# FLOODPROOFING

## FLOODPROOFING

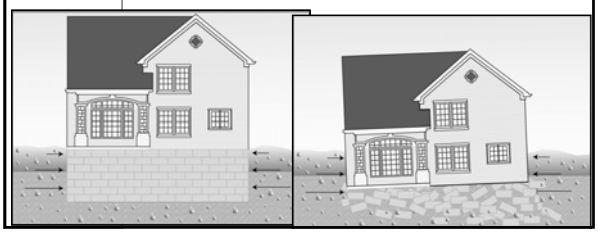
- Combination of adjustments or additions of features to the structure and surroundings designed to reduce or eliminate the damages from a flood.
- NFIP recognizes floodproofing for non-residential structures certified by an engineer or architect.

## FORCES ON A STRUCTURE

- Hydrostatic
- Buoyant
- Hydrodynamic
- Debris Impact
- Erosive

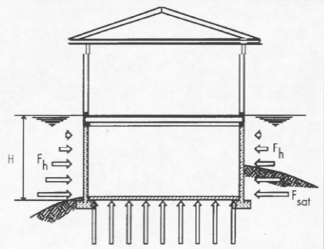
# HYDROSTATIC FORCES

- Lateral force acting on the walls of a structure
- Continues to act below the ground surface



HYDROSTATIC PRESSURES BY WATER DEPTH

| HEIGHT (H) (WATER DEPTH) | Ph (LBS/SQ.FT.) |
|---|---|
| | 62.4 |
| 2 | 124.8 |
| 3 | 187.2 |
| 4 | 249.6 |
| 5 | 312.0 |
| 6 | 374.4 |
| 7 | 436.8 |
| 8 | 499.2 |
| 9 | 561.6 |
| 10 | 624.0 |




Buoyancy Force

Resultant Lateral Force Due to Hydrostatic Pressure from Freestanding Water:

$F_h = \frac{1}{2}wH^2$

where: $F_h$ is the lateral force from freestanding water (in pounds per linear foot of surface)

w is the specific weight of water (62.4 pounds per cubic foot)

H is the height of the standing water (to the floodproof design level)

If any portion of the building is below grade, then calculate the Resultant Cumulative Lateral Force Due to Hydrostatic Pressure from Saturated Soil:

$F_{sat} = \frac{1}{2}SD^2 + F_h$

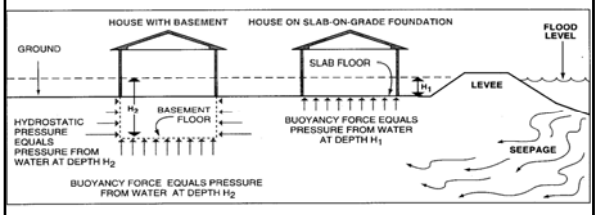
where: $F_{sat}$ is the lateral force from saturated soil

S is the equivalent fluid weight of saturated soil (in pounds per cubic foot)

D is the depth of saturated soil (in feet)

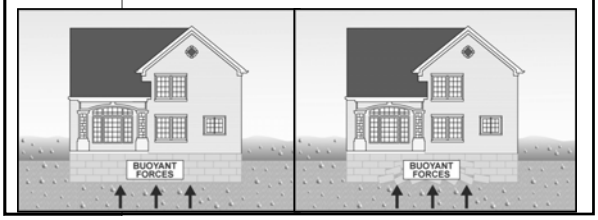
$F_h$ is the lateral force from freestanding water

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.




## BUOYANT FORCES

- Acts on the bottom floor of the structure pushing the structure upwards
- Continues to act below the ground surface




Buoyancy Force:

$F_b = wAH$

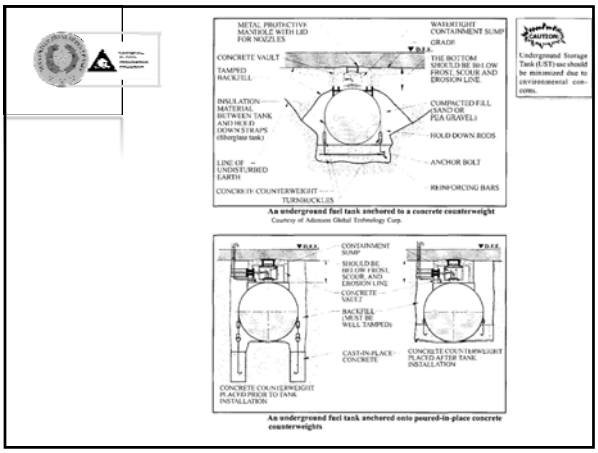
where: $F_b$ is the force due to buoyancy

