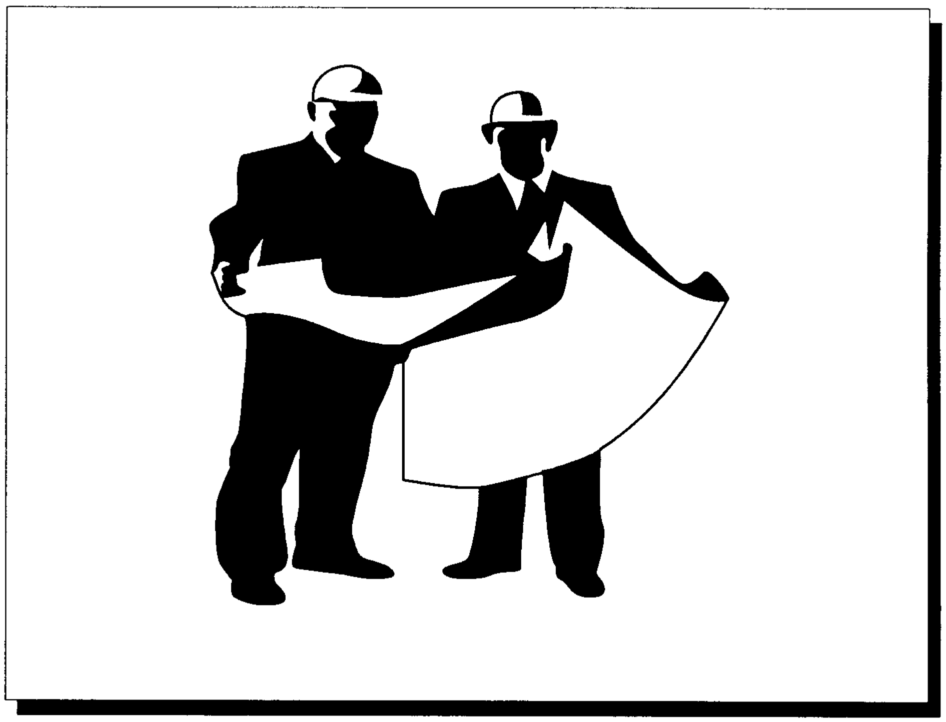
CHAPTER III

PARAMETERS OF RETROFITTING



Featuring:

Examination of Owner Preferences
Community Regulations and Permitting
Technical Parameters

