CHAPTER 14

PROCEDURES

SECTION 1400.0 SCOPE

Sec. **1400.1 PURPOSE**: The purpose of this chapter is to present and explain some practical aspects of flood-proofing and to show by means of examples and diagrams the effects of flood-related loads on structural elements of a building and other protective constructions. The structural elements discussed include concrete and masonry basement walls, concrete and masonry retaining walls, basement floor slabs, and closure panel assemblies. Also included are some concepts of foundation drainage, examples of floodwalls and dikes, and concepts of closure panels, devices and assemblies.

SECTION 1401.0 CRITICAL ASPECTS OF A FLOOD

Sec. **1401.1 GENERAL**: No attempt is made here to provide an elaborate definition of the term flood nor to define a typical flood. Instead, critical aspects of a flood are listed below in the order of greatest importance as related to flood damages and their impact on flood-proofing measures.

Sec. **1401.2 DEPTH**: Depth of flood waters around a structure is by far the most critical element to be considered in planning and designing flood-proofing measures. The depth of flood waters determines to a great extent the strength and stability requirements for the structure as a whole and for individual structural elements below the design flood level. Except for very special structures and for massive or very high buildings, it is assumed herein that the maximum practical flood depth for which flood-proofing measures are economically effective is 10 feet of free water above grade for a building or structure having a 10-foot space or basement height below grade.

Sec. **1401.3 VELOCITY**: Velocity of flood water during overbank flow conditions affects scouring, sediment transportation, debris load, and dynamic loading on structures and obstructions. Flood velocities vary from point to point in a flood plain and over the area of inundation. From a practical standpoint, velocities up to five (5) feet per second are not uncommon or unusual and their effects on structures may be dealt with by application of normal design methods and procedures. Velocities up to 10 feet per second could occur, particularly in close proximity to the channel, but are believed to be unusual and to require special methods and techniques. A velocity of 10 feet per second is considered to be the upper limit for which flood-proofing measures are economically effective, except for special structures and facilities built at the edge of a channel, where permitted.

Sec. **1401.4 DURATION**: The duration of a flood, as measured from the time the stream overflows its banks, reaches its crest elevation, and then recedes to within its banks, is important from the standpoint of saturation of soils and building materials, of seepage, achievement of full pressure in soils and under foundations, and other time dependent effects. In addition, the duration of the flood affects the provisions for standby utilities and services.

Sec. **1401.5 RATE OF RISE AND FALL**: The rate of rise and fall of a flood to and from its crest affects the sizing of flooding and draining provisions, where such are required. It also affects in certain cases the implementation of contingent or emergency flood-proofing measures, and must be recognized in investigations of slope stability for a condition of quick drawdown.

Sec. **1401.6 ADVANCE WARNING**: The length of advance warning available from flood forecasting is all-important, particularly in relation to contingent flood-proofing methods which require definite amounts of lead time for protective measures to be placed into effect.

Sec. 1401.7 DEBRIS LOAD: The amount and type of floating debris carried by the flood waters can result in substantial loads against buildings and structures and can cause blockages of channels and passageways. Debris load includes logs, tree branches and trees, lumber, displaced sections of frame structures, drains, tanks, and runaway boats and barges. One type of floating solids borne by flood waters which is predominant in certain areas of the country during early spring floods consists of broken up ice blocks and at times of large masses of broken up ice sheets. Ice blockage of channels or ice jams that frequently occur in certain areas contribute significantly to the flood hazard and related problems.

Sec. 1401.8 WAVE ACTION: A degree of wave action is inherent to all large expanses of water under the action of the wind. For typical riverine floods, wave action is nominal and allowances can be made for it by providing a suitable freeboard. Wave action is most significant for coastal floods which are caused by persistent storms, e.g. Nor'easters, tsunami waves or hurricanes. These cases are beyond the scope of the Flood-Proofing Regulations and require special design considerations and procedures.

SECTION 1402.0 FLOOD DAMAGES

Sec. 1402.1 GENERAL: Floods are a natural and inevitable part of life in communities along the rivers of our country. The transformation of tranquil rivers into destructive floods occurs hundreds of times each year. No part of the United States is spared. Every year, some 75,000 Americans are driven from their homes by floods. On the average, 80 persons are killed each year. These destructive overflows cause property damages that currently average $1 billion a year. Damages to property, human suffering, and loss of life resulting from floods have been increasing year by year in spite of the expenditure of over seven billion dollars for flood control works. The increase in flood damages has been due primarily to the rapid growth of flood damageable improvements in the flood plains of the rivers and seacoasts. No dollar values can be assigned to human suffering and loss of life caused by a flood. Flood damages to property can be assessed and are substantial. As a rule, damages increase rapidly with depth of flooding. Damages to a building and its contents, as they relate to damage to finishes, trimwork, furniture, appliances, equipment, and storage materials represent a substantial portion of the total loss. For the purpose of this publication however, major emphasis is placed on structural damage to the building or structure or to structural elements thereof, including complete collapse or displacement of the structure.

Sec. 1402.1.1: When flood waters reach a structure they induce unbalanced pressures and loadings on all wetted surfaces which increase rapidly with increased depth. Once interior spaces become flooded, water pressures are automatically equalized. Unbalanced lateral pressures on walls may cause excessive lateral displacement, cracking, tilting, sliding, on and up to complete collapse of the wall. These same pressures can cause overloading and failure of vertical and horizontal framing members of the structure into which the walls are framed. Uplift pressures under basement and floor slabs can displace and collapse the slabs. Saturation of soils on which footings are supported and uplift pressures under the footings and within the soil can greatly reduce the bearing capacity of the soil and cause the footing to become unstable and fail. Uplift pressures under raft or mat foundations with integral walls can cause the entire structure to become bouyant and displace vertically upward, or to become unstable and overturn. In this latter case, unbalanced lateral pressures are also often at work. Dry, checked wooden beams and other structural materials lose their strength, swell, and deflect excessively as they become water-logged. This can cause floors and partitions to settle and sag, frames to become distorted, and plaster walls and ceilings to crack. When the beams, for example, dry up and attempt to return to their original shape, they are prevented from doing so by settled floors and partitions above, and can fail or cause the failure or displacement of other supporting members. The following sections contain examples of structural elements of buildings investigated under hydrostatic loads related to flood waters.

SECTION 1403.0 LOADS

Sec. 1403.1 GENERAL: Flood waters surrounding a structure induce hydrostatic and hydrodynamic loads on the structure itself. Hydrostatic loads (pressures) are induced by water which is either stagnant or moving at low velocity. Hydrodynamic loads result from the flow of water against and around a structure at moderate or high velocities. Impact loads are imposed on the structure by water borne objects and their effects become greater as the velocity of flow and the weight of objects increase.

Sec. 1403.2 HYDROSTATIC LOADS: These loads or pressures, at any point of flood water contact with the structure, are equal in all directions and always act perpendicular to the surface on which they are applied. Pressures increase linearly with depth or "head" of water above the point under consideration. The summation of pressures over the surface under consideration represents the load acting on that surface. For structural analysis purposes, hydrostatic loads are defined to act *vertically downward* on structural elements such as roofs, decks and similar overhead members having a depth of water above them; *vertically upward* or in *uplift* when they act at the underside of generally horizontal members such as slabs and footings and the net effect is upward; *laterally* when they act in a horizontal direction on walls, piers, and similar vertical structural elements. For the purpose of these Regulations, it has been assumed that hydrostatic conditions prevail for still water and water moving with a velocity of less than five (5) feet per second. It is estimated that hydrodynamic effects up to the stated velocity can be conservatively recognized in the freeboard allowance.

Sec. 1403.3 HYDRODYNAMIC LOADS: As the flood waters flow around a structure at moderate to high velocities they impose additional loads on the structure. These loads consist of frontal impact by the mass of moving water against the projected width of the obstruction represented by the structure, drag effect along the sides of the structure and eddies or negative pressures on the downstream side. For the range of velocities discussed in 1401.3 (0-10 feet per second), it is considered most practical to make allowances for the hydrodynamic effects by converting them into an equivalent hydrostatic condition. For special structures, conditions, and for velocities greater than 10 feet per second, a more detailed analysis and evaluation should be made utilizing basic concepts of fluid mechanics and/or hydraulic models.

Sec. 1403.4 IMPACT LOADS: These loads are induced on the structure by solid objects and masses carried by or floating on the moving water surface. These loads are the most difficult to predict and define with any degree of accuracy, yet reasonable allowances must be made for these loads in the design of affected buildings and structures. To arrive at a realistic allowance, a great deal of judgment must be used, along with reliance on the designers experience with debris problems at the site, and consideration of the degree of exposure of the structure.

SECTION 1404.0 STRUCTURAL ELEMENTS

Sec. 1404.1 GENERAL: The following sections present a discussion of loading assumptions and design criteria for structural elements of buildings, such as basement and retaining walls, floor slabs and closure panels, under the effects of flood related loads. All the examples herein assume a "structurally" flood-proofed structure, (Classification W1 or W2 of the Regulations), where flood waters are prevented from reaching interior spaces and full imbalanced hydrostatic loads attain on the exterior of the structure. Secondary loading effects associated with flood waters, such as wave action, debris loads and hydrodynamic loads are not included in this discussion.

Sec. 1404.2 BASEMENT SLABS: Under flood conditions, and often under normal non-flood conditions in cases where conditions of high water table prevail, basement slabs may be subjected to high uplift pressures. To overcome this condition, the slab can be made thick enough to have sufficient weight to counteract the uplift pressures. This solution is very seldom economical.

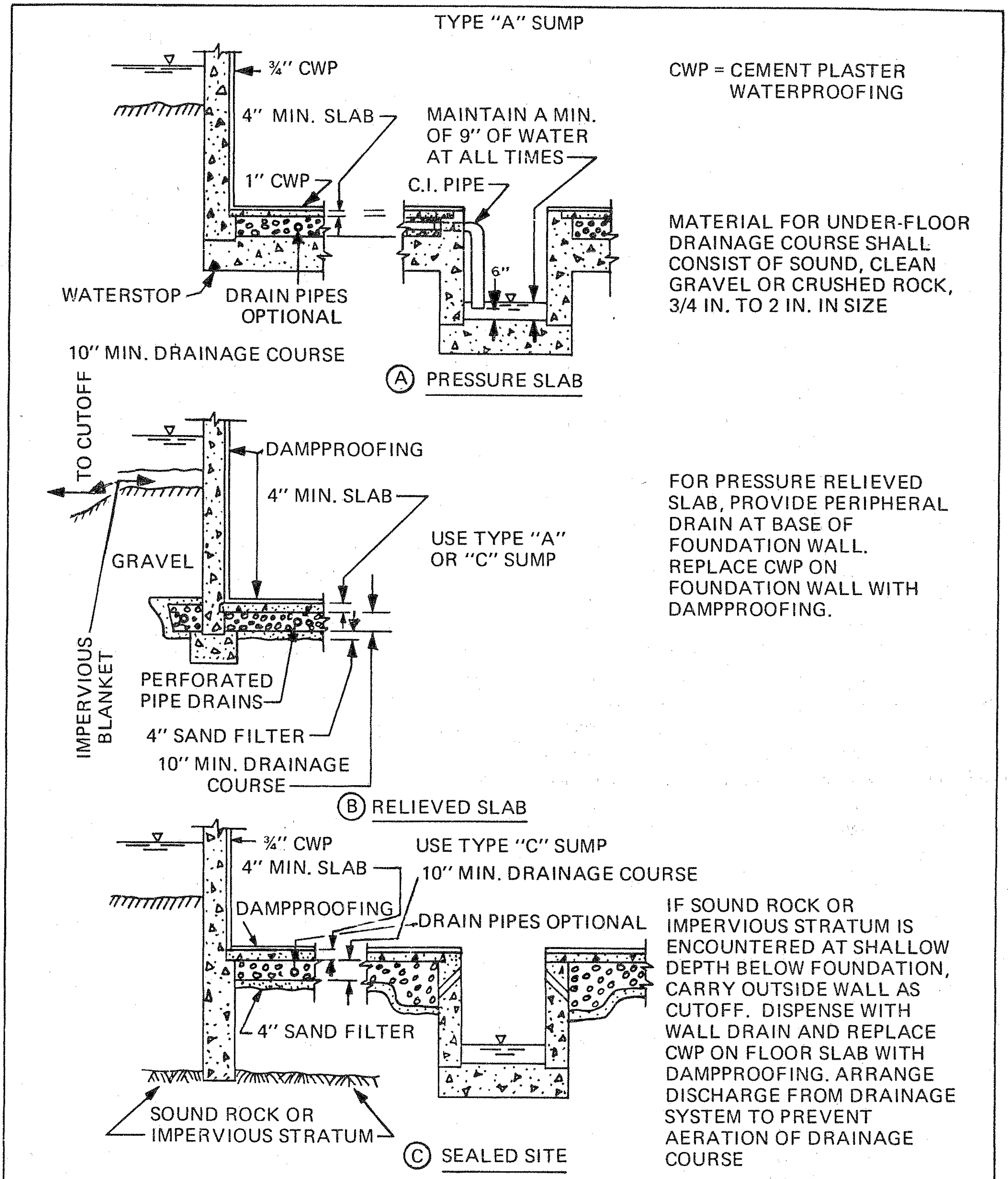
Sec. 1404.2.1: For relatively large, heavy structures, a more economical solution would be to design thinner reinforced concrete slabs that are tied into the footings, walls and columns, such that the overall weight of the structure is utilized in resisting the uplift forces acting on the floor slabs. This type of construction would then provide the additional stability required to prevent flotation and overturning of the structure from other flood loads. The slab (commonly referred to as mat or raft type construction) must be capable of resisting all applied loads and distributed pressures, either when uplift pressures are acting at full intensity, as is the case during a flood, or when such loads are non-existent, as could be the case under normal condition. Integral slab construction can be utilized equally well for buildings supported on piles. In these cases, column and wall loads are supported by the piles, and the uplift pressures are transferred by the reinforced slab to the columns and walls so as to utilize the building loads (weight) as the downward resistive force.