$w$ is the specific weight of water (62.4 pounds per cubic foot)

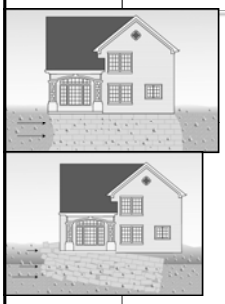
$A$ is the area of horizontal surface (floor or slab) being acted upon (in square feet)

$H$ is the depth of building below the floodproofing design level (in feet)

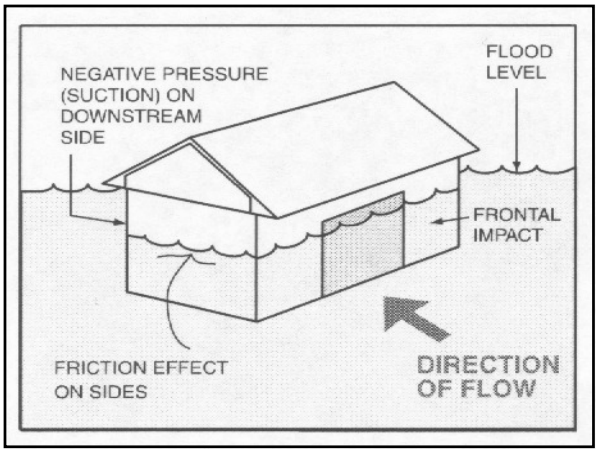
Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.




## Hydrodynamic Forces



- Lateral force acting on the walls of a structure
- Increase by the square of the velocity
- If the velocity doubles, the forces quadruple
- Impact force at the upstream wall
- Friction forces along the walls parallel to the flow
- Negative pressure (suction) on the downstream side



Hydrodynamic Force:

$F_d = C_d m ½ (V)^2 A$

where:

- $F_d$ is the lateral force due to hydrodynamic pressure
- $C_d$ is the drag coefficient
- m is the mass density of water (1.94 slugs per cubic foot)
- V is the velocity of the water (in feet per second)
- A is the area of the wall affected (in square feet)

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

## Debris Impact Forces

- Increase with the velocity and mass of the projectile
- Objects are estimated to be 1,000 pounds but can be reduced to 500 pounds where there is potential for only minor debris
- Impact duration is assumed to be 1 second
- Mountainous and ice flow areas should be considered as special cases

Debris Impact Force:

$$F_i = \frac{WV}{gt}$$

where:

- $F_i$ is the Impact Force
- w is the weight of the object (in pounds)
- v is the velocity of the object (in feet per second)
- g is the acceleration due to gravity (32.2 feet per second$^2$)
- t is the duration of impact (in seconds)

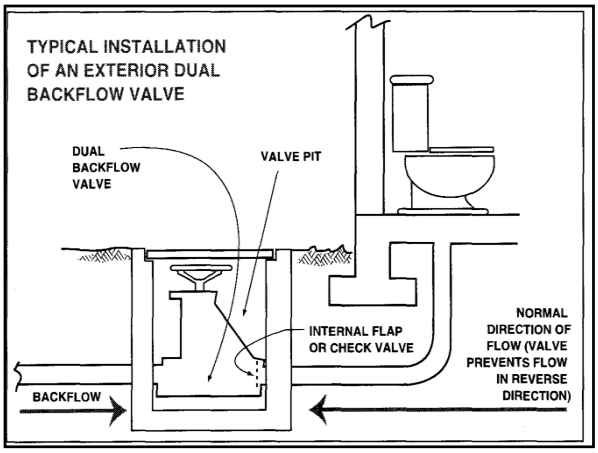
Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