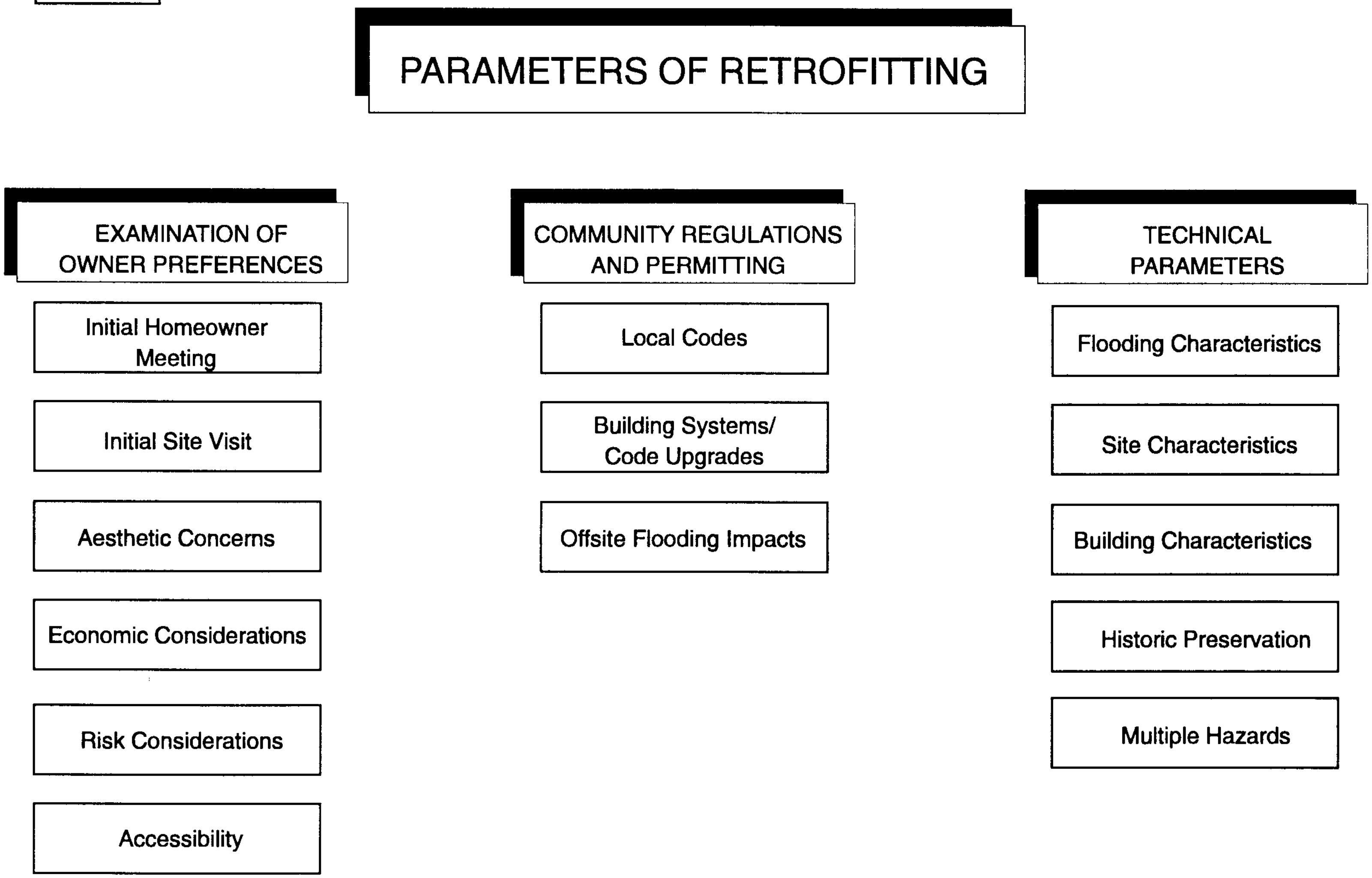

PARAMETERS OF RETROFITTING
EXAMINATION OF OWNER PREFERENCES
Initial Homeowner Meeting
Initial Site Visit
Aesthetic Concerns
Economic Considerations
Risk Considerations
Accessibility
COMMUNITY REGULATIONS AND PERMITTING
Local Codes
Building Systems/ Code Upgrades
Offsite Flooding Impacts
TECHNICAL PARAMETERS
Flooding Characteristics
Site Characteristics
Building Characteristics
Historic Preservation
Multiple Hazards

Table of Contents

PROFICIENCY CHECK

Answer the questions below to the best of your ability. When you are finished, turn the page to check your answers. If you have answered the questions thoroughly, you may turn to the end of this chapter and answer the summary questions.

1. List four major considerations addressed during the designer and homeowner meeting. Discuss whether or not each is a subjective phenomenon and how that affects the retrofitting decision process.

2. Describe a local code requirement which may require expensive structural modifications or necessitate a change in the retrofitting measure selected.

3. What are three of the major characteristics of flooding that are essential to the retrofitting decision making process?

4. Briefly describe the three main building components. Explain how flood and non-flood related forces and hazard effects influence each one.

5. Why are combinations of flood-related hazards and non-flood related hazards particularly dangerous? Why does the designer need to take non-flood related hazards into account while retrofitting a house for flood protection?

PROFICIENCY CHECK ANSWERS

Your answers should include most of the following information.

1. Aesthetic concerns: subjective decision of homeowner. This decision has an influence on most retrofitting measures and is particularly important when elevation, floodwalls, levees, or dry floodproofing is being considered.

   Accessibility: a subjective decision based on individual needs. Several retrofitting measures, such as wet and dry floodproofing, can be done in certain cases without affecting the existing accessibility of the structure.

   Economic concerns: generally an objective decision based on the homeowner's financial constraints although the homeowner may place her or his own further restrictions on the maximum to be spent. Relocation can be expensive initially but may save money in the future. Wet floodproofing is frequently less expensive than many other measures but is subject to greater expenses during floods.

   Risk considerations: an objective phenomenon based on probabilities and the history of flood threats to the area. A reasonable estimate of the likelihood of a significant flood can give the designer and the homeowner an idea of when a flood will occur. Relocation out of the floodplain is the only method that will eliminate all flood risks.

2. The requirement to bring a structure into compliance with current building codes and floodplain management requirements can have a significant impact on the cost and selection of a retrofitting measure.

3. The depth, velocity, and duration of the flood are each significant factors in choosing a retrofitting measure.

4. Substructure: transfers both dead and live loads to the ground. Forces to consider are therefore the buoyant uplift of floodwater, horizontal loads, and effects of multiple hazards such as wind and earthquakes.

   Superstructure: building envelope above grade. It is subject to uplift, suction, shear and other pressures (including debris impact) from floods, wind, and other environmental hazards.

Support services: elements providing energy, communications, and disposal of water and waste. The impact of various forces depends on the arrangement of each system and will need to be taken into account by the designer as individual cases arise.

5. Flood-related hazards as well as non-flood related hazards must be a part of the decision-making process because the combination of many of them often increases the damage that each one does individually. For example, an earthquake can weaken foundation and other structural components making them more susceptible to flood-related forces. Elevating a structure to eliminate flood hazards can make the structure more susceptible to wind forces. The converse may be true as well; retrofitting a structure for flood loads can often improve resistance to earthquake damage.

If your answers included all or most of the above points, turn to the end of this chapter and answer the Summary Questions.

If your answers did not include these points, it would be advisable for you to complete the programmed instruction for this chapter which begins on the following page.

PARAMETERS OF RETROFITTING

In this chapter, the factors that influence retrofitting decisions are examined and compared with various methods to determine the viability of specific retrofitting techniques. These factors include:

- homeowner preferences,
- community regulations and permitting requirements, and
- technical parameters.

Factors such as homeowner preference and technical parameters are key elements in identifying appropriate retrofitting measures, while consideration of the multiple flood-related and non-flood-related hazards is critical in designing the retrofitting measure and/or avoiding the selection of a poor retrofitting method.

This selection of alternatives can be streamlined through the use of two generic retrofitting matrices, which are designed to help the designer narrow the range of retrofitting options:

Preliminary Floodproofing / Retrofitting Preference Matrix (Figure III-1), which focuses on factors that influence homeowner preference and those measures allowable under local regulations.

Retrofitting Screening Matrix (Figure III-3), which focuses on the objective physical factors that influence the selection of appropriate retrofitting techniques.

EXAMINATION OF OWNER PREFERENCES

The proper evaluation of retrofitting parameters will require a series of homeowner coordination and design input meetings. Ultimately the homeowner will have to deal with the flood protection environment on a daily basis. Therefore, the functional and cosmetic aspects of the retrofitting measure, such as access, egress, landscaping, appearance, etc., need to be developed by including the homeowner's thoughts and ideas. Most retrofitting measures are permanent and should be considered similar to a major home addition or renovation project. The design should incorporate the concepts of those who will be using the retrofitted structure.

