FLOOD

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1.0 SCOPE

This data sheet provides recommendations for the prevention and mitigation of losses due to flooding and storm water runoff. Flood prevention and mitigation is an approach that relies on permanent solutions and emergency actions. Solutions include flood gates and barriers, flood pumps, waterproofing, emergency power, permanently relocating equipment, flood defense systems, etc. Permanent solutions are preferred whenever practical.

Detailed guidance on the design of flood protection for locations subject to direct wave action associated with coastal flooding is beyond the scope of this document. Avoid building in such areas. The forces associated with direct wave action will challenge the integrity of buildings unless the buildings and grounds are properly designed. Each coastal location is unique and requires a full understanding of the geotechnical issues along with dynamic wave and wind impacts.

The design, inspection, and maintenance of dams and levees are also beyond the scope of this document. Refer to Data Sheet 10-2, *Emergency Response,* for information on flood emergency response plans (FERPs).

This data sheet does not address how to find or interpret flood information or maps.

1.1 Hazards

Flooding can occur adjacent to bodies of water, on normally dry land far from flood sources, or from a combination of exposures. For the purposes of this data sheet, flood exposures have been grouped into the following categories:

A. River, riverine, fluvial flooding: Rivers, lakes, man-made drainage channels, smaller watercourses overflowing due to upstream heavy rains, melting snow, and dam releases.

B. Alluvial fan flooding: Flooding that occurs in areas at the base of steep-sloped areas; as the water exits the steep area it fans out in the flat areas in a random manner.

C. Coastal flooding: Oceans, bays, estuaries, and rivers affected by coastal waters overflowing due to abnormal high tides, coastal storms, high winds or tsunamis. It is not uncommon for inland areas along rivers to be affected by tidal flooding; for example, for the Thames River in England or the Yangtze River in China, coastal flooding can influence the river for 100 km and 200 km, respectively, from the river's mouth.

D. Storm water flooding: Storm water flooding is caused by the accumulation of runoff on land and paved areas from rainfall before it enters a stream, river, body of water, or a manmade drainage system. Storm water flooding often happens due to poor drainage, insufficient drainage, overtaxed drainage systems, inappropriate landscaping, and building design. Another term for storm water flooding is surface water flooding.

It is important to note that the above flood types may mix as flooding occurs. Coastal rivers and estuaries may be affected by both river flooding due to upstream rains and coastal storms. Flooding in these areas may flood solely due to upstream rainfall or a coastal storm or a combination. Another example of mixed flooding is a flood event that may be exacerbated by a storm water event occurring at the same time as a river or coastal flood.

When flood water enters a building, it not only damages the structure itself and the contents inside, but can also leave a facility's stored or in-process products stained, rusted, and deformed. Flood water also can cause equipment to malfunction. Electrical switchgear and electronics may require major repair or replacement. Water may fill below-grade areas and remain there after the flood recedes. Business interruption can vary from a few days to more than a year based on the depth of water, duration of flooding, wave and water velocity impact, and sensitivity of the occupancy to water damage.

A facility that is not properly designed to minimize the effects of flooding will have more costly and frequent flood losses; possibly even a major loss that jeopardizes market share and bottom line for years to come.

1.2 Changes

October 2019. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Flooding can be caused by bodies of water (rivers, streams, oceans, bays, lakes, canals, etc.) overflowing their normal boundaries, or as the result of storm water runoff accumulating in normally dry areas. Protecting a facility from the negative effects of flooding, however, is not as simple as merely locating it outside known flood zones; inappropriate site layout and building design can create a storm water runoff flood exposure anywhere. In addition, off-site flooding can block access routes to and from the site, as well as interrupt vital utilities.

If a facility is located within a known flood zone, the challenge of managing the flood risk is greatly increased. The goals then become to ensure that:

A. operations can continue without interruption, and

B. the facility suffers the least possible amount of physical damage.

These goals can be achieved by developing a flood-mitigation strategy throughout the facility that addresses overall layout, electrical and mechanical systems, and vital utilities, and applying it during all phases of the site's lifespan, including design and construction. While instituting the flood-mitigation strategy is most effective during the design and construction phases, practical mitigation solutions included in this data sheet can be very effective for existing locations.

It is important to recognize that flood prevention and mitigation is a systemic strategy to protect property and business continuity. This section contains recommendations that can be implemented individually or in combination with each other. Effective and successful flood prevention and mitigation will often require the application of multiple recommendations simultaneously and systematically in a timely manner (see Section 3.4 and Table 3).

Use FM Approved products whenever they are applicable and available. For a list of FM Approved products, see the *Approval Guide,* an online resource of FM Approvals (www.approvalguide.com)

2.2 Construction and Location

2.2.1 Site Selection for New Construction

Proper site selection is the best solution for avoiding the effects of flooding. Selecting the correct site is far less difficult than designing a facility located in a flood zone to resist the effects of flooding.

2.2.1.1 Select a location where the entire site and all access routes (highway, marine, railroad, etc.) are outside 0.2% annual exceedance (500-year) flood zones (by both elevation and footprint). Verify flood studies for the selected site are up-to-date by having a qualified hydrologist review the study and recent flood data.

2.2.1.2 Select a building site that is above the predicted 0.2% annual exceedance (500-year) flood elevation and includes 1 to 2 ft (0.3 to 0.6 m) of freeboard. The building site should be at least 500 ft (152 m) from direct wave impacts and or high flood-flow velocities (i.e., above 7 fps [2 m/s]).

2.2.1.3 Select a site that is not in an area protected by a levee or other man-made flood control works.

2.2.1.4 Ensure electrical and communication services, drinking and process water, wastewater treatment, steam supplies, etc. obtained from off-site locations will remain unaffected during flooding in their area. If this cannot be ensured, establish alternative sources for backup.

2.2.2 Storm Water Runoff and Terrain Management

Proper design of the facility's storm water management system is needed for all locations to ensure a flood exposure isn't created or flooding made worse by the layout, grading, storm-water management system, etc.

2.2.2.1 Ensure new or existing drainage systems are capable of conveying or storing the 100-year rainfall-induced runoff without causing property damage.

As storm-water systems are designed for low return period events (5 to 25 years) surface ponding during the 100 year event is acceptable provided there is no damage to property and key assets.

The duration of the design 100-year rainfall is selected to maximize site flooding (the critical rainfall duration is the combination of peak intensity and rainfall duration that causes the maximum flooding for a given return period event). Both subsurface routing (drainage piping) and overland flow capacity can be used to store and direct the runoff away from key assets.

2.2.2.2 Ensure the facility's storm-water management system uses grading sufficient to route predicted rain-water and snow-melt runoff away from buildings, outside storage, and equipment.

2.2.2.3 Ensure water runoff originating from off-site areas is included in the facility's site water management plan.

2.2.2.4 If on-site ponding or storm water routing is essential, ensure it is arranged so water will not enter or come into contact with buildings, outside storage, or equipment. All possible water ingress points, doors, windows, and pipes chases into the building envelope should be at least 6 in. (0.15 m) above the 100-year overland flow paths or ponding levels. Consider larger freeboard if there is a risk of inlet drains being blocked or the drainage system backing up.

2.2.2.5 Use customary drainage design features to limit soil erosion and avoid excessively high flow velocities. Table 1 lists the erosion threshold velocities for common materials.

2.2.2.6 Use grates, trash racks, curbs, etc. to protect the inlet to all drains and storm-water drainage systems against debris blockage.

2.2.2.7 Do not use landscaping materials, such as wood chips, pine needles, etc., that can be easily dislodged by rain water. They may obstruct or clog drainage systems, catch basins, culverts, or overland flow patterns.

Table 1. Erosion Threshold Velocities

	Mean Channel Velocity	
Bank Material	ft/s	m/s
Sandy silt	2	0.61
Clay	6	1.83
Gravel	6	1.83
Grass-lined earth	6	1.83
Sandstone	8	2.44
Solid rock	20	6.10

2.2.2.8 Do not locate buildings, outside storage, or fire protection equipment within natural storm water drainage flow paths such as small streams or swales.

2.2.2.9 Ensure walls, fences, and landscaping do not direct water on to buildings, outside storage, or fire protection equipment.

2.2.2.10 Install a backflow valve equipped with manual shutoff valves on each side of the backflow valve on effluent-discharge lines that connect to combined sewer systems (wastewater and storm-water runoff), drain lines that daylight to flood exposed areas, and any other areas that have a history of backups. Additionally, provide a backflow valve bypass line and normally closed shut-off valve on combined sewer drain lines to allow for maintenance.

2.2.2.11 Have systems with a history of blockages, surcharging, or flooding buildings modified to prevent reoccurrences.

2.2.2.12 For storm-water systems in desert areas or where windblown dust and/or sand can be an issue, include the possibility of partial or total loss of pipe capacity in the design.

2.2.2.13 Separate pumped drainage from basements from storm-water by means of backwater valves or other devices to prevent backflow during an extreme rainfall event.

2.2.3 Elevating the Entire Site

If it is not possible to comply with the recommendations in section 2.2.1, Site Selection, the risk of flooding may be greatly reduced by building up land levels.

2.2.3.1 Build up the entire site so it is above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.2.3.2 Do not raise the land in areas subject to high or moderate velocity flows (above 7 fps[2 m/s]). If this cannot be avoided, provide erosion protection designed by a qualified engineer.

2.2.3.3 Design fill material to be stable when exposed to flood action, including rapid rise and drawdown, prolonged inundation, scour, and erosion.

2.2.3.4 Ensure the facility and grounds are designed by a qualified registered civil or structural engineer with previous experience in flood-related loading and geotechnical conditions.

2.2.3.5 Ensure the geotechnical properties used for the foundation design (e.g., bearing and frictional resistance, active and passive pressure, and settlement) are based on diminished structural capacities that are associated with flood level and floodwater action.

2.2.3.6 Comply with all of the recommendations in Section 2.2.2, Storm Water Runoff and Terrain Management.

2.2.4 Elevating Individual Buildings and Key Equipment

If it is not possible to comply with the recommendations in Sections 2.2.1, Site Selection, or 2.2.3, Elevating the Entire Site, the risk of flooding to specific buildings and equipment may be greatly reduced by designing them to be above the flood elevation.

2.2.4.1 Design buildings, outside storage areas and equipment (whether owned by the facility or a utility company) to be above the predicted 0.2% annual exceedance (500-year) flood elevation by using raised foundations or elevated structures. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.2.4.2 Design foundations, buildings, and outdoor structures to withstand the predicted 0.2% annual exceedance (500-year) flood elevation to resist erosion from high water velocity. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.2.4.3 Do not build foundations in areas subject to high or moderate velocity flows (above 7 fps [2 m/s]). If this cannot be avoided, provide erosion protection designed by a qualified engineer.

2.2.4.4 Avoid narrowing, re-routing, or changing the onsite watercourse. If this cannot be avoided, have an engineer specializing in hydraulics ensure the hydraulic capacity or stability of the watercourse is not reduced.

2.2.4.5 Design and build structures to adequately resist all flood-related loads and conditions, including hydrostatic loads, hydrodynamic loads, breaking wave action, debris impact, ice floes, ice and debris jams, rapid rise and drawdown of floodwaters, prolonged inundation, soil liquefaction, soil consolidation and subsistence, sediment deposition, mud slides, and wave-induced and flood-related erosion and scour. Consider long-term erosion over the design life of the structure when determining the effects of flooding on building and foundation design.

2.2.4.6 Ensure design considerations also account for other applicable loads (e.g., gravity and wind) that will act on the structure concurrently with the flood.

2.2.4.7 Consider all appropriate load combinations when analyzing flood loads for actions, including overturning, sliding, undermining (erosion and scour), and uplift (buoyant forces).

2.2.4.8 Use load combinations, load factors, and resistance factors as specified in the governing model codes and standards. Where local codes do not specify load combinations with flood loads, use load combinations from the most recent editions of ASCE 7 or the International Building Code (IBC). However, in no case use flood load factors of less than 1.3 in strength design or 1.0 in allowable stress design.

2.2.4.9 Comply with all of the recommendations in Section 2.2.2, Storm Water Runoff and Terrain Management.

2.2.4.10 Retain a qualified registered civil/structural engineer with previous experience in flood-related loading and flood-related geotechnical conditions to design buildings, structures, and protective works (e.g., flood walls, retaining walls, bulkheads, levees, dams, channels, and diversions).

2.2.5 Lessening Damage for New Buildings Not Built Above Flood Levels

If the recommendations in sections 2.2.1, 2.2.3, or 2.2.4 cannot be complied with, adhere to the recommendations in this section to lessen the impact of flooding.

2.2.5.1 Ensure the lowest floors of buildings are built at the highest elevation possible. 0.2% annual exceedance (500-year) flood levels aren't reached during every event, so increasing the building's lowest floor elevation will reduce the number of flood losses.

2.2.5.2 Use building construction and finish material that will minimize damage and speed cleanup. Use materials that will ensure walls can be easily cleaned, dried, and sanitized. For example, concrete walls will be easier to restore than walls with fiberglass insulation and gypsum wallboard. Ceramic tile floors will suffer less damage than wood floors. Metal and glass doors will suffer less damage than wooden doors.

