# CHAPTER I


# INTRODUCTION

## *A. CONCEPT OF FLOODPROOFING*

Floodproofing is a combination of adjustments and/or additions of features to individual buildings that are designed to eliminate or reduce the potential for flood damage. Some examples of floodproofing include the placement of walls or levees around individual buildings; elevation of buildings on fill, posts, piers, walls, or pilings; anchorage of buildings to resist flotation and lateral movement; watertight closures for doors and windows; reinforcement of walls to resist water pressure and floating debris; use of paints, membranes, and other sealants to reduce seepage of water; installation of pumps to control water levels; installation of check valves to prevent entrance of floodwaters at utility and sewer wall penetrations; and location of electrical equipment and circuits above expected flood levels.

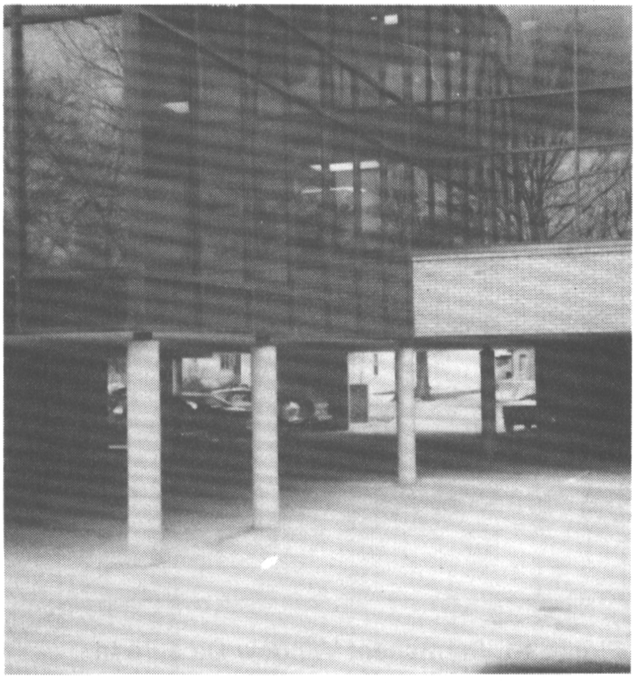
For the purpose of this manual, floodproofing of new buildings should primarily be viewed as any method or combination of methods that serve to meet the elevation or watertight floodproofing standards of the National Flood Insurance Program (NFIP) for non-residential structures. Many of these same concepts and methods can also be applied to existing non-protected construction to reduce or eliminate future flood damage.

## *B. CLASSIFICATION OF FLOODPROOFING*

Floodproofing techniques can be classified on the basis of the type of protection that is provided as follows: (1) *permanent measures* (always in-place, requiring no action if flooding occurs); (2) *contingent measures* (requiring installation prior to the occurrence of a flood), and (3) *emergency measures* (improvised at the site when flooding occurs). However, it should be recognized that these classifications are not always clearly defined. For example, a floodwall would normally be considered to be a 'permanent' protection measure even though the success of a particular floodwall design may be dependent upon installation of one or more gates to seal openings. The advantages and disadvantages of alternative floodproofing techniques are also presented in this chapter. Chapters III and IV provide more specific information that can be used to develop preliminary design concepts for the techniques described herein.

## *C. PERMANENT FLOODPROOFING MEASURES*

Permanent floodproofing measures are those which, once installed, require no further action to be taken when flooding occurs. These measures include closures and sealants, watertight cores, floodwalls and levees, and elevation of the structure. In general, permanent floodproofing measures are most effective when used in areas that are subject to frequent flooding, relatively high flood depths, or where insufficient flood warning time is available to implement contingent floodproofing measures.



For several reasons, permanent floodproofing measures are preferred over contingent or emergency-type techniques. Permanent floodproofing measures reduce reliance on a sophisticated flood warning and preparedness system because the evacuation of the structure occupants may be the only activity that is required prior to the flood. In addition, the effectiveness of these measures during a flood is not jeopardized by human error in installing any portion of the system under adverse conditions that often precede a flood. Furthermore, operation and maintenance costs associated with the floodproofing system will often be less with permanent measures because there is no need to store or maintain parts and supplies that would be required for contingent and emergency floodproofing techniques, and there is no need to train and maintain manpower for installing the floodproofing equipment. Also, permanent floodproofing measures will often meet the minimum floodplain management requirements of the National Flood Insurance Program.

There are also some disadvantages associated with permanent measures. Initial construction costs may be relatively high, particularly for some existing structures and for large floodwall or levee protection projects. Another primary disadvantage to permanent floodproofing is that adjustments made to prevent water from entering a facility may restrict access to and use of certain parts of the structure.

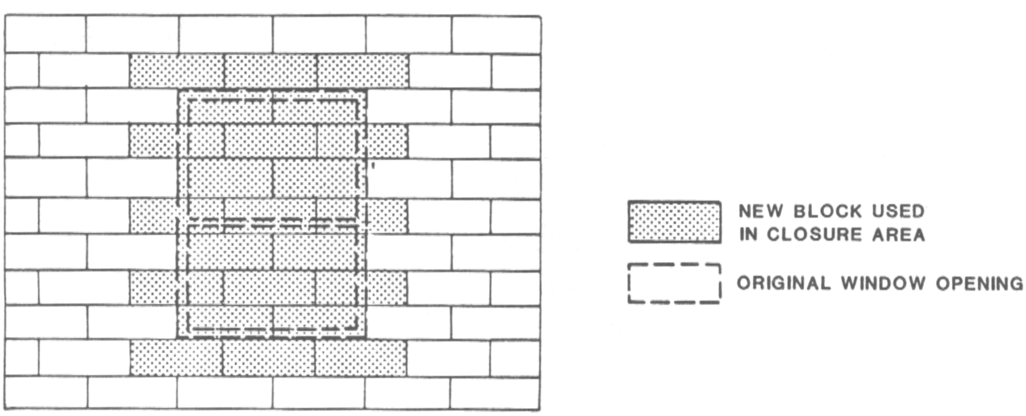



Figure I-1. Permanent Window Closure in existing masonry wall.

## *D. TYPES OF PERMANENT MEASURES*

### 1. PERMANENT CLOSURES AND SEALANTS.

A permanent closure basically involves filling an existing window, door, or other opening with some form of water-resistant material, such as concrete blocks, bricks, or cast-in-place concrete (see Figure I-1). The exterior walls and closures will prevent water from entering a building. It is important that *walls are impermeable and strong enough to support the expected hydraulic loading, and that the windows and/or doors are not required for the operation of the facility.*

Older cast-in-place walls and brick walls generally develop small cracks that allow water to penetrate. In addition, masonry walls are not inherently impermeable; therefore, some seepage can occur through them when they are subjected to floodwaters for extended periods of time. One method that can be used to prevent seepage through a masonry wall is the use of sealants.