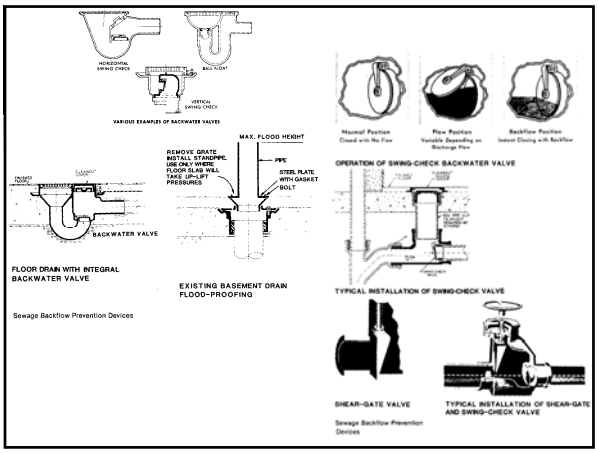
## Erosive Forces and Scour

- Increase with velocity of water
- Increase with volume of material in water
- Can act on soil or structure materials

## Flood Proofing Techniques

- Wall and levees
- Elevation of buildings on fill or piers
- Anchoring structures to resist flotation and lateral forces
- Reinforcement of walls to resist hydrostatic pressure and debris impact
- Sealing walls to reduce seepage
- Installing pumps
- Installing check valves
- Elevating electrical equipment
- Relocation






## Classification of Flood Proofing

- Permanent – Always in place, no action required during a flood
- Contingent – Requires installation during a flood
- Emergency – Improvised as the flood occurs

## Permanent Flood Proofing

- Pros
  - Protect the structure with a barrier on or away from the structure
  - Typical for areas that flood frequently or where insufficient time is available to implement contingent measures
  - Reduce human error
  - Reduced maintenance
  - May meet minimum requirements for NFIP (non-residential structures)

## Permanent Flood Proofing

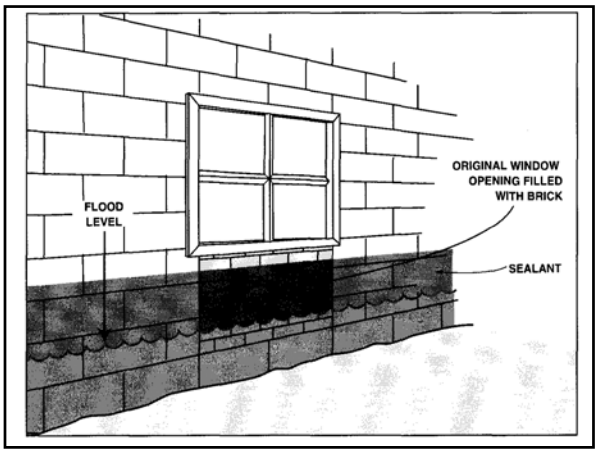
- Cons
  - Expensive initial construction cost
  - May restrict access to structure
  - May block weep holes that allow ventilation to remove condensation between the brick and interior sheet rock

## Types of Permanent Measures

- Closures (sealed windows and doors)
- Sealants
- Watertight Cores
- Floodwalls
- Levees
- Elevation

## Permanent Closures

- Fill an existing window, door, or other opening with a water-resistant material
- Materials: concrete blocks, bricks, glass blocks, cast-in-place concrete, metal plates
- Materials must be impermeable and able to withstand hydraulic forces



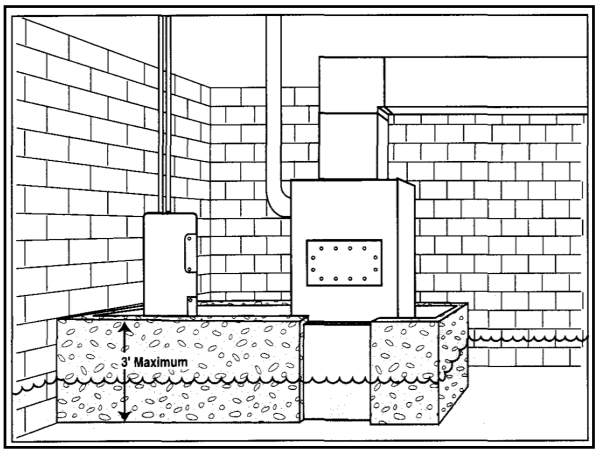

## Permanent Sealants

- Waterproof coating
- Applied to an existing or new wall
- Asphalt or polymeric compound
- UV resistant
- Polyethylene sheets can provide additional protection
- Walls must be able to withstand hydraulic forces since sealant adds no additional strength
- May be significant maintenance