2.2.5.3 Design exterior walls and building entry points to keep out water as long as possible without relying on any human actions (e.g., closing flood gates). Do not install access that will compromise the integrity (completeness) of the barriers; install ramps or stairways that go over the barriers instead.

2.2.5.4 Comply with all of the recommendations in Section 2.2.2, Storm Water Runoff and Terrain Management.

2.2.6 Lessening Damage for Existing Buildings and Equipment

In order to successfully implement flood mitigation, a series or system of improvement actions must be undertaken to waterproof the perimeter of a site, building, and selected areas within a building or equipment. These actions include closing openings, waterproofing walls, sealing wall penetrations, and installing FM Approved flood abatement pumps, non-return valves, backflow valves, backwater valves, etc. Failing to address every water entry point can lead to flood damage.

A. Site Protection

This concept involves permanent, designed flood defenses along the perimeter of a site using floodwalls, earthen embankments, roadway gates, raised ground, etc., or a combination of each.

Flood pumps should be considered to reduce the likelihood that ponding from rainfall, seepage, or other bodies of water will create a flood risk within the perimeter.

B. Building Protection

This concept involves flood-proofing the exposed perimeter of the building to reduce exposure. The walls, floors, openings, doorways, vents, and penetrations of the building perimeter (including below grade) are addressed using a combination of permanently or temporarily installed flood barriers, flood pumps, backwater valves, and other flood-proofing products. The walls (including below grade) and floors should be non-permeable or improved.

C. Partial Building Protection

This concept involves flood-proofing a portion of a building. This allows water to enter the building, but protects key areas to reduce loss and expedite recovery. It may include protecting an exterior corner of a building along with two internal walls, one external wall, and three interior walls or a room that has only interior walls. There are multiple combinations.

D. Protection Of Equipment, Production Lines, and/or Storage

This concept involves flood-proofing specific equipment, production lines, or storage areas. It may include the permanent (preferred) or temporary elevation of equipment above flood levels, or the use of permanent or temporary barriers to protect a given space.

E. Relocation

This concept involves permanently relocating equipment and/or storage to a higher floor, another non-exposed building onsite or offsite.

Mobile equipment and vehicles should not be located in flood-exposed areas.

F. Temporary Perimeter Flood Protection Systems

These systems may be used as part of a design or can be used in an emergency basis. In an emergency, the devices would be placed over ground that hasn't been designed/studied to support the flood loads. Temporary flood protection systems rely on a crew to set up the system as the flood is approaching, thus adding a level of uncertainty.

G. Hybrid Solution

This method involves a mixture of the above concepts to provide a feasible and cost-effective solution.

Figure 1 shows a representation of the concepts described above. Buildings 1 and 2 and the outdoor equipment area are protected by a designed site protection system. Building 3 is protected by a building protection system. Building 4 shows key areas that utilize partial building protection along with an area with protection of equipment. There is also an outdoor area to the right of Building 3 that demonstrates the protection of equipment for outdoor areas. The offices in Building 4 are shown as relocated to an upper floor and demonstrates the relocation concept. The entire figure demonstrates a hybrid type of solution.

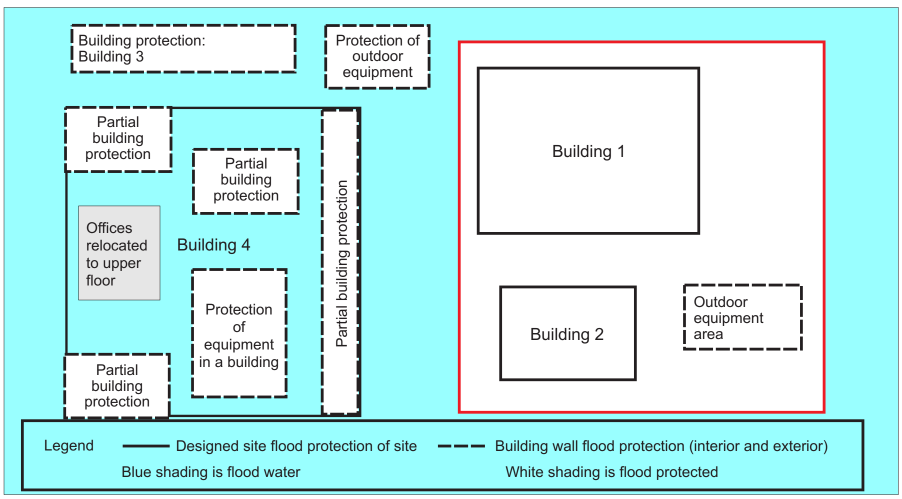

Fig. 1. Schematic for lessening damage at existing sites using a hybrid solution

2.2.6.1 Permanent Site Flood Protection Systems

This section focuses on permanent flood protection systems, levees, and floodwalls specifically designed for the site. A successful design will address the local flood scenario and requires knowledge of structures, hydrology, hydraulics, interior drainage configuration, soils, and the owner's technical ability to operate and maintain the system. Site flood protection must form a complete line of protection, surrounding the site or tying into sufficient high ground that it will not be circumvented by flood water upstream or downstream of the site. Interruption to normal site access routes and utility supplies while the flood protection system is in place should be considered in the design. This section is not intended as a design standard, but provides minimum guidelines.

2.2.6.1.1 Clients of FM Global should submit request for proposal (RFP) specifications and plans to FM Global well before the let of any contract. The conceptual plan for providing site-level protection should be shared with FM Global early in the planning stage. This will allow for a common understanding of the flood scenario and appropriate flood control system design, including the site protection as well as storm water removal, blocking underground conduits for flood water, temporary site access and utility supply.

2.2.6.1.2 Ensure the design is based on an up-to-date flood study that details the flood levels for the 1% annual exceedance (100-year) and 0.2% annual exceedance (500-year) recurrence intervals. The use of the most severe historical flood levels, while useful for the calibration of the detailed study, is discouraged as a design criteria. If such information is not readily available or current, have a hydrology and hydraulics study performed to determine the 1% annual exceedance (100-year) and 0.2% annual exceedance (500-year) water-surface elevations.

2.2.6.1.3 Retain a qualified firm experienced in the design and construction of flood protection systems. Design of the individual flood protection components differs from the “dry” design (e.g., retaining walls) because flood-exposed structures need to include static and dynamic water loads. Care is required to account for changes due to soil properties during flood loading and hydrostatic uplift forces. **Use a minimum factor of safety of 1.5.** Ensure the design incorporates the flood duration and any features needed to minimize the potential for foundation failure. The design should include not only the static hydraulic forces on the wall, but also the momentum dependent upon the expected water velocity, as well as floating debris in the flood water.

2.2.6.1.4 The height of riverine/fluvial systems should preferably be 0.2% annual exceedance (500-year) plus a minimum of 3 ft (0.9 m) of floodwall and levee freeboard or a value as determined by the designer based on the local conditions. Local conditions for assessing the floodwall and levee freeboard should include kinetic energy, super-elevation at bends, uncertainties in the estimated flood level and topographic data, changes in the flood levels during the life of the defense, settlement of the flood defense over its life, and wave action.

Exceptions to the riverine/fluvial 3 ft (0.9 m) floodwall and levee freeboard should be supported by engineering analyses to demonstrate the adequacy of a reduced floodwall and levee freeboard. The analyses should include a review of all the factors affecting the floodwall and levee freeboard requirement under local conditions, and the stability of the levee under flood conditions with regard to wave overtopping and erosion.

2.2.6.1.5 Coastal systems should also be designed for the 0.2% annual exceedance (500-year) water level and to prevent overtopping from associated wave action. The floodwall and levee freeboard should include the design wave or wave run-up (whichever is greater) plus 1 ft (0.3 m). The wave run-up is assumed to include wave setup.

2.2.6.1.6 Ensure the designer uses nationally recognized levee and floodwall standards (see Section 4.2.1). The United State Army Corps of Engineers (USACE) standards or international equivalents are acceptable to establish design criteria. Note that if the entire design configuration includes crediting for structures such as railroad embankments, highways, buildings, walls, and similar features they should be analyzed by the designer and proven to be able to withstand the design flood event.

The design should minimize pedestrian, roadway, or railroad openings that will require deployment of barriers during flooding. Selection of the barrier type should be based on the owner’s capability to deploy the barrier prior to the arrival of the flood. In addition, the opening type should be based on the magnitude of the warning time. The opening’s foundation should be designed to account for flood loading, seepage, and the closure device loading (see Section 2.2.6.1.3).

2.2.6.1.7 Assemble an written inventory of all water entry points that penetrate the flood protection system and allow water to enter the protected area. This includes storm sewers, sanitary sewers, various utilities conduits, tunnels, and similar penetrations. Flood water entry points should be designed to prevent backflow from the flooding source. Drain lines should be provided with backwater valves. Use the written inventory as part of the flood protection actions implemented prior to the flood.

2.2.6.1.8 Ensure the design includes details related to the flood abatement pumps to remove the rainwater, seepage, and smaller bodies of water that freely flow through the site during non-flood conditions. Reliable power sources and anti-siphon devices should be included in the design. Where possible, FM Approved flood abatement pumps should be provided.

2.2.6.1.9 An operations and maintenance manual that details how the system will be operated during a flood should be provided by the designer. A maintenance schedule for the life of the system should also be provided.

2.2.6.2 Complete And Partial Building Protection

2.2.6.2.1 Hire a structural engineer to review the stability and waterproofing capabilities of buildings walls, floors, and foundations and to identify other water entry points.

Most buildings are not waterproof or are not strong enough to rely on existing walls to keep water out. Two examples are wood-framed buildings and metal panel walls. Buildings of substantial construction, such as reinforced concrete, concrete block, etc. can be used for flood depths lower than 3 ft (0.9 m), often without the need for reinforcing. Flood depths of more than 3 ft (0.9 m) above floor level will subject the ordinary walls and floors to loads that cannot be withstood unless the building was originally designed to do so;

providing structural improvements usually is not a cost-effective solution. Additionally, flood depths of more than 3 ft (0.9 m) will increase the likelihood of grade or below-grade floors lifting and buckling due to hydrostatic uplift and may therefore require extensive reinforcing.

2.2.6.2.2 Have all water intrusion points in the floors and walls sealed, including the following:

A. Sanitary systems: Automatic closing devices such as backflow valves on waste water systems should be used. Manual devices can be used, but are not preferred; examples include ball valves, closed gates, and air-filled bladders.

B. Sanitary sewer, combined sewers, storm drains, and floor drains: Automatic closing devices such as backflow valves should be used. Manual devices can be used, but are not preferred; examples include sluice gates, air-filled bladders, etc.

C. Pipe penetrations: Gaps should be permanently sealed with water-resistant materials.

D. Ventilation ductwork and shafts: Ventilation equipment is lightweight and typically can’t withstand the forces developed by flood waters. Ductwork should be rerouted above the flood level, and the remaining openings should be blocked and sealed.

E. Electrical and signaling conduits: Gaps should be permanently sealed with water-resistant materials. This includes penetrations into electrical panels mounted on the wall that may not be apparent without opening the panels.

F. Construction floor and wall joints: Construction joints should be sealed. Walls and floors should be waterproofed to minimize through seepage.

G. Cracks caused by settling, impact, etc.

2.2.6.2.3 Plan for seepage and flood waters to collect in unexpected areas; FM Approved flood abatement pumps should be provided inside the building where walls and barriers are used to keep flood waters from entering the facility. Provide a primary and a backup pump designed to remove a minimum of 50 gpm (190 L/m) in case of seepage or water-pipe leaks. These pumps should be connected to emergency power. Use a certified engineer to estimate seepage rates in order to size the pumps.

2.2.6.2.4 Use FM Approved flood gates, stop logs, etc. for each flood-exposed opening, including doors, windows, air brick/air vent, and garage and loading dock entrances that cannot be permanently sealed. If automatic gates are used, they should be designed to be manually deployable as well. Flood-protection devices should only be installed in buildings that can support the predicted flood loads. The barrier should include 1 to 2 ft (0.3 to 0.6 m) of freeboard where possible. The total height of the barrier should not exceed 3 ft (0.9 m) unless the building can withstand the flood loads. Installation of opening barriers in close proximity to seams between the building floor and the outside sidewalk should be avoided or properly filled so hydrostatic pressure does not introduce a point of entry for water behind the barrier.

Opening barriers listed in the *Approval Guide* will have a leakage rate of not more than 0.08 gal/hr/linear ft (1 L/hr/m). They have not been evaluated for their ability to control coastal high-energy wave action that can occur with hurricanes, typhoons, or cyclones.

2.2.6.2.5 Flood gates can be used in higher velocity areas (flow of greater than 7 fps [2 m/s]) with flood depths up to 3 ft (0.9 m); however, a qualified structural engineer should evaluate the wall’s and gate’s ability to resist the hydrodynamic loads.