A sealant is a waterproof coating that can be applied to the outside of an existing wall, or beneath the veneer of a new wall to reduce or eliminate the wall's permeability. This coating is generally an asphalt-based or polymeric compound that can be painted or sprayed onto the wall. In some cases, polyethylene plastic sheets have been applied in conjunction with these coatings. Some basic considerations for determining whether sealants and closures might be used are:

- Are the walls of the facility strong enough to withstand the flood-induced loadings without significant structural damage?
- Can these walls be adequately sealed to prevent seepage?
- Can the door, window, or other opening be permanently closed without significantly impairing use of the facility?
- Can a sufficient bond be provided between a closure and the existing wall so that the closure will not fail or crack when subjected to flood loadings?
- Is the floor strong enough to withstand anticipated hydrostatic uplift or buoyancy loads or will a sub-floor drainage system be required?

**2. WATERTIGHT CORES.** Many existing non-residential buildings do not have watertight walls and often cannot be waterproofed due to physical or economic constraints. In many of these cases some degree of flood-damage reduction can be provided by installing a watertight wall around items within the building that are particularly susceptible to flood damage. This type of watertight enclosure is normally constructed of cast-in-place concrete. However, concrete block or brick may be used if an effective waterproofing compound is applied and sufficient strength can be developed. Watertight cores are particularly effective when costly items are located together in a small part of the building and it is not feasible to relocate them to non-floodprone areas. For example, important records, vital utilities, or expensive equipment might be enclosed by such a core. (See Figure I-2.) If properly designed and constructed, a watertight core can be a very cost effective damage-reduction tool for a facility which could not otherwise be floodproofed.

**3. FLOODWALLS AND LEVEES.** Another method of floodproofing a non-residential structure is the use of small floodwalls or levees. Although these have traditionally been considered as structural flood control alternatives for protecting a large area or a number of structures, they can be a practical and economical floodproofing technique for protecting single or small groups of structures. Floodwalls and levees have been constructed in a wide variety of shapes and sizes throughout the United States. Basically, these facilities act to keep water away from a structure.

Floodwalls are generally of masonry or concrete construction and there are a wide variety of configurations to meet different site conditions. Some of the more common shapes are shown in Figure I-3.

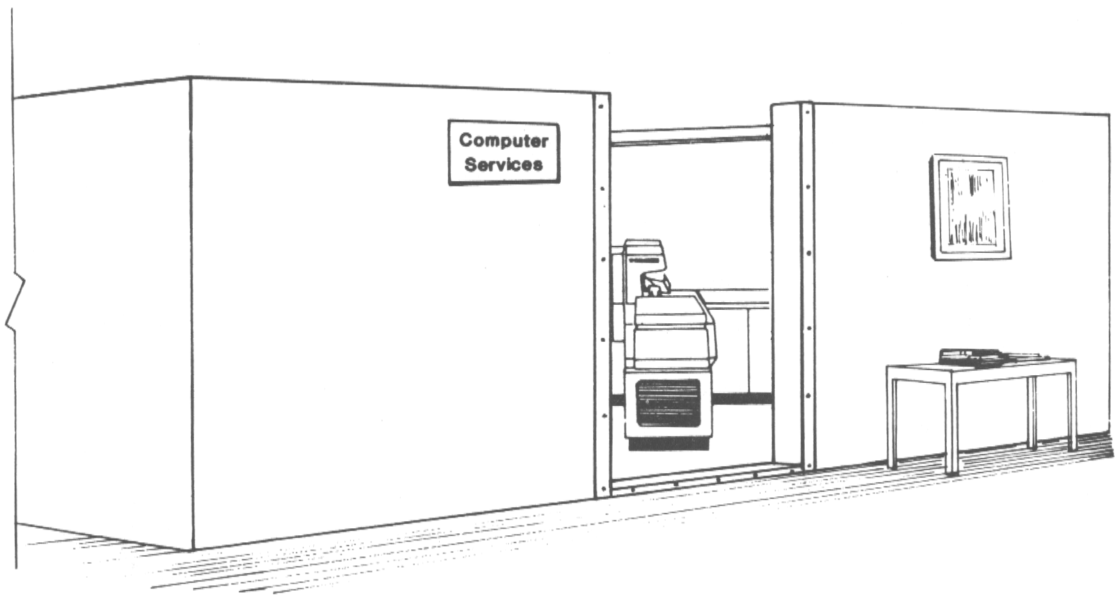



Figure I-2. Typical Applications of Watertight Core Floodproofing

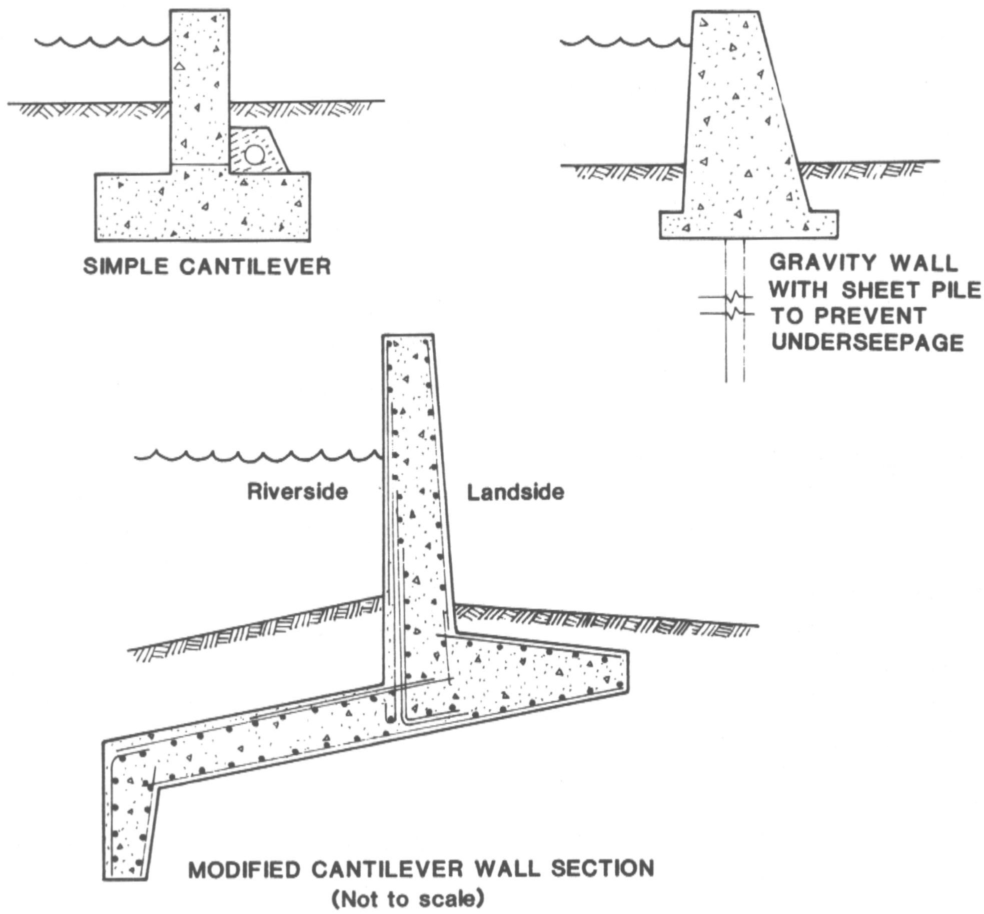



Figure I-3. Typical Floodwall Configurations

Levees are earth embankments that have low-to-moderately sloped sides, a wide crest, and a cut-off trench or wall as shown in Figure I-4. The side slopes are usually 3:1 or less to provide greater structural mass and stability. The crest can vary in width from a minimum of 2 feet depending on stability requirements related to the height of the levee and on any allowances which need to be made to facilitate access for vehicles or maintenance equipment.