## Watertight Cores

- Watertight wall within a building
- Storage for expensive equipment, important records, and vital utilities


Typical Applications of Watertight Core Floodproofing

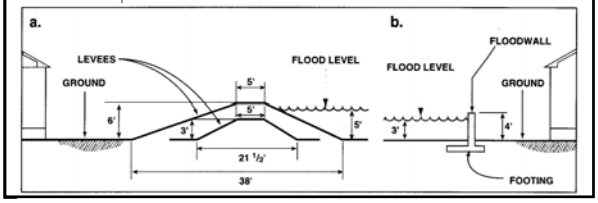


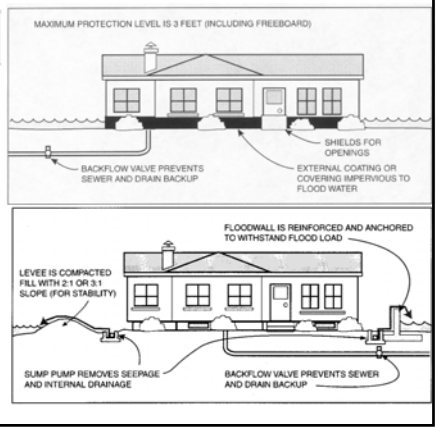

## FLOODWALLS AND LEVEES

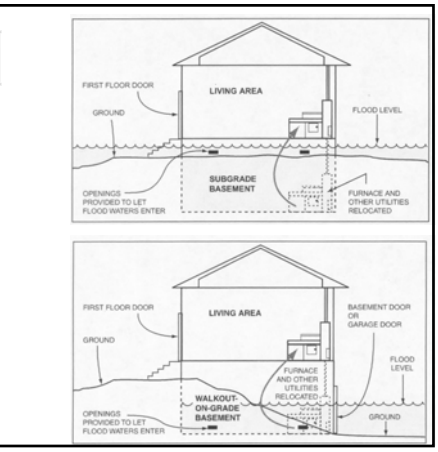
- Watertight wall surrounding one or more structures
- Structurally designed to resist hydrodynamic forces
- Could hinder access to site but allow more access to the building
- Need to provide internal drainage with a sump and pump

## FLOODWALLS

- Floodwalls are generally concrete or masonry
- Levees
  - Earthen structures
  - Require a large "footprint"
  - Can be used for other activities such as a trail