2.2.6.2.6 Flood gates, stop logs, etc. should be readily accessible and protected from the elements when stored.

2.2.6.2.7 Flood gates, stop logs, etc., whether permanently installed or for temporary use, should be designed so the facility’s staff can easily install the devices in time to prevent flooding. This installation must be included as part of the FERP. When common storage is used for multiple barriers, ensure the barriers are marked to indicate the proper location for deployment

2.2.6.2.8 Flood gates, stop logs, etc. and mounting devices should be protected from vehicle damage or theft; concrete bollards may be an option.

2.2.6.2.9 Confirm the following on a regular basis, plus after flooding and prior to predicted flooding.

A. On a monthly basis, confirm the following:

1. The gates are inspected and listed on the inspections forms.

2. The protected openings and gates are well maintained and don't show signs of damage or housekeeping problems.

3. The openings are kept clear of debris that may impact the barrier's functionality.

4. The gasket and securement system hasn't deteriorated.

5. Any new openings that have been added below the predicted flood elevation are properly sealed to withstand pressures during the design event.

6. Flood pumps are properly maintained.

B. On an annual basis, confirm the following:

1. Gate maintenance is adequate (painting, greasing, etc.).

2. Flood gates have been installed, and itemized records kept of these inspections.

3. The gate installation plan is part of the FERP.

4. Installation instructions are available.

2.2.6.3 Protection or Relocation of Equipment, Production Lines, and/or Storage

When it is not feasible to provide site perimeter or building protection, consider protecting or relocating equipment, production lines, or storage to reduce the potential flood damage.

2.2.6.3.1 Permanently (preferred) or temporarily elevate key equipment, production lines, or storage above the anticipated flood level. Providing raised floors, platforms, or storage racks is an option.

2.2.6.3.2 Relocate key equipment production lines or storage to upper floors or to a building or site that is not flood-exposed.

2.2.6.3.3 Use protection-in-place strategies when elevation or relocation of equipment, production lines, or storage is not an option. Protection-in-place strategies follow many of the same recommendations as site or building protection recommendations discussed in Sections 2.2.6.1 and 2.2.6.2, but are focused on smaller areas or critical equipment.

2.2.6.4 Temporary Perimeter Flood Protection Systems

The suitability of temporary barriers as part of a design needs to be evaluated with regard to warning time ahead of the flood, deployment time for the barrier, and available staffing to ensure it is deployed in time to prevent flood damage.

Temporary perimeter flood protection systems typically will have leakage rates greater than floodwalls and levees. Temporary perimeter barriers listed in the Approval Guide will have a leakage rate of not more than 15 gal/hr/linear ft (186 L/hr/m). The temporary perimeter barrier's Approval testing is conducted on a concrete surface; leakage rates on other surfaces are not part of Approval testing, nor have the systems been evaluated for their ability to control coastal high-energy wave action during hurricanes, typhoons, or cyclones.

2.2.6.4.1 Use FM Approved temporary perimeter barriers.

2.2.6.4.2 Have the temporary perimeter flood protection system designed by a qualified engineering firm. Follow recommendations in Section 2.2.6.1, Permanent Site Flood Protection Systems.

2.2.6.4.3 The time it takes to initiate the flood response, collect materials, gather the response crew, and deploy the protection should be less than half of the warning time determined for the site. If an adequate warning time cannot be provided, formulate an alternative flood protection plan.

2.2.6.4.4 Store temporary perimeter barriers at an accessible location on the site, and protect them against environmental damage and theft.

2.2.6.4.5 Inspect temporary perimeter barriers on a regular basis. Also inspect the temporary barrier installation footprint to ensure changes have not occurred that will render the temporary barriers ineffective or impossible to install.

2.2.6.4.6 Hold annual deployment drills to confirm the system will function as designed.

2.2.6.5 Hybrid Solutions

This concept involves a mixture of the above concepts to provide a feasible and cost-effective solution.

2.3 Occupancy

If the recommendations in Sections 2.2.1, 2.2.2, 2.2.3, or 2.2.4 cannot be complied with, adhere to the recommendations in this section to lessen the impact of flooding.

2.3.1 For each structure, identify areas and floors that are likely to be flooded, and ensure they are used solely for nonessential operations.

2.3.2 Ensure valuable storage is located above the 0.2% annual exceedance (500-year) flood level.

2.3.3 Locate all of the following on floors and in areas above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

A. Emergency power equipment

B. Spare parts, motors, and equipment including their controls and supporting equipment.

C. Building, construction and equipment plans, maintenance manuals, etc.

D. The maintenance department and its stores. Undamaged spare parts, maintenance equipment, and hand tools are vital to a quick return to normal operations.

E. Important equipment. If the equipment cannot be relocated to a building that is not flood-exposed, permanently relocate the equipment to mezzanines, platforms, pads or pedestals (plinths) that are above the flood level.

2.3.4 Do not locate any product or equipment that can leak oil, solvent, fuel, etc., in areas that are likely to flood. Doing so may slow the cleanup of the building.

2.3.5 Do not build basements and machinery pits. If they are unavoidable, adhere to the following recommendations:

2.3.5.1 Use noncombustible construction and finish materials that will minimize the damage from water.

2.3.5.2 Seal all piping, wiring, conduit, and penetrations to prevent seepage.

2.3.5.3 Install primary and backup FM Approved flood abatement pumps, with backup power, designed to remove a minimum of 50 gpm (190 L/m), in case of seepage or water-pipe leaks.

2.3.5.4 Do not install equipment vital to production, lighting, heating, or ventilation in this area.

2.3.5.5 Do not place high-value electronic equipment or store critical records in this area.

2.4 Protection

2.4.1 Locate fire pumps, dry-pipe sprinkler system air supplies, gaseous suppression systems, etc., and their associated electrical equipment outside flood-prone areas or above the expected flood level.

2.5 Equipment and Processes

If the recommendations in Sections 2.2.1, 2.2.2, 2.2.3, or 2.2.4 cannot be complied with, adhere to the recommendations in this section to lessen the impact of flooding.

2.5.1 Install process equipment on platforms, pads, or pedestals to be above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m)of freeboard. If this is not possible, build a permanent flood barrier around the equipment.

2.5.2 If equipment vital to processes, production lines, or the building's operation is located below the predicted 0.2% annual exceedance (500-year) flood elevation, ensure it is flood-proof if the equipment supports building or process lines expected to remain operational during the flood. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard. Flood-proof electrical equipment is designed for use while being continuously submerged and has an electrical ingress protection (IP) rating of IPX8.

The International Electrotechnical Commission's *International Protection Marking,* IEC standard 60529, lists the categories of protection for mechanical and electrical enclosures from the ingress of body parts, dust, accidental contact, and water. International Protection (IP) listings use the designation “IPXX,” with the X’s standing for a number that refers to the protection level. The first X is for solids and the second X is for liquid ingress.

Such specialty equipment is custom-built for the application and can be costly, but will prove invaluable if it keeps vital operations in service during a flood.

2.5.3 Provide all structures that may float or experience lateral movement when subjected to flood-related loads with properly designed anchorage to resist the forces of buoyancy, moving water, and wave impact. Structures of concern include storage tanks, silos, bins, sealed conduits and pipes, duct banks, lined pits, and sumps. In addition to protecting the structures themselves, proper anchorage will prevent them from becoming flood-borne debris that could cause damage to surrounding buildings and equipment.

When designing the anchorage, use the conditions that will produce the most severe loads. For example, assume storage tanks are empty when designing tank hold-downs and foundations to resist uplift and overturning, and assume storage tanks are full when designing supports and foundations to resist maximum gravity loads.

Data Sheet 7-88, *Ignitable Liquid Storage Tanks,* Section 2.2.6, Protection Against Flooding, provides design guidance. This guidance can also be used for tanks storing other liquids or materials.

2.6 Utilities

For locations where the predicted 0.2% annual exceedance (500-year) flood will result in onsite flooding, design onsite utilities as follows:

2.6.1 Ensure all utilities are located above the predicted 0.2% annual exceedance (500-year) flood elevation or are flood resistant. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.6.2 Ensure foundations for platforms and plinths used to elevate key equipment (including substations, whether owned by the facility or not) are designed to withstand damage from flooding, including erosion from high-velocity flood water and mechanical impact from floating debris.

2.6.3 Locate climate-control utilities, such as heating, air-conditioning and ventilation (HVAC) systems, chillers, and environmental-control equipment, above the predicted 0.2% annual exceedance (500-year) flood elevation.

Include 1 to 2 ft (0.3 to 0.6 m) of freeboard. Supply these systems from substations that are not exposed to flooding to ensure a controlled environment can be maintained inside a flooded facility to prevent humidity damage.

2.6.4 Design HVAC and utility systems to segregate flood-prone areas from non-flood prone areas.

2.6.5 Locate boilers, their controls and supporting equipment (including blower fans) above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.7 Electrical

If the recommendations in Sections 2.2.1, 2.2.2, 2.2.3, or 2.2.4 cannot be complied with, adhere to the recommendations in this section to lessen the impact of flooding.

2.7.1 Install electrical equipment above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard. This includes all motor control centers (MCCs), distribution panels, switchboards, motors, generators, transformers, communication and control equipment, batteries, battery chargers, uninterrupted power systems (UPSs), electrical outlets, and lighting.

2.7.2 Ensure electrical systems in areas of the facility that are likely to be flooded are isolated from electrical systems in areas that are not.

This will allow the rest of the facility to continue to operate in the event of a flood.

2.7.3 If is not possible to install electrical equipment above the predicted 0.2% annual exceedance (500-year) flood elevation, adhere to the following recommendations:

2.7.3.1 Use electrical equipment that is rated for use while being continuously submerged. Equipment rated for this use has an ingress protection (IP) rating of IPX8.

2.7.3.2 Ensure any cables run below flood level have protected metallic armoring or shields and are designed for use in a wet environment.

2.7.3.3 Protect outdoor, elevated cable runs from high-velocity flood waters that could undermine the cable run support foundations or cause mechanical damage to the cable supports from floating debris.

2.7.3.4 Install water-tight covers over cable trenches to prevent the trenches from being filled with silt and debris carried by flood waters.

2.7.3.5 Locate cable joints and cable terminations above the predicted 0.2% annual exceedance (500-year) flood elevation. Include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

2.7.3.6 Install water sensors and relay devices that will either automatically alarm to a constantly attended location or shut off nonessential electrical devices before flood damage occurs. Have these devices tested as recommended by the manufacturer on an annual basis.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Avoid the Zone

The best way to avoid flooding is to build in areas that are outside the predicted flood footprint and above the predicted 0.2% annual exceedance (500-year) flood elevation, for the following reasons:

A. Flooding is governed by nature and therefore its exact results can be very unpredictable and difficult to model.

B. Flooding is dynamic; flood studies can become outdated due to land development.

C. Flood flows and weather patterns may have changed since the last study.

D. Flood mapping analysis is a complex process often limited by available information and resources.

3.2 Flood Maps and Data

Flood maps provide a static representation of a flood exposure and represent the flooding potential at the time the map was developed. Typically, maps will show a high hazard (1% annual exceedance) flood footprint and a moderate hazard (0.2% annual exceedance) flood footprint.

The terminology used on flood maps varies by country. In Australia, high hazard flooding also factors in flood depth and velocity. In other parts of the world, the use of base flood elevation or 100-year return frequency in place of the equivalent the 1% annual exceedance is used. Similarly 500-year return frequency is another way of expressing the 0.2% annual exceedance. It is important to understand the terminology of the map or data source before making conclusions on the exposure.

In general, flood maps do not show the more likely events (10% annual exceedance [10-year], 2% annual exceedance [50-year]). Thus, the maps do not show how early flooding will start at a facility. A facility may start to flood much earlier than the 1% annual level and result in significant flood depths.

The chances of the facility flooding are based on where the floor level is as compared to the flood level associated with the return frequency. Table 2 displays the probability of flooding for various return periods.

Table 2. Probability of Flooding at Least Once during the Facility's Lifetime

Exposure Level Return Period	*Facility Life (Years)*			
	10	25	50	100
	Flooding Probability			
10 years (10% annual exceedance)	65%	93%	99%	100%
25 years (4% annual exceedance)	34%	64%	87%	98%
50 years (2% annual exceedance)	18%	40%	64%	87%
100 years (1% annual exceedance)	10%	22%	39%	63%
500 years (0.2% annual exceedance)	2%	5%	10%	18%

Other limitations include the following:

A. Frequently, flood losses occur at locations that are not shown to be in a mapped flood zone. Examples not normally covered by a standard flood map include collapse of a road embankment across the floodplain during an event, blockage by debris of a structure diverting floodwaters off the watercourse, diversion of floodwaters via a navigation canal, and faulty operation or failure of a dam.

B. Connections from adjacent flood zones to below-grade areas are not always covered by flood maps.

C. The flood maps may not address smaller bodies of water (e.g., small streams, local drainage ditches, small culverts passing below buildings).

D. Flood defense systems may be shown on flood maps, but the current condition of the flood defense sometimes is not well represented by the maps, which may have been developed years earlier. The system may have reached the end of its designed lifespan, have been poorly maintained, or the flood map might not show the increased extent of flooding caused by upstream development or changes in the environment since the map was developed.