Issues that should be addressed include:

- retrofitting aesthetics,
- economic considerations,
- risk considerations,
- accessibility,
- local code requirements,
- building mechanical/electrical/plumbing system upgrades, and
- offsite flooding impacts.

In order to avoid any future misunderstandings, designers should use their skills and knowledge of retrofitting projects to address technical implications while working with homeowners. Many owners have little or no technical knowledge of retrofitting and naturally look to the designer or local official for guidance and expert advice.

The Preliminary Floodproofing/Retrofitting Preference Matrix, (Figure III-1), assists the designer in documenting the initial consultation with the homeowner. The first consideration "measure allowed by community," enables the designer to screen alternatives that are not permissible and must be eliminated from further consideration. Discussion of the considerations for the remaining measures should lead to a "no" or "yes" for each of the boxes. Ex-

Owner Name: ____________________ Prepared By: ____________
Address: ____________________ Date: ____________
Property Location: ____________________

Floodproofing Measures / Considerations	Elevation on Foundation Walls	Elevation on Fill	Elevation on Piers	Elevation on Posts and Columns	Elevation on Piles	Relocation	Dry Flood-proofing	Wet Flood-proofing	Floodwalls and Levees
Measure Allowed or Owner Requirement									
Aesthetic Concerns									
High Cost Concerns									
Risk Concerns									
Accessibility Concerns									
Code Required Upgrade Concerns									
Off-Site Flooding Concerns									
Total "x's"									

Instructions: Determine whether or not floodproofing measure is allowed under local regulations or homeowner requirement. Put an "x" in the box for each measure which is **not** allowed. Complete the matrix for only those measures that are allowable (no "x" in the first row). For those measures allowable or owner required, evaluate the considerations to determine if the homeowner has concerns which would impact its implementation. A concern is defined as a homeowner issue which if unresolved would make the retrofitting method(s) infeasible. If the homeowner has a concern, place an "x" in the box under the appropriate measure/consideration. Total the number of "x's." The floodproofing measure with the least number of "x's" is the most preferred.

Figure III-1: Preliminary Floodproofing/Retrofitting Preference Matrix amination of the responses will help the homeowner and designer select retrofitting measures for further examination that are both viable and preferable to the owner.

THE INITIAL HOMEOWNER MEETING

The first step in the homeowner coordination effort is the educational process for both the designer and the property owner. This step is a very important one.

The Homeowner Learns:

- How it was determined that the home is in the floodplain;
- Possible impacts of an actual flood;
- Benefits of flood insurance;
- Physical, economic, and risk considerations, and
- What to expect during each step in the retrofitting process.

The Designer Learns:

- Flood history of the structure;
- Homeowner preferences;
- Financial considerations;
- Special issues, such as handicapped accessibility requirements, and
- Any available information on the subject property such as:

- topographic surveys,
- site utility information, and
- critical home dimensions.

During this initial meeting, the designer and homeowner should jointly conduct a preliminary assessment of the property to determine which portions of the structure require flood protection and the general condition of the structure. This initial evaluation will identify the elevation of the lowest floor, and the elevation of potential openings throughout the structure whereby flood waters may enter the residence.

INITIAL SITE VISIT

A Low Point of Entry Determination, illustrated in Figure III-2, determines the elevation of the lowest floor and each of the structure's openings, and may include:

- basement slab elevation;
- windows, doors, and vents;
- mechanical/electrical equipment and vents;
- the finished floor elevation of the structure;
- drains and other floor penetrations;
- water spigots, sump pump discharges, and other wall penetrations;
- other site provisions that may require flood protection, such as storage sheds, wellheads, and storage tanks; and
- the establishment of an elevation reference mark on or near the house.

Once the Low Point of Entry determination has been completed, the designer/owner can determine the flood protection elevation and/or identify openings, which need to be protected (in the case of dry floodproofing).

> The evaluation of information obtained during the initial meeting with the homeowner will help the designer and owner address the flood threat to the entire structure and the vulnerability of specific openings to floodwater intrusion.

> Sometimes it is necessary for a field survey to be conducted by a professional land surveyor before design documents are developed. However, frequently the homeowner and designer may be able to develop a rough elevation relationship between the expected flood elevation, the elevation of the lowest floor, and the low points of entry to the structure sufficient for an initial evaluation.

A detailed discussion of how to evaluate the costs of different alternatives and the effect of the Low Point of Entry may be found in the chapters on Benefit/Cost Analysis.

The approximate height of retrofitting measure can be used by the owner and designer as they evaluate each of the parameters of retrofitting discussed in this chapter. In addition to determining the Low Point of Entry, this initial site visit should be used to assess the general overall condition of the structure.