One of the primary advantages of floodwalls and levees is that they can be used to protect any type of structure. There is no need to alter the building, to block in windows or doors, or to build interior barriers. Floodwalls and levees also have an advantage in that they can be used in areas with relatively high flood depths. However, high floodwalls and levees are very expensive and pose a significant safety hazard if they are not designed and constructed properly, or their design protection level is overtopped.

One major drawback to the use of levees is the amount of space which they require. For example, if a levee with 3:1 side slopes and height of eight to ten feet is placed on a two-acre site, the levee will occupy approximately one-half of the site (this relationship will vary based on the shape of the site). However, with its relatively flat slopes, the levee can provide open space that may be used for storage or some other activity that does not conflict with proper levee maintenance. Figure I-5 demonstrates how levee width varies with height.

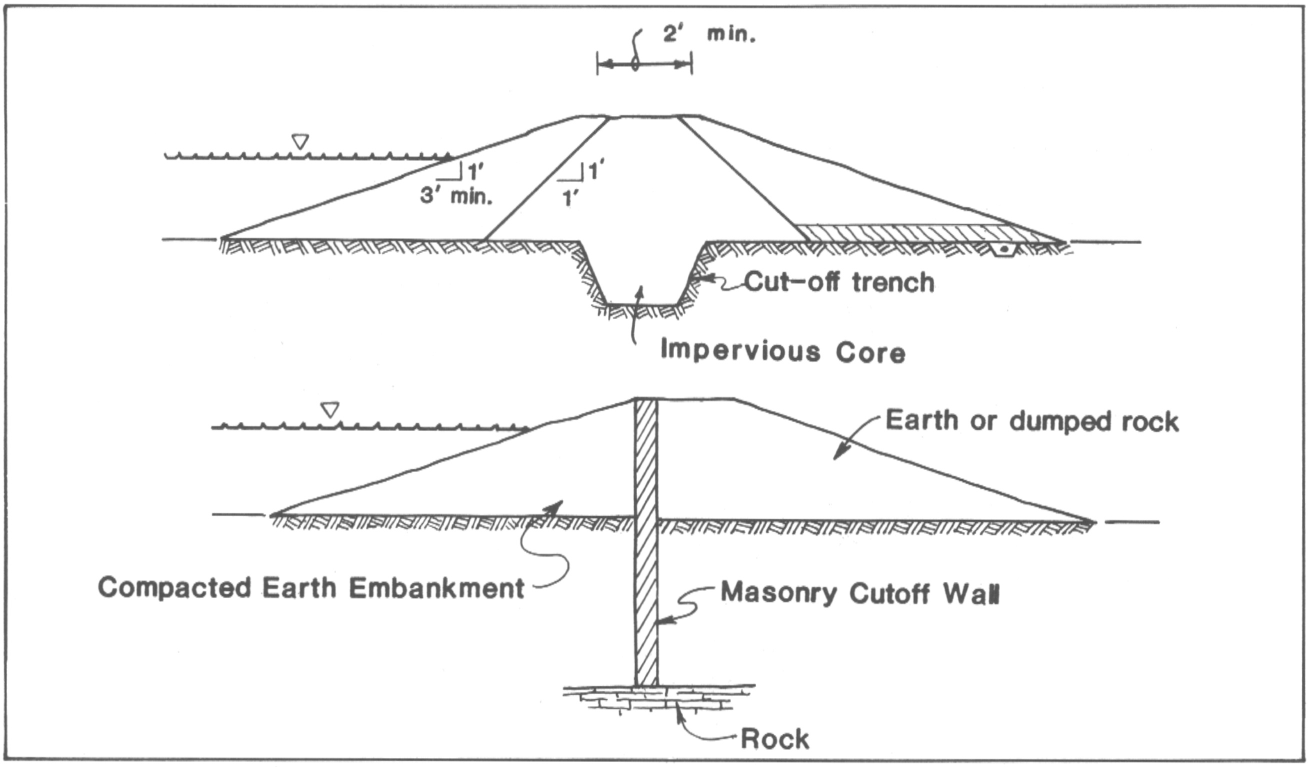



Figure I-4. Typical Levee Configurations

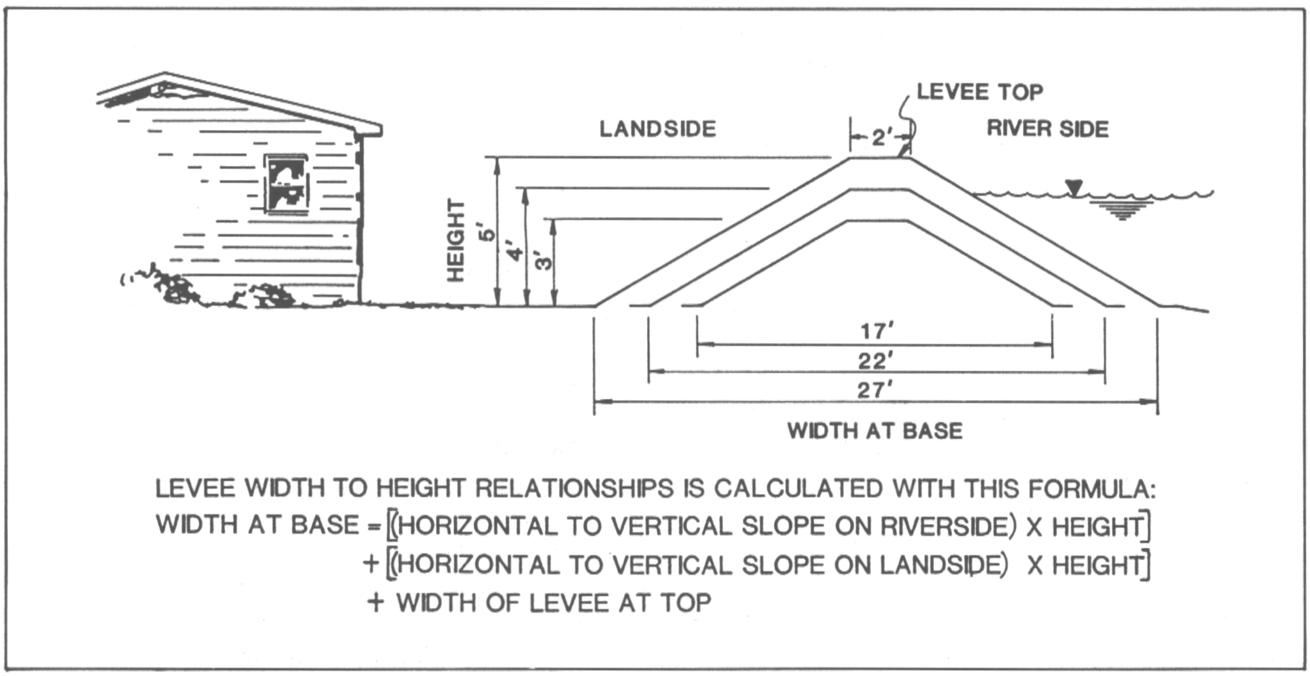



Figure I-5. Section View of Protective Levee

Another common problem associated with levees and floodwalls is related to the need to provide for drainage of rainfall and runoff that collects behind them. Normally this is accomplished by draining all internal water to a central point. Interior drainage may be pumped to the other side of the floodwall or levee, or a valve may be provided to allow drainage by gravity, while preventing backflow during flood periods (see Figure I-6). Also of considerable importance in the design and construction of floodwalls and levees is underseepage. In areas where the soils are pervious or floods are of considerable duration, seepage under the structure could result in flooding of the site behind it. In such cases, some type of pump system, cut-off trench, sheet piling, or wall should be provided as shown in some of the examples in Figures I-3 and I-4.

**4. ELEVATION.** Elevation of a non-residential structure above the base flood elevation is a protective measure that is often feasible for new construction and selected existing structures. Structures may be elevated on concrete columns (Figure I-7), on compacted fill (Figure I-8), or a variety of other foundation types. Elevation of a building on walls, columns, piles, posts, or piers can be accomplished within the same amount of space that would be required without elevation. If a structure is to be elevated on fill, a considerably larger amount of space may be required to accommodate grade changes on the sides of the structure.