E. Flood maps across the world take various approaches to mapping the flood exposure protected by flood defense systems. Some maps may not take into account flood defenses and show an area as flooding, while some maps will show the same area as not even being flood exposed.

F. As flood maps are developed, the results are checked and compared to historical events whenever good data is available. Frequently, the model assumptions or input data are adjusted so the results will match or closely approximate the historical event. Unfortunately, the historical data almost always covers a short period of time in relation to the frequency intervals being determined. The base time period may not accurately represent weather patterns expected over 100 or 500 years for the area.

The available flood maps may have been developed based on historical flooding that occurred in the spring when the ground is not frozen. A severe winter rainstorm landing on top of frozen earth will develop runoff almost like rain landing on pavement. A severe thunderstorm after a particularly rainy or heavy snowmelt period results in rainfall onto ground already saturated, causing increased runoff. Such events could generate higher-than-expected flood levels even if the initiating event had a 100-year or 500-year frequency. Factors such as ground saturation level, snow water content, and snow melt rate also reduce the accuracy of flood-forecasting agencies.

3.2.1 Levees Don't Eliminate the Threat

Building a levee, dike, or floodwall to protect a site is not equivalent to building in areas that are outside the predicted flood footprint. Levees reduce the likelihood of flooding but do not eliminate it. Levees may fail due to poor maintenance, design and construction, unanticipated reasons, or could be overtopped by a flood larger than the design flood elevation. In either case the resultant failure can lead to a greater level of damage due to increased water depths and velocity. Additionally, building a levee system is very costly and requires the following:

- Significant ongoing maintenance.

- A great deal of manual intervention in order to be effective at the time of the flood (e.g., closing gates, operating pumps, etc.).
- Extensive training and emergency planning in order to ensure a successful flood fight.

Levee systems owned by public or private authorities protecting large areas have the same concerns and can be subject to budgetary constraints that force the authority to reduce maintenance and training. The largest drawback of a publicly or privately owned system is that the protected facility is forced to count on others to manage their flood risk.

3.2.2 Site-Specific Flood Studies

If flood maps for a particular area do not exist, are out-of-date, or were developed on a scale that does not adequately address the site's local factors, an in-depth flood study is required. Hiring a qualified firm to review existing flood maps is sound advice prior to site selection for new facilities, facilities undergoing major renovations, and facilities that have experiences recent close-call flooding events.

Most government flood maps are developed for land planning purposes or government property insurance programs. The maps are developed on a large scale and may not have the accuracy needed at the local or site-specific scale. For example, the United Kingdom Environmental Agency's flood maps contain the following disclaimer: "This map is for land-use planning. If you are planning a development, you will need to undertake a more detailed flood risk assessment to show how the flood risk to the site, or elsewhere as a result of proposed changes to the site, can be managed as part of your development proposal."

Governmental maps also may not be updated on a frequent enough basis and may not reflect recent flooding or changes to a body of water or a natural or man-made environment.

3.2.3 Flood Protection Breach Studies

The recent improvements to computer technology and software, and accurate topographic data (such as LiDAR) has made modeling flooding due to levee and floodwall breach analysis possible. Understanding how a potential levee and floodwall breach will affect a site and impact normal business will help a company develop a better strategy to address the flood exposure. Breach studies will help define the warning time available, evacuation plans, the depth of water expected across the property and in buildings, and the water velocity.

3.3 Strategy to Understanding the Flood Potential

In order to determine the correct strategy to address the potential of flooding and its impact on a facility, the flood scenario must be understood. The steps are as follows:

A. Determine which types of flooding expose the site. Sites can be exposed to flooding from more than one source.

B. Determine the expected flood depths.

C. Determine the warning time for flood.

D. Determine the duration of flooding:

1. Consider the impact of long-term flooding as the amount of time flood water remains inside a building. This is a factor in how badly a building and its contents will be damaged.

2. Locations next to large rivers or located in flat flood plains can be impacted longer by standing flood water.

3. Access to the site and transportation routes can be interrupted for extended periods of time.

4. Utilities may be adversely affected longer than the site itself.

E. Determine the property damage and business interruption risks and existing flood mitigation opportunities.

3.4 Understanding Flood Sources and Their Characteristics

Intense rainfall events or melting snow can cause rivers, small streams, lakes, arroyos, etc. to overflow into the surrounding flood plain or cause storm-water flooding.

3.4.1 Flood Sources

3.4.1.1 River Flooding

Rivers and streams are naturally occurring drainage features. Their characteristics vary due to climate, geology, and man-made features and can be altered by redirecting the watercourse or lining the channel with concrete or similar. These can cause changes in river or stream cross sections that change flood elevations and flow patterns. The magnitude and amount of advanced warning of flooding within a river basin is correlated with the size, slope, and duration of the rainfall event relative to the size of the river basin.

3.4.1.2 Dry Stream Bed Flooding (Wadis, Ephemerals, Arroyos, Dry Gulches and Washes)

Typically, these channels drain areas of minimal or sporadic rainfall, which are therefore characterized by rocky, sandy terrain with little vegetation. Flooding that involves dry stream beds will most likely be flash floods associated with heavy, concentrated rainfall. There will be little or no advance warning (few hours at most); high wave fronts; high velocity; high sediment load; possible obstructions at bridges, culverts, etc. causing water to back up; considerable erosion; and short duration.

3.4.1.3 Channel constrictions

Channel constrictions, such as bridges, culverts, diversion channels, pipes, and sluice ways, can become obstructed by debris or ice carried by flood water.

Types of debris are limitless but include trees, ice, lumber, furniture, process tanks, vehicles, rocks, sheds, concrete pipes, gravel, and coal. In large floods, items that normally are not transported in an annual flood will be carried downstream due to flood waters reaching new areas. A single object, for example an uprooted tree caught in a constriction, can collect smaller debris.When enough debris is gathered, flood waters will back up until relieved. It is not uncommon for debris dams to impound large volumes of water that are suddenly released, causing flood volumes and elevations greatly above the expected flood level.

Relief can occur with breakout flow, which results in flood exposures to sites or buildings not previously exposed. Consequently, some locations identified as not exposed, or exposed at an infrequent recurrence with unconstricted flow in the main channel, would then experience flooding at a higher frequency than anticipated. A bridge choked by debris or ice can cause an upstream levee to be overtopped.

Typical government flood profiles are computed under the assumption that bridges and culverts are unobstructed; 100% open and clear. Depending on the characteristics of the stream, full or partial obstruction of these constrictions can occur. The obstruction alters the flood profile by causing the water surface to rise above the unobstructed flood profile and it might cause breakout flow that conveys flood waters outside of the unobstructed constriction.

Some rivers have an annual issue with ice jamming. Ice jams can be classified into six categories: freeze-up ice jams; break-up ice jams; moving ice jams; stationary ice jams; floating ice jams; and grounded ice jams. Only break-up ice jams result in significant flooding.

Break-up ice jams are frequently associated with rapid rises in river stage, resulting from rainfall and/or snowmelt, and usually occur in the late winter or early spring. Because of the large volume of ice that may be involved and the greater discharges from rain or snowmelt, break-up ice jams can cause flooding of a magnitude similar to, or in excess of, the 100- and 500-year flood.

Ice jam flooding will normally be characterized by several hours to several days' advance notice; rapid rise once the obstruction has occurred; duration dependent upon the weather and emergency action (using explosives to dislodge the ice); low velocity; low sediment loading; impact and push damage from heavy floating ice plates and blocks; and slight erosion hazard.

As the temperature increases or the ice jam is impacted, it may break free, float, and jam again as it impacts other ice, a bridge, etc. or it may break up into large floating plates and blocks. The backed-up water will be released as the jam breaks free, creating a fast moving surge of water. The water surge and the accompanying large pieces of ice can cause increased physical damage to property. While the presence of an ice jam can be monitored, the location, time, and magnitude of release and associated results may be difficult to predict. The effects of ice jam flooding can be much more severe than warm water flooding of the same stream to the same level.

3.4.1.4 Flood Control Dams

Most flood-control dams are constructed in conjunction with a reservoir. Flooding downstream is reduced as water is retained behind the dam. Discharge through the dam is restricted, and resultant downstream flows and flood levels are reduced. In many cases, the published 100-year, 500-year, etc. flood levels consider the many effects of the upstream flood structure and reservoir. Items factored into the flood projections include the duration of the rainfall event, the capacity of the reservoir and its assumed water level at the time of the event, the location of the rainstorm in the watershed, and the effect of other dams and reservoirs.

While a flood-control project upstream may serve to reduce the extent of flooding from a specified design event or scenario, it is still possible that downstream flooding may result from a different scenario. For example, a flood-control dam located 100 miles (161 km) upstream of a site on a moderate-sized river may be designed to provide protection against a regional rainstorm event. However, a very intense, slow moving, localized rainfall event centered downstream of the dam could cause flooding similar in magnitude to the flood the dam was designed to limit (different storm position and intensity; different scenario; same flood level).

Changes to the flood-control systems in a watershed after a study or map is completed can affect the expected flood levels. Flood-control dams are built to a design frequency based on economic feasibility. Some flood-control dams may be built to the 50-year event, while others may be built to the 100-year event or greater. However, a dam built to the 100-year event in 1950 may not contain the 100-year event today due to changes in the watershed since 1950. Local authorities may be aware of the design frequency of the flood-control dam but may not be aware that changes in the watershed may have reduced the effectiveness of the dam.

3.4.1.5 Interior Drainage Flooding Behind Flood Protection

Flooding may occur in a “protected” floodplain even though the main levee, floodwall, or sea wall is not breached or overtopped. Flooding can be caused by rain, interior streams, or from seepage under the levee or sea wall.

3.4.1.6 Coastal Flooding

Coastal flooding is the result of increased sea levels caused by storm force winds. Coastal flooding is usually caused by large ocean storms. Wide and gently sloping continental shelves produce higher storm surges than narrow, steep continental shelves. Normal sea levels will increase and wind will generate waves. Sheltered harbors and bays often have smaller waves.The storm force winds also push water inland across normally dry areas. Coastal storms can create flood levels from 15 to 30 ft (4.6 to 9.1 m) or more above high tide.

Coastal storms can also cause inland flooding. As a storm moves inland, it usually reduces in strength since it is no longer being powered by the rising warm, moist ocean air. When this occurs, the remaining storm will release intense rain over the inland area. This intense rain may lead to severe inland river or storm-water flooding.

3.4.1.7 Alluvial Fan Flooding

Alluvial fans are located at the base of steep-sloped mountainous areas. Often they are located in areas that typically receive very little rainfall. When a major storm occurs, alluvial flooding is sudden and severe and may affect small or large areas.

On these very flat flood plains, the flow tends to be at high velocity, undergoes unpredictable changes in direction, and carries large amounts of sediment. The soils found on alluvial fans tend to be easily eroded and highly porous.

3.4.1.8 Seiche Flooding

A seiche is an oscillation of the water in a lake, sea, or bay caused by seismic disturbances, winds, waves, or abrupt, unusual changes in atmospheric pressure. Large storms with unusually low pressure and high winds can cause water elevation differences of several feet (meters) from one side of a lake to another. The elevation of the water surface coupled with wind-driven waves causes coastal areas to flood and tributary rivers to back up and overflow their banks.

3.4.1.9 Storm-Water Flooding

Natural terrain or insufficient drainage design can cause flooding. Storm-water flooding can be classified into three categories: surcharged drainage systems, ponding, and sheet flow.

In many parts of the world, underground drainage is not designed for severe rainstorms. During unusually heavy rainfall, the lack of drainage capability may cause water to back up and enter buildings if not considered during the design. Unfortunately, typical urban drainage systems are sized to handle at most the 25-year storm. Due to the lack of capacity, onsite storm water runoff may require the use of retention or detention basins to safely handle the 100-year storm-water run-off.

3.4.1.10 Groundwater

The groundwater level is governed by adjacent rivers, lakes, and streams. Depending on the soil conditions, the groundwater level will respond to changes in adjacent water body levels. Usually, this response is slow. However, for long-duration flood events, the groundwater table might affect building basements.

3.4.1.11 Tsunamis

Tsunamis are usually caused by undersea earthquakes. The earthquake causes a displacement of the earth's crust at the bottom of the ocean. Although they are rare events, tsunamis can reach heights of from 30 to 50 ft (11 to 15 m) as they approach the coast at more than 500 mph (805 km/h).

3.4.1.12 Combined Sewer Systems

Combined sewer system are not always able to handle increased flows during heavy rainfall or flooding. As a result, the system will back up and flow out of manhole covers, drainage inlets, toilets, floor drains, and sinks. Because the water is dirty, the cleanup is complicated due to contaminates.

3.4.1.13 Roof Drainage Flooding

This is localized flooding due to roof drains and downspouts emptying on ground or paved surfaces that don't drain away from a building. See Data Sheet 1-54, *Roof Loads for New Construction.*

3.4.2 Flood Characteristics

Table 3 gives some general characteristics of the major types of flooding.