Sec. 1404.2.2: In many cases, however, where uplift pressures are excessive, the most practical solution would be to relieve (or reduce) these uplift pressures under the slab by providing adequate and dependable drainage, combined where necessary with impervious blankets and cutoffs on the outside of the structure. Illustrations of foundation drainage methods that may be used for relief of uplift pressures are shown on Figure 5. Where it is found impractical to stabilize the slab and structure by one of the methods shown on Figure 5, or a combination thereof, it may be more expedient to anchor the slab and/or structure to the ground (and preferably to an underlying rock formation) or to provide the required protection by means of dikes, levees, retaining walls, or floodwalls.

Sec. 1404.3 BASEMENT AND RETAINING WALLS: Under normal or nonflood conditions, the primary loading on basement and retaining walls consists of lateral soil pressures caused by the backfill material. For selected granular backfills and normal heights of the wall, this load is relatively small. Other secondary or associated loads on walls are lateral loads resulting from surcharge conditions, loads resulting from frost action, and any vertical or other applied loads which the wall is intended to resist. Under flood conditions, by far the most significant load on a wall is that caused by lateral hydrostatic pressures. This load amounts to several times the intensity of the normal loads and as such will govern the strength and stability requirements for the wall. Provisions of backfill drainage are commonly used to reduce water pressure behind a wall and are known to be effective for ground water control if carefully designed, constructed and maintained. In the case of walls subject to flood loading, a reduction in water pressure behind the wall is not considered practical nor dependable. When an infinite source of water exists and free water stands above grade, the most efficient drainage provisions are likely to be inadequate. For cases where the wall is protected by impervious membranes, blankets and cutoffs, even a minimal rupture, separation or failure of the membrane or blanket, or cutoff, can cause the attainment of full hydrostatic pressures on the wall and cause failure of an inadequately designed wall.

Sec. 1404.4 CLOSURE OF OPENINGS: All exterior wall openings and other openings located below the RFD should be closed and sealed for effective flood protection. Existing structures shall be reviewed to assure that walls and supporting members can safely support the added pressures induced by closing the openings. Under no circumstances should a building be made watertight if the additional flood loads can not be satisfactorily transferred to the walls or supporting members. Closing the openings under these conditions may lead to a structural failure that could be much more serious than the damages resulting from unrestricted flooding. In designing new structures, all openings which are not necessary for proper functioning of the structure should be omitted, or at least kept to a minimum, both in number and size.

Sec. 1404.4.1: Openings should be provided with either permanent closures or closure assemblies that can be easily installed or positioned in an emergency flooding situation. Openings that are no longer necessary for building operation should be permanently closed and sealed. Permanent closures can be accomplished with reinforced concrete plugs, concrete masonry units, or metal assemblies that are keyed or anchored to the existing wall and supports. Additional support and strengthening may have to be provided to carry the additional loads from flood waters acting on the closure assemblies.



TYPICAL FOUNDATION DRAINAGE AND WATERPROOFING

ADAPTED FROM NAVFAC DM-7

Figure 5

Sec. 1404.4.2: The closure or closure assembly must be designed for the full water pressure resulting from the heights calculated from the highest and lowest points of the closure to the RFD. Consideration must be given to loads resulting from debris impact and other loads as specified in these Regulations. The closure should be supported along at least three (3) edges and be capable of being secured around the opening perimeter by some self-acting means or latching devices. Bolting may be used as a means of securing the closure in place; however, it is recommended that such a procedure be avoided if at all possible and especially for closures at large and/or critical openings. A bolted type closure would generally require more lead time (flood warning) to assemble, transport, and install equipment held in storage, generally require trained personnel to affect the installation, and might well depend on the use of material handling equipment or additional personnel to handle large, heavy, or cumbersome closure panels or assemblies.

Sec. 1404.4.3: Whenever possible or required, the closure assembly should attach to a metal frame that surrounds the opening and be of sufficient width to provide an adequate watertight sealing surface. The frame may attach or be connected to the adjacent wall or supporting members or be constructed as an integral part thereof and be strong enough to transfer the closure loads to the building structural components without exceeding the allowable stresses. The walls are to be designed to transfer the loads to the building structural system and conform to the structural requirements of the Building Code. The seal may be attached to the closure door (panel, etc.) or sealing frame and with sealing to be achieved by applying pressure through bolting or latching of the closure or some other self-acting and positive means.

Sec. 1404.4.4: All closures, whenever possible, should be external to the opening, such that the water pressure helps in providing a continuous seal, thereby eliminating the need for extensive anchors, blocking and bolting, as would be required for reverse loading cases.

Sec. 1404.4.5: Horizontal closures should be designed to support the full weight of water above the closure assembly to the RFD. The closure should be supported and have a watertight seal along its entire perimeter. A frame with a smooth sealing surface and capable of transferring the load to the structure is to be provided.

Sec. 1404.4.6: Permanent closures of an opening may be accomplished by any structural means or system that would not require further actions during a flood. These closures may consist of walling an unneeded window, vent, chute, etc. with masonry units, reinforced concrete plugs, metal shields or other approved materials. All closure systems used shall provide the required protection to the RFD.

Sec. 1404.4.7: Closures for openings in existing structures that would have to be assembled and set in place in preparation for a flood would be classified as temporary or emergency flood-proofing closures. These openings are necessary for the continual operation of the building and their functions will be disrupted when the closures are set. Closures should be of metal construction and sized for easy and quick assembly and installation. Closure panels should be stored at a convenient location near the opening and should be properly marked and identified for each opening. Bolts, latches, and other equipment used to install the closures should be similarly stored and identified. Examples of emergency closures, are closures used to block doors, windows, vents, loading docks, or chutes.

Sec. 1404.4.8: Contingent closures may be set into position by either mechanical or manual operation of the assembly. Design of the assembly must take into consideration the type of placement operations, weight of the closure, space required, esthetic considerations, available work force, and total number of openings to be closed. Mechanical placement of closures can be accomplished through rollers, cable and weights, levers, and hinges.

Sec. 1404.4.9: Seals on all closures should be watertight and preferably of rubber or neoprene. The entire closure and frame should be inspected and tested periodically to insure that they are still functional and in good condition.

Sec. 1404.4.10: Some permanent closures may be designed to protect against flood waters and still maintain the functions of the opening. A window could be designed with intermediate supports consisting of reinforced concrete beams or structural members encased in concrete. The window would then be made up of tempered plate glass sections capable of withstanding impact loads spanning between intermediate supports. Metal doors can be made to protect against floods by providing a watertight seal and adding stiffeners and latching devices to the door. Examples of opening reinforcement, fastening methods and devices, and closures for typical conditions are illustrated in Figures 6 through 18.

Sec. 1404.5 ADDITIONAL CONSIDERATIONS: It should be noted that the preceding design examples do not contain coverage of several structural elements and framing methods used in normal practice. Included in this category are wall and column footings, mats or rafts, integral or continuous wall and slab construction, horizontally framed walls, and other similar items. Also omitted are examples of bearing masonry walls, curtain walls, percast concrete, metal and "sandwich" panels, and similar items. These items either involve too many variables, or are too complex for tabulated treatment, or relate to highly specialized technology. In all cases, coverage of these topics did not lend itself to a simplified treatment and was thereby omitted.

SECTION 1405.0 ALTERNATE METHODS OF FLOOD-PROOFING

Sec. 1405.1 SITE SELECTION: The one method of assuring complete flood hazard protection of a building or structure is to select a site or structure location which places all spaces in the structure above the "flood plain flood." This could apply to sites both inside or outside the flood plain limits. Locating a structure outside the flood plain would eliminate the need to consider flood water loads in the building design. The building could be located in the flood plain and be protected to design-flood level by dikes, levees, or floodwalls; also eliminating the need for flood load consideration in the building design for flooding to a design-flood level.

Sec. 1405.2 FLOOD-PROOFING BY ELEVATING THE BUILDING:

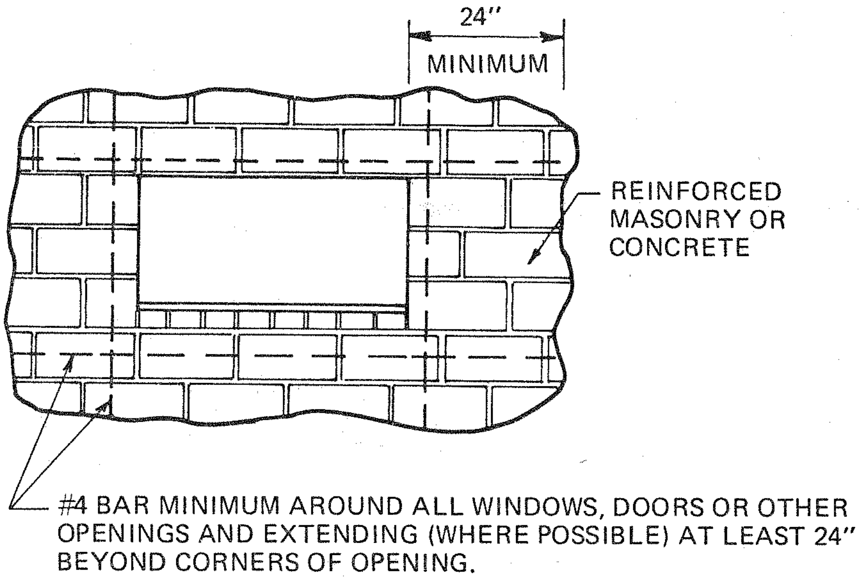
Sec. 1405.2.1 NATURAL TERRAIN – Structures constructed above the RFD and outside the regulatory-flood plain will not be subject to loads from regulatory-flood waters if basements are not used. The effect of soil saturation on basement walls and foundations may still have to be considered. Natural slopes should be investigated for stability and scour potential if the structure is to be built at the regulatory-flood-run-out line on the ground surface. A building located outside the regulatory-flood plain is shown at the left side in Figure 19.