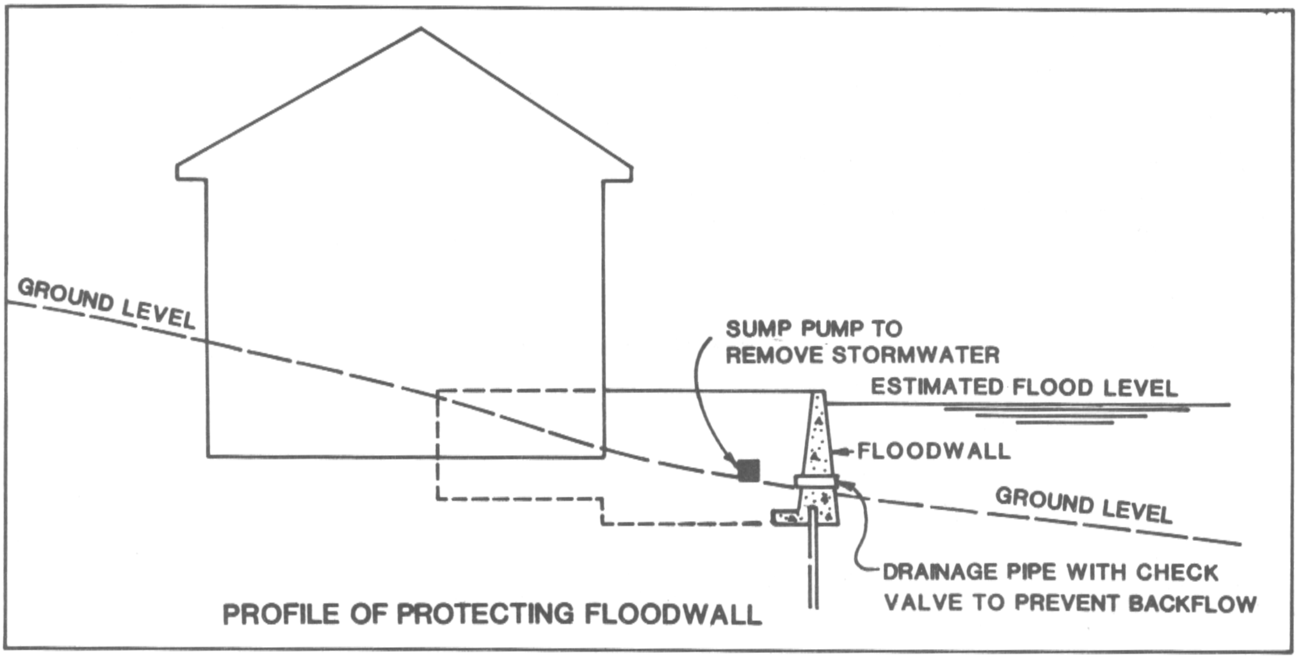



Figure I-6. Flood Protection With Low Floodwall


Figure I-7. Elevation on Columns

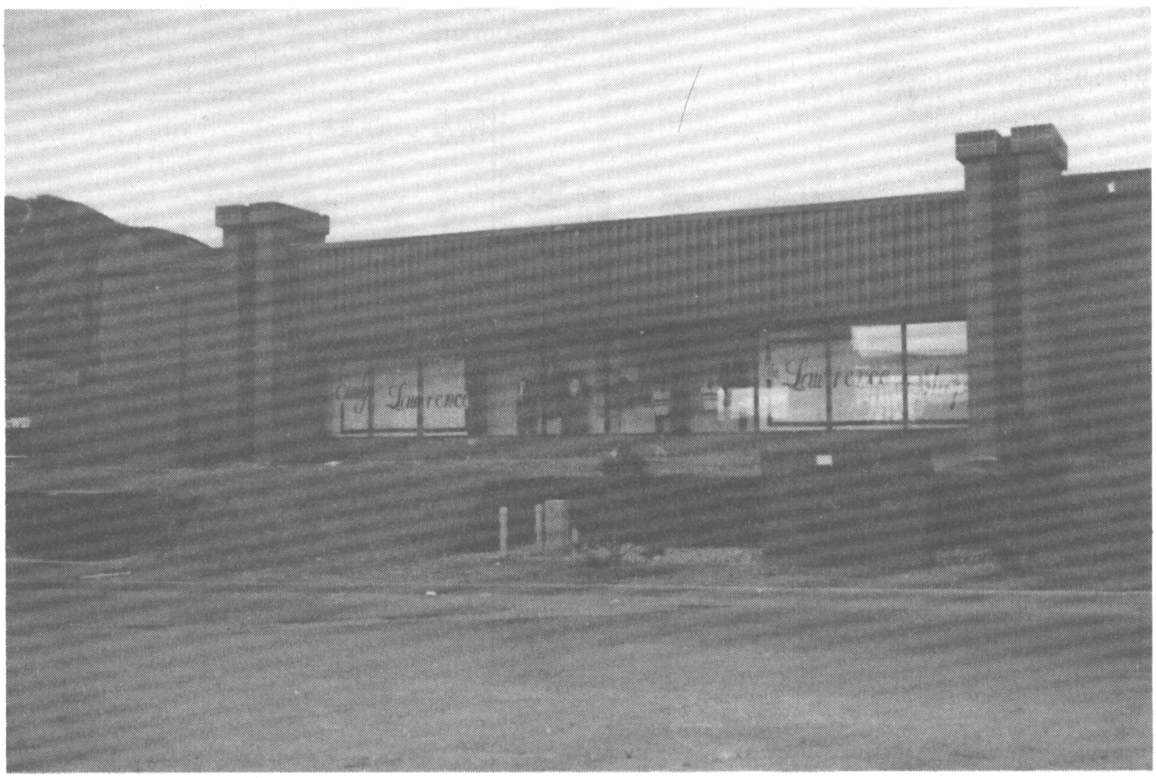


Figure I-8. Elevation on Compacted Fill

Elevated structure design must be capable of resisting the loads caused by flooding including hydrostatic, hydrodynamic, and debris impact. Substantial modifications to standard walkways, steps, ramps and utility systems may also be required. The elevated structure's floor must be insulated and the utility systems leading to the structure must be protected from damage associated with floods and temperature extremes. In addition, elevation of the structure must be designed so that it does not interfere with access to the structure. For example, if a warehouse is to be elevated, some provision must be made for maintaining the required dock height. This problem might be resolved by raising the loading dock area on fill material (see Figure I-9). Similar problems may be encountered if the facility to be elevated is situated near a railroad or river dock. Ideally, plans for an elevated structure should include provisions for safe exit from the structure during a flood. This may be accomplished by elevated walkways or through appropriate grading of the site. For structures where this is not possible, adequate flood warning and evacuation plans must be developed to ensure that occupants are not stranded in the facility during a flood.

Although elevation is most applicable for new construction, there are some cases where this technique can be used successfully to protect existing structures from flood damage. Techniques are available to raise almost any type of structure. However, cost effective elevation of existing structures is generally limited to light, 1-2 story buildings that have a floor system that can be lifted with the structure walls as a single unit. Generally, wood frame buildings constructed on a crawl space or basement foundation are the most suitable candidates for elevation.

## *E. CONTINGENT FLOODPROOFING MEASURES*

Although permanent floodproofing measures certainly have advantages in terms of providing protection from flood damages, they often have accompanying disadvantages such as restricted access and inefficient utilization of space. When these factors represent major obstacles to the application of permanent floodproofing techniques, the use of contingent floodproofing measures may be appropriate.

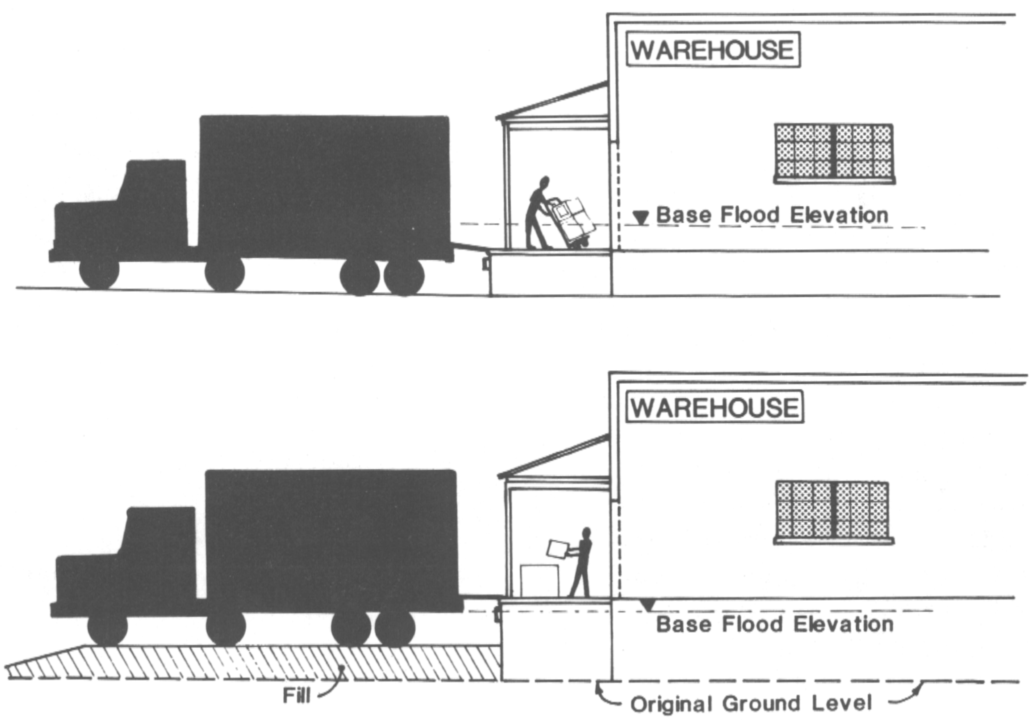



Figure I-9. Elevation of an Existing Warehouse

