Chapter 4
Spillway Crest Gates

4-1. General

Similar to navigation lock gates, spillway crest gates use a horizontal framing system. As with navigation lock gates, vertical framing systems are not structurally efficient and require special framing to accommodate roller guides for hoisting operations. Hence, vertical framing is not recommended for new vertical lift gates, except for replacement in kind. Most spillway crest gates use a fixed-wheel end support system. Tractor and slide gates have been used for spillway crest gates; however, their use is not very common for this type of application. Paragraph 2-2*b* describes the different arrangements of spillway crest gates. Much of the information regarding framing, loads, and load types provided in this chapter references information provided in Chapter 3. Only information unique to spillway crest gates is provided in this chapter.

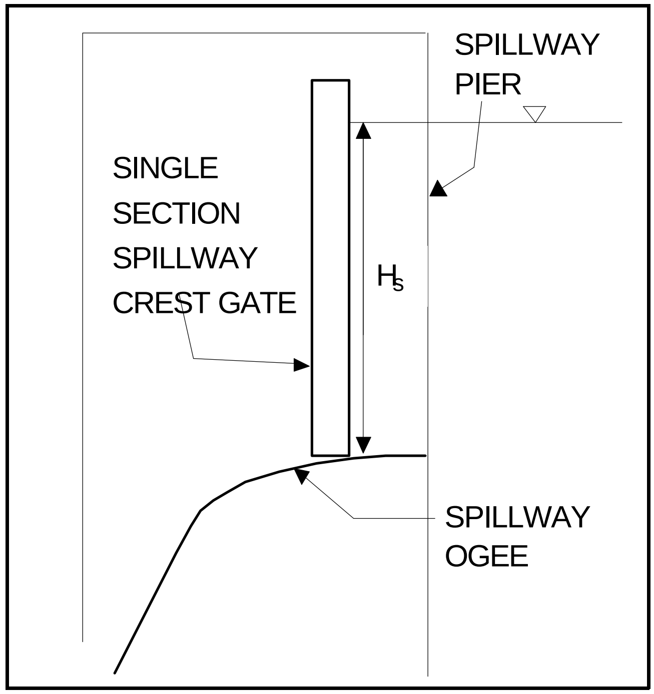

Figure 4-1. Single-section spillway crest gate

4-2. Framing Systems

Horizontal girder framing is the most common type of framing system used for spillway crest gates. They may be framed with plate girders or rolled shapes. This type of framing system is described in paragraph 3-2*a*.

4-3. Load Types

The following load types are applicable to vertical lift gates used in navigation lock structures:

a. Hydrostatic. The hydrostatic load H_s shall be determined based on site-specific conditions that account for the differential between headwater and sill bearing at the spillway crest. Headwater is determined from reservoir regulation studies for the dam.

(1) For single-section gates, flow is under the gate. No consideration is given to water passing over the top of the gate. H_s represents hydrostatic head differential between headwater and the sill bearing at the spillway crest, and is represented in Figures 4-1 and 4-2. In addition, H_s acts as uplift on the bottom of the gate when passing flows through the spillway. The net uplift shall be determined from combined effects of downpull forces *R*.