Table 3. Flood Types and Characteristics

Flood Type	*Depth*	*Velocity*	*Warning Time*	*Duration*	*Flow Paths/ Drainage*
Large, long rivers	Varies widely, governed by valley shape; levee-protected areas can be deep.	Low: velocity not expected to increase damage.	Up to 2 weeks or more	Days or weeks	Overbank
Smaller sized rivers	Varies widely, governed by valley shape; levee-protected areas can be deep.	High in steep areas; velocity damage possible. Low in flat areas. Low in ponding areas.	Short; very short in steep-sloped areas	Short: less than 1 day to several days. Flash flood in steep areas: <3 hours.	Overbank
Dry stream beds	High wave fronts; backup at obstructions.	High; velocity damage possible.	Short (few hours at most)	Short: less than 1 day to several days	Flash flooding
Interior drainage behind flood protection	Low level: <3 ft (1 m).	Low; velocity not expected to increase damage.	Short, but varies by flood type	Longer: Varies by flood type	1. Rain or interior streams; 2. seepage under levee or sea wall
Coastal	From 15 to 30 ft (5 to 10 m) or more above high tide	High near coastline; velocity damage possible.	Storm formation: up to 1 week; action stage for facility 2 to 3 days prior to landfall; 1 day out evacuation may be ordered	Short: hours	Ocean water pushed onto land
Alluvial Fan	High level: <3 ft (1 m).	High; velocity damage possible.	Short: <3 hours	Short: <3 hours	Onto base of steep-sloped mountains
Seiche	Several feet (meters).	High; velocity damage possible.	Short: hours	Short: hours	From water oscillation in a lake, sea, bay
Storm water	Low level: <1 ft (0.3 m) except for below grade spaces.	Potentially high for steep slopes;low for ponding areas.	Short: minutes to 1 hour	Short: minutes to 1 hour	Surcharged drainage systems, ponding, and sheet flow
Groundwater	Low level: <1 ft (0.3 m).	Low; velocity not expected to increase damage.	Long: 1 day to days	Long: 1 day to days	From adjacent rivers, lakes, and streams
Sewer systems	Typically low level: <1 ft (0.3 m).	Low; velocity not expected to increase damage.	Short: minutes to 1 hour	Short: minutes to 1 hour	Flow out of toilets, floor drains, and sinks

3.5 Understanding the Flood Impact

Critical facility assets should be inventoried and the impact of flood considered. In addition to building damage, items to consider include equipment that, once damaged, will cause a bottleneck in resuming operations; information systems; long lead-time equipment; switch gear; and electrical feeds.

Flood damage to fire protection equipment presents a number of significant issues. Flood water often carries heavy debris that can rupture ignitable liquid tanks and damage ignitable liquid and flammable gas piping. Electrical short circuits and other ignition sources are available to start a fire. Once a fire starts, the local fire service may not be able to reach the fire due to flooding. The automatic sprinkler and fire pumps may also be damaged. Therefore, always locate automatic sprinkler valves and pumps outside flood-prone areas.

The impact to utility services should be understood. Be aware of underground substations, equipment, and transformer vaults. Water service, sewage and disposal, electrical service (generation, transmission & distribution), telecommunication, natural gas service, refrigeration, steam, etc. may be affected.

Access to the site may be restricted or closed even if the site is unaffected. Normal supply routes, including highways and railroads, may be closed due to flooding for extended periods of time.

3.6 Understanding All Possible Solutions; Building or Retrofitting in a Flood Prone Area: A Strategy is Needed

This data sheet addresses a wide variety of physical solutions to reduce the severity of flooding to a facility when building in these areas can't be avoided. Human element solutions (those that require humans to respond during flooding) should only be relied upon after all practical physical solutions have been incorporated into the design.

A carefully planned strategy has to be developed and executed during the project's design and construction phases in order to minimize the damage flooding will cause. The ultimate strategy is to ensure that as much of the facility can continue operating without pause during flooding.

There are many concepts that can be used to help reduce flood damage and downtime. The logical options in order of reliability are:

A. Designing the facility to be constructed outside of any flood hazard (new construction) or permanently relocating the existing facility.

B. Raising the site above the 0.2% annual exceedance (500-year) level (new construction).

C. Building permanent 0.2% annual exceedance (500-year) flood defenses around the site.

D. Protecting a portion of the site's critical assets by raising above or protecting to 0.2% annual exceedance (500-year) standards (e.g., building low-level earthen embankments or flood walls, landscaping, and walls to redirect storm water and sheet flow away from important areas).

E. Deploying emergency devices and emergency response plans until permanent solutions are made. This can include relocation of equipment and production lines to areas higher than the flood. See Data Sheet 10-2, *Emergency Response.*

F. Developing plans to make up production while the site is repaired.

If achieving the 0.2% annual exceedance (500-year) standard is not feasible or cost-effective, the 100-year should be considered instead. When deciding on the best strategy, the likelihood of flooding, expected damage, and insurance costs, impact on public image and customers during the lifetime of the site should also be considered.

One of the drawbacks to elevating the entire site outside of the flood hazard is that it can be expensive and not always practicable. When elevating the entire site is not possible, it then becomes necessary to determine which buildings and areas of the facility are likely to be flooded and focus on minimizing the impact the flooding would have to the lower areas, both in terms of physical damage and interruption to business.

Often the most effective flood mitigation approach is a combination of approaches. Proper design of the buildings that will potentially be flooded is required to keep damage to a minimum. Shallow flood waters that fill basements seldom damage the basic structure or the floor above. Structural damage becomes a possibility when deep waters rise up to the first story walls. Wall damage at grade and below level floor does not normally occur when water rises equally both inside and outside, as the forces are hydrostatically balanced. However, waters rising on the outside only can quickly over-stress a wall and floors at grade or below and cause its collapse or uplift. A rise of several feet of water against one side of an unreinforced brick or concrete block wall is cause for concern.

One of the most important steps ensuring flood damage is minimized after the flood has receded from buildings is to quickly clean up the damage the flood has created. In order to accomplish a fast cleanup, power, heating, and air conditioning has to be restored quickly.

Therefore, when designing the location or selecting equipment for power and HVAC systems, consider the following:

A. Electrical equipment, particularly dry-type transformers, high-voltage air circuit breakers, and modern control equipment that uses semi-conductor circuitry are highly susceptible to water damage.

B. Boilers, furnaces, and ovens will sustain extensive damage. If flood waters rise while the unit is firing or still hot, the unit is susceptible to considerable permanent deflection. Fine silt will penetrate combustion, air, and gaseous fuel piping as well as burner assemblies.

C. Tanks can sustain major damage. Below-floor along with elevated tanks may be hydrostatically damaging the tank, building floor and surrounding equipment. Storage tanks may also move and fill, and supply or vent lines may break. Released contents may contaminate other areas.

D. Equipment located outside, although adequately weather resistant, is susceptible to the same damage as equipment located indoors. Weather protection is usually not sufficiently tight enough to keep out flood water. Velocities of greater than 7 fps (0.2 m/s) will knock over outside equipment that hasn't been specifically designed to resist the force of moving flood water.

Basements flood more often due to the fact they are lower in elevation. Key electrical, process, and analytical equipment is often located in basements and minor flooding events involving the basement has caused large property damage and long closure of facilities or production lines.

3.6.1 Freeboard is a Key Design Consideration

Freeboard is the difference between a building's floor elevation, equipment elevation, storage elevation, etc., or the top of a flood defense system elevation and the flood level. It is a safety factor to account for uncertainties in the calculation (hydrology, hydraulics, topography, etc.) of the flood level due to flood modeling inaccuracy, manmade and natural changes to the watercourse, increased runoff due to urbanization, changes in the flood exposure over the lifetime of the site (climate change), or to provide a buffer against unexpected waves due to vehicle traffic or wind. Providing freeboard as part of the design criteria will help reduce the likelihood or the amount of damage that an unanticipated change will cause over the lifetime of a site.

Selecting the amount of freeboard to use should be based upon critical factors such as the following:

A. Susceptibility of the building to damage. Occupancies that can't tolerate any water in or near the building should use more freeboard. Examples of highly susceptible occupancies include hospitals, pharmaceutical operations, and locations with clean rooms.

B. Areas with frequent flooding approaching or exceeding the regulatory flood level (e.g., design levels incorrect or in need of an update).

C. Areas for which the flood maps and studies are older than 10 years.

D. Areas in which upstream development of vacant land has drastically increased (or is projected to increase) since the last flood map was developed.

E. Water levels affected by blockage by debris, landslides, or incorrect operation of hydraulic structures.

F. A minimum of 2 ft (0.6m) freeboard is recommended.

3.7 Selecting Barriers to Protect Building Openings

Whenever possible, all unnecessary openings that will allow flood water to enter a building should be eliminated. For the rest, flood barriers can be used in conjunction with other cost-effective improvements to reduce the likelihood of large amounts of water penetrating the building envelope. If it is impractical to prevent water from entering the building, it is still possible to limit damage by constructing interior protection.

For example, construction of flood protection walls around key interior rooms and manufacturing or equipment areas can be a cost-effective way to reduce flood damage. Another method is waterproofing and strengthening existing partitions and equipping openings with flood gates around vital mechanical equipment such as furnaces, boilers, computers, and electronic switchgear. The goal of this guidance is to reduce the amount of water that will penetrate and collect in the building's interior to a few inches (centimeters) in depth. Facilities that cannot tolerate any water penetration should be relocated to another area, and critical occupancies should be raised above the predicted 0.2% annual exceedance (500-year) flood elevation and include 1 to 2 ft (0.3 to 0.6 m) of freeboard.

Often, it is not possible to seal or provide curbs around every personnel or vehicle opening. Part of the flood protection scheme may have to include gates that require assembly. Therefore, an FM Approved flood gate should be selected that can be installed on short notice. A flood gate that is permanently mounted adjacent to the opening and can be rapidly deployed is the best choice. Ideally, the gate should be designed to allow an untrained person to close it. Another benefit of permanently mounted gates is that they are less likely to be stolen or misplaced. Drawbacks to these gates, however, are that they can be more expensive than other types, and often are not aesthetically pleasing.

3.7.1 Permanently Mounted Flood Gates

3.7.1.1 Hinged/Pivot Gates

These gates are permanently in place and shut by swinging the barrier closed. Some barriers are hinged to walls like doors; other barriers are hinged to the floor and flip out when deployed. (See Figures 2, 3, and 4)

Ease of operation/training needed:

- A properly designed hinged gate is very easy to close.
- Hinged gates protecting personnel doors can be closed by one person.
- Hinged gates for vehicle openings may require several people to close.
- Well-designed doors require minimal training.

Deployment time: Gates can be closed in minutes.

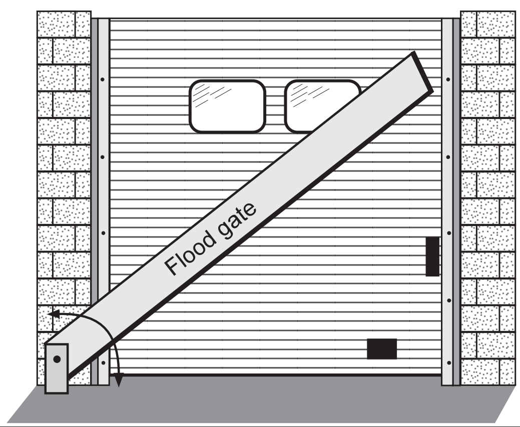

Fig. 2. Pivot-type gate with a single pivot point

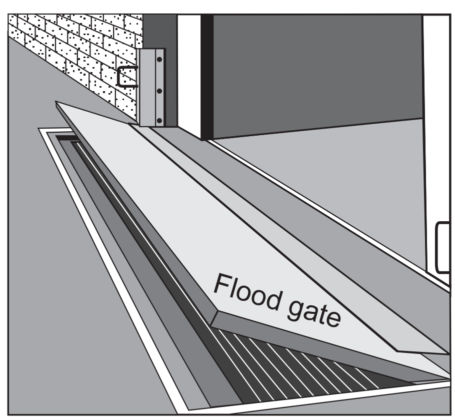

Fig. 3. Stored in-ground hinged-type gate, partially deployed

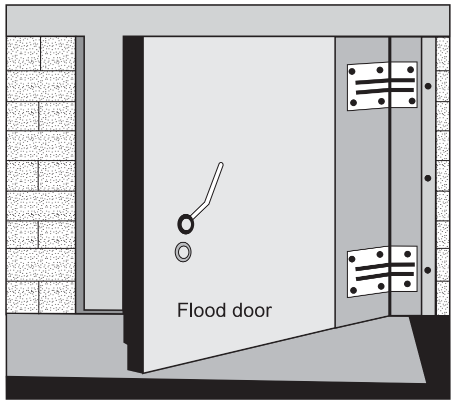

Fig. 4. Door-style gate hinged flood, partially deployed

3.7.1.2 Rolling Gates

Rolling gates are permanently in place and shut by rolling the barrier closed. The rolling mechanism needs to be inspected regularly and kept clear of debris and standing water. In cold climates, ice may accumulate in the tracks and hinder prompt operation. (See Figure 5.)