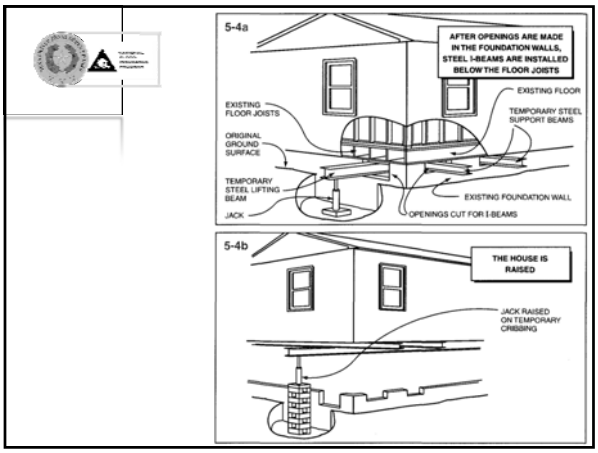


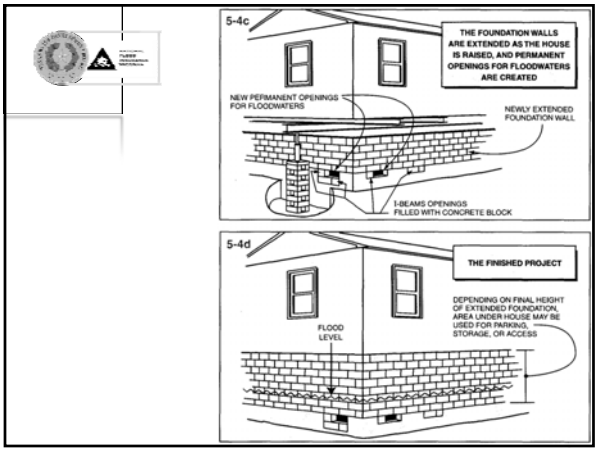


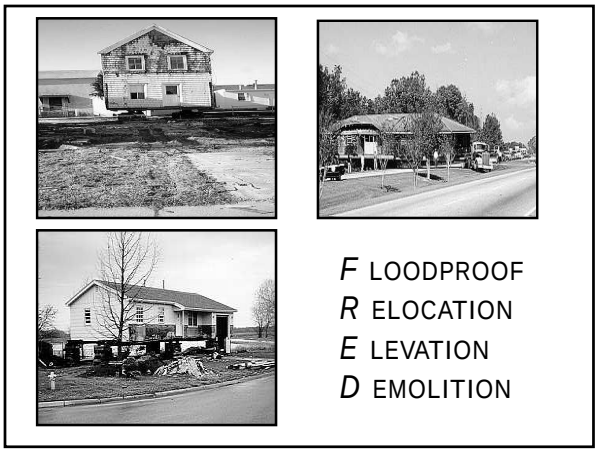




## ELEVATION

- Feasible for new construction or some existing structures
- Elevation can occur on piers, fill, walls, piles, or posts
- Must resist erosive, hydrostatic, hydrodynamic, and debris impact forces
- Should be used in areas where adequate warning time can allow occupants the opportunity to vacate


5-4a
AFTER OPENINGS ARE MADE IN THE FOUNDATION WALLS, STEEL I-BEAMS ARE INSTALLED BELOW THE FLOOR JOISTS
EXISTING FLOOR JOISTS
EXISTING FLOOR
TEMPORARY STEEL SUPPORT BEAMS
ORIGINAL GROUND SURFACE
TEMPORARY STEEL LIFTING BEAM
JACK
EXISTING FOUNDATION WALL
OPENINGS CUT FOR I-BEAMS
5-4b
THE HOUSE IS RAISED
JACK RAISED ON TEMPORARY CRIBBING


5-4c
THE FOUNDATION WALLS ARE EXTENDED AS THE HOUSE IS RAISED, AND PERMANENT OPENINGS FOR FLOODWATERS ARE CREATED
NEW PERMANENT OPENINGS FOR FLOODWATERS
NEWLY EXTENDED FOUNDATION WALL
I-BEAMS OPENINGS FILLED WITH CONCRETE BLOCK
5-4d
THE FINISHED PROJECT
DEPENDING ON FINAL HEIGHT OF EXTENDED FOUNDATION, AREA UNDER HOUSE MAY BE USED FOR PARKING, STORAGE, OR ACCESS
FLOOD LEVEL


*F* LOODPROOF
*R* ELOCATION
*E* LEVATION
*D* EMOLITION

## Increased Cost of Compliance

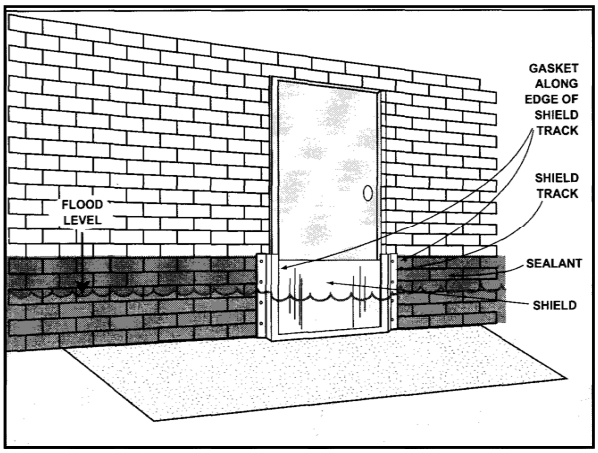
- $30,000
- Provides for the payment of a claim to help pay for the cost to comply with community floodplain management standards
- After a flood event in which a building has been declared substantially or repetitively damaged.