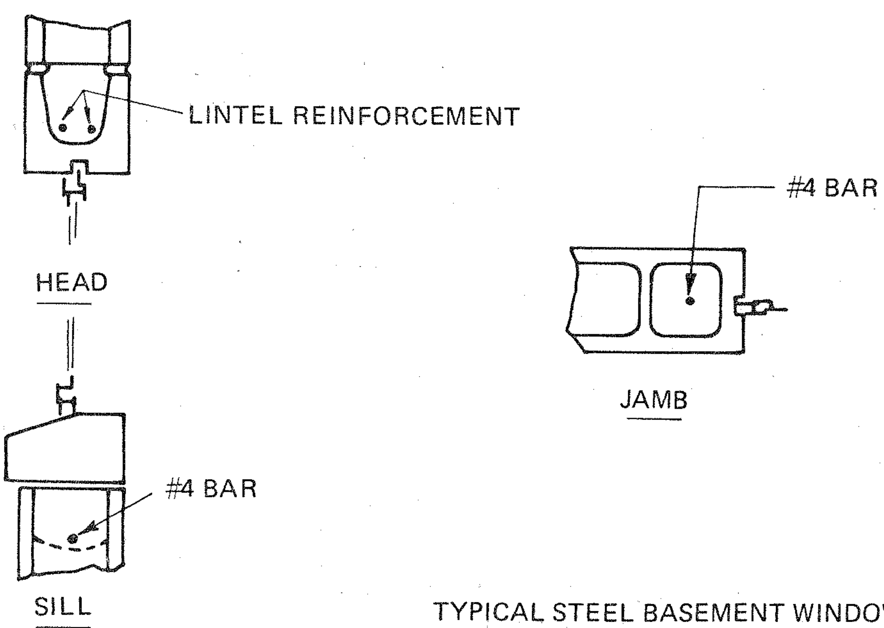
Sec. 1405.2.2 BUILDING ON FILL – Buildings can be located within the flood plain or primary flood hazard area on a fill constructed to an elevation above the RFD. This method of protection can be accomplished by constructing an earth fill either partially or entirely within the flood plain, as also shown in Figure 19. Such a design should provide assurances that the fill does not restrict or obstruct the flow of flood waters or reduce the hydraulic efficiency of the channel, which in turn could cause flood water back-up and resultant higher flood water elevations upstream of the filled building site.

Sec. 1405.2.2.1: The fill material should be suitable for the intended purpose as determined by an investigation of the soil properties. The earth fill should be compacted to provide the necessary permeability and resistance to erosion or scour. Where velocities of floodwaters are such as to cause scour, adequate slope protection should be provided with vegetation or stone protection as required. Slope stability should be analyzed by an experienced soils engineer to assure its adequacy.

Sec. 1405.2.2.2: Where the fill is partially within the flood plain, access and utilities should be provided from the "dry" side. If the fill is entirely in the flood plain, access and utilities could be provided by constructing an access road or bridge to an elevation above the RFD.

RECOMMENDED REINFORCEMENT AROUND SMALL OPENINGS
AND FOR SHALLOW DEPTH OF FLOODING

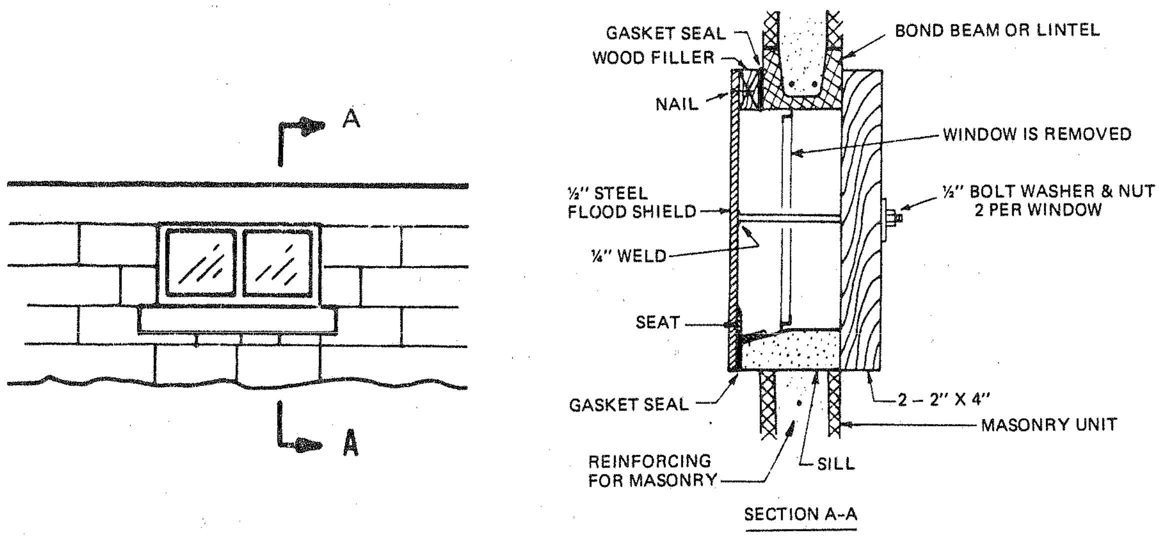




TYPICAL STEEL BASEMENT WINDOW
FOR REINFORCED MASONRY WALLS

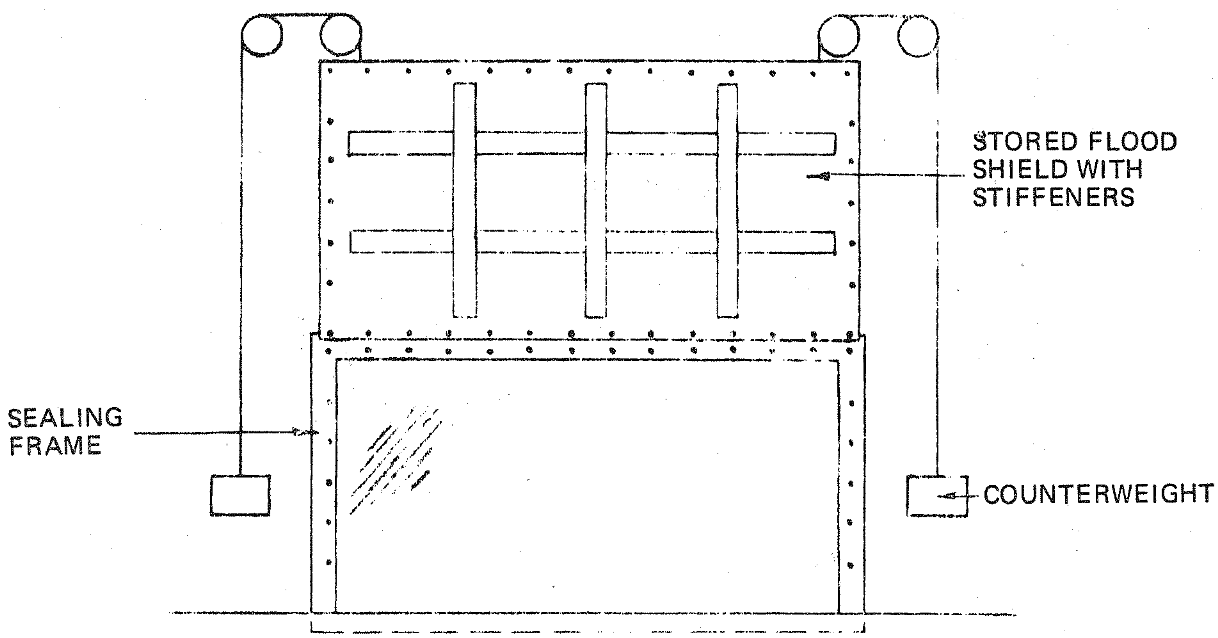
NOTE:
IF OPENING BEGINS AT THE TOP OF A FOOTING, HORIZONTAL REINFORCING SHALL BE PROVIDED AT THE TOP OF THE FOOTING.

Figure 6



CLOSURE PANEL FOR BASEMENT WINDOW
FOR SMALL WINDOWS AND SHALLOW DEPTH OF FLOODING

Figure 7



FLOOD SHIELD BEHIND WINDOW
LOWERED INTO POSITION & ATTACHED TO
FRAME WITH QUICK DISCONNECT TYPE FASTENERS.

Figure 8

BOND BEAMS & VERTICAL REINFORCEMENT AT LARGE OPENINGS

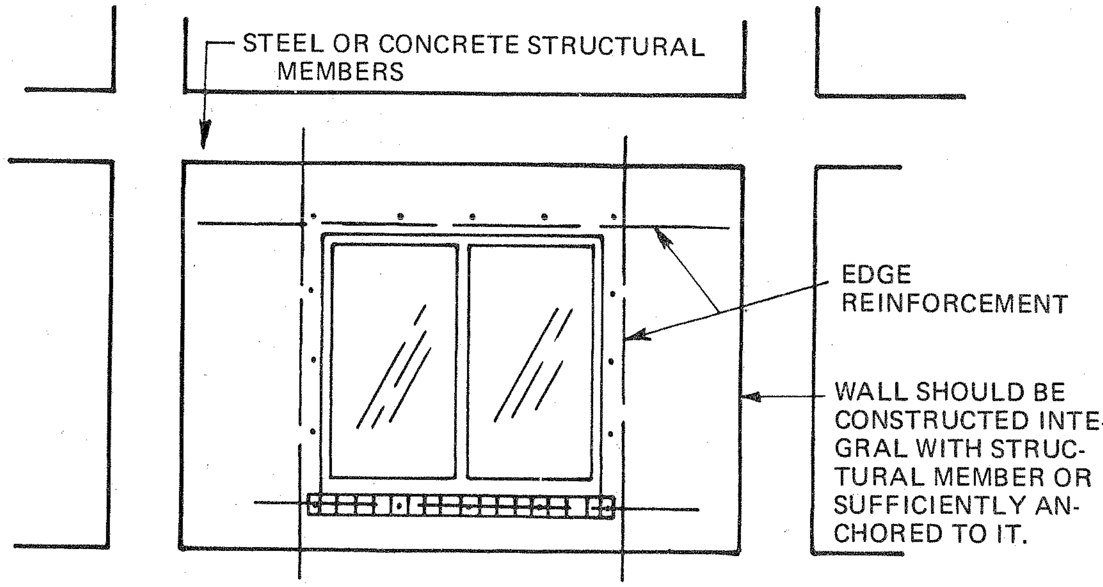
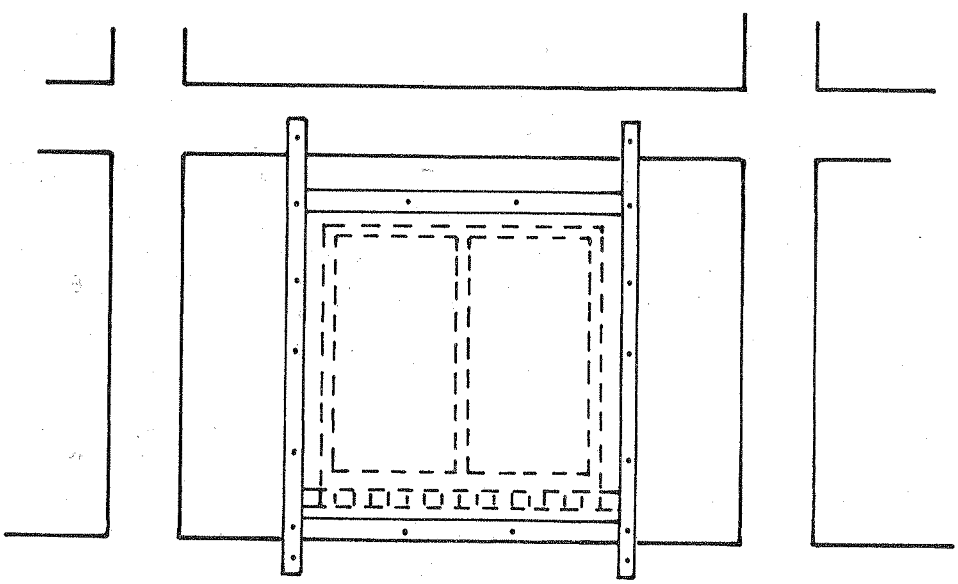
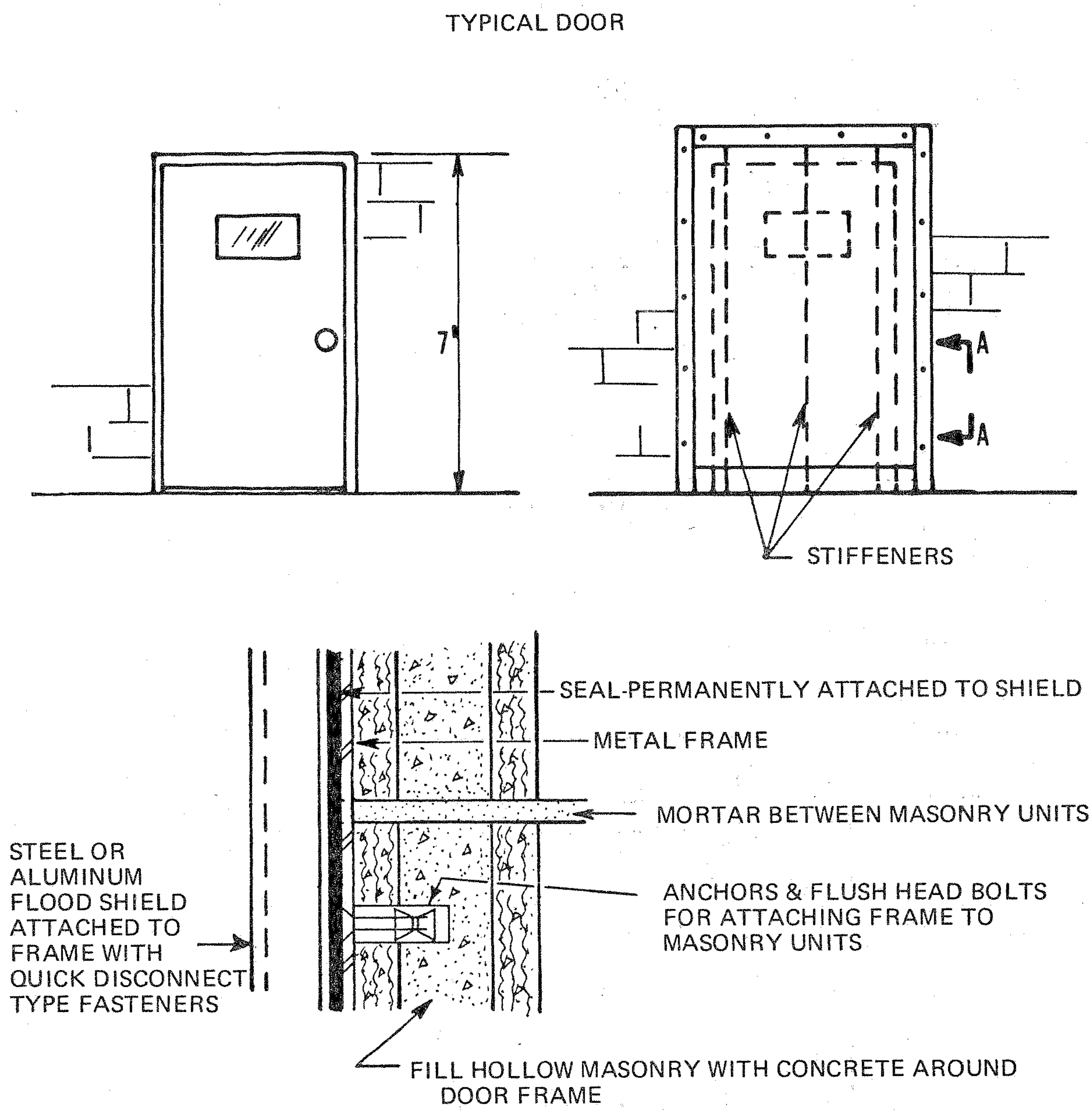