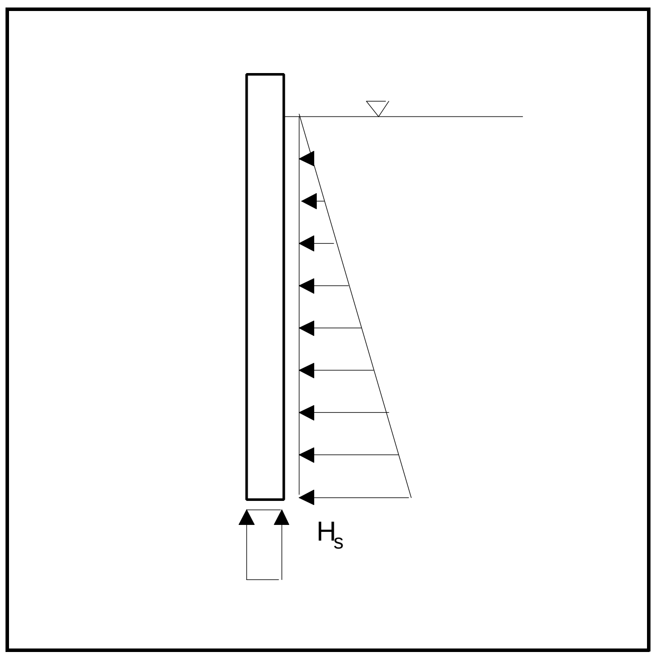

Figure 4-2. Single-section spillway crest gate, hydrostatic loading diagram

(2) For multiple-section gates, consideration must be given to water passing over the top of the sections of the gate because the gate can be split to allow flow at various sections. For each section, H_s represents hydrostatic head differential between headwater and the bottom of each section, with the bottom section at the sill, bearing at the spillway crest. This is represented in Figures 4-3 and 4-4. These gates may

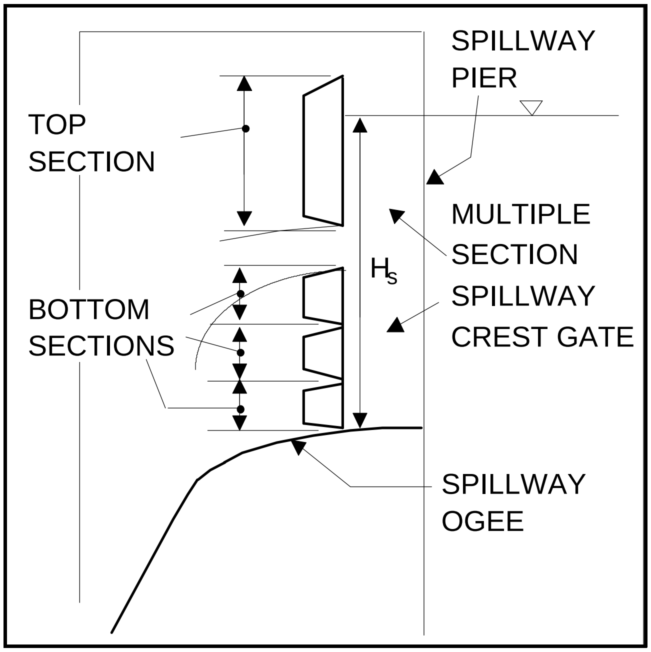

Figure 4-3. Multiple-section spillway crest gate

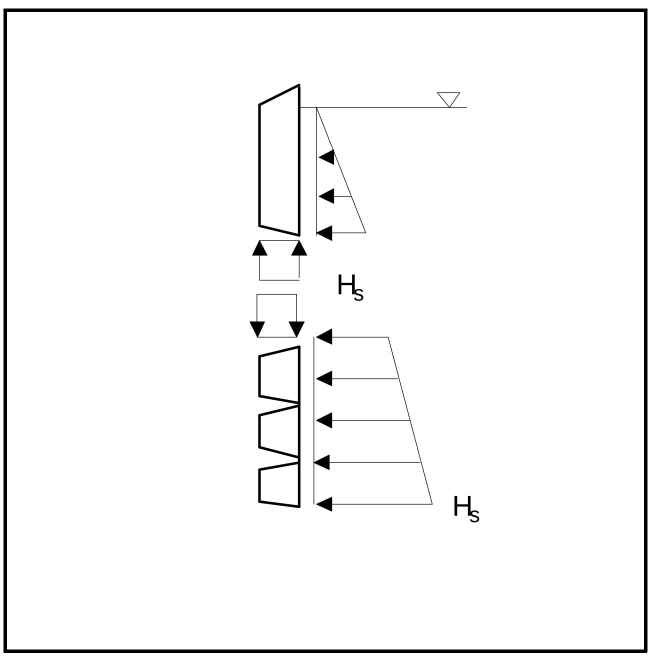

Figure 4-4. Multiple-section spillway crest gate, hydrostatic loading diagram, top and bottom sections split

be used as a single-section gate. For this condition, H_s will act as uplift on the bottom of the gate when flow is through the spillway. The net uplift shall be determined from combined effects of downpull forces *R*.