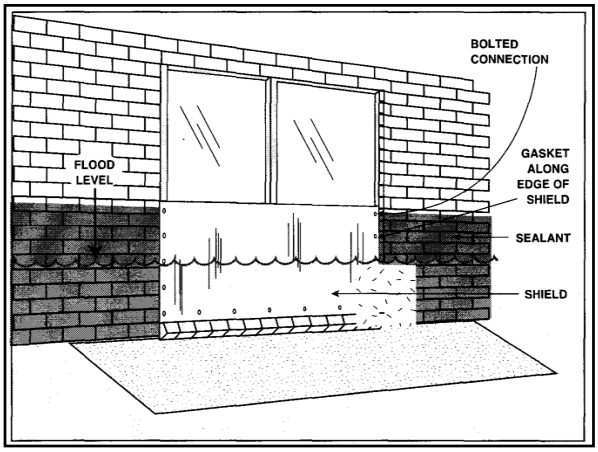
## Contingent Floodproofing Measures

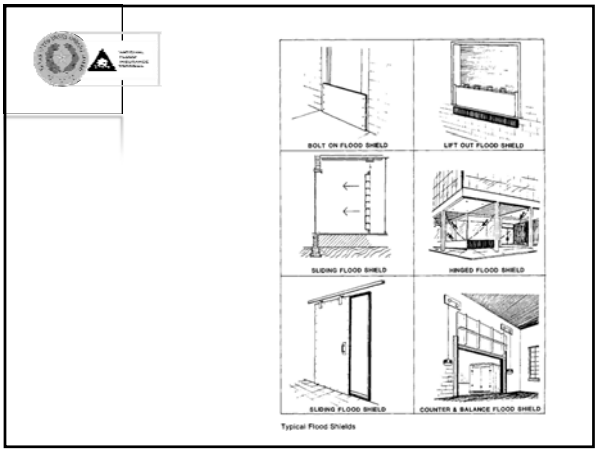
- Require installation, activation, or preparation just prior to a flood event
- System must be manned, activated automatically, or remotely activated
- Includes flood shields, moveable flood walls, and watertight doors
- Adaptable to any structure

## Flood Shields

- Watertight barrier installed against doors, windows, ventilation shafts, and other openings
- Made of steel, aluminum, or plastic
- Gasket material to create seal
- Bolted (or otherwise attached) to the opening
- Should be located as near as possible to opening requiring quick, easy access

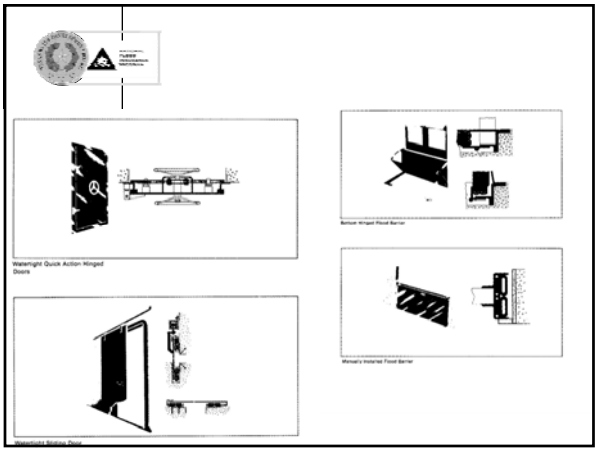

GASKET
ALONG
EDGE OF
SHIELD
TRACK
SHIELD
TRACK
FLOOD
LEVEL
SEALANT
SHIELD


BOLTED
CONNECTION
FLOOD
LEVEL
GASKET
ALONG
EDGE OF
SHIELD
SEALANT
SHIELD


BOLT ON FLOOD SHIELD
LIFT OUT FLOOD SHIELD
SLIDING FLOOD SHIELD
HINGED FLOOD SHIELD
SLIDING FLOOD SHIELD
COUNTER & BALANCE FLOOD SHIELD
Typical Flood Shields