Contingent floodproofing measures are those that require some type of installation, activation, or other preparation immediately prior to the occurrence of a flood. These measures include flood shields, watertight doors, and moveable floodwalls. In some cases, flood protection provided by levees, floodwalls, or waterproof cores will require access openings that must be sealed with shields or doors during flood events. Obviously, the success of this type of system is dependent upon the ability to install and secure the flood shields and other protective devices prior to flooding. *As with permanent floodproofing measures, the walls and floors must be strong enough to withstand loading forces and significant leakage.*

The primary advantage of contingent floodproofing systems is that components may be moved aside or stored during non-flood periods allowing full access to the doors, windows, and other openings. In addition, contingent floodproofing methods are often very cost effective when protecting against relatively shallow flood depths, especially when a small number of openings are involved. Another advantage of contingent measures is that they are often the most adaptable and feasible techniques for use of existing non-residential structures. Also, these techniques may satisfy the minimum floodplain management requirements of the National Flood Insurance Program.

Although convenience, cost, and adaptability provide major incentives to the use of contingent floodproofing measures, there are several potential disadvantages that must be considered. The major disadvantage is that a contingent system is subject to human error associated with applying the system's components. Inappropriate response may involve inadequate recognition of flood hazards, improper installation, failure to install an element of the system due to an oversight, inability to find elements or installation equipment due to poorly planned or maintained storage areas, or improper training of the installation team. Each of these factors must be carefully considered during the selection and design of contingent floodproofing measures.

## *F. TYPES OF CONTINGENT MEASURES*

**1. FLOOD SHIELDS.** Flood shields are the most commonly used contingent floodproofing method. A flood shield is a watertight barrier designed to prevent the passage of water through doors, windows, ventilation shafts, or any other opening in a structure that might be exposed to flooding. Flood shields have customarily been made of steel or aluminum. However, any material that can be easily maintained and is capable of providing sufficient strength and water resistance may be used.

So that access to protected areas is maintained, flood shields are usually installed only when flooding is imminent. Normally some type of gasket or seal is required to ensure that the shield is watertight. Additionally, the shield should be attached by bolts or some other means to provide proper contact for sealing. It must be stressed that flood shields may only be installed where the walls of the building and the opening's framing system are strong enough to withstand flood-induced forces.