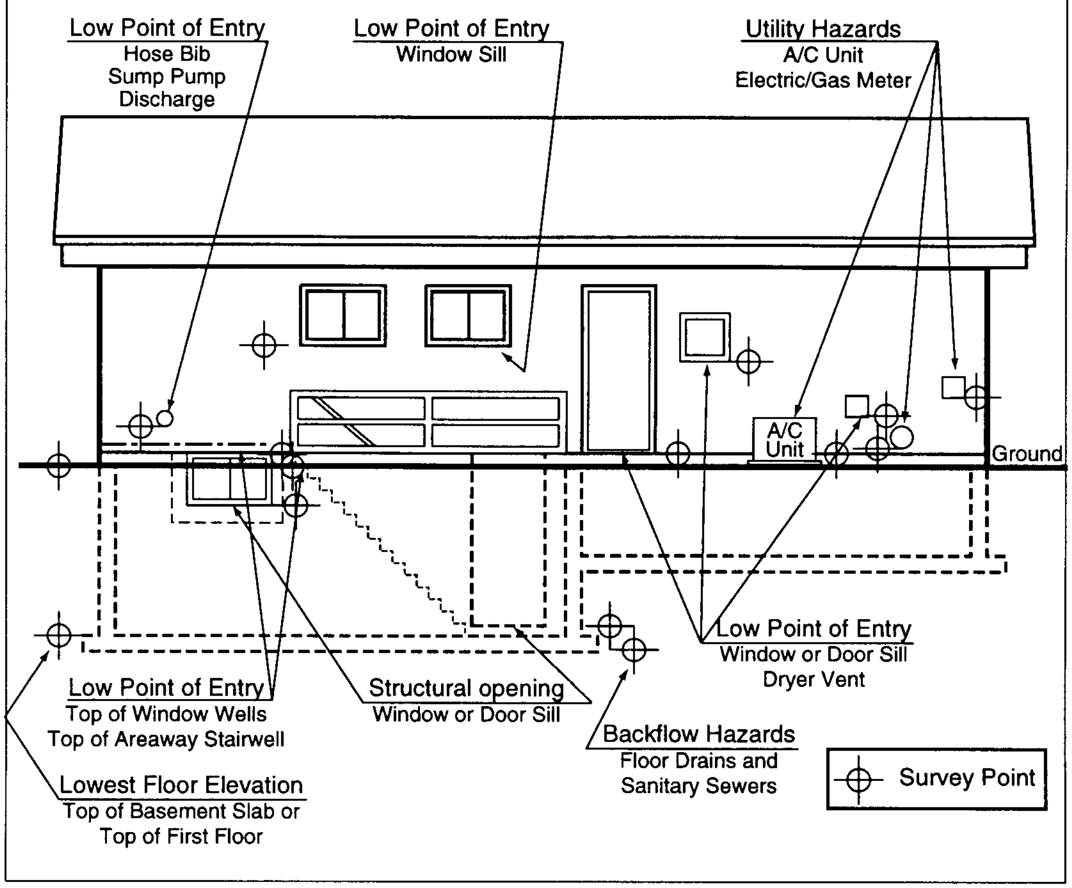


Figure III-2: Low Point of Floodwater Entry Survey for a Typical Residential Structure

QUESTION III-1

Mark all that are appropriate.

Why is the homeowner's input important?

1. The homeowner's participation allows both designer and owner to work together ensuring that the retrofitting project fulfills economic, technical and personal requirements.

2. Maintenance and intervention will be the responsibilities of the homeowner who should therefore have some influence in the decision-making process.

3. Generally, the homeowner is aware of considerations not permissible in the community.

4. The homeowner has information about the structure which may not be readily available nor obvious to the designer.

5. Aesthetics, such as modification of the landscape or the structure, should not fall solely in the designer's domain.

6. The NFIP requires that the designer identify placement of sump pump discharges, water spigots and storage tanks, which only the homeowner can provide.

ANSWER III-1

Answers 1, 2, 4, and 5 are valid reasons to include the homeowner's input from the start.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

AESTHETIC CONCERNS

Sometimes property owners are reluctant to participate in retrofitting measures because they are concerned with how the work will alter the physical appearance of their property. Such reluctance may be overcome with a video display of before and after scenes of a building. This can be accomplished with a personal computer (PC) and a video camera. The PC can be loaded with a video capture card, which will allow transfer of a video image to the PC. The camcorder or VCR image is captured while in the pause mode and projected to the PC monitor. Images can then be edited to portray them in various surroundings and with structure modifications. These simulated pictures in color or black and white can be developed with currently available computer software.

Although physical and economic considerations may help determine feasible retrofitting measures for individual buildings, the homeowners may consider other factors equally or more important. Aesthetics, for example, is a subjective issue.

The homeowner may reject a measure that scores high for all considerations except aesthetics. On the other hand, what may be aesthetically pleasing to the homeowner may not be technically appropriate for a project. Here, a designer must use skill and experience to achieve a common ground. In doing so, the homeowner's preference should be considered, while not jeopardizing the structural, functional, and overall success of the proposed project.

An aesthetically pleasing solution that also performs well as a retrofitting alternative can be achieved through an understanding of the relationship between the existing and proposed modifications, creative treatment and modification of surrounding landforms, proper landscaping techniques, and preservation of essential and scenic views.

ECONOMIC CONSIDERATIONS

At this point, the designer should not attempt to conduct a detailed cost analysis. Rather, general estimates of the cost of various retrofitting measures should be presented to the homeowner.

As discussed in Chapter I, the cost of retrofitting will depend on a variety of factors including the building's condition, the retrofitting measure to be employed, the design flood elevation, the choice of materials and their local availability, the availability and limitations of local labor, and other site-specific issues (i.e., soil conditions and flooding levels) and other hazards.

The following costs are nationwide averages that may need to be adjusted for local conditions. They were derived from various sources including the USACE document, *Flood Proofing, How to Evaluate Your Options* and various post-disaster documents prepared by FEMA as a result of the Midwest Flood of 1993, Hurricane Andrew in Florida (January 1993), the Northridge, California earthquake (January 1994), and flooding in Southeastern Texas (November 1994). They are provided to assist in economic analysis and preliminary planning.

