Reinforcement shall be sufficient to prevent breakup of the slab during design conditions, even if the soil under the slab is undermined by erosion. Slabs-on-grade installed on structural fill shall be placed so that there is no loss of supporting soil during the design flood conditions.

Exception: When located under an elevated building, slabs-on-grade shall not be reinforced or use turned-down edges.

2.5.2 Footing Design

Footings shall support the structure during design flood conditions, including prolonged inundation and scour and erosion if expected during design flood conditions, to prevent flotation, collapse, and lateral movement.

Footings that are also intended to act as grade beams shall comply with the provisions of Section 4.5.9.

2.6 ENCLOSURES BELOW THE DESIGN FLOOD ELEVATION

Enclosed areas that are used solely for parking, building access, or storage shall be permitted below the DFE provided the enclosed areas meet the requirements of this section.

2.6.1 Required Openings in Foundation Walls

Foundation walls that enclose an area below the DFE, and that do not meet the dry-floodproofing requirements of Section 6.2, shall contain openings to allow for automatic entry and exit of floodwaters during design flood conditions. These openings shall meet the requirements of Section 2.6.2.

2.6.1.1 Openings in Breakaway Walls

Openings to allow for the automatic entry and exit of floodwaters during design flood conditions shall be installed in breakaway walls in flood hazard areas other than Coastal High Hazard Areas. Openings shall meet the requirements of Section 2.6.2 or Section 4.6.2.

Openings in breakaway walls in Coastal High Hazard Areas shall not be required.

2.6.2 Design of Openings

Openings shall meet the nonengineered requirements of Section 2.6.2.1 or the engineered opening requirements of Section 2.6.2.2.

2.6.2.1 Nonengineered Openings

Nonengineered openings shall meet the following criteria:

1. There shall be a minimum of two openings on different sides of each enclosed area; if a structure has more than one enclosed area below the DFE, each area shall have openings;
2. The total net area of all openings shall be at least 1 square inch for each square foot of enclosed area;
3. The bottom of each opening shall be no more than 1 ft above the adjacent ground level;
4. Openings shall not be less than 3 in. in any direction in the plane of the wall;
5. Any louvers, screens, or other opening covers shall not block or impede the automatic flow of floodwaters into and out of the enclosed areas; and
6. Openings meeting requirements 1 through 5 above installed in doors and windows are acceptable; however, doors and windows are not deemed to meet the requirements of this section.

2.6.2.2 Engineered Openings

Engineered openings shall meet the following criteria:

1. Each individual opening, and any louvers, screens, or other covers, shall be designed to allow automatic entry and exit of floodwaters during design flood or lesser flood conditions;
2. There shall be a minimum of two openings on different sides of each enclosed area; if a structure has more than one enclosed area below the DFE, each area shall have openings;
3. Openings shall not be less than 3 in. in any direction in the plane of the wall;
4. The bottom of each required opening shall be no more than 1 ft above the adjacent ground level;
5. The difference between the exterior and interior floodwater levels shall not exceed 1 ft;
6. In the absence of reliable data on the rates of rise and fall, assume a minimum rate of rise and fall of 5 ft/h; where an analysis indicates the rates of rise and fall are greater than 5 ft/h, the total net area of the required openings shall be increased to account for the higher rates of rise and fall; where

an analysis indicates the rates of rise and fall are less than 5 ft/h, the total net area of the required openings shall remain the same or shall be decreased to account for the lower rates of rise and fall; and

7. The minimum total net area of the required openings in non-breakaway enclosure walls shall be calculated using the equation:

$$A_o = 0.033\,(1/c)(R)(A_e)$$

where

A_o = the total net area of openings required (in.^{2});

0.033 = coefficient (in.$^2 \cdot$ h/ft^3) corresponding to a factor of safety of 5.0;

c = opening coefficient of discharge given in Table 2-2;

R = worst case rate of rise and fall (ft/h); and

A_e = the total enclosed area (ft^2).

3.0 HIGH RISK FLOOD HAZARD AREAS

3.1 SCOPE

The requirements of Section 3 shall apply to new construction and substantial improvements in High Risk Flood Hazard Areas subject to one or more of the following hazards: alluvial fan flooding, flash floods, mudslides, erosion, high velocity flows, high velocity wave action, breaking wave heights greater or equal to 1.5 ft (Coastal High Hazard Area and Coastal A Zone) and damage-causing ice or debris. In addition to the requirements of Section 3, the basic requirements of Section 2 shall apply to High Risk Flood Hazard Areas other than Coastal High Hazard Areas and Coastal A Zones.

Table 2-2. Flood Opening Coefficient of Discharge

Opening Shape and Condition	c
Circular, unobstructed during design flood	0.60
Rectangular, long axis horizontal, short axis vertical, unobstructed during design flood	0.40[a]
Square, unobstructed during design flood	0.35
Rectangular, short axis horizontal, long axis vertical, unobstructed during design flood	0.25[b]
Other shapes, unobstructed during design flood	0.30

[a] When the horizontal dimension is twice or more the vertical dimension, use 0.4; as the dimensions approach a square, interpolate from 0.4 to 0.35.

[b] When the horizontal dimension is half or less the vertical dimension, use 0.25; as the dimensions approach a square, interpolate from 0.25 to 0.35.