Some mechanical means of transportation and placement should be incorporated in the design of large, heavy shields. As shown in Figure I-10, shields may be mounted on tracks or hinges so that they can be slid or lowered into place. Heavy flood shields may also be placed with a fork lift, overhead hoist system, or any other type of mechanical or electrical device. It is critical that the selected system must have an independent power source because power outages often accompany major floods.

One disadvantage of this floodproofing system is the storage requirement for flood shields. Shields must be located as near to the opening as possible along with any tools required for installation. If storage requirements are improperly implemented, the entire system for protection can fail.

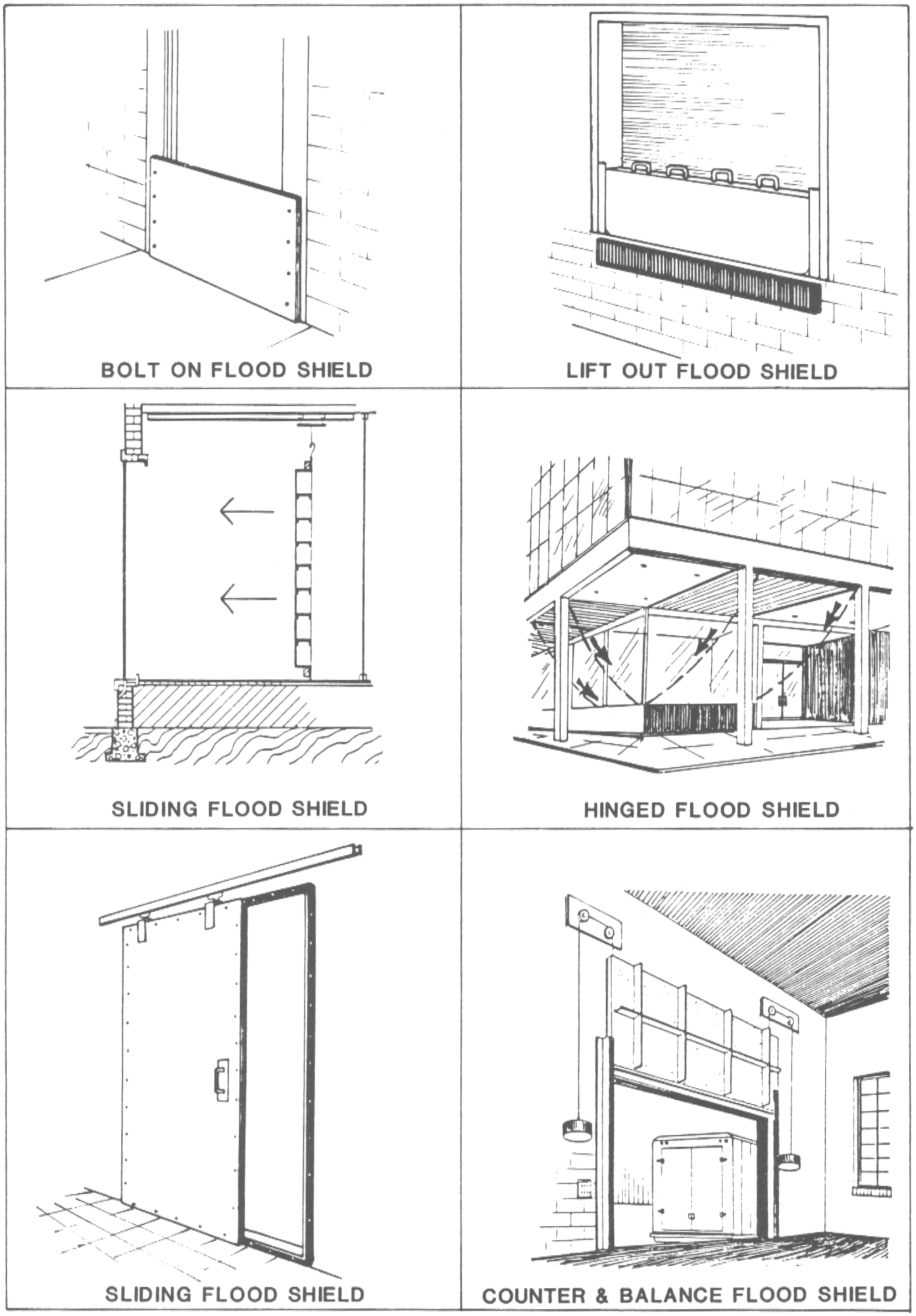



Figure I-10. Typical Flood Shields

**2. WATERTIGHT DOORS.** Watertight doors are very similar to sliding or hinged flood shields in purpose, yet they are designed to function as actual doors that are used during normal operating conditions. This type of door can be closed and sealed by a simple latch mechanism (see Figure I-11), without the use of bolts that are normally used to secure a flood shield.

Many of the advantages of watertight doors are obvious. Because they are permanently mounted at the area where they are to be used, a separate storage area is not required. Because they will be used on a regular basis, they are more likely to be kept in proper working condition. For structures where all openings could be protected with this type of closure, there would be no need for a contingency plan to floodproof the facility during non-working hours. Waterproof doors are easily secured, thus their use would reduce the amount of time required to implement a floodproofing plan that contained other contingent or emergency measures.

The primary disadvantages to this type of door include their weight (which makes frequent opening and closing difficult), and their cost.

**3. MOVABLE FLOODWALLS.** Movable floodwalls may be installed in situations where the construction of a conventional floodwall or levee is not acceptable because of related impacts on accessibility or aesthetic values. Several movable floodwall designs have been developed to date. A few of the more common designs are described in this section.

The folding floodwall consists of a flood barrier which is hinged along the bottom so that it can be lowered to a horizontal position to form a walk, or to fit flush with existing ground or pavement. A floodwall in Monroe, Louisiana is based on this concept. Figure I-12 shows a section view of the floodwall in both the raised and the lowered position.