Table III-1 **Elevation and Relocation Cost Guide**

Type	Elevation Cost	Relocation Cost	Per
Wood-Frame Building on Open Foundations (Piles, Posts or Piers)	$18	$28	square foot
Wood-Frame Building on Solid Foundation Walls	$13	$23	square foot
Brick Building	$24	$39	square foot
Slab-on-Grade Building	$22	$37	square foot

Table III-1 Assumptions:

1. Elevation costs include foundation, extending utilities, and miscellaneous items, such as sidewalks and driveways.
2. Elevation unit cost is based on a 2-foot raise. Add $0.75 per square foot for each additional foot raise up to eight feet. Above 8 feet, add $1.00 per square feet.
3. Relocation costs include off-site relocation (less than 5 miles) and new site development for a 1,000 SF building. Extrapolation of this unit cost to larger buildings may result in artificially high estimates because the costs of relocation do not increase proportionally with building size.

In relocating a structure, the cost of preparing the new site and cleaning up the old site must be considered.

Table III-2 **Floodwalls and Levees Cost Guide**

Type	Cost	Per
Floodwalls, two feet above ground level	$77	linear foot
Floodwalls, four feet above ground level	$113	linear foot
Floodwalls, six feet above ground level	$160	linear foot
Levees, two feet above ground level	$34	linear foot
Levees, four feet above ground level	$63	linear foot
Levees, six feet above ground level	$105	linear foot
Floodwall costs are based upon typical foundation depth of 30 inches. Levee costs are based upon typical foundation depth of one foot, 10-foot top width, and 1:3 side slopes. Levee costs include seeding and stabilization. Additional costs that may need to be estimated for both floodwalls and levees are as follows:		
Interior Drainage	$3,800	lump sum
Closures	$66	square foot
Riprap	$28	cubic foot
Sidewalk (3' wide)	$9	linear foot
Driveway (asphalt)	$6	square yard
Driveway (concrete)	$16	square yard

Table III-3 Dry Floodproofing Cost Guide		
Type	**Cost**	**Per**
Sprayed-on cement (1/8 inch)	$3	square foot
Asphalt (2 coats below grade)	$1	square foot
Periphery drainage	$28	linear foot
Plumbing check valve (6")	$600	lump sum
Pump (submersible sump)	$500	lump sum

Table III-4 Flood Shields Cost Guide		
Type	**Cost**	**Per**
Metal	$66	square foot
Wood	$21	square foot

Additional costs should include:

- temporary living quarters that may be necessary during construction (estimate: relocation - 3 to 4 weeks; elevation - 2 to 3 weeks)
- professional or architectural design (10% of the costs of selected retrofitting measures), and
- contractors' profit (10% of the estimated costs).
- contingency to account for unknown or unusual conditions.

Table III-5 can serve as a guide for developing the initial planning level estimate for each retrofitting alternative being considered.

Table III-5 **Preliminary Cost Estimating Worksheet**

Owner Name: **Prepared By:**

Address: **Date:**

Property Location:

Cost Component	Unit	Unit Cost	Quantity	Total
Subtotal Retrofitting Measure				
Contractor's Profit (10%)				
Design Fee (10%) (optional)				
Loss of Income (optional)				
Displacement Expenses (optional)				
Contingency				
Subtotal Other Costs				
Total Costs				

RISK CONSIDERATIONS

Another element that is included in the evaluation of retrofitting measures is the risk associated with a do-nothing approach. Risk can also be established among the various measures by knowing the exceedence probability of floods and the design flood levels for competing measures. Relocation is an example of how retrofitting can eliminate the risk of flood damage. On the other hand, a levee designed to protect against a 10-percent chance annual exceedence probability (10-year) flood would have an 88-percent chance of being overtopped during a 20-year period. Such information will assist the homeowner in evaluating the pros and cons of each measure. Table III-6 provides the probabilities associated with one or more occurrences of a given flood magnitude occurring within a specific number of years.

Table III-6 **Flood Risk**

	Frequency-Recurrence Interval (Year-Event)					
		10	25	50	100	500
Length of Period (Years)	1	10%	4%	2%	1%	0.2%
	10	65%	34%	18%	10%	2%
	20	88%	56%	33%	18%	5%
	25	93%	64%	40%	22%	5%
	30	96%	71%	45%	26%	6%
	50	99+%	87%	64%	39%	10%
	100	99.99+%	98%	87%	63%	18%

The table values represent the probabilities, expressed in percentages, of one or more occurrences of a flood of given magnitude or larger within a specified number of years.

Flood probabilities are also useful in evaluating the homeowner inconvenience aspects of retrofitting. Reducing cleanup and repairs, lost time from work, and average non-use of a building from once in two years to once in ten years could be a powerful incentive for retrofitting even though other aspects may be less convincing.

ACCESSIBILITY FOR THE DISABLED

Accessibility for the disabled is an issue that must be addressed primarily on the specific needs of the owner. Many retrofitting measures can create access problems for a house that was previously fully accessible. The Americans with Disabilities Act (ADA) of 1990 the Fair Housing Amendment Act (FHA) of 1988 and other accessibility codes and regulations do not specifically address private single-family residences, which are the focus of this course. However, the above-mentioned regulations contain concepts that may be of assistance to a designer representing a disabled property owner.

It is important for the designer to remember that the term disabled does not refer simply to someone confined to a wheelchair. Other disabilities may include:

- limited mobility requiring the use of a walker or cane, which can inhibit safe evacuation;
- a person's limited strength to open doors, climb stairs, install flood shields, or operate other devices; and
- partial or total loss of hearing or sight.

Special considerations such as small elevators may be needed.

Discussion of the above factors with the homeowner and utilization of the **Preliminary Retrofitting Preference Matrix** will allow the designer to prioritize the retrofitting methods by homeowner preference.

QUESTION III-2

Determine which of the following considerations are valid points of discussion between the designer and the homeowner.