## Watertight Doors

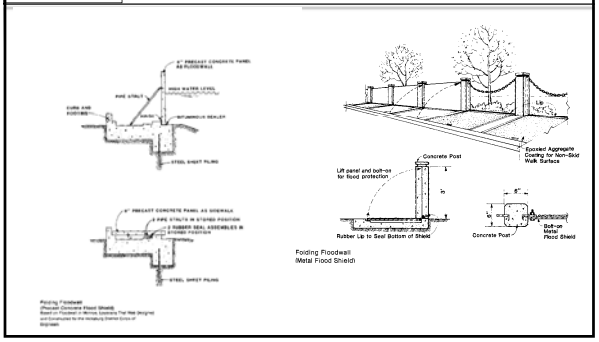
- Similar to flood shields but function as a door
- Can close and seal every time that the door is used
- Can eliminate the need for contingency measures
- However:
  - Doors are heavy
  - Doors are costly



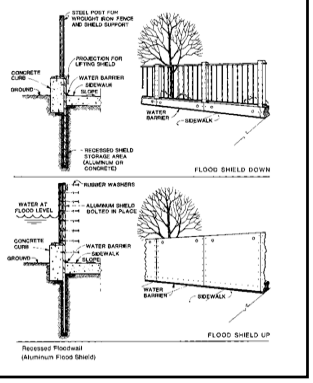
## Moveable Floodwalls

- Used in situations where accessibility may be an issue
- More aesthetic than permanent floodwalls
- May require installation with mechanical assistance due to weight

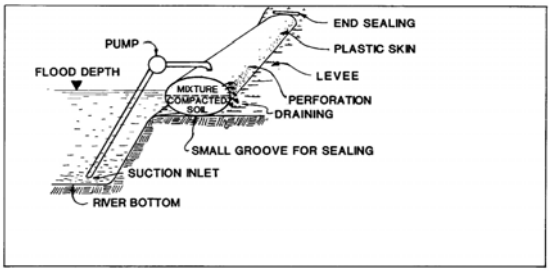
## Folding Floodwall




## Mountable Floodwall



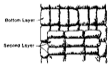

## Inflatable (Water) Floodwall



## Emergency Floodproofing Measures

- Short notice
- On-hand or easily accessible materials
- Labor intensive
- Not useful when a flood rises quickly or has high velocities
- Do NOT satisfy NFIP requirements for floodproofing

## Sand Bag Dikes



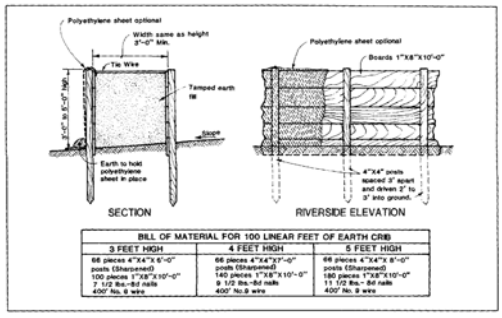
Notes:
1. ALTERNATE DIRECTION OF SACKS, I.E., BOTTOM LAYER PLACED LENGTHWISE PARALLEL TO THE SLOPE, NEXT LAYER PLACED PERPENDICULAR TO FIRST, ETC.
2. LAP UNFILLED PORTION UNDER NEXT BAG.
3. TYING OR SEWING OF BAGS IS NOT NECESSARY.
4. BAGS SHOULD BE APPROXIMATELY ONE-HALF TO TWO-THIRDS FULL.
5. TAMP THOROUGHLY IN PLACE.

MATERIALS REQUIRED FOR 100 LINEAR FEET

| Height Above Ground | Approx. Bags Required | Cu. Yds. |
|---|---|---|
| 1 Ft. | 600-800 | 10-13 |
| 2 Ft. | 1400-2000 | 23-33 |
| 3 Ft. | 2200-3400 | 37-57 |
| 4 Ft. | 5300 | 88 |
| 5 Ft. | 7600 | 137 |
| 6 Ft. | 10000 | 187 |