(3) For double-section gates, consideration must be given to flow over the top section. The amount of hydrostatic head flowing over the top section of the gate is determined from hydraulic studies and operational criteria for the reservoir. Operation of the bottom section should consider uplift (bouyant effects) on the bottom of the gate. H_s represents hydrostatic head differential between headwater and the bottom of both sections, with the bottom section at the sill, bearing at the spillway crest. This is represented in Figures 4-5 and 4-6. The net uplift shall be determined from combined effects of downpull forces *R*.

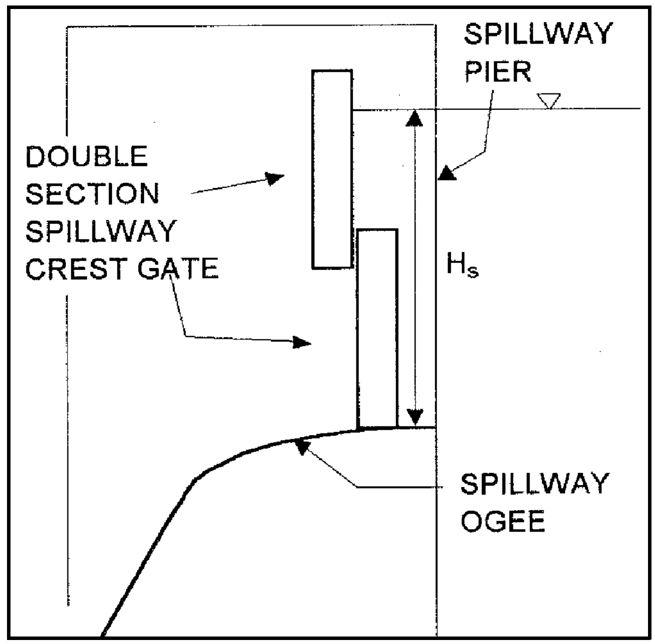

Figure 4-5. Double-section spillway crest gate

b. Hydrodynamic. The hydrodynamic loads H_D shall be determined based on site-specific conditions for vertical loads from water flowing over sections of spillway gates. The amount of head flowing over the sections of the gate is determined from hydraulic studies and operational criteria for the structure. H_d is applied similar to water flowing over leaves of submersible gates, shown in Figure 3-8.

c. Gravity. These loads shall be applied as described in paragraph 3-3*c*.

d. Operating equipment. *Q* is the maximum inertial load that can be exerted by the operating machinery. This shall consider the inertial effects of the deadweight, and in the case of double- or multiple-section gates, the inertial effects of the hydrodynamic load, H_d, ice *C*, and mud *M*, while using the gate for passing ice and debris.

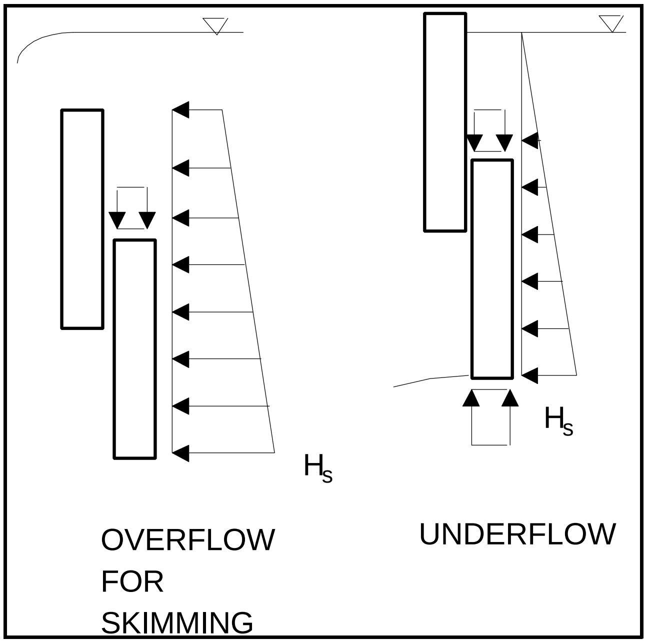

Figure 4-6. Double-section spillway crest gate, hydrostatic loading for overflow and underflow operation

e. Impact. Spillway crest gates are subject to debris or ice impact *I* of 5 kips/ft along the gate at the upstream water elevation. Impact loads need only be applied to main load-carrying members. For example, skin plate and intercostals need not be designed for impact loads.