1. economic considerations -- the financial resources of the various retrofitting communities combined with the budgetary constraints of the homeowner

2. neighborhood concerns -- the extent to which retrofitting measures affect property values and the social fabric of the community

3. accessibility -- the ability to enter the structure during both flood and non-flood conditions, a particular consideration for disabled people

4. aesthetic concerns -- the physical appearance of the physical structure only.

5. risk considerations -- the continued possibility of flood damage and its consequences after any retrofitting measure has been installed

ANSWER III-2

Answers 1, 3, 4, and 5 are valid considerations.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

COMMUNITY REGULATIONS AND PERMITTING

LOCAL CODES

> A designer should become familiar with the prevailing conditions, codes, and legal restrictions particular to a building's location.

Most local governments regulate building activities by means of building codes as well as floodplain and zoning ordinances and regulations. With the intent of protecting health and safety, most local codes are fashioned around the model building codes discussed in Chapter II. The designer should be aware that modifications may be undertaken to make the model codes more responsive to the local conditions and concerns in the area, such as seismic and hurricane activity, extreme cold, or humidity.

Determination of which retrofitting measures are allowed under local regulations is an important step in compiling the Preliminary Floodproofing/Retrofitting Preference Matrix. Retrofitting measures not allowed under local regulations will be screened and eliminated from further consideration.

> Some communities require that structures undergoing substantial rehabilitation, either because of previous damage or significant improvements/additions, be brought into compliance with current building codes. In addition to floodplain management requirements, these requirements could include items such as the addition of fire alarms, removal of lead water pipes, upgrades in electrical wiring, etc.

BUILDING SYSTEMS/CODE UPGRADES

Other local code requirements must be met by owners' building improvements. Most building codes require approval when elevation is considered, especially if structural modification and/or alteration and relocation of utilities and support services are involved.

If more stringent laws have been adopted since a building was constructed, local code restrictions can seriously affect the selection of a retrofitting method because construction may be expected to comply with new building codes.

OFFSITE FLOODING IMPACTS

Where a chosen retrofitting measure requires the modification of site elements, a designer shall consider how adjacent properties will be affected.

Addressing offsite impacts and issues is as much a matter of responsible practice and conscience as it is a requirement of most building codes and floodplain management ordinances.

- Will construction of levees and floodwalls create diversions in the natural drainage patterns?
- Will new runoffs be created that may be detrimental to nearby properties?
- If floodproofing disturbs the existing landscape, will regrading and relandscaping undermine adjacent streets and structures?
- Will the measure be unsightly or increase the possibility of sliding and subsidence at a later date?
- If a building is to be relocated to another portion of the current site, or if it is to be elevated, will it encroach on established easements or rights-of-way?
- Will the relocated building infringe on wetland areas or regulated floodplains?

NFIP, state, and local regulations do not allow construction within a floodway or, in some cases, within a floodplain that would back up and increase flood levels.

These and other questions must be addressed and satisfactorily answered by the designer and homeowner in selecting the most appropriate retrofitting measure. Both must be aware of the liabilities that may be incurred by altering drainage patterns and other large-scale site characteristics. The designer should insure that any modified runoffs do not cause negative impacts on the surrounding properties. The means necessary to collect, conduct, and dispose of unwanted flood or surface water resulting from retrofitting modifications must be understood and clearly resolved.

TECHNICAL PARAMETERS

Once the designer has resolved preliminary retrofitting preference issues with the owner, a more intensive evaluation of the technical parameters is normally conducted, including flooding, site, and building characteristics. Figure III-3 provides a Retrofitting Screening Matrix (worksheet) that can be used to evaluate which measures are appropriate for individual structures. Instructions for using this matrix are presented in Figure III-4. The remainder of this chapter provides background information on each of the technical parameters which will be useful to the designer in completing the Retrofitting Screening Matrix.

Owner Name: ______________________________ Prepared By: ____________
Address: ______________________________ Date: ____________
Property Location: ______________________________

Category	Parameters \ Measures	Elevation on Foundation Walls	Elevation on Fill	Elevation on Piers, Piles, Posts, and Columns	Relocation	Dry Flood-proofing	Wet Flood-proofing	Floodwalls and Levees
	Measure Permitted by Community or Preferred by Homeowner							
Flooding Characteristics	**Flood Depth**							
	Shallow (<3 feet)							
	Moderate (3 to 6 feet)					N/A		
	Deep (>6 feet)					N/A	N/A	N/A
	Flood Velocity							
	Slow/Moderate (≤5 fps)							
	Fast (>5 fps)	1	1	1		N/A		1
	Flash Flooding							
	Yes (<1 hour)					2	2	2
	No							
	Ice and Debris Flow							
	Yes	6		4		N/A		4
	No							
Site Characteristics	**Site Location**							
	Floodway	5	5	5	5	5	5	5
	Other A Zone							
	Soil Type							
	Permeable					3		3
	Impermeable							
Building Characteristics	**Building Foundation**							
	Slab on Grade							
	Crawl Space					N/A		
	Basement		6	6		6		
	Building Construction (Framing)							
	Concrete or Masonry							
	Wood and Others							
	Building Condition							
	Excellent to Good							
	Fair to Poor	6	6	6	6	6		

Figure III-3: Retrofitting Screening Matrix

The Retrofitting Screening Matrix (Figure III-3) is designed to screen and eliminate retrofitting techniques that should not be considered for a specific situation.

Step 1: Screen alternatives which are not permitted nor preferable to the homeowner and are eliminated from further consideration, by inserting N/P (not permitted) in the appropriate box(es) on the Measures Permitted by Community row. If a N/P is placed in a column representing a retrofitting measure, that alternative is eliminated from consideration.