Figure 9



REINFORCING FOR BOND BEAMS AND VERTICAL STEEL MAY BE REDUCED IF FORCES ARE TRANSMITTED TO STRUCTURAL MEMBERS BY THE FLOOD SHIELD FRAME AS SHOWN ABOVE.

Figure 10

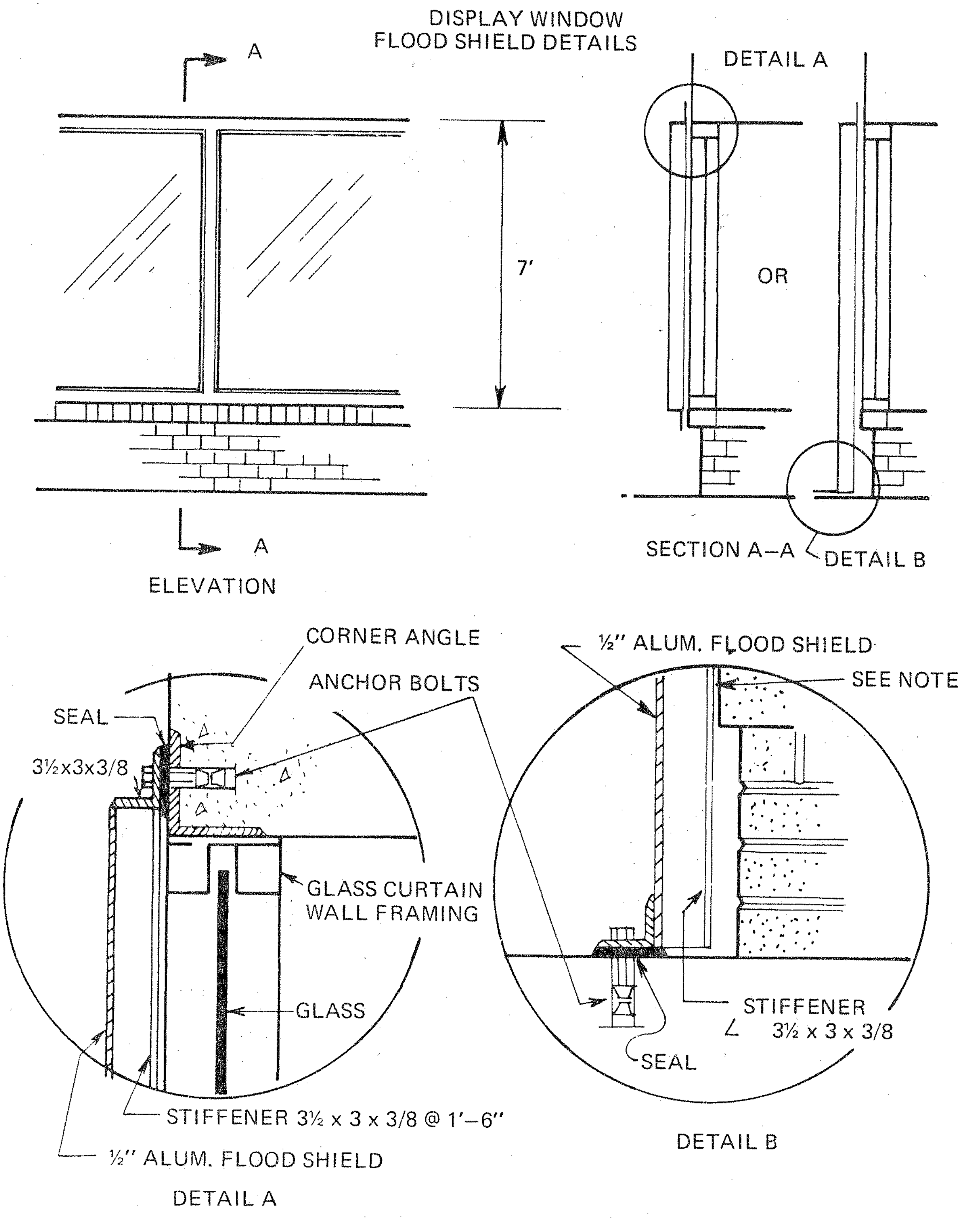


SECTION A–A

ALL CELLS AROUND OPENINGS IN HOLLOW MASONRY CONSTRUCTION SHOULD BE FILLED WITH CONCRETE. LARGE OPENINGS SHOULD HAVE BOND BEAMS, VERTICAL REINFORCEMENT, AND METAL FRAMES AROUND OPENING.

MORTAR JOINTS THAT LIE WITHIN FLOOD SHIELD SHOULD BE STRUCK FLUSH WITH THE MASONRY UNITS SO THERE WILL BE A BETTER SEAL.

Figure 11



NOTE:

SUPPORT IS ASSUMED AT THIS LOCATION. WHERE SUPPORT IS NOT AVAILABLE, INCREASE SIZE OR NUMBER OF STIFFENERS AND PROVIDE SUPPORT AT BOTTOM.

MEMBERS ARE SIZED FOR WATER LEVEL AT TOP OF DISPLAY WINDOW.