3.2 ALLUVIAL FAN AREAS

Structures shall not be constructed at the apex of an alluvial fan and in the fan's meandering flow paths. Construction in other areas of the alluvial fan shall meet the following requirements:

1. The elevation of the lowest floor shall be a minimum of 1 ft above the highest adjacent grade, or higher, if required on a community's flood hazard map;
2. Foundations shall be designed and constructed to resist scour caused by the actual flow velocity but not less than 5 ft/sec. Determination of actual flow velocities shall be based on a review of a community's flood hazard map and flood hazard study or on hydraulic calculations; and
3. Design and construction shall resist all load combinations specified in Section 1.6.2.

3.2.1 Protective Works in Alluvial Fan Areas

Structures shall not be allowed in alluvial fan areas unless protective works (whole alluvial fan flood damage reduction project) have been designed and constructed:

1. To safely pass the design flood at the apex, within the capacity of the constructed channel(s);
2. Such that it does not divert flood flows and debris toward other structures, nor increase flood velocities and depths elsewhere on the alluvial fan; and
3. Such construction satisfies the requirements of Section 1.4.2, and a maintenance and operations plan for the protective works is provided.

3.3 FLASH FLOOD AREAS

Structures shall not be constructed in areas subject to flash flooding equal to or less than design flood conditions.

Areas suspected of being subject to flash floods shall be investigated to obtain historical information on past events. The investigation shall also include analysis of historic rainfall and runoff data for the watershed. Results of such analyses shall be documented in an engineering report, which defines the methodology and data used to conclude whether the area in question has the potential for flash flooding.

This standard generalized the equation derived in Ref. [C17] to account for different rates of rise and factors of safety.

Discharge coefficients shown in Table 2-2 were taken from or derived from standard hydraulics texts. The coefficient represents the ratio of the actual flow through an opening divided by the ideal flow, where ideal flow is given by

$$Q = A\,(2\,g\,H)^{0.5}$$

and where Q = ideal flow (cfs), A = cross-sectional area of opening (sq ft), H = depth of flow at opening (ft), and g = gravitational constant (32.2 ft/s^2).

In the case of circular openings, hydraulics references tell us the discharge coefficient for a vertical circular, sharp-edged orifice will be approximately 0.60 under low head conditions, which are required here (maximum head difference across opening equal to 1 ft). Coefficients for the rectangular and square openings were calculated for typical opening sizes (i.e., 12 in. × 12 in. or 8 in. × 16 in., corresponding to nominal masonry unit sizes) using the ideal flow discharge relationship above and the following discharge relationship for a contracted rectangular weir:

$$Q = 3.330(L - 0.2\,H)\,H^{1.5}$$

where

Q = flow through opening in cfs;
L = horizontal length, ft; and
H = depth of flow through opening, ft.

Other shapes were assigned a coefficient of 0.30 based upon flow through a V-notch or trapezoidal weir. If the designer is certain the potential for blockage by debris is small, discharge coefficients between 0.25 and 0.60 should be used depending upon the opening shape.

The minimum dimension of the opening in any direction in the plane of the wall should be 3 in. This minimum dimension will help prevent blockage by small debris and sediment. The opening may be any shape as long as the appropriate discharge coefficients are used to reflect the shape (circular, square, rectangular, etc.)

C3.0 HIGH RISK FLOOD HAZARD AREAS

C3.1 SCOPE

The nature of the hazards listed in Section 3.1 makes the identification of High Risk Flood Hazard Areas difficult and the design and construction in such areas problematic. In addition, the state or local authority having jurisdiction may have additional requirements or may not permit any building in these areas. The intensity, spatial extent, duration, and probabilities associated with these hazards are difficult to predict, leading to uncertainties associated with the delineation and management of High Risk Flood Hazard Areas. Ref. [C4] provides general guidance for management of High Risk Flood Hazard Areas. Unfortunately, the scenic beauty of many areas in which high risk flood hazards occur attracts development interest and poses a serious challenge to floodplain managers and building officials.

The basic requirements of Section 2 apply in High Risk Flood Hazard Areas that are not identified as Coastal High Hazard Areas (V zones) and Coastal A Zones. Section 3 provides additional requirements for construction in many High Risk Flood Hazard Areas contingent upon the design and construction of protective works. However, the designer is cautioned that the same problems and uncertainties, identified above, that make the identification of High Risk Flood Hazard Areas difficult also make design and construction of protective works difficult. Construction of protective works, or reliance on existing works, to protect a structure in a High Risk Flood Hazard Area may be ill-advised, especially where uncertainties about flood hazards are great.

In High Risk Flood Hazard Areas, poor maintenance or improper operation of protective works and facilities, including pumping plants, can cause damage to or failure of those protective works and facilities, and will almost certainly result in damage or destruction of structures behind the protective works. Therefore, all protective works should include implementation of a well-conceived plan for periodic inspection, maintenance, repair, and testing.

C3.2 ALLUVIAL FAN AREAS

Alluvial fan areas represent one of the most hazardous floodplain areas. Alluvial fans are geomorphic features characterized by cone- or fan-shaped deposits of boulders, gravel, sand, and fine sediments that have been eroded from upstream watersheds, and then deposited on the adjacent valley floor. Flooding that occurs on active alluvial fans is often characterized by debris and sediment-laden flows. Channel avulsion or overbank flows can result in unconfined flows on alluvial fans where flow paths are unpredictable and subject to lateral migration. In addition, these fast-moving flows present hazards associated with erosion, debris