f. Earthquake. These loads shall be applied as described in Paragraph 3-3*f*.

g. Downpull. Downpull forces *R* (sometimes referenced as downdrag) shall be determined based on flow conditions and the shape of the gate. These shall be determined by hydraulic studies or extrapolation of data from previous testing.

h. Wind loads. Wind loads shall be based on site-specific conditions. ANSI A.58.1/ASCE 7-95 (ANSI/ASCE 1995) may be used to determine wind pressures acting on the gate. Wind load shall be applied normal to the projected surface of the gate.

4-4. Load and Resistance Factor Design

a. Design guidance. Spillway crest vertical lift gates shall be designed using LRFD methods in accordance with EM 1110-2-2105. A synopsis of the methodology and general guidance for use of LRFD for HSS is presented in EM 1110-2-2105 and will not be repeated here. Design strength factors shall conform to the requirements in EM 1110-2-2105.

b. Load cases and load factors. Lift gates shall have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in the following load combinations. The most unfavorable effect may occur when one or more of the loads in a particular load combination is equal to zero. For each load combination the gate should be considered supported on either its fixed supports or by the hoisting equipment. For Equation 4-1, *Q* or *R* should be taken as zero when resting on its fixed supports.

$$1.2D + 1.6(C + M) + (1.3W \text{ or } 1.2\,Q \text{ or } 1.0\,R) \qquad (4\text{-}1)$$

$$1.0D + 1.0(C + M + \mathrm{H_d}) + 1.2Q \qquad (4\text{-}2)$$

$$1.2D + 1.4\,H_S + kI \qquad (4\text{-}3)$$

where

$k = 1.0$ for debris with no ice and $k = 1.6$ for ice

$$1.2D + 1.2\,H_s + 1.6\,H_d \qquad (4\text{-}4)$$

$$1.2D + 1.2H_s + 1.0E \qquad (4\text{-}5)$$

where

D = deadweight load of the gate

C = weight of ice

M = weight of mud or debris

W = wind load acting on the exposed portion of the gate

Q = maximum inertial effects of machinery forces

R = downpull forces

H_d = hydrodynamic head due to waves or flow over gate leaves

H_s = hydrostatic load due to differential head

I = lateral impact forces from ice or debris

E = lateral seismic forces from adjacent water

4-5. Commentary on Loads and Load Factors

a. Loads.

(1) Hydrostatic. The loadings in Figures 4-1 to 4-6 represent the gate seals on the upstream face. This would be the general arrangement for this type of gate.

(2) Hydrodynamic. The total amount of head overtopping the sections of a multiple-section and double-section gate shall be determined by investigation of river hydraulics and operational criteria. For gate sections that are replacing old gates in the same structure, H_d shall be determined by existing operational data or conditions. Because loads from ice or debris will be greater than wave forces, loads resulting from wave forces may be neglected.

(3) Gravity. Ice and silt or mud vary based on site-specific information. Data or observations for replacement of existing gates may be used to determine *C* or *M*. Usually the skin plate for a spillway crest gate is located on the upstream side, which prevents silt from building up on the girders of the gate. Hence mud is not a contributing factor. Ice can build up on the gate and contribute significant forces, depending on the regional and ambient conditions.

(4) Operating equipment. Coordination between the structural and mechanical engineers is required to determine the operating equipment loading. The mechanical engineer will need gate deadweight *D* and hydrodynamic load H_d, ice *C*, mud *M*, and downpull *R* to determine operating equipment requirements, including inertial effects.

(5) Impact. Impact values are taken from EM 1110-2-2702. For gates used in extreme weather conditions, further information for ice loadings may be obtained from EM 1110-2-1612.