Figure I-11. Watertight Hinged Door

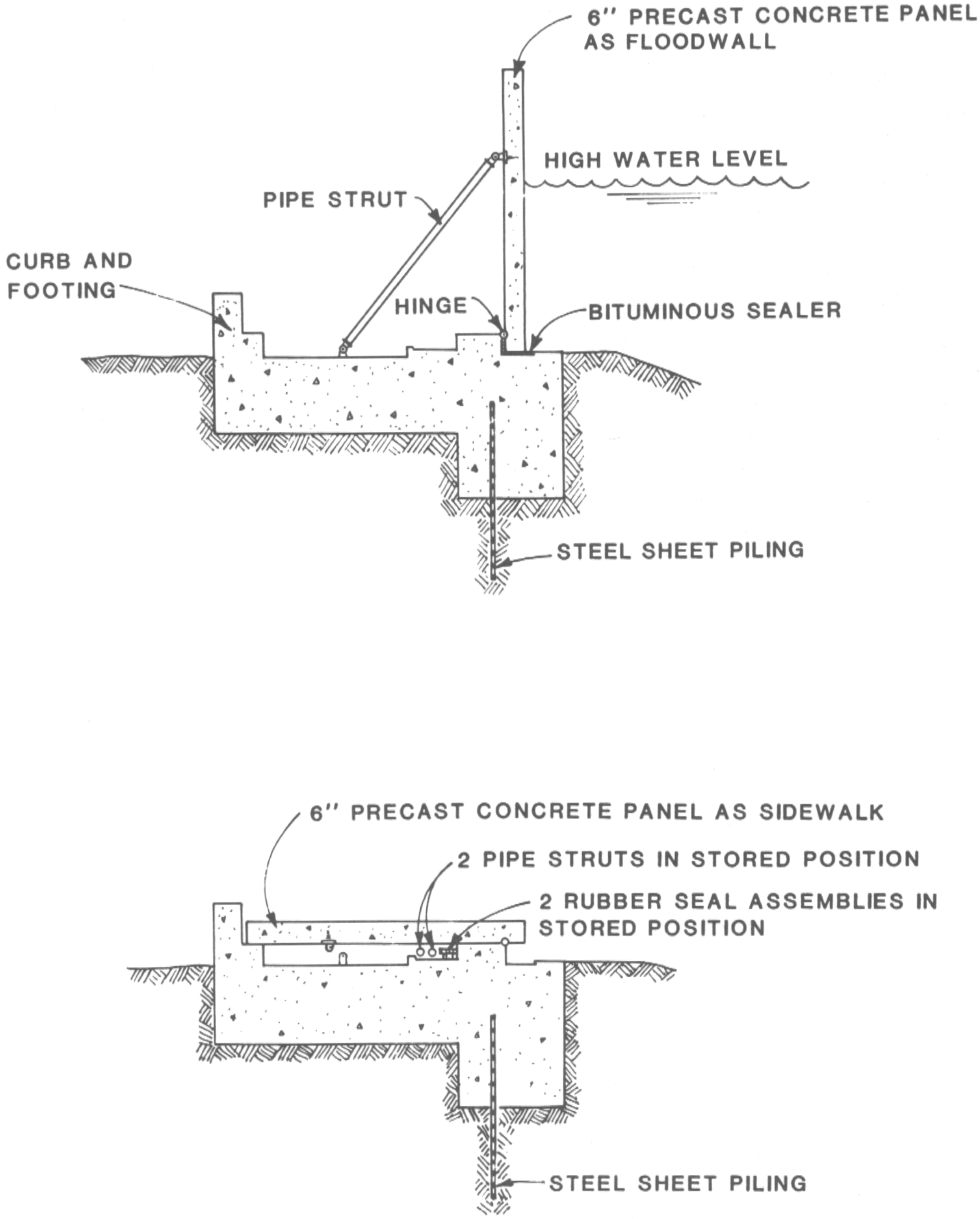



Figure I-12. Folding Floodwall
(Precast Concrete Flood Shield)
Based on Floodwall in Monroe, Louisiana That Was Designed and Constructed by the Vicksburg District Corps of Engineers

Because these panels are quite heavy (about 500 pounds per foot of length), they must be raised and lowered by means of a mechanical hoist and must be held in place while the bolts are manually secured. This system is not particularly quick to install. Another floodwall of this type includes a pneumatic lifting system and telescoping struts so that air compressors could be used to lift the panels, thereby substantially reducing installation time.

For those cases where relatively shallow flooding is expected (water depths of two feet or less), a folding floodwall could be constructed using metal shields. These shields could be braced by either permanent or movable posts. The shield faces that are exposed when they are in the lowered position would need to be surfaced with an appropriate texture for any pedestrian or vehicular traffic that would be expected (see Figure I-13).

Another movable floodwall that is suitable for low depth areas involves mounting a flood shield so that it can slide up and down in a recessed area below grade and the flood barrier position as shown in Figure I-14. This particular design has an advantage over the flood shield wall because of the convenient location of the panels. It also has some advantage over the folding or hinged floodwall in that any type of walk, pavement, or grassed area can be accommodated on each side.

If a movable floodwall is correctly designed, built, maintained, and installed it should provide complete protection for a non-residential structure while allowing full view of and access to the structure during normal business operation. However, these advantages must be weighed against disadvantages associated with relatively high construction cost and maintenance requirements.

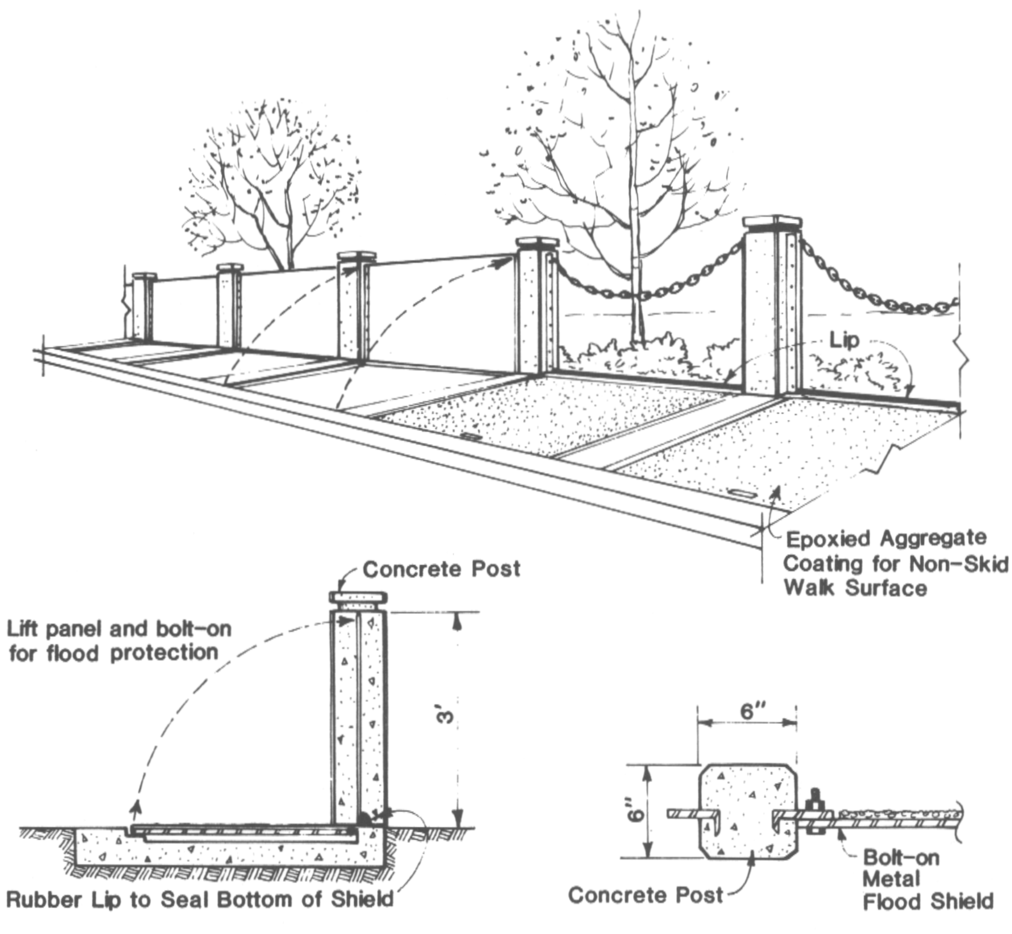
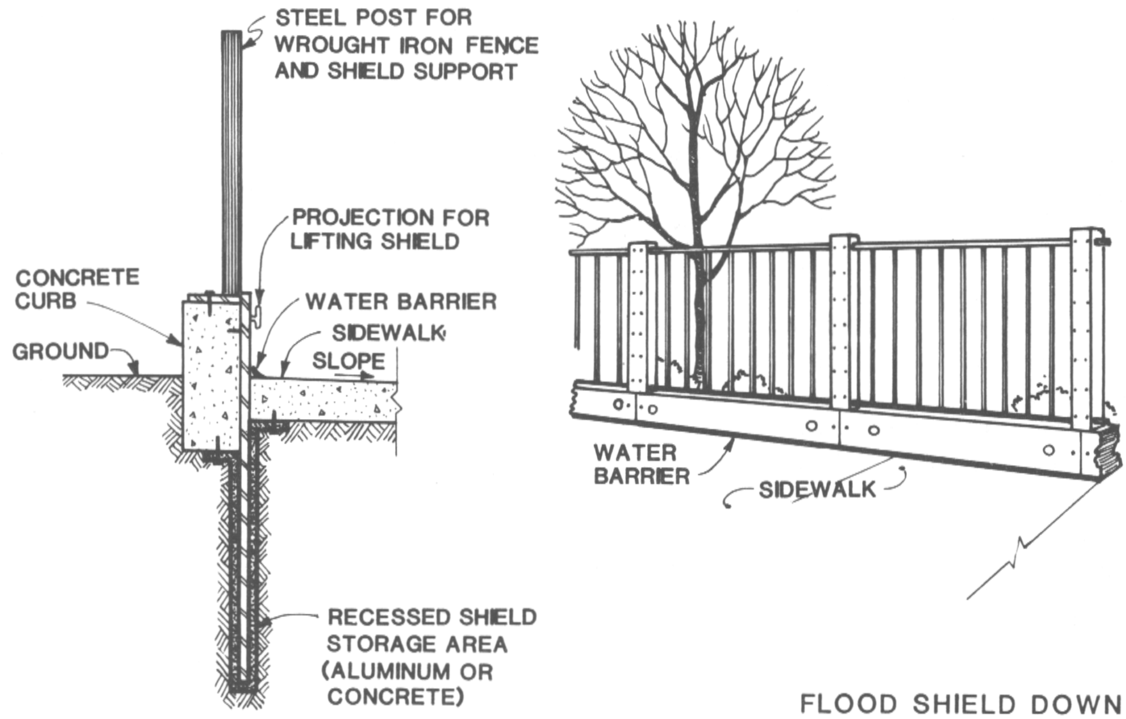