Step 2: Select the appropriate row for each of the nine characteristics that best reflect the flooding, site, and building characteristics.

Step 3: Circle the N/A (not advisable) boxes that apply in the rows of characteristics selected. Do not circle any N/A boxes where there is a plan to engineer a solution to address the specific characteristic.

Step 4: Examine each column representing the different retrofitting measures. If one or more N/A boxes are circled in a column representing a retrofitting measure, that alternative is eliminated from consideration.

Step 5: The numbers enclosed in the boxes represent special considerations (detailed below) which must be accounted for to make the measure applicable. If the consideration cannot be addressed, the number should be circled and the measure eliminated from consideration.

Step 6: Retrofitting measures that remain should be further evaluated for technical, benefit-cost, and other considerations. A preferred measure should evolve from the evaluation.

N/A Not advisable in this situation.

N/P Not permitted in this situation.

1 Fast flood velocity is conducive to erosion and special features to resist anticipated erosion may be required.

2 Flash flooding usually does not allow time for human intervention; thus, these measures must perform without human intervention. Openings in foundation walls must be large enough to equalize water forces and should not have removable covers. Closures and shields must be permanently in place, and wet floodproofing cannot include last-minute modifications.

3 Permeable soils allow seepage under floodwalls and levees; therefore, some type of subsurface cutoff feature would be needed beneath structures. Permeable soils become saturated under flood conditions, potentially increasing soil pressures against a structure, therefore some type of foundation drain system or structure may be needed.

4 Ice and debris loads should be considered and accounted for in the design of foundations and floodwall/levee closures.

5 Any retrofitting alternative considered for the floodway must meet NFIP, state, local, and community floodplain requirements concerning encroachment/obstruction of the floodway conveyance area.

6 Not advisable in this situation, unless a specific engineering solution is developed to address the specific characteristic or constraint.

FLOODING CHARACTERISTICS

Riverine flooding is usually the result of heavy or prolonged rainfall or snowmelt occurring in upstream inland watersheds. In some cases, especially in and around urban areas, flooding can also be caused by inadequate or improper drainage. In coastal areas subject to tidal effects, flooding can result from wind-driven and prolonged high tides, poor drainage, and storm surges with waves, and tsunamis.

There are several different flood characteristics that must be examined to determine which retrofitting measure will be best suited for a specific location. These characteristics not only indicate the precise nature of flooding for a given area, but can also be used to anticipate the performance of different retrofitting measures. These factors are outlined below.

Flood Depth

Determining the potential depth of flooding for certain flood frequencies is a critical step because it is often the primary factor in evaluating the potential for flood damage.

A building is susceptible to floods of various depths. Floods of greater depth occur less frequently than those of lesser depths. Potential flood elevations from significant flooding sources are shown in Flood Insurance Studies (FIS) for most participating NFIP communities. For the purpose of assessing the depth of flooding a structure is likely to endure, it is convenient to use the flood levels shown in the study, historical flood levels, and flood information from other sources. The depth of flooding affecting a structure can be calculated by determining the height of the flood above the ground elevation at the site of the structure.

For those areas outside the limits of a FIS or state, community, or privately prepared local floodplain study, determination of flood depth may require a detailed engineering evaluation of local drainage conditions to develop the necessary relationship between flow (discharge), water-surface elevation, and flood frequency. The designer should contact the local municipal engineer, building official, or floodplain administrator for guidance on computing flood depth in areas outside existing study limits.

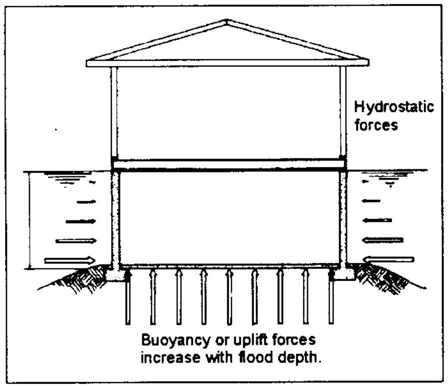


Figure III-6: Hydrostatic Forces

Floodwaters can impose hydrostatic forces on buildings. These forces result from the static mass of water acting on any point where floodwater contacts a structure. They are equal in all directions and always act perpendicularly (or normally) to the surfaces on which they are applied. Hydrostatic loads can act vertically on structural members such as floors and decks (buoyancy forces) and laterally (hydrostatic forces) on upright structural members such as walls, piers, and foundations. Hydrostatic forces increase linearly as the depth of water increases. Figure III-6 illustrates the hydrostatic forces generated by water depth.

If a well-constructed building is subject to flooding depths of less than three feet, it is possible that unequalized hydrostatic forces may not cause significant damage. Therefore, consideration can be given to using barriers, sealants, and closures as retrofitting measures. If shallow flooding (less than three feet) causes a basement to fill with water, wet floodproofing methods can be used to reduce flood damage to basements.

If a residential building is subject to flooding depths greater than three feet, elevation or relocation are often the most effective methods of retrofitting. Water depths greater than three feet can often create hydrostatic forces with enough load to cause structural damage or structure collapse if the house is not moved or elevated. One other potential method (provided the cost is not prohibitive) is the use of levees and floodwalls designed to withstand flooding depths greater than three feet.

QUESTION III-5

Deep floodwaters can result in significant hydrostatic forces acting on a building. How can these forces result in vertical loads? Why must the designer consider this during the decision making process?