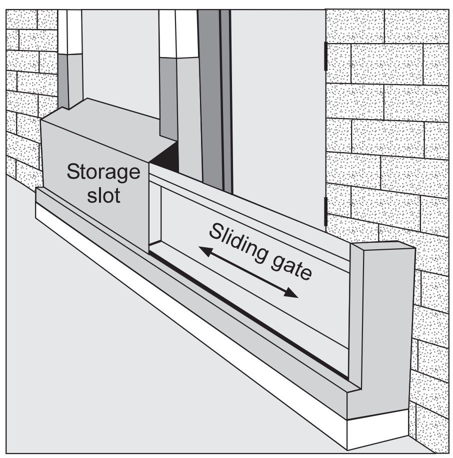

Fig. 5. Rolling gate, shown deployed

Ease of operation/training needed:

- A properly designed rolling gate is very easy to close.
- Rolling gates protecting personnel doors can be closed by one person.
- Rolling gates for vehicle openings may require several people to close.
- Well-designed doors require minimal training to close.

Deployment time: Gates can be closed in minutes.

3.7.1.3 Drop-From-Above Gates

These gates have preventive maintenance, ease of operation, and training issues similar to rolling gates. (See Figure 6.)

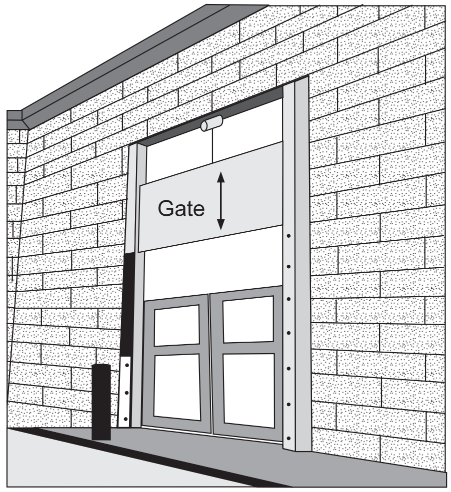

Fig. 6. Drop-from-above gate, shown in storage position

Ease of operation/training needed:

A. A properly designed drop-from-above gate is very easy to close.

B. Gates protecting personnel doors can be closed by one person.

C. Large gates for vehicle openings may require mechanical equipment to close; this equipment should be designed as part of the gate.

D. Well-designed gates require minimal training to close.

Deployment time: Gates can be closed in minutes if closure equipment is part of the design.

3.7.1.4 Automatic Flood Barriers and Gates

An automatic flood barrier can be installed in an existing doorway (see Figure 7). When not needed, it is vertically stored below the floor. This allows for normal access to the room until a flood occurs. The first flow of water to the barrier will cause it to automatically deploy. The use of this barrier eliminates the need for curbing at the opening. Installation requires removal of a floor section and pouring of a foundation to install the barrier.

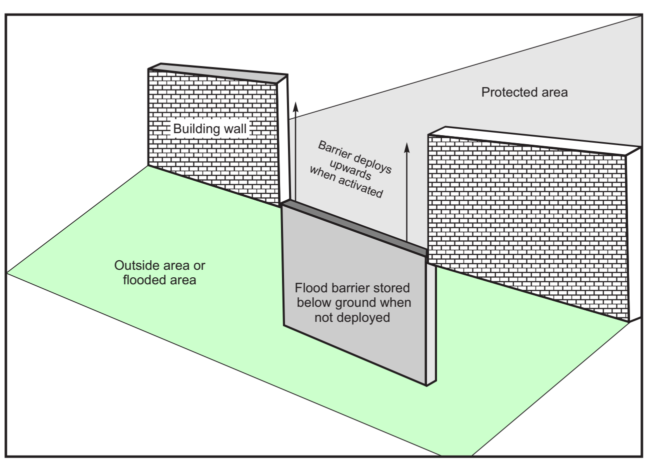

Fig. 7. Automatic flood barrier

Ease of operation and training needed:

A. Fully automatic operation.

B. Should be designed to allow for manual deployment for inspection and maintenance or to ensure it is deployed.

C. Installation is available either inside or outside of exterior doors.

D. Must be kept free of debris to allow for proper operation

Deployment time: Automatic or manually opens in minutes.

3.7.1.5 Window Opening Protection

This type of flood barrier can be installed over or in existing windows (see Figure 8). The protection devices are made of metal and can be hinged from the top or sides. They are closed manually.

Ease of Operation and training needed:

A. Deployed manually

B. Typically, closing the device is easy.

C. Annual assembly drill is recommended.

Deployment time: Closure of this type of gate can be done quickly as it is permanently mounted.

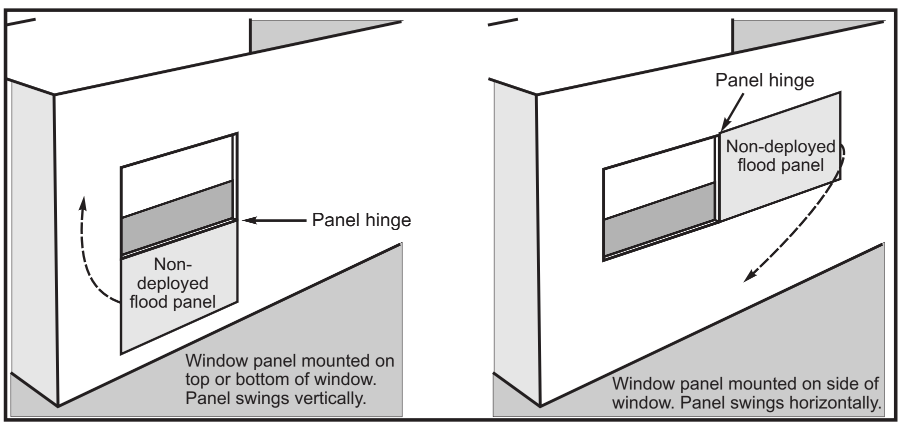

Fig. 8. Window opening protection

3.7.1.6 Single or Double Pedestrian Doors

These doors are designed to function as normal pedestrian doors when there is no flood. To prevent impact damage from water-conveyed debris, the doors are metal. Some doors have additional latches that must be closed as the flood is approaching.

Ease of Operation and training needed:

A. Fully automatic operation or have simple closing latches.

B. Must be kept free of debris to allow for proper operation.

3.7.2 Flood Gates That Require Assembly

3.7.2.1 Stop Logs

This type of gate is assembled in the opening. A series of “logs” (wooden, steel, or aluminum planks) are assembled in the opening on an as-needed basis. Usually, the opening that is being protected will have a permanently mounted frame on each side of the opening that accepts the logs (see Figure 9). For large openings, an intermediate or several intermediate supports are used to span the opening. These intermediate supports must be anchored to the floor via fastening bolts or a foundation channel (see Figure 10). These gates may require the installation of rubber gaskets between the stop logs, building, and sill. Frequently, tear-resistant plastic sheeting and sandbags are added in front of the stop logs to further reduce water seepage.

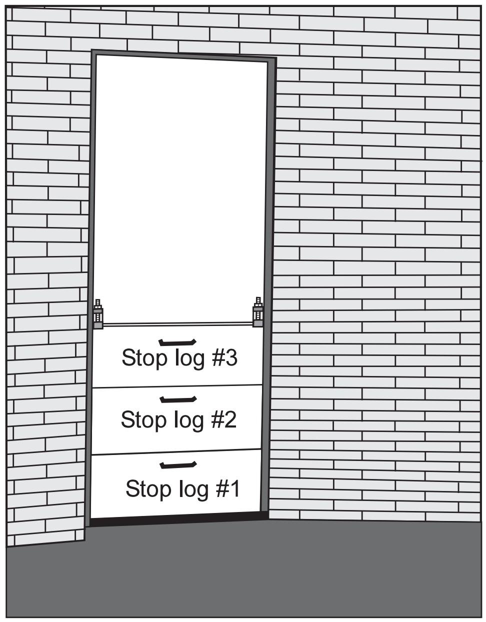

Fig. 9. Three stop logs deployed in a doorway

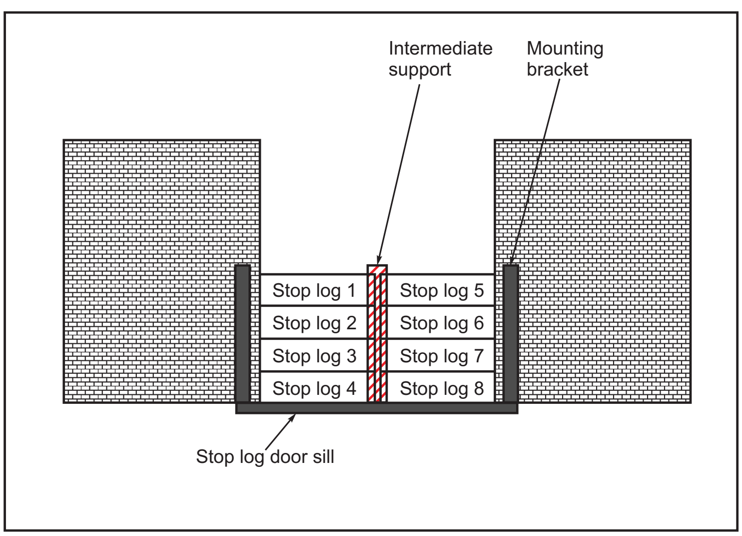

Fig. 10. Large opening protected by stop logs with intermediate support

Stop logs protecting personnel doors are designed to be able to be picked up by one or two people and put in place. The height of the individual stop log will vary based on the span being covered and the weight of the individual stop log. Typically, stop logs vary in height from 6 to 24 in. (15 to 60 cm). Stop logs for roadway and vehicle doors may require lift equipment and vertical support at mid-span.

Ease of operation/training needed:

A. The stop log mounting brackets are typically permanently installed.

B. This system has multiple components to install, including multiple stop logs and fasteners.

C. The first stop log installed at floor level typically has a larger seal at the bottom.

D. All systems have a fastener on each side that is installed at the top and is designed to compress the gaskets. Some designs also will have two fasteners for each stop log.

E. Incorrect stop log installation order jeopardizes the sealing. FM Approved stop logs are marked to indicate which side should face the flood water to ensure proper sealing.

F. Annual training/assembly is recommended.

G. The logs and assembly parts are often stored in another location.

Deployment time: Installation of stop log assembly across an 8 ft (2.4 m) opening will take less than 1.2 hours if the mounting brackets have been previously installed. The marshalling of staff and equipment needed to transport the gates from the storage location and assemble them can be significant and should be included in the time estimates. A test assembly must be conducted to understand the time, equipment, and staff necessary to assemble the gate.

3.7.2.2 Drop-in-Place Gates

This type of gate consists of a single barrier that slides into a permanent sill and frame. These gates are typically made of aluminum to keep the weight low. (See Figure 11.)

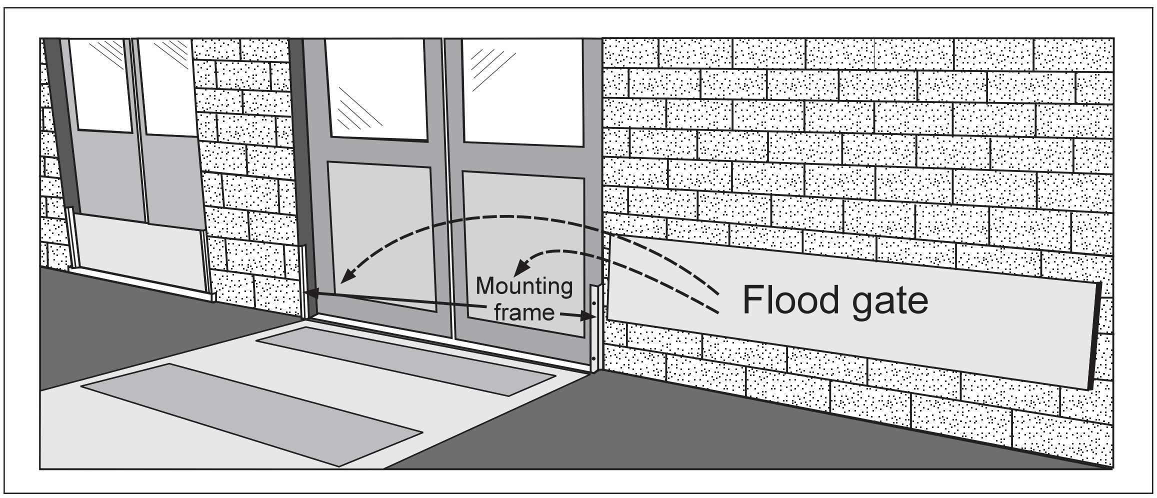

Fig. 11. Drop-in-place gate, shown in storage position next to doorway

Ease of operation, training needed:

A. The mounting brackets are typically permanently installed.

B. Drop-in-place gates are usually a single panel. Typically, they are easy to install. The weight of the panels may require more than one person to lift them or the use of a mechanical lift.