Figure 12

CLOSURES FOR HORIZONTAL OPENINGS BELOW RFD

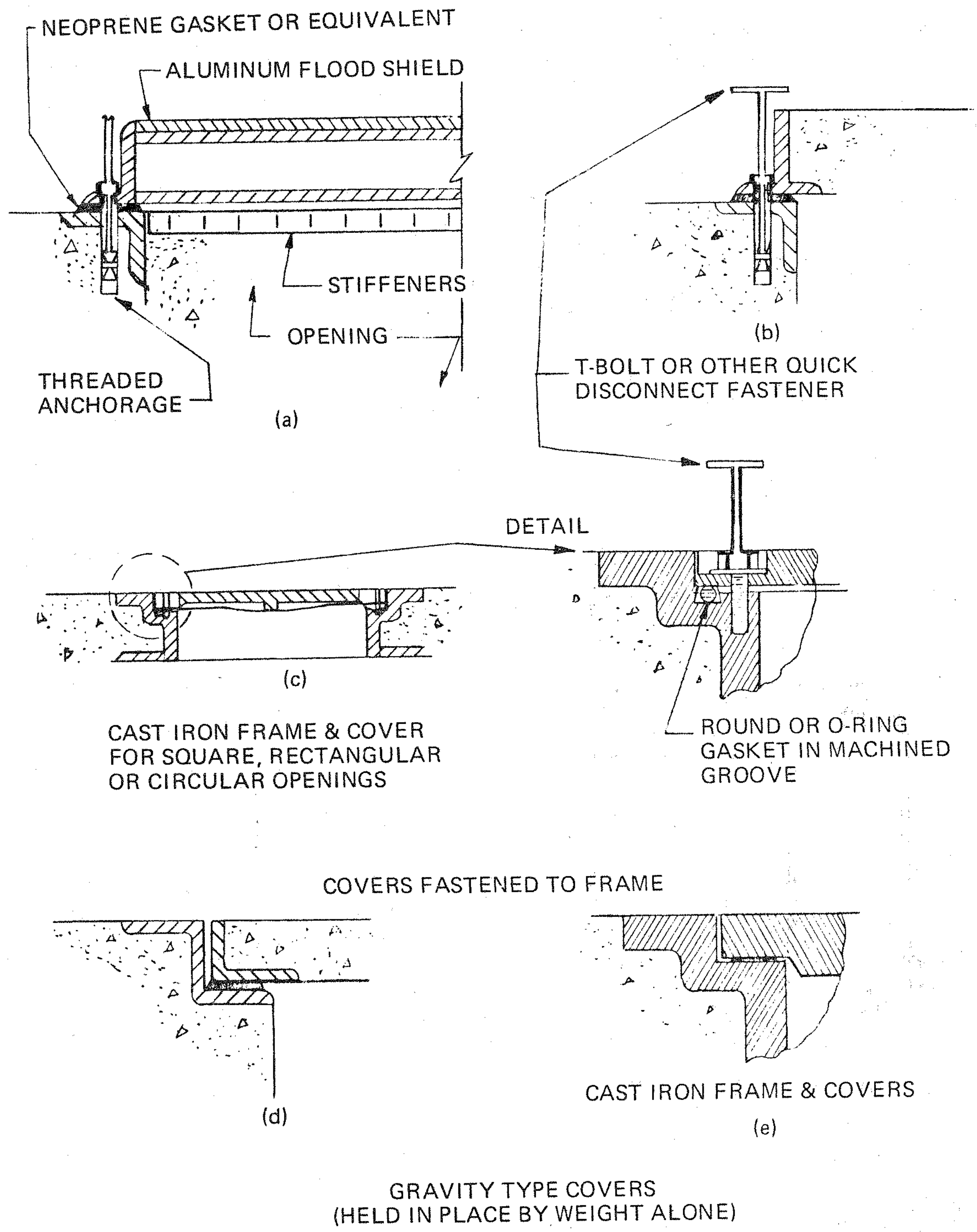


Figure 13

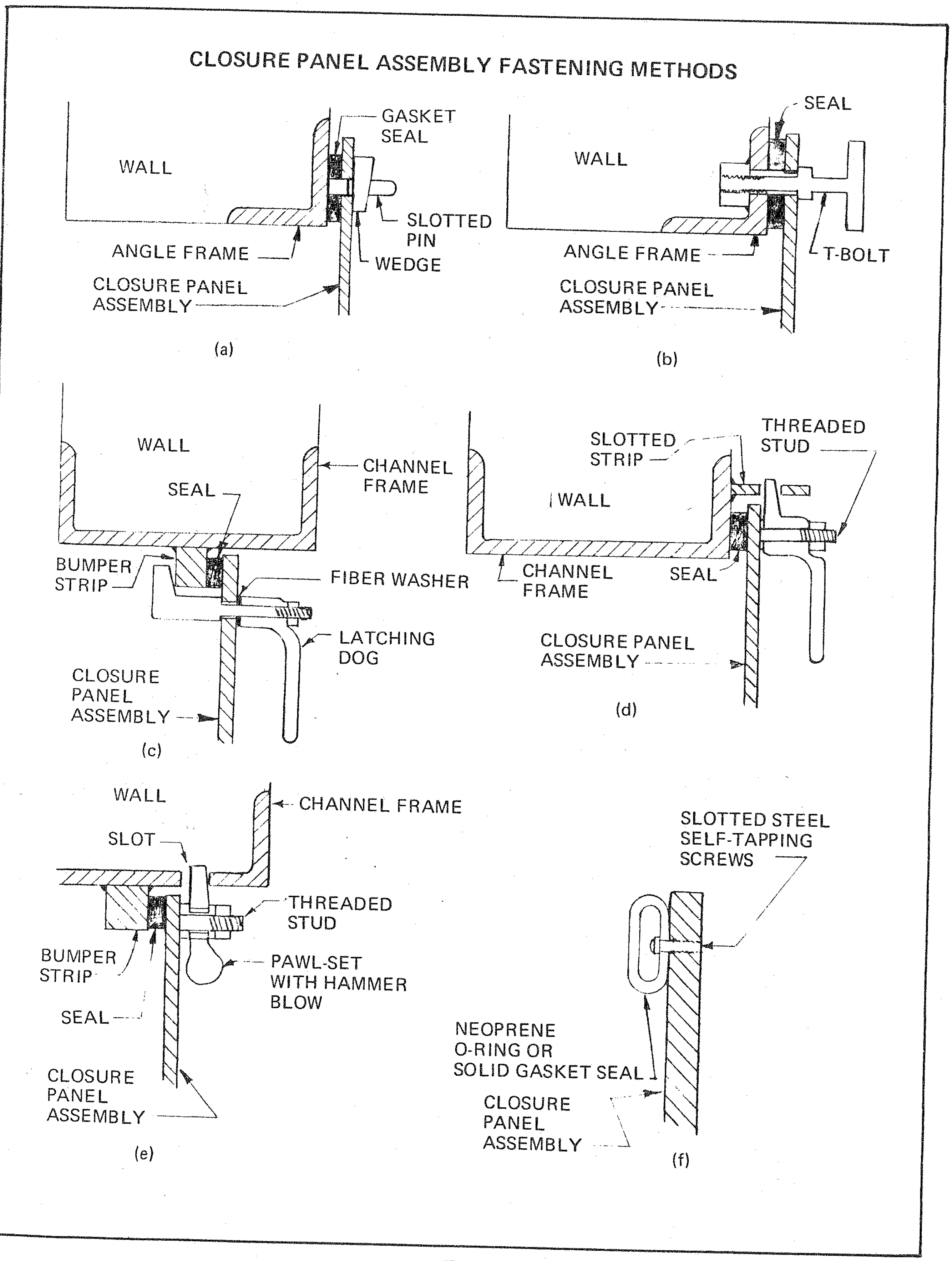
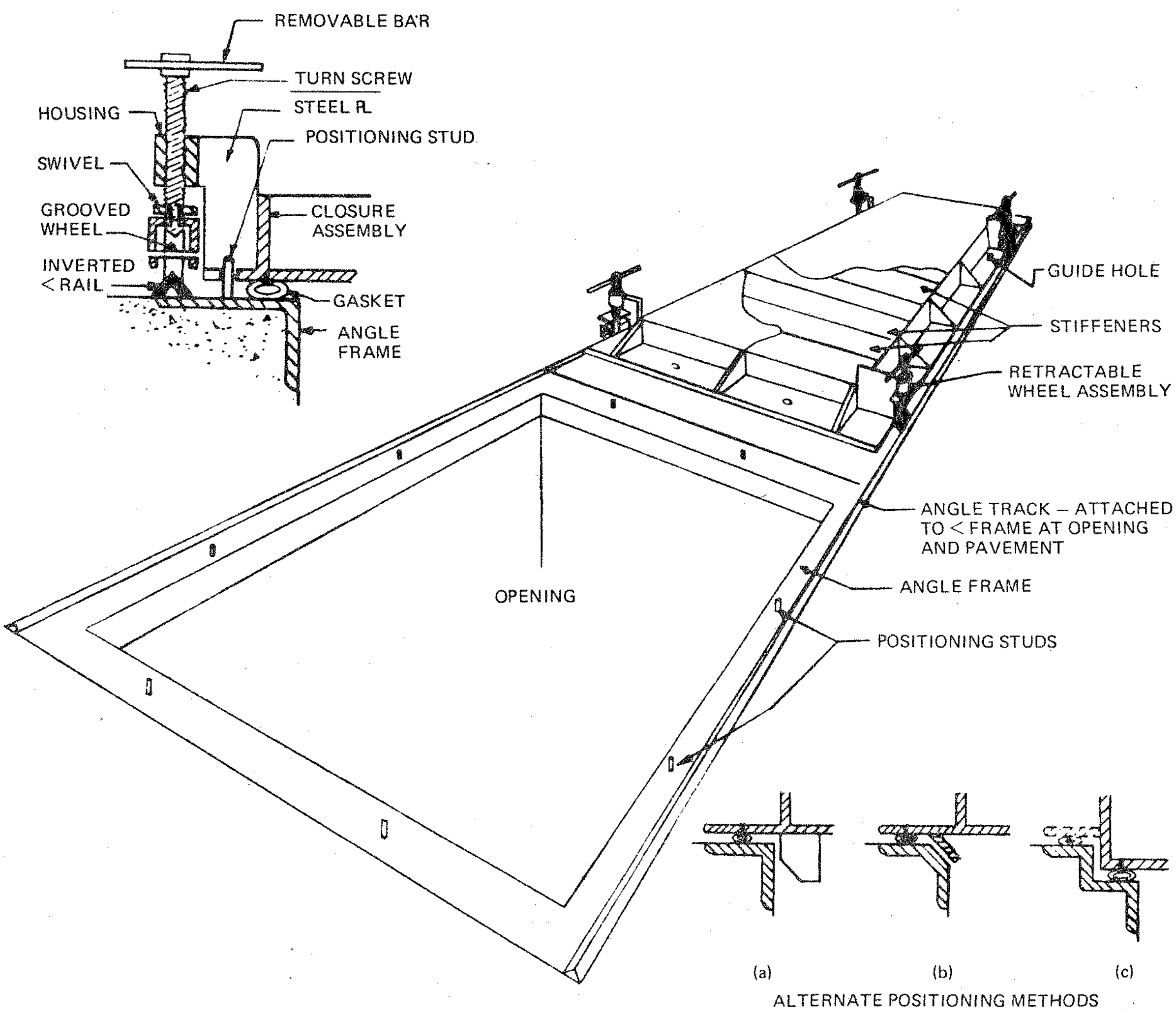

CLOSURE PANEL ASSEMBLY FASTENING METHODS
WALL
GASKET SEAL
SLOTTED PIN
WEDGE
ANGLE FRAME
CLOSURE PANEL ASSEMBLY
(a)
SEAL
WALL
T-BOLT
ANGLE FRAME
CLOSURE PANEL ASSEMBLY
(b)
WALL
CHANNEL FRAME
SEAL
BUMPER STRIP
FIBER WASHER
LATCHING DOG
CLOSURE PANEL ASSEMBLY
(c)
SLOTTED STRIP
THREADED STUD
WALL
CHANNEL FRAME
SEAL
CLOSURE PANEL ASSEMBLY
(d)
WALL
CHANNEL FRAME
SLOT
THREADED STUD
BUMPER STRIP
PAWL-SET WITH HAMMER BLOW
SEAL
CLOSURE PANEL ASSEMBLY
(e)
SLOTTED STEEL SELF-TAPPING SCREWS
NEOPRENE O-RING OR SOLID GASKET SEAL
CLOSURE PANEL ASSEMBLY
(f)

Figure 14

FLOOD-PROOFING CLOSURE FOR LARGE HORIZONTAL OPENING BELOW RFD



PROCEDURE

BEFORE FLOOD – Closure assembly remains in stored position and rests on blocks to keep assembly weight off O-Ring or flat sealing gasket-wheels in an up position and operating bars removed. Wheel assembly is coated with heavy grease and covered with plastic or canvas sheet.

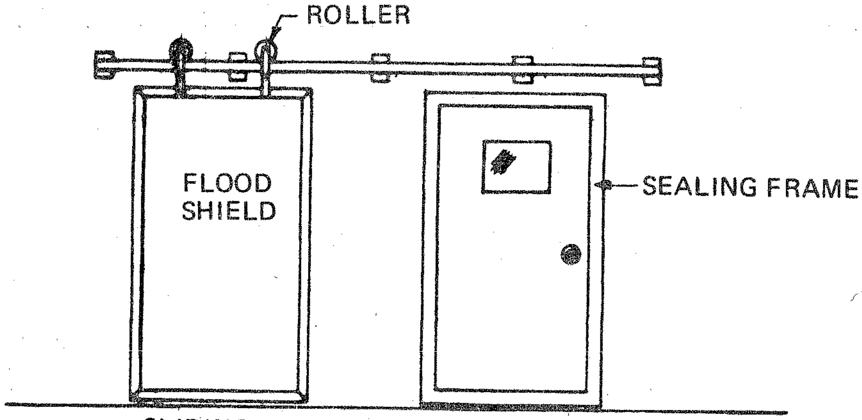
DURING FLOOD – When flood warning is received, operating bar(s) inserted in retractable wheel assembly and wheels lowered to engage rails, raising closure assembly off storage blocks and high enough to clear positioning studs; closure assembly rolled into position where guide holes are directly over positioning studs; closure assembly lowered to engage studs until all wheels are free of guide rails and contact established between gasket and frame; operating bars then removed from wheel assembly. Positive seal is maintained during flood by weight of closure assembly and flood water weight; positioning studs prevent displacement or movement of closure assembly.

AFTER FLOOD – Closure assembly washed down to clear mud and debris, raised into rolling position, rolled to storage location and positioned, inspected for possible damage, then "moth-balled" for future use.

NOTE: This illustrates only one of many schemes that may be considered for horizontal opening flood-proofing. Closure assemblies should be of durable materials for repeat type use, should require minimum maintenance, and require minimal installation effort. Variations may include hinged and/or counter-balanced assemblies; lever, ratchet or hydraulic systems for movement and positioning of assembly; positioning lugs, wedges, recesses, etc. where exposed studs cannot be tolerated; and use of positive fastening methods and devices for special locations or situations. The methods, procedures, and equipment that may be utilized are limited only by the designer's imagination and the owner's pocketbook.