ANSWER III-5

Hydrostatic loads act vertically on a structure when floodwaters are deep enough to float the structure off its foundation or cause slab failure. Once the building is not resting properly on its foundation, it can be subject to twisting or other forces which can result in significant structural damage. Retrofitting measures that eliminate or equalize hydrostatic pressures are applicable in this situation.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Flood Velocity

> The use of existing and historical data can be very useful in analyzing the flood threat. Through interviews with residents, approximate dates of flooding may be established, as well as remembered depths of flooding, types of velocity (moving or standing water), duration of flooding, etc. Once the dates have been established, the designer can check other sources such as newspapers and the National Weather Service for additional information.

The speed at which floodwaters move (flood flow velocity) is normally expressed in terms of feet per second (fps). As floodwater velocity increases, hydrodynamic forces imposed by moving water are added to the hydrostatic forces from the depth of still water, significantly increasing the possibility of structural failure. Hydrodynamic forces are caused by water moving around an object and consist of positive frontal pressure against the structure, drag forces along the sides, and negative pressures on the building's downstream face. Greater velocities can quickly erode, or scour, the soil supporting and/or surrounding buildings. Thus, the impact, drag, and suction from these fast-moving waters may move a building from its foundation or otherwise cause structural damage or failure.

Unfortunately, there is usually no definitive source of information to determine potential flood velocities in the vicinity of specific buildings. Hydraulic computer models or hand computations based on existing floodplain studies may provide flood velocities in the channel and overbank areas. Where current analysis data is not available, historical information from past flood events is probably the most reliable source.

Figure III-7: Fast moving floodwaters caused scour around the foundation and damage to the foundation wall.

QUESTION III-6

In situations of high flood velocity, what are the forces that cause a building to be moved from its foundation?

ANSWER III-6

Hydrodynamic forces imposed by the moving water and hydrostatic forces from the depth of still water combine when floodwater velocity increases, increasing the possibility of structural failure. The impact, drag and suction from the fast-moving waters may move a building from its foundation or otherwise cause structural damage or failure.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Onset of Flooding

> Flash flooding will usually preclude the use of any retrofitting measure that requires human intervention.

In areas of steep topography or those areas with a small drainage area, floodwaters can rise very quickly with little or no warning. This condition is known as flash flooding. High velocities usually accompany these floods and may preclude certain types of retrofitting, especially those requiring human intervention. In a flash flooding situation, damage usually begins to occur within one hour after significant rainfall. If a building is susceptible to flash floods, insufficient warning time can preclude the installation of shields on windows, doors and floodwalls, as well as the activation of pump systems, and back-up energy sources. Temporarily relocating movable contents to a higher level may also be impractical. However, such measures may be effective if a building is not subject to flash flooding and the area has adequate flood warning systems, such as television and radio alerts.

> A detailed hydrograph can provide information on duration of flooding. However, such information is usually not available, and the cost of creating a new study is usually prohibitive. One potential source of information is to check **similarly**-sized drainage basins in neighboring areas to see if historical data exists.

Flood Duration

In areas of long-duration flooding, certain measures such as dry floodproofing may be inappropriate due to the increased chance for seepage and failure caused by prolonged exposure to floodwaters.

QUESTION III-7

Match the following flooding characteristics with their sources of information. Some may have more than one source, and some sources may provide information for more than one characteristic.

Characteristics	Sources
1. Flood Depth	a. historical data
2. Flood Velocity	b. an evaluation of drainage conditions
3. Flood Duration	c. comparisons with similar basins
	d. Flood Insurance Studies (FISs)
	e. a detailed hydrograph
	f. other sources of flood information
	g. no definite source

ANSWER III-7

1. a,b,d,f

2. a,f,g

3. a,c,e

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SITE CHARACTERISTICS

Site characteristics such as location, underlying soil conditions, and erosion vulnerability play a critical role in the determination of an applicable retrofitting method.

Site Location

The floodplain is usually defined as the area inundated by a flood having a 100-year flood frequency. The riverine floodplain is often further divided into a floodway and a floodway fringe.

As defined earlier, the floodway is the portion of the floodplain that contains the channel and enough of the surrounding land to enable floodwaters to pass without increasing flood depths greater than a predetermined amount. If there are high flood depths and/or velocities, this area is the most dangerous portion of the riverine floodplain. Also, since the floodway carries most of the flood flow, any obstruction may cause floodwaters to back up and increase flood levels. For these reasons, the NFIP and local communities prohibit new construction or substantial improvement in identified floodways that would increase flood levels. Relocation is the recommended retrofitting option for a structure located in a floodway. Community and state regulations may prohibit elevation of structures in this area. However, elevation on an open foundation will allow for more flow conveyance than a structure on a solid foundation.

The portion of the floodplain outside the floodway is called the floodway fringe. This area normally experiences shallower flood depths and lower velocities. With proper precautions, it is often possible to retrofit structures in this area with an acceptable degree of safety.

QUESTION III-8

What is the recommended retrofitting option for a structure located in a floodway?

ANSWER III-8

Relocation is the recommended option, but if elevation of structures is not prohibited, an open foundation that allows for unobstructed flood flow is recommended.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

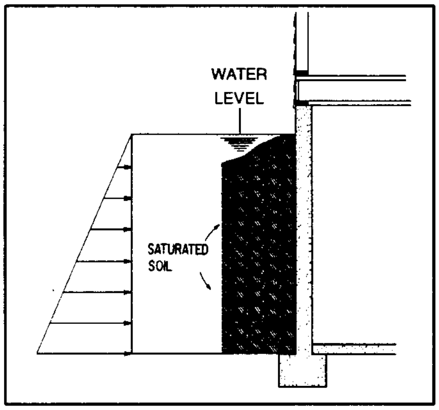


Figure III-8: Lateral Forces Resulting From Saturated Soil