C. Annual assembly drill is recommended.

D. The gates and assembly parts are often stored in another location.

Deployment time: Closure of this type of gate can be done quickly if the gate is stored close to the opening. If a mechanical lifting unit is required due to the weight of the gate, the deployment time will be longer if the lifting unit is located away from the opening. The marshalling of staff and equipment needed to transport the gates from the storage location and assemble them can be significant and should be included in the time estimates. A test assembly must be conducted to understand the time, equipment, and manpower necessary to assemble the gate.

Deployment time: Automatic or minutes if manual latches are needed.

3.7.2.3 Expandable Gates With or Without Mounting Hardware

These are gates that can use existing door frames or can be used with permanently installed mounting hardware. These gates may be used in series if intermediate mounting hardware is installed. The gates expand into the door frame or mounting hardware. These gates are typically made of a steel or aluminum frame with a waterproof membrane and gaskets to minimize leakage while keeping the weight manageable.

Ease of operation, training needed:

A. The device must fit in the door frame or permanently installed mounting hardware. The device will need to avoid the door’s opening hardware, including door latches, hinges, and panic bars.

B. Typically they are easy to install and can be put in place by one person.

C. If multiple gates are to be installed by one person, rest periods may be needed during the installation period.

D. An annual assembly drill is recommended.

E. The gates are often stored in another location.

Deployment time: Closure of this type of gate can be done quickly if the gate is stored close to the opening. The marshalling of staff and equipment needed to transport the gates from the storage location and assemble them can be significant and should be included in the time estimates. A test assembly must be conducted to understand the time and staff necessary to assemble the gate.

Deployment time: 5 minutes or less for a well-trained responder.

3.7.2.4 Hatch Covers

These devices cover non-water-tight hatches (see Figure 12). The hatches can be on floors or other ground surfaces, or on vertical surfaces.

Ease of operation and training needed

A. The complexity of installation will vary based on the access hatch size, location, and design.

B. An annual assembly drill is recommended.

Deployment time: Varies based on design.

3.8 Temporary Perimeter Barriers Remote from Buildings

3.8.1 Bladders Filled with Water

This type of flood protection uses tubing made of durable, impermeable material; typical materials include polyester-coated fabric, nylon, and PVC (see Figure 13). The tubes are placed on an area that is free of debris or sharp objects. The tubes are anchored to the ground via anchoring straps to prevent floating or movement due to water velocity; the location and spacing of anchors will vary based upon product and soil conditions. Anchor spacing can be as close as 5 ft (1.5 m).

Engineering analysis is required to evaluate soil conditions and determine anchoring requirements. In certain instances (installations on grassy/loose soil), concrete pads are recommended for attachment of anchoring devices. The anchors are either permanent or installed as the tube is being deployed. The anchoring straps are needed to prevent rolling, floating, and movement due to waves or water velocity. Sandbagging to prevent rolling also may be recommended by the manufacturer. Some manufacturers also cover the tubes with plastic sheeting adhered to solid surfaces to reduce leakage. They cannot be deployed on hills, but can tolerate minor ground roughness.

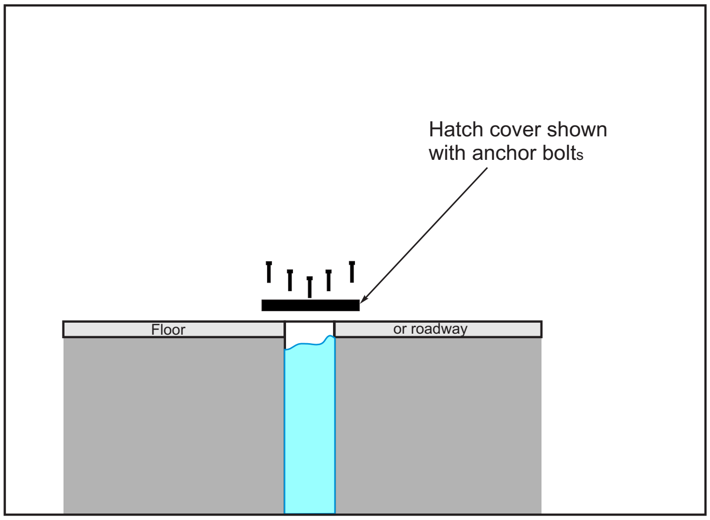

Fig. 12. Hatch cover for vertical tunnel

Ease of operation/training needed:

These devices need a skilled/trained work force to assemble. Multiple employees are needed for deployment. The weight of the empty tubes can be significant. The tubes will also need to be filled via a water pump or another water source. The manufacturer's anchoring guidelines need to be followed. If more than one tube is needed, the connection point between two tubes requires careful attention when assembling. The assembly crew should also be prepared to repair leaks.

Deployment time: These tubes require significant time to assemble. The marshalling of staff and equipment needed to transport and assemble them can be significant. Consult with the manufacturer on estimated deployment times during the selection process. A test should be conducted to understand the time, equipment, and staff necessary to properly assemble the tubes once delivered.

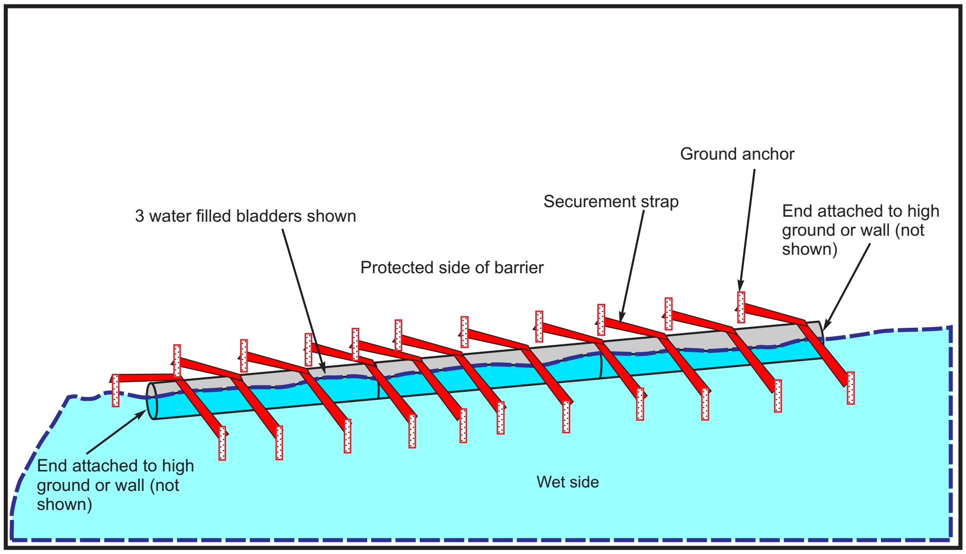

Fig. 13. Bladders filled with water; plastic sheeting may also be needed

3.8.2 Rigid/Shaped Containers Filled with Water or Sand

This type of flood protection uses a series of rigid and shaped containers, usually made of plastic or metal, that are deployed once a flood is forecast to cause damage (see Figures 14 and 15). Designs vary and some units require anchors to prevent movement. Follow the manufacturer's guidance in regards to installation method.

Ease of operation/training needed:

These containers require equipment to fill the devices, and lifting equipment or several workers to install. The flood responders will need to be able to use mechanical equipment to fill the containers with sand or water. The crew will also need to be able to repair punctures, particularly between each section.

Annual training/assembly is needed. The crew must be prepared to follow the manufacturer's installation manual. Installation methods will vary and may include anchoring the units to ground, interlocking units together, and filling the units with water, sand, or a mixture of sand and gravel, etc.

Deployment time: These panels require significant time to assemble. The marshalling of staff and equipment needed to transport and assemble them can be significant, even with proper pre-planning. Consult with the manufacturer on estimated deployment times during the selection process. A test should be conducted to understand the time, equipment, and staff necessary to properly assemble once delivered.

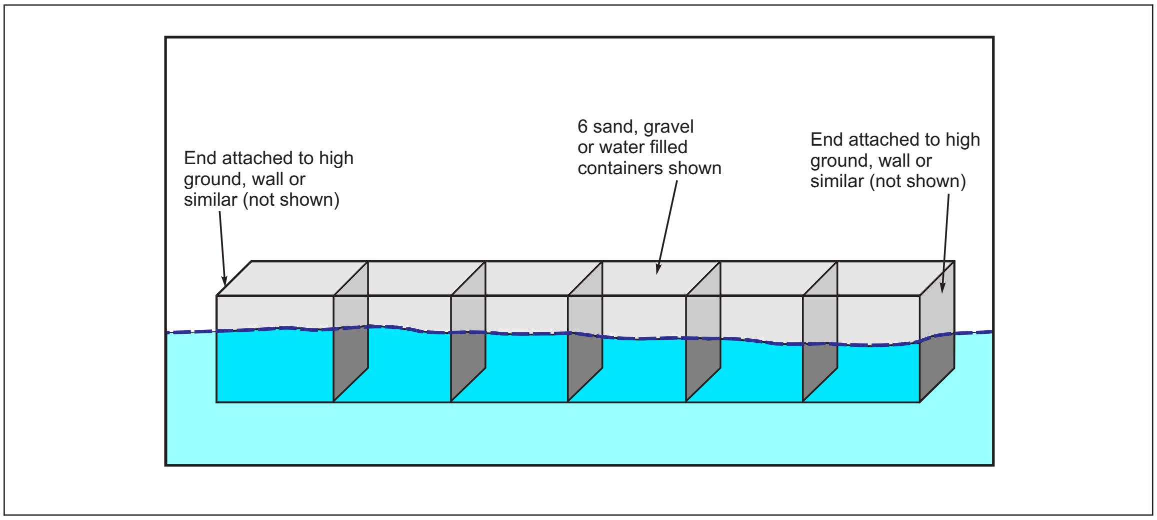

Fig. 14. Rigid/shaped containers filled with water or sand

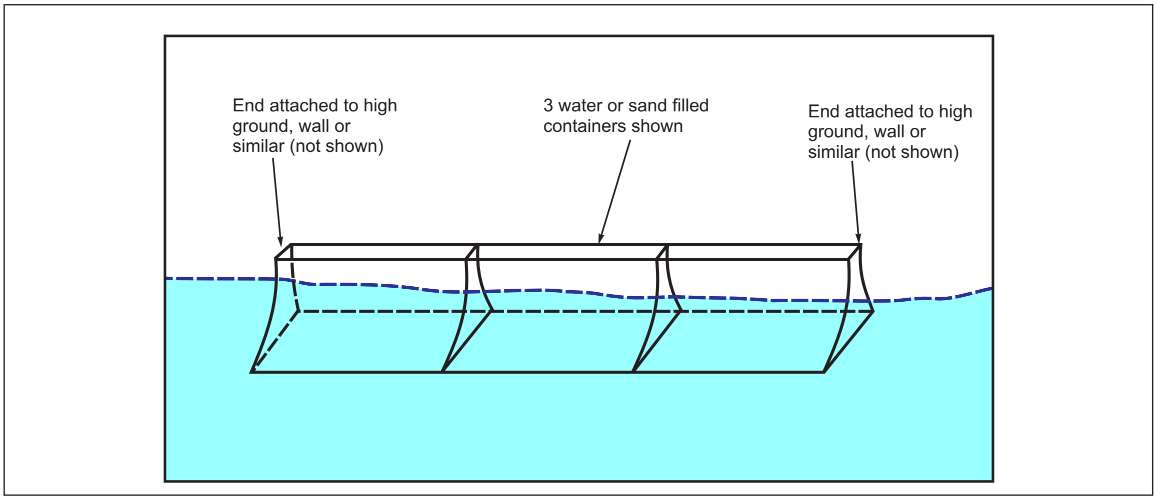

Fig. 15. Rigid/shaped containers filled with water or sand

3.8.3 Flexible Containers Filled with Gravel or Sand

This type of flood protection uses a series of flexible containers that are deployed once a flood is forecast to cause damage (see Figure 16). The containers may contain either a rigid wire or wooden frame and a waterproof membrane material. A waterproof membrane or plastic sheeting may be deployed in front containers, as well, to reduce leakage. These containers will leak at various rates based upon design and installation; careful planning must be done to ensure the flood abatement pumps can keep up with the anticipated inflow.

Ease of operation/training needed:

These containers typically are lighter than rigid containers, so they may not require lifting equipment to position. Material handling equipment for loading the fill material will be needed.

Annual training/assembly is needed. The crew must be prepared to follow the manufacturer's installation manual. Installation methods will vary and may include anchoring the units to the ground and interlocking the units together. The flood responders will need to be able to use mechanical equipment to fill the containers with sand or gravel. The crew will also need to be able to repair punctures, particularly between each section.

Deployment time: These devices require significant time to deploy. The marshalling of staff and equipment needed to transport and fill them can be significant, even with proper pre-planning. Consult with the manufacturer on estimated deployment times during the selection process. A test should be conducted to understand the time, equipment, and staff necessary to properly assemble once delivered.