Figure I-13. Folding Floodwall
(Metal Flood Shield)



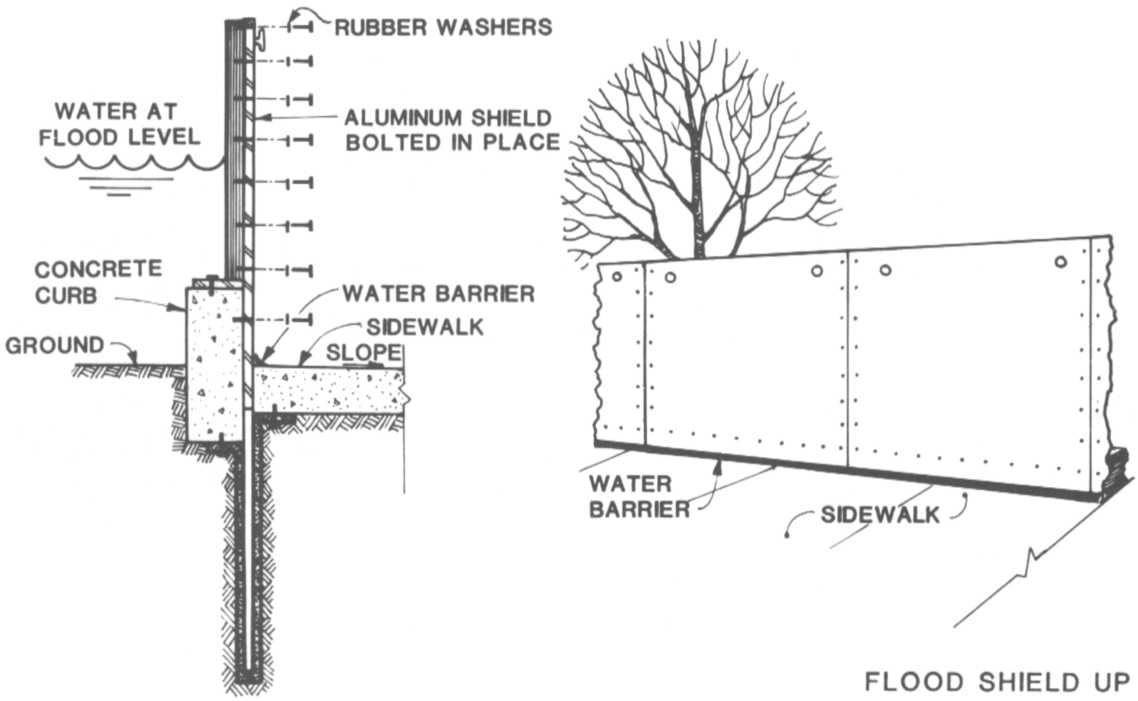




Figure I-14. Recessed Floodwall
(Aluminum Flood Shield)

## *G. TYPES OF EMERGENCY FLOODPROOFING MEASURES*

Emergency floodproofing measures are discussed in detail in Chapter IV and are summarized below. These techniques are characterized by their ability to be initiated on relatively short notice using previously obtained and stored materials.

The primary advantage of an emergency method is low cost. Sand and timber are the primary materials and although these measures labor intensive, volunteers are often used. These methods are most effective in flood areas where water velocities are low and depths are shallow, and where floodwaters rise slowly.

A major disadvantage of emergency measures is that substantial advance warning is required to mobilize personnel and install emergency barriers. In addition, in the event of an unexpected increase in the flood magnitude or rate of rise, the emergency measures may fail. It should be noted that emergency measures do not satisfy the minimum requirements for watertight floodproofing as set forth by the National Flood Insurance Program (NFIP), due to their reliance on human intervention. The most common techniques for emergency flood protection include the following:

**1. SANDBAG DIKES** - This is the most common emergency technique and consists of stacking plastic burlap sandfilled bags atop one another.

**2. EARTHFILL CRIB RETAINING WALLS** -These temporary walls are typically constructed by placing soil between two timber formed walls.

**3. STOP LOG BARRIERS** - Stop log barriers are typically constructed by stacking small timber planks on top of each other by dropping them into permanent side channels.

Other techniques used to reduce flood damages are discussed in Chapter IV.