(6) Earthquake. See discussion in paragraph 3-5*a*(6).

(7) Downpull. Downpull force on a gate is the result of a reduction of pressure on the bottom of the gate from the static head, or may be viewed as a reduction in upthrust or reduction in buoyancy. These forces contribute to the hoisting requirements as well as the vertical load capacity of the gate. Factors that affect the amount of downpull include the location of the gate seals (upstream or downstream), gate seal friction, upward thrust component due to energy head acting on the bottom of the gate, shape of the bottom of the gate, and flow over the top of the gate. EM 1110-2-1602 and its referenced publications may be used to determine these loads acting on the gate. Other published data for methods of determining the effect of downpull forces may be obtained from U.S. Army Corps of Engineers Hydraulic Design Criteria (HDC) Sheets 320-2 to 320-2/3; Sagar and Tullis (1979); and Sagar (1977a, 1977b, 1977c).

(8) Wind. Wind loads for spillway crest gates will not control the main member sizes and overall geometry of the gate; however, wind will affect the stability of the gate while in the raised condition. For single-section gates, a significant portion of the gate will be raised out of the slot while passing flood flows. Depending on the hoisting arrangement and dogging positions of the gate, wind may cause stability problems with the gate. For the same reason, latching mechanisms for multiple-section gates that are raised above the gate slot should be designed to resist wind loads that induce shearing forces in the latch pins. These shearing forces are a result of rotation of the exposed portion of the gate relative to the postion of the gate fixed in the slot.

b. Load cases and load factors. The commentary presented in paragraph 3-5(b) is applicable to spillway crest gates and is not repeated in this chapter except as noted. Equations 4-1 and 4-2 are intended to provide a check on maximum vertical loads to hoisting equipment and lifting anchor points. Wind will add forces to the gate and gate latching mechanism when raised in the slot. In this case 1.3*W* should be substituted in Equation 4-1 with *Q* or *R* taken as zero. The addition of 1.0*R* to Equation 4-1 is to account for downpull while *W* may cause shear forces in the gate latching mechanisms to be greater than either *Q* or *R*. The greater affect of *W*, *Q*, or *R* shall be applied. Equation 4-2 provides a check for vertical components of hydrodynamic forces H_d that act in conjunction with operating equipment loads *Q*. The constant *k* in Equation 4-3 accounts for either debris or ice. In mild climates, ice does not form; however, debris does add additional load to the gate. Therefore, two load factors are given, one for ice and one to account for debris in mild climates. Where conditions present loads from both ice and debris, the greater of the two shall be applied.

4-6. Serviceability Requirements

Serviceability requirements presented in paragraph 3.6 for navigation lock vertical lift gates are applicable to spillway crest vertical lift gates and are not repeated in this chapter.

4-7. Fatigue and Fracture Control

Fatigue and fracture control requirements for members and their connections are discussed in paragraph 3-7 for navigation lock vertical lift gates. For spillway crest vertical lift gates, the total number of loading cycles is based on the projected frequency of usage over the life of the gate. Generally, spillway gates are not operated as frequently as navigation lock gates; hence the fatigue may not play a significant role in the design of the gate. Where projected usage of the gate is expected to place the members and connections into fatigue stress categories listed in AISC (1995), then the requirements in paragraph 3-7 for navigation lock vertical lift gates shall apply.

4-8. Material Selection

Material selection for spillway crest vertical lift gates shall follow the same guidelines established in paragraph 3.8. Framing methods and material types are similar to those of navigation lock vertical lift gates and are not repeated here.

4-9. Weldments

Weldments for spillway crest vertical lift gates shall follow the same guidelines established in paragraph 3.9. Welding materials and procedures are similar to those of navigation lock vertical lift gates and are not repeated here.

4-10. Design Details

Design details for spillway crest vertical lift gates shall follow the same guidelines established in paragraph 3-10. Seals, wheels, tracks, guides, and fatigue and fracture details are similar to those of navigation lock vertical lift gates and are not repeated here.