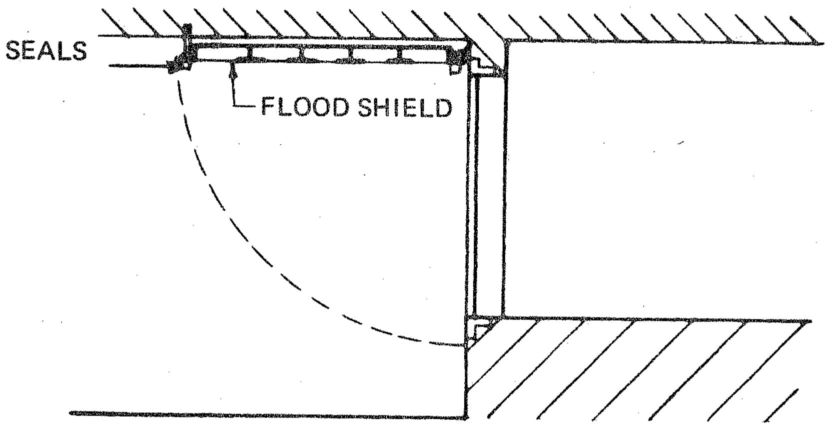
Figure 15

FLOOD SHIELD INSTALLATIONS



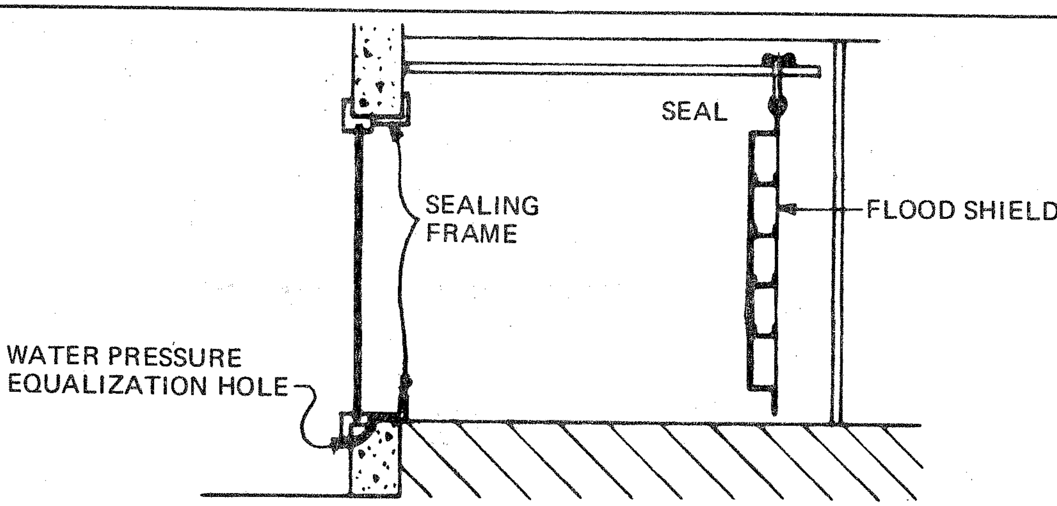
SLIDING FLOOD SHIELD FOR DOOR

Figure 16



HINGED FLOOD SHIELD FOR LOADING DOCK

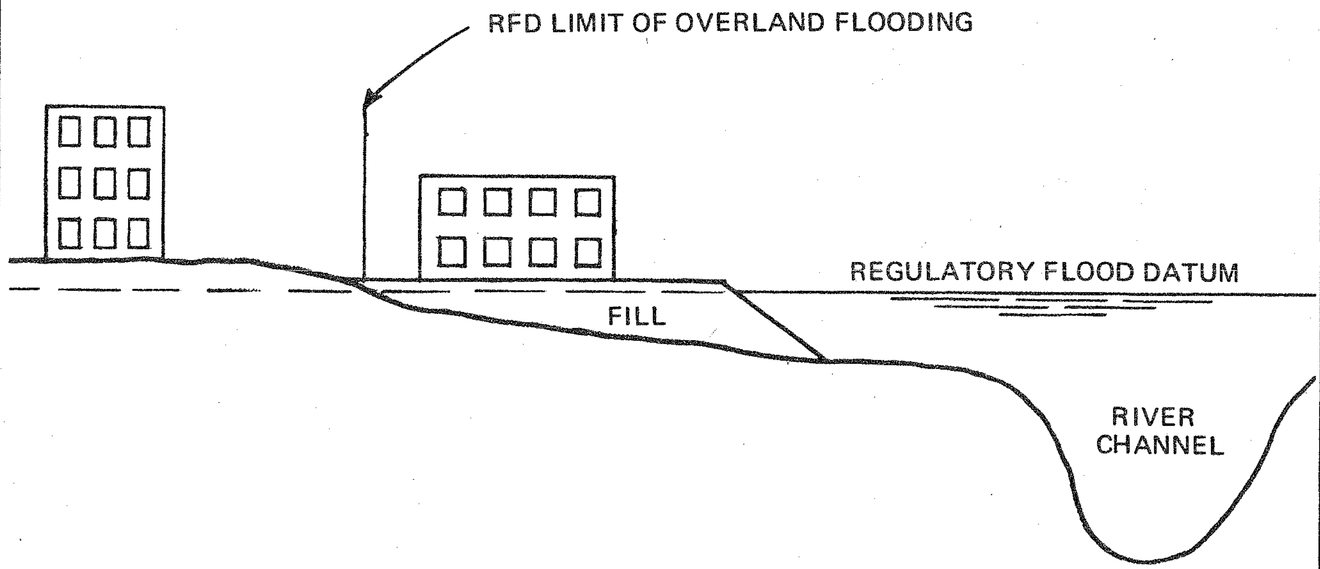
Figure 17



STORED FLOOD SHIELD BEHIND WINDOW

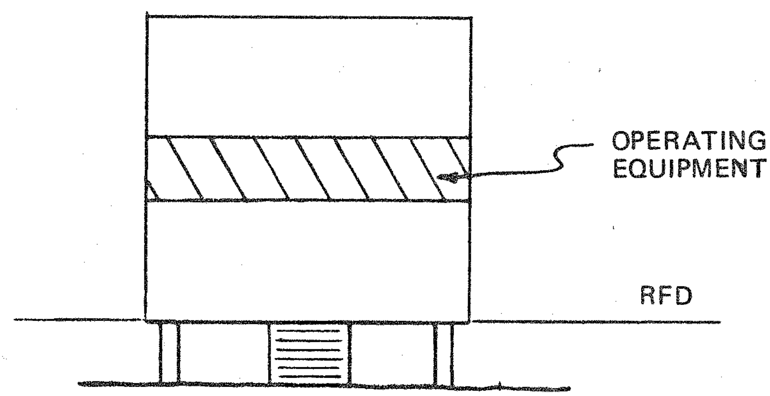
Figure 18

SECURED TO SEALING FRAME BY LATCHING DOGS, WEDGE ASSEMBLIES, OR OTHER QUICK DISCONNECT FASTENERS.



STRUCTURES ON NATURAL TERRAIN OR FILL

Figure 19



BUILDING ON STILTS

Figure 20

Sec. 1405.2.3 **BUILDING ON STILTS** – Often it is geographically undesireable or economically not feasible to locate a structure outside the flood plain. Available land areas are being developed rapidly and communities are finding it necessary to permit construction in the fringe areas of floodways. In these areas, structures can be built which place all functional aspects above the RFD by building on "stilts" as shown in figure 20.

Sec. 1405.2.3.1: In elevating a building on "stilts", piles, columns, piers, and walls, or other similar members are used to raise the functional floors or spaces of the building above the RFD elevation. The design should consider the loads that result from possible debris blockage between supporting members and impact of floating debris.

Sec. 1405.2.3.2: The open space created at ground level below the functional floors could be used as a plaza, parking area, materials handling, or recreational area, or for storage of special nondamageable materials, equipment, etc. This open space would be essentially free from the damaging effects of flood water, except that lobbies and entrance would have to be protected by some approved flood-proofing method.

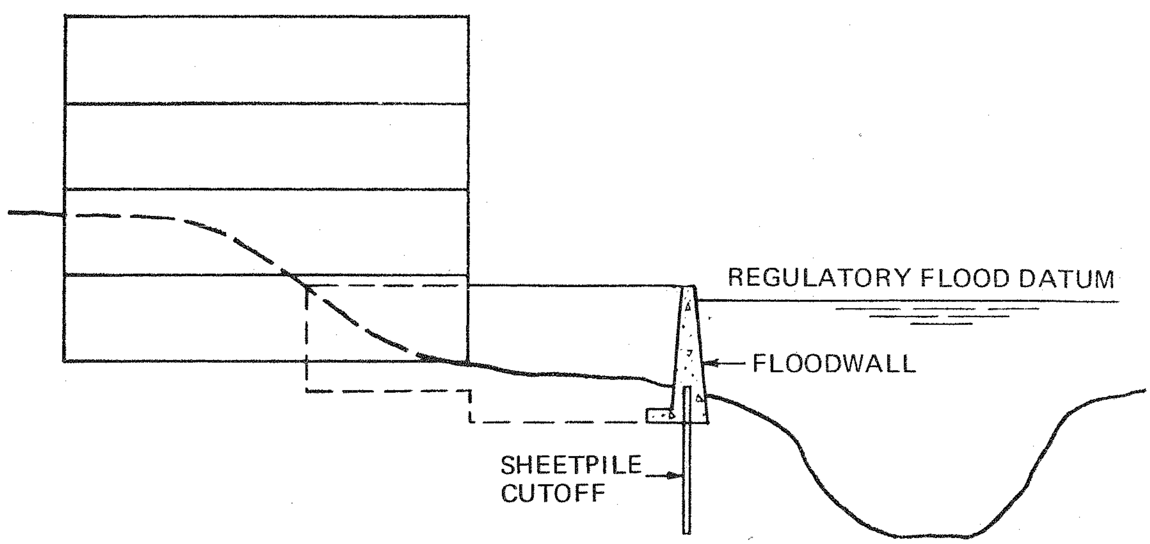
Sec. 1405.2.3.3: The equipment necessary to maintain building functions should be located safely above the RFD. If access to the building were provided from a location above the RFD, the normal building activities would not be disrupted and the building could continue to function during the flood emergency.

Sec. 1405.3 **PROTECTION BY DIKES' LEVEES AND FLOODWALLS:** As an alternate to providing flood protection through building or structure modifications, the necessary protection may be achieved by detached dikes, levees or floodwalls. The primary purpose of these constructions is to prevent the flood from reaching the structure and associated functional land areas. The choice of using a dike or floodwall is made on the basis of economic considerations when compared to structural flood-proofing modifications, the ability of a structure to be structurally modified, and the degree of protection to be provided. The type of protection barrier depends on location, availability of material, foundation conditions, and right-of-way restrictions. Floodwalls would be used in tight, restriced areas where foundation conditions are favorable. Dikes or levees would be used where adequate space and material are available. The dike or floodwall may not have to completely surround a structure. Protection may be required only on the low sides as illustrated in Figures 21 and 22. The ends of the works would be tied into the existing high ground or to the structure depending on local conditions.

Sec. 1405.3.1 **DIKES** – If used, dikes should be constructed to a section capable of supporting the imposed loads and providing the required impermeability. Suitable material preferably should be available at the site and should be tested and approved for use prior to constructing the dike. An investigation should also be made of the foundation material to determine the presence of, location, and extent of unsuitable materials and necessity for drainage of cutoff provisions.

