an open top must have adequate anti-vortex devices. Splitter type anti-vortex devices must be placed in line with the barrel. An anti-vortex device is not required if weir control is maintained in the riser through all flow stages. Risers with a top slab do not require anti-vortex devices.

Corrugated Metal Pipe Riser Design

- Corrugated metal pipe risers and barrels are discouraged; however, they may be used on low hazard dams under 20 feet in height. Corrugated metal pipe risers and barrels are not acceptable on significant and high hazard dams or low hazard dams over 20 feet in height (measured from the downstream toe to the low point on the dam crest).

- Each metal pipe must be coated with a protective coating adequate to prevent corrosion for the planned life of the dam, or the design report must include an estimate of the expected service life of the pipe, the expected life of the dam, and a plan for replacement of the pipe when it no longer functions as designed. Coatings that are damaged during installation must be repaired.

- Corrugated metal pipe conduits and risers must conform to the requirements of AASHTO Specifications M-245 and M-246 (polymer coated pipe); M-274 (aluminum coated pipe); or, M-196 or M0211 (aluminum pipe). Both must have watertight coupling bands or flanges.

- Corrugated metal pipe risers must be constructed with a single length of pipe.

- The connection between a corrugated metal pipe riser and barrel must be welded the full circumference of the barrel pipe.

- Cathodic protection must be provided for corrugated steel pipe where the saturated soil resistivity is less than 4,000 ohms-cm or the pH is lower than five (5).

Concrete Riser Design

- Note that for all dams/small ponds, the Department prefers that the riser be cast-in-place. Cast-in-place construction is required where a dam embankment is greater than 20 feet in height, receives greater than 640 acres of drainage area, has greater than 50 acre-feet storage at top of dam, or is a significant or high hazard structure. Pre-cast top slabs are acceptable for these structures.

- For small ponds (i.e., those meeting the height, drainage area, storage volume, and hazard classification criteria to qualify for NRCS Maryland Pond Code 378), pre-cast construction is acceptable provided the entire riser (base/walls) are cast in one piece. Separate pre-cast top slabs are acceptable. The pre-cast shop drawings must be approved by the design engineer before casting. The pre-cast risers must include provision for watertight connection to the pipe barrel.

- Where cast-in-place construction is required (as indicated above), the design shall incorporate the requirements of the latest edition of American Concrete Institute (ACI) 318 Building Code Requirements for Structural Concrete and ACI350 Code Requirements for

Environmental Engineering Concrete Structure.

- Where pre-cast riser wall heights equal or exceed ten (10) feet, the design must incorporate the requirements of ACI 350.

- The minimum compressive strength of concrete used in any part of construction of a dam, small pond, or outlet works (excluding mud mats or pipe cradles) must be 4,000 psi. In general, MDOT SHA Mix #6 is adequate.

- The maximum permissible water-cement ratio (w/c) is 0.42. Where cementitious materials in addition to Portland cement are used, the water-cementitious material ratio required is that which would be expected to give the same level of compressive strength at the time the concrete is exposed to the design environment as would be given by a mixture using no cementitious material other than Portland cement.

  Continuous PVC waterstops (9" minimum width) are required in all riser joints. The PVC waterstops should be located in the center of the riser wall and supported during the concrete pour. PVC waterstops must be located to not interfere with the placement of the reinforcing steel.
- All pipe connections to the riser must include bentonite waterstops in the center of the riser walls.

- Aggregates proposed for use in concrete structures associated with high and significant hazard dams must be tested for alkali-silica reactivity. Aggregates susceptible to alkali-silica reactivity are not acceptable. MDOT SHA 2022 Standards Specifications for Construction and Materials, Section 902.10 include one acceptable methodology for determining acceptable aggregates.

Trash Rack Design

- Trash racks are required in front of all openings in the riser. All trash racks should be capable of removal to allow for maintenance and replacement.

- Trash racks must be designed and built to provide positive protection against clogging of the riser opening at any point.

- Each acceptable trash rack must be constructed of material of sufficient strength to withstand the impact of the material that could reasonably strike the inlet during heavy flows.

- Flush grates for trash racks are prohibited. Risers that have flow over the top (e.g., corrugated metal pipe risers) must have a non-clogging trash rack extending 8-inches below the weir opening/crest, which allows passage of water from underneath the trash rack into the riser (e.g., such as a hood-type inlet).

- Bar-type trash racks must project at least six (6) inches out from the riser no less than 6 inches below the invert or crest of the opening.

- Openings for trash racks must be no larger than 1/2 of the barrel conduit diameter, but in no case less than six (6) inches (with the exception of low-stage releases as described below).

- Trash racks must have a minimum of six (6) inches clearance below the trash rack to the grading around the riser.

- Low stage releases where the minimum opening dimension is six (6) inches or greater must have a non-clogging trash rack with openings no larger than half the smallest low flow opening dimension. Low stage releases where the opening is smaller than six (6) inches must be protected by a non-clogging draw-down device with openings no larger than one (1) inch and a total opening area greater than four (4) times the low stage release opening area.

- For trash racks that are not easily accessible for cleaning, the maximum velocity through the rack should be limited to two (2) feet per second. If the rack is accessible for cleaning the velocity may approach five (5) feet per second. The maximum velocity of flow should be calculated with the reservoir five (5) feet above the top of the trash rack or at the crest of the emergency spillway whichever is lower. Velocity will be computed on the basis of the net area of opening through the rack.

Additional Information

Questions about this policy or other items relating to ponds and dams can be directed to the Chief of the Dam Safety Permits Division at 410-537-3552. Additional suggested guidance documents include, but are not limited to the following:

- United States Department of the Interior, Bureau of Reclamation (USBR), Design of Small Dams, 1987
- USBR Design Standards No. 3, Water Conveyance Systems, Chapter 12, General Structural Considerations
- US Army Corps of Engineers (USACE) EM 1110-2-2000, Standard Practice for Concrete for Civil Works Structures
- USACE EM 1110-2-2102, Waterstops and other Preformed Joint Materials for Civil Works Structures
- USACE EM 1110-2-2400, Structural Design and Evaluation of Outlet Works
- NRCS National Engineering Handbook, Part 636 Structural Engineering, Chapter 52, Structural Design of Flexible Conduits
- NRCS TR-30, Structural Design of Standard Covered Risers, 1965
- NRCS TR-67, Reinforced Concrete Strength Design, 1980