Sandbag Dike Construction Techniques

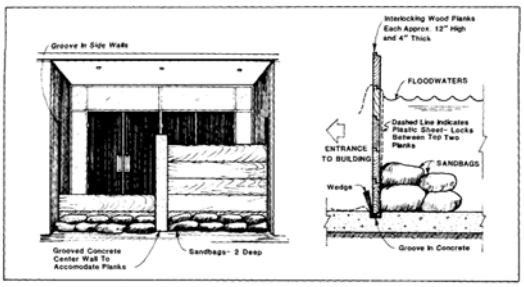
## Earthfill Crib Retaining Walls




BILL OF MATERIAL FOR 100 LINEAR FEET OF EARTH CRIB

| 3 FEET HIGH | 4 FEET HIGH | 5 FEET HIGH |
|---|---|---|
| 66 pieces 4"X4"X 6'-0" posts (Sharpened)<br>100 pieces 1"X8"X10'-0"<br>7 1/2 lbs.-8d nails<br>400' No. 9 wire | 66 pieces 4"X4"X7'-0" posts (Sharpened)<br>140 pieces 1"X8"X10'-0"<br>9 1/2 lbs.-8d nails<br>400' No.9 wire | 66 pieces 4"X4"X 8'-0" posts (Sharpened)<br>180 pieces 1"X8"X10'-0"<br>11 1/2 lbs.- 8d nails<br>400' No. 9 wire |

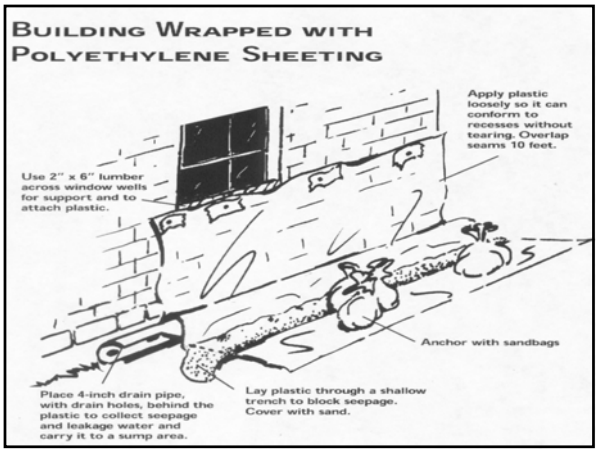
## Stop Log Barriers




Typical Stop Log Barrier

## Wraps and Plastic Sheeting

- Attached to buildings with sufficient structural strength to withstand hydrostatic forces
- Not suitable in moving water
- Guard against tears from nails, downspouts, and other sharp edges
- Can be spliced with duct tape



## Wet Floodproofing

- Allows portions of the interior of a structure to become wet
- Allows for hydrostatic equalization between the interior and exterior wall
- Will NOT reduce residential flood insurance premiums
- Should provide elevated location to store furniture and contents during a flood
- Clean-up after the flood

## Wet Floodproofed Appliances

- Elevated, in a floodwall, wrapped in plastic sheeting, or in a plastic bag
- Turn off power, gas, and the pilot light
- May need to remove hoses to allow adequate application of plastic sheeting or bags

## Flood Resistant Materials

- Suitable for the depth and duration of the design flood
- Do not deteriorate over the life of the structure
- Can be easily maintained and cleaned

## Structural Flood Resistant Materials

- Steel, treated wood, and concrete for pilings and piers
- Treated wood, brick, masonry, and concrete for foundations
- Steel, aluminum, concrete, and treated wood for framing

## Corrosion Resistant Flood Resistant Materials

- Structural damage typically starts at a joint
- Connectors in coastal environments should be resistant to corrosion from ocean salts
- Salt spray can come from breaking waves and onshore winds
- Salt may be significant 3,000 feet inland
- Joist hangars, truss plates, hurricane straps, nails, and screws are all susceptible
- Galvanized steel is 50 times more resistant than plain steel
- Paint coatings can be effective provided that they are properly applied and maintained

## Flooring Flood Resistant Materials

- Clay, stone, or brick tile with waterproof grout
- Solid vinyl floors with cement set adhesives
- Stained concrete and terrazzo
- Treated wood

## Wall Flood Resistant Materials

- Vinyl siding and moldings
- Concrete siding
- Masonry and rock with waterproof grout
- Treated lumber
- Sheet rock can be used above the flood level

## Insulation Flood Resistant Materials

- Closed cell insulation
- Fiberglass batting will allow wicking and will remain wet for extended periods providing a haven for molds