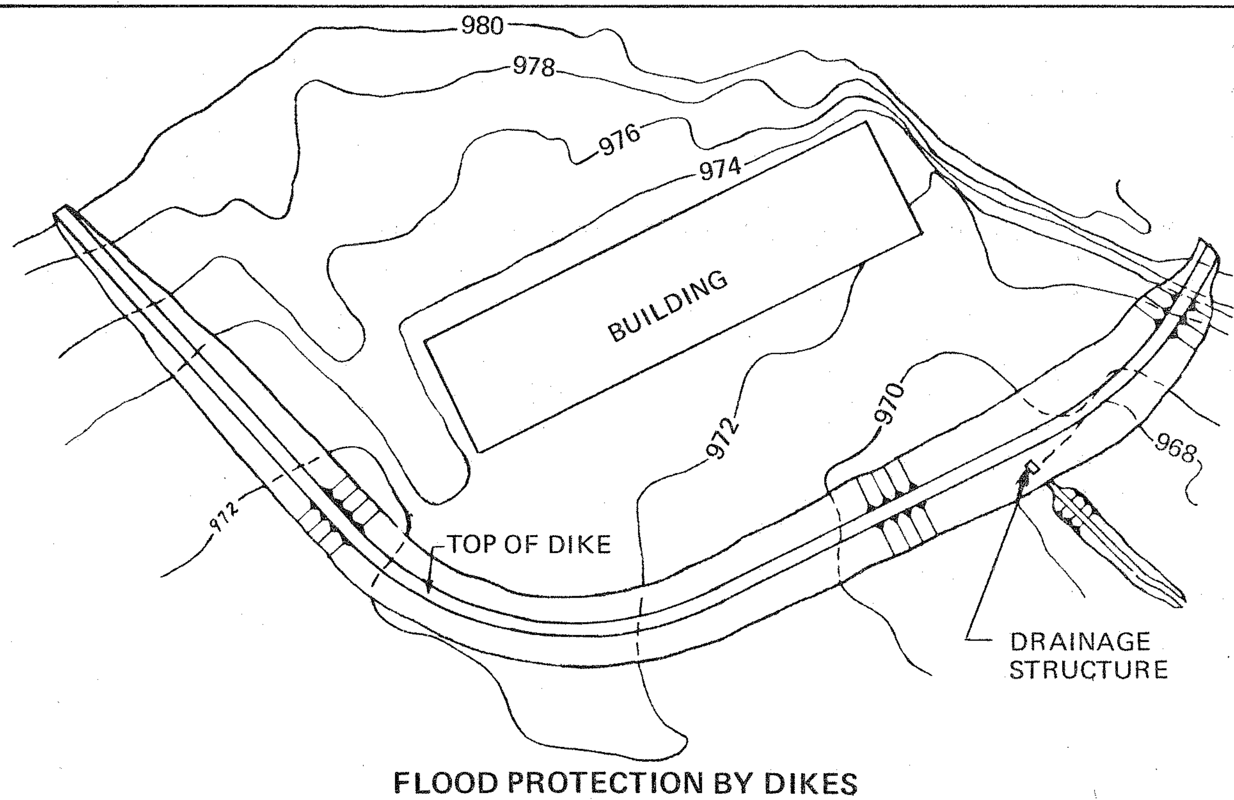
Sec. 1405.3.1.1: At locations where the foundation material has a high degree of permeability, an impervious cutoff may be necessary to reduce seepage through the in-situ foundation materials. The cutoff may be a sheet pile wall, compacted barrier of impervious soil, fabric reinforced membrane, concrete wall, or a grouted cutoff. As no cutoff is totally impermeable, provisions should be made to collect the excess seepage and any seepage from less permeable soils without cutoffs. The excess seepage can be collected with drainage blankets, pervious trenches, or perforated pipe drains placed at the toe of the embankment and on the dry landward side. Typical dike sections, cutoffs, and drainage provisions are shown in Figures 23, 24, and 25.

Sec. 1405.3.1.2: If any drain pipes or related structures are within a dike, they should be designed to resist all applicable loads and be provided with gates to prevent backflow to the dry side. Backflow through conduits can be prevented by installing flap gates, manually operated valves, or slide gates that would be closed when flood waters would reach critical elevations.



FLOOD PROTECTION WITH FLOODWALLS

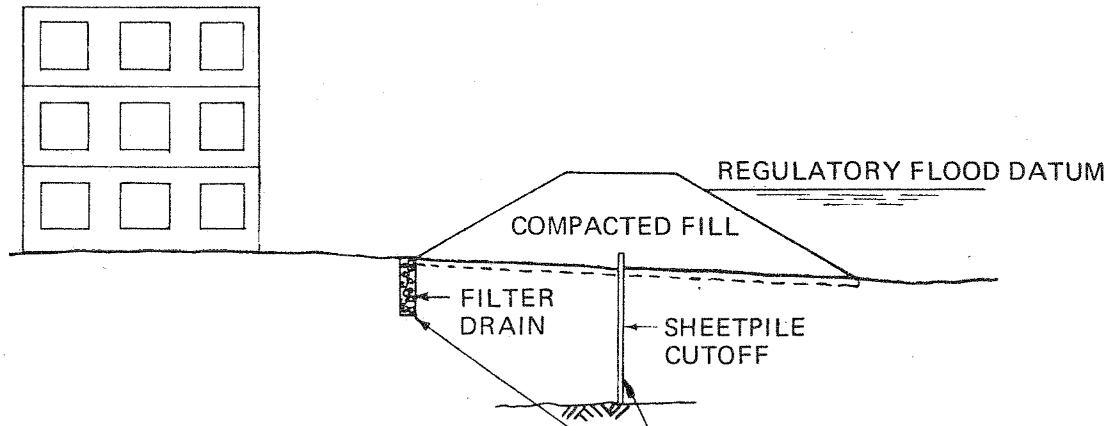
Figure 21



FLOOD PROTECTION BY DIKES

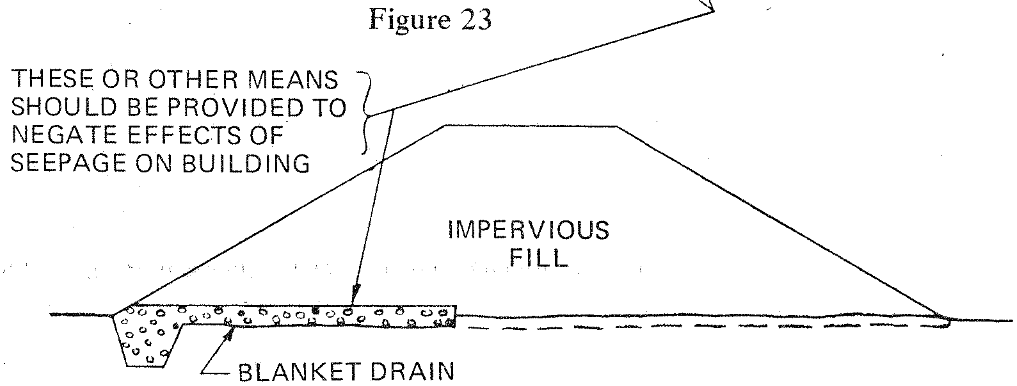
Figure 22

DIKE OR LEVEE PROTECTION



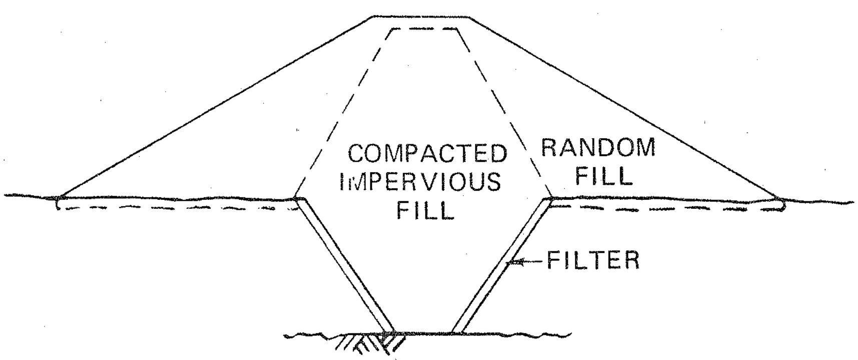
FLOOD PROOFING WITH DIKES

Figure 23



DIKE WITH BLANKET DRAIN

Figure 24



DIKE WITH IMPERVIOUS CORE

Figure 25

Sec. 1405.3.2 FLOODWALLS – A floodwall is subject to hydraulic loading on one side with little or no earth loading as a resisting force on the opposite side. Floodwalls can be constructed as cantilever I-type sheet piling walls, cellular walls, buttress walls, or gravity walls.

Sec. 1405.3.2.1: The walls should be founded on and keyed into rock where suitable rock is encountered reasonably close to the founding elevations. Where the soil provides inadequate bearing capacity and removal of unsuitable material and replacement is costly, an adequately designed system of piling should be considered. Cutoffs and drains should be used to intercept seepage as required in 612.3.2. Drain pipes should not be placed directly under the wall base and any drainage provided should not be considered as a factor for reduction of uplift pressures. The problem of scour should be further investigated and corrective measures provided where necessary.

Sec. 1405.3.2.2: Drainage features through flood walls should be equipped with the necessary devices to prevent backflow. Typical sections of various flood wall types are shown in Figure 26.

Sec. 1405.4 CONTROLLED OR INTENTIONAL FLOODING: In many situations, the basement walls and floor slab(s) of existing buildings and structures lack the structural strength required to withstand flood loadings. The expense of reinforcing an existing structure or replacement with a new structure at the same location to withstand such flood loadings is, in most cases, not justified. As an alternate means of flood-proofing these structures, provisions may be made for flooding of the structure interior to balance the external flood pressures on the building components. This intentional flooding would have to be accomplished in such a manner as to keep the unbalanced hydrostatic pressures safely within the load carrying capacity of the slab and walls. Provisions must be made for interconnections through and around all floors and partitions in order to prevent unbalanced filling of chambers or spaces within the structures.

Sec. 1405.4.1 FLOODING: Flooding should be with potable water from a piping or storage system of adequate capacity to fill the basement at a rate consistent with the anticipated flood water rise. The provisions should be such as to keep the internal water surface as nearly even with the outside as possible. All spaces should be provided with air vents to prevent the trapping of air by the rising water surface.

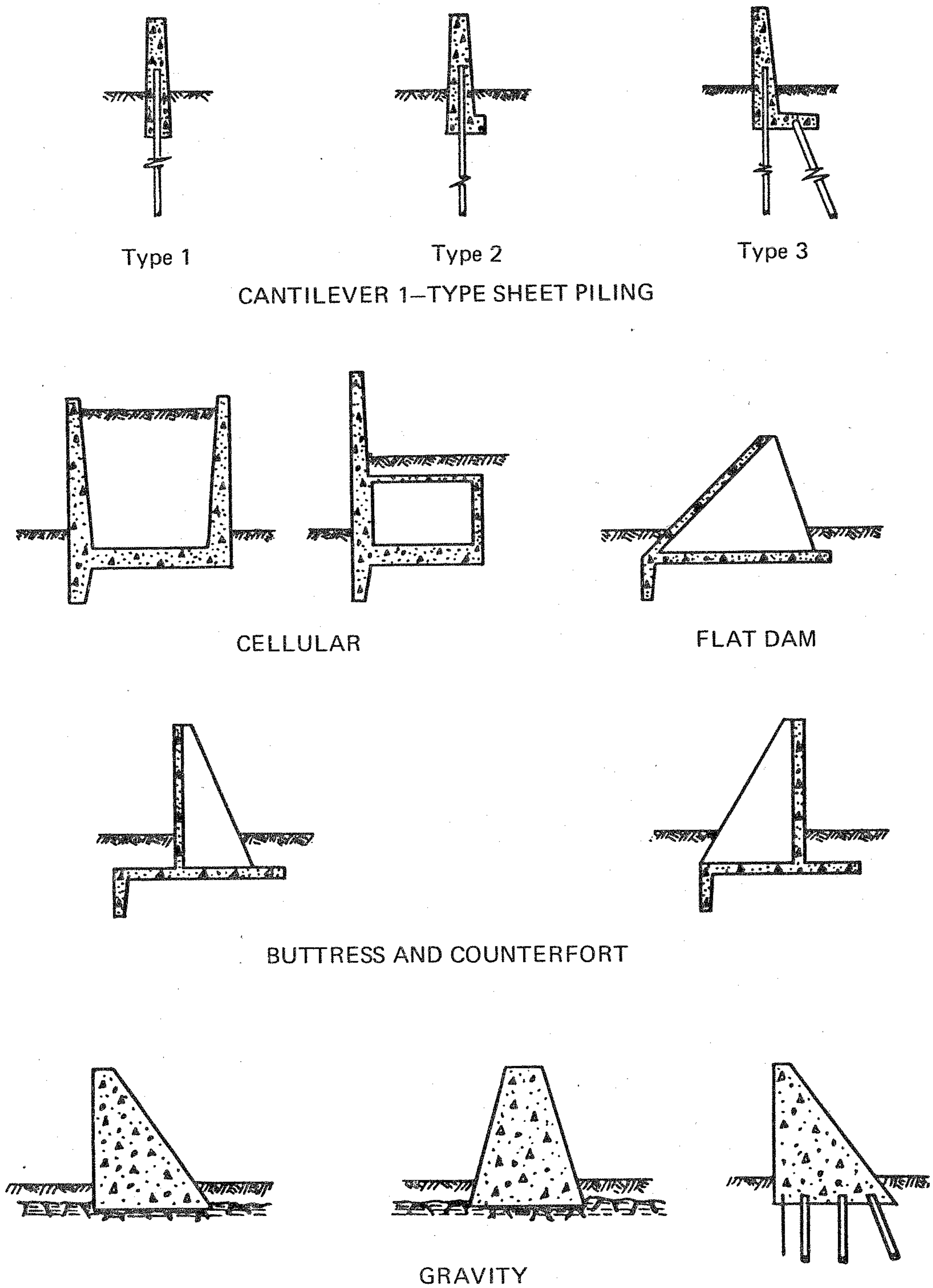
Sec. 1405.4.2 DRAINING: Outlets to drain the water as flood waters recede should be located to completely drain the structure and all spaces at a uniform rate corresponding to that of the receding waters. The water level in all interior spaces should be kept even and all spaces should be completely drained. Upper spaces and levels should be drained before the lower spaces. All watertight walls should be designed for an internal hydrostatic pressure resulting when waters trapped in the building are higher than those of the receding floodwaters outside; a possibility with malfunction of required drains.