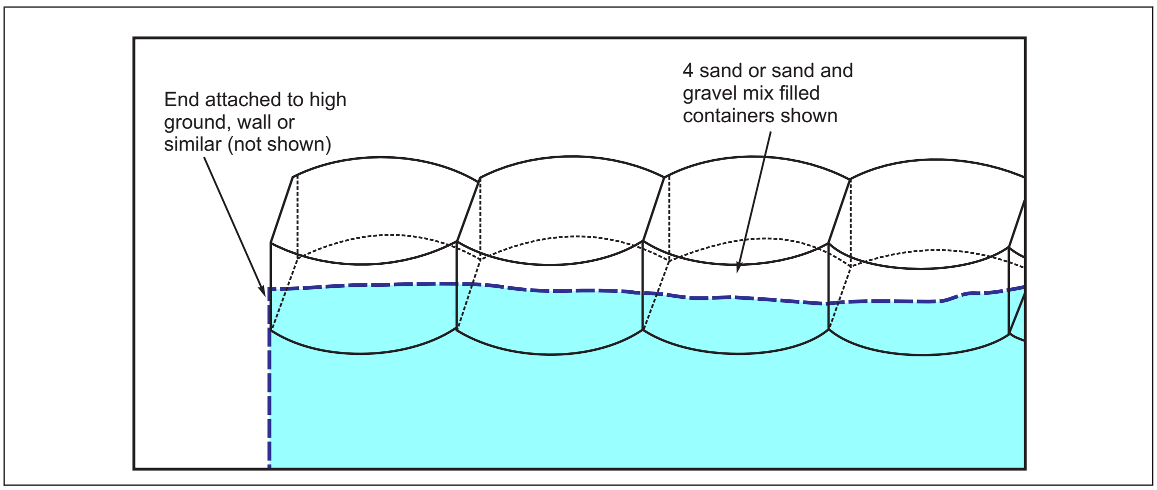

Fig. 16. Flexible containers filled with gravel or sand

3.8.4 Deployable Flood Walls Without Foundations

This type of flood protection uses flood panels that are deployed once a flood is forecast to cause damage (see Figure 17). Some types use the product's design and weight of water to prevent movement. Other types may require anchoring to the ground. The location and spacing of anchors will vary based on product and soil conditions. Engineering analysis is required to evaluate soil conditions and determine anchoring requirements. In certain instances (i.e., installations on grassy/loose soil), concrete pads are recommended for attachment of anchoring devices. They should not be deployed on sandy, silty, or unstable ground. Uneven ground requires concrete foundations.

Ease of operation/training needed:

These panels will require lifting equipment or several workers to install. Annual training/assembly is needed. The crew must be prepared to repair rips of the waterproofed canvas between panels.

Deployment time: These panels require significant time to assemble. One manufacturer suggests a team of 10 to assemble 328 ft (100 m) in 1 hour. The marshalling of staff and equipment needed to transport and assemble them can be significant; consult with the manufacturer on estimated deployment times during the selection process. A test should be conducted to understand the time, equipment, and staff necessary to properly assemble the tubes once delivered.

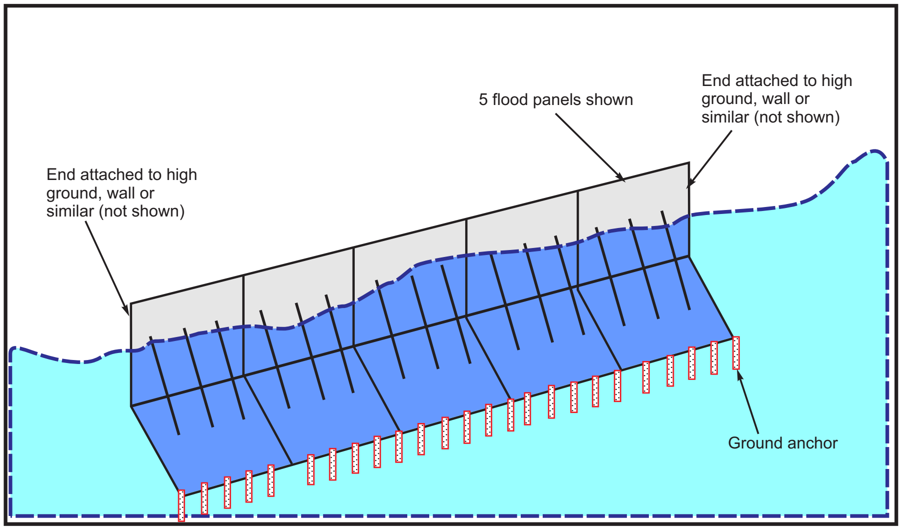

Fig. 17. Deployable flood walls without foundations

3.8.5 Waterproof Fabric Cofferdams

There are two types of fabric cofferdams. The first is a temporary perimeter barrier that is designed to be rolled out and secured to the ground by use of anchors or sandbags. This design relies on the water to help fully deploy in terms of height, sealing along the ground, and positioning (see Figure 18). Successful deployment may require the use of dowels or other items to create a sail area to collect the flood water at the beginning of the flooding.

Another design uses a rigid frame, and the waterproof fabric is attached to the frame (see Figure 19).

Ease of operation/training needed: The cofferdam without the rigid frame is easy to deploy and does not require use of specialist material handling or lift equipment. Annual training is recommended. The cofferdam with the rigid frame may require material handling equipment.

Deployment time: Deployment time is quick once the materials are brought to the area where it will be deployed.

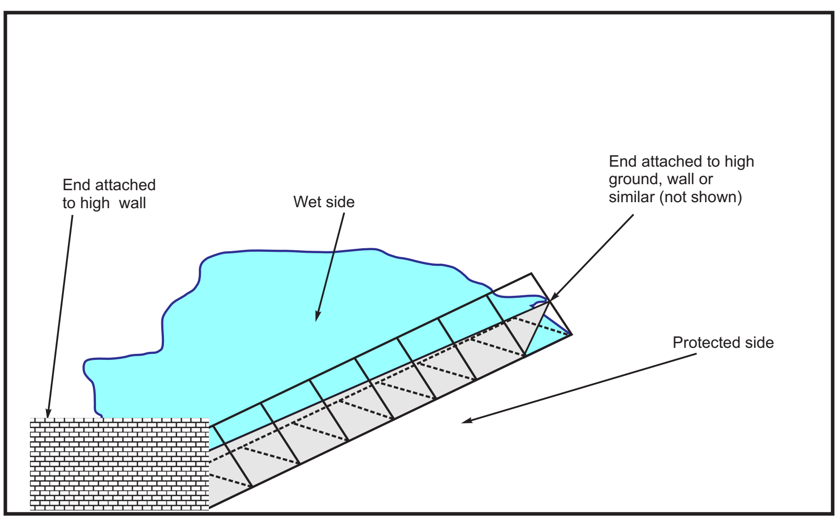

Fig. 18. Waterproof fabric cofferdams without rigid frame; water holds fabric open

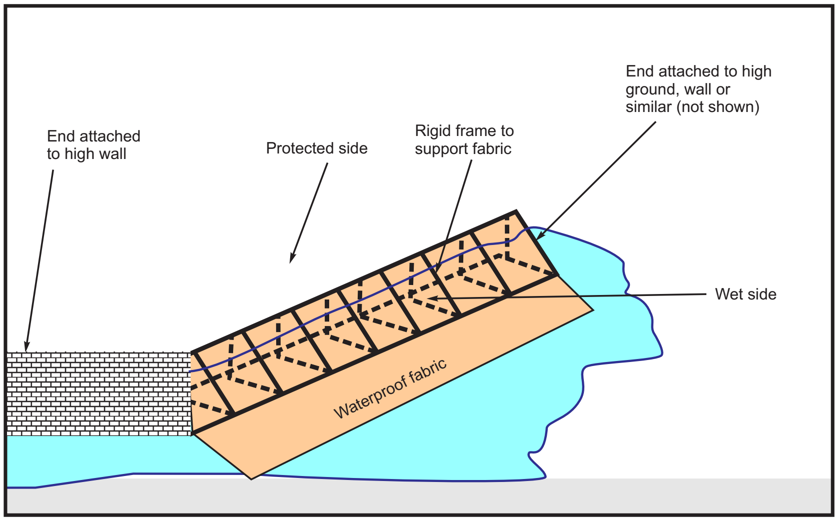

Fig. 19. Waterproof fabric cofferdams with rigid frame

3.9 Designed, Semi-Permanent Deployable Flood Walls

These systems are typically deployed in areas where a permanent flood wall is not an option, as the need for access or maintaining views when there is not a flood is required.

These devices are essentially a series of stop logs that are installed between vertical support members. This system requires a designed foundation along the length of the system (see Figure 20). The stop logs must have a good foundation to develop a good seal, and the vertical support members must have a rigid foundation to support the forces created by the flood water. See Section 2.2.6.1, Permanent Site Flood Protection Systems, for additional guidance.

Ease of operation/training needed: This type of system will require significant training to assemble properly. Material area handling equipment will be needed to transport the materials from the storage to the deployment area. The weight of the vertical support members often will require lifting equipment to install the supports into the designed foundation.

Deployment time: These systems require significant time to assemble. The marshalling of workers and equipment needed to transport and assemble the walls can be significant; consult with the manufacturer on estimated deployment times during the selection process. A test should be conducted to understand the time, equipment, and workers necessary to properly assemble the system once they are initially delivered.

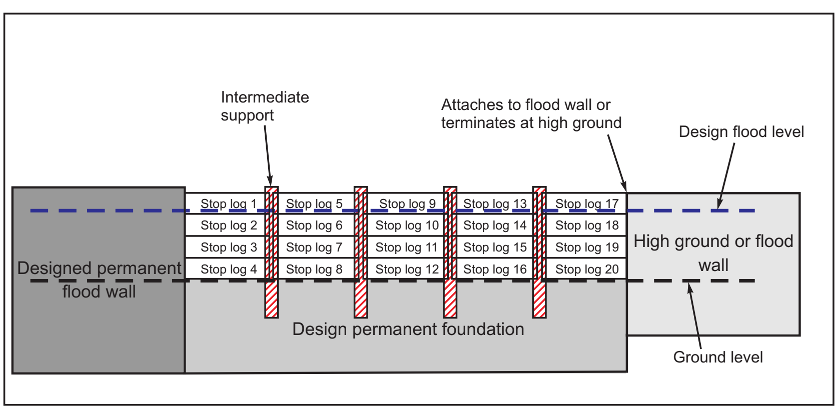

Fig. 20. Designed, semi-permanent deployable flood walls

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Data Sheet 10-2, *Emergency Response*

4.2 Other

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Federal Emergency Management Agency. FEMA Technical Bulletin 1-93, *Openings in Foundation Walls.*

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4.2.1 Some Nationally Recognized Levee and Floodwall Standards

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US Army Corps of Engineers (USACE). *Design, Construction, and Maintenance of Relief Wells.* USACE Engineering Manual No. 1110-2-1914.

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US Army Corps of Engineers (USACE). *Mechanical And Electrical Design Of Pumping Stations.* USACE Manual EM1110-2-3105.

APPENDIX A GLOSSARY OF TERMS

FM Approved: Products or services that have satisfied the criteria for Approval by FM Approvals. Refer to the Approval Guide for a complete list of products and services that are FM Approved.

APPENDIX B DOCUMENT REVISION HISTORY

October 2019. Interim revision. Minor editorial changes were made.

April 2019. Interim revision. Minor editorial changes were made.

October 2018. Interim revision. Added support information to Section 3.2 Flood Maps and Data, and Section 3.4 Understanding Flood Sources and Their Characteristics, covering historical flood data, floodway constrictions, and flood control dams.

October 2016. The following major changes were made:

A. Expanded the document to better address solutions for existing buildings. Rewrote parts of the data sheet to better emphasize flood prevention and mitigation, which is an approach that relies on permanent solutions and emergency actions.

B. Added new recommendations on lessening damage for existing buildings and equipment (Section 2.2.6). Topics in this section include the following: Permanent Site Flood Protection Systems, Complete and Partial Building Protection, Protection or Relocation of Equipment, Production Lines or Storage, and Temporary Perimeter Flood Protection Systems.

C. Added three recommendations (2.2.2.11, 2.2.2.12, and 2.2.2.13) to Section 2.2.2, Storm Water Runoff and Terrain Management. These recommendations cover storm water systems with a history of flooding, desert storm systems, and basement pumped drainage systems.

D. Revised Section 3.0, Support for Recommendations, to help the building owner better understand the flood scenario and select an appropriate solution to retrofit buildings. Added or expanded information on the following topics: flood maps and data, site-specific flood studies, flood protection breach studies, understanding the flood potential, understanding flood sources and their characteristics, understanding the impact, and building or retrofitting in a flood-prone area. Added examples on opening-protection solutions, and a section on temporary perimeter protection.

October 2014. Interim revision. Minor editorial changes were made.

July 2014. Interim revision. Minor editorial changes were made.

July 2012. The following changes were made:

- Sections 2.2.6 and 3.7 have been added to the data sheet.

September 2010. Minor editorial changes were made.

February 2010. Minor editorial changes were made.

October 2007. Minor editorial changes were made for this revision.

March 2007. This data sheet has been completely rewritten and incorporates material formerly contained in Data Sheets 9-13, *Evaluation of Flood Exposure*, and 9-2, *Surface Water*, which are now obsolete.