Sec. 1405.4.3 USE: Where provisions are made for internal flooding, all floors and spaces below the RFD should be restricted as to types of use permitted. Examples of controlled flooding of structures with restricted use are shown on Figures 27 and 28.

Sec. 1405.4.4 BACKFLOW: Where intentional flooding with potable water is proposed (or where flood water backflow through the sewer system may occur), backflow preventers should be installed in the sewer lines. Various types of backflow preventers are illustrated in Figure 29.

SECTION 1406.0 TOTAL APPROACH

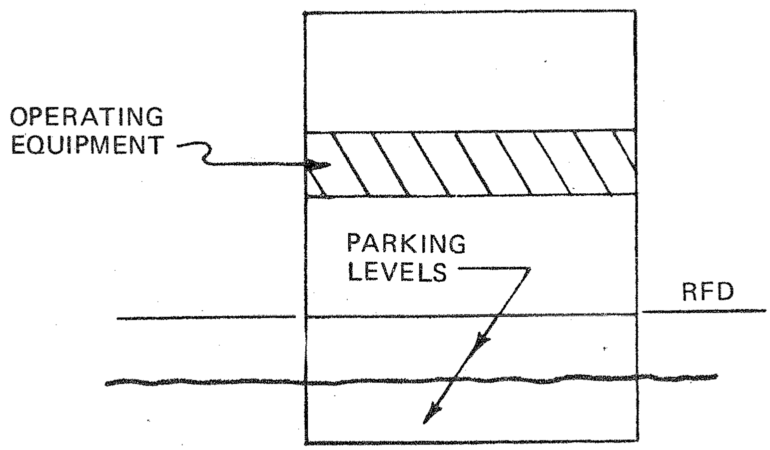
Sec. 1406.1 GENERAL: The design and implementation of flood-proofing systems and procedures requires a total approach. No element or item, regardless of how minute it might appear, should be overlooked or left to chance. The most elaborate, extensive, and expensive flood-proofing system may be rendered useless by a minor omission or by the failure of a weak link in the system.



VARIOUS FLOOD WALL TYPES

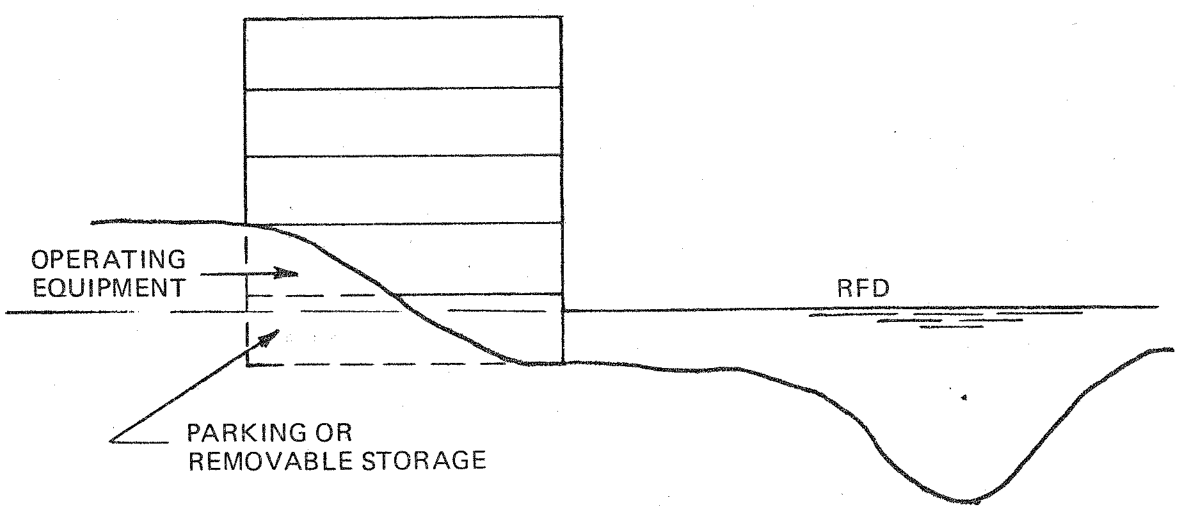
Figure 26

STRUCTURE WITH RESTRICTED USE



STRUCTURE ON NATURAL TERRAIN OR FILL

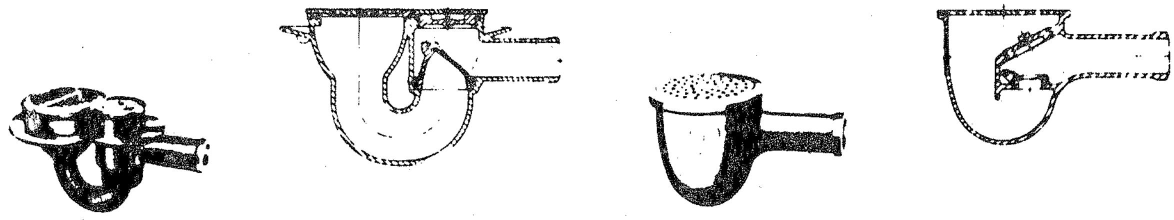
Figure 27



STRUCTURE ON NATURAL TERRAIN OR FILL

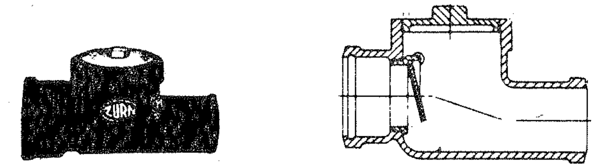
Figure 28

PREVENTION OF BACKFLOW THRU SEWER SYSTEM

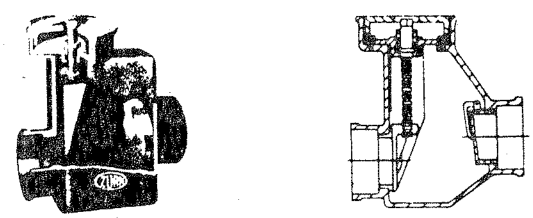


(a) (b)

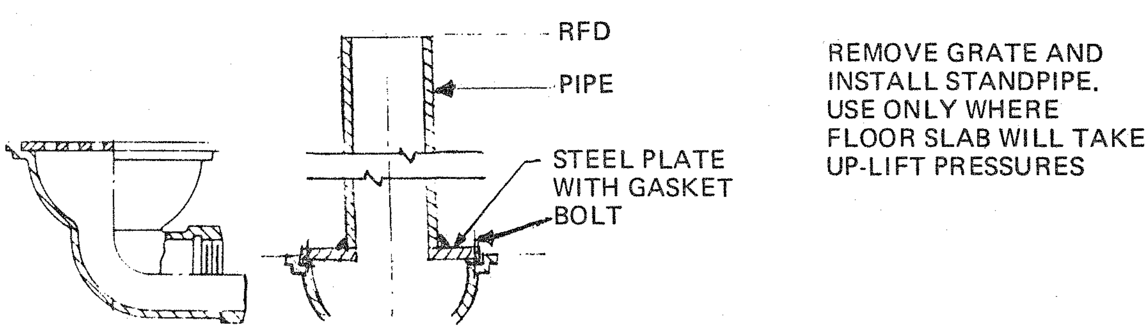
FLOOR DRAIN WITH INTEGRAL BACKWATER VALVE



BACKWATER VALVE – FLAPPER TYPE – AUTOMATIC



BACKWATER VALVE – GATE TYPE COMBINATION – MANUAL & AUTOMATIC



EXISTING BASEMENT DRAIN FLOOD-PROOFING

Figure 29

Sec. 1406.2 STANDARD OPERATING PROCEDURE: The same "in toto" approach is necessary in establishing detailed procedures for making a contingently flood-proofed system ready for an expected flood. Standard operating procedure for mobilizing and implementing the flood-proofing measures, referred to in these Regulations as "The Owner's Contingency Plan", should be developed by the original designer of the system. It requires a degree of completeness such that all details, sequences, and implementing personnel assignments are fully spelled out. The building owners and all other personnel assigned to implement the Plan should be thoroughly acquainted with all aspects of the operation and procedure. All personnel should periodically inspect the system and participate in scheduled "dry runs" or exercises of the flood-proofing plan. The standard operating procedure should be in the format of a manual containing all descriptive information and operational sequences, along with necessary illustrations, drawings, and maintenance requirements for all measures. Personnel designated to perform each task should be noted and, if possible, alternatives should be assigned to assist during times of emergencies or to take over and act if the regularly assigned personnel are absent or unavailable for flood emergency duties. In addition, summarized procedures should be be posted at prominent building locations to facilitate and expedite the operation. Color-coding of flood-proofing implements, such as closure panels, backflow valves, and similar features would be helpful in assuring the most efficient implementation of the Plan.

Sec. 1406.2.1: As preparation of a building for a flood event often involves auxiliary personnel, equipment, and materials, planning for simple logistics should be developed and be closely keyed to available advance time. In this respect, information from flood forecasting and warning sources must be obtained at the earliest possible time. Since floods can occur at any time of the day or night, or even on weekends or holidays, a plan for emergency readiness must be established. It should include establishment of definite lines of communications and control, and identification of key personnel who can be counted on to respond whenever needed.

Sec. 1406.2.2: All systems and implements of flood-proofing must be kept in a perfect state of readiness and be easily accessible at all times. The emphasis on periodic inspection, testing, and continued maintenance cannot be adequately stressed.

REFERENCES

1. Design of Welded Structures, Omer W. Blodgett, The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio

2. Introduction to Flood Proofing, John R. Sheaffer, The Center of Urban Studies, 1967, University of Chicago, Illinois

3. Wall Design, Flood Walls, Part CXXV Chapter 1, January 1948, Dept. of the Army, Corps of Engineers, Office of the Chief of Engineers, Washington, D.C.

4. Design Manual – Soil Mechanics, Foundations and Earth Structures NAVFAC DM-7, March 1971, Dept. of the Navy, Naval Facilities Engineering Command, Washington, D.C. 20390

5. Flood-Proofing: An Element in a Flood Damaged Reduction Program, John R. Sheaffer, Chicago: University of Chicago, Dept. of Geography, Research Paper No. 65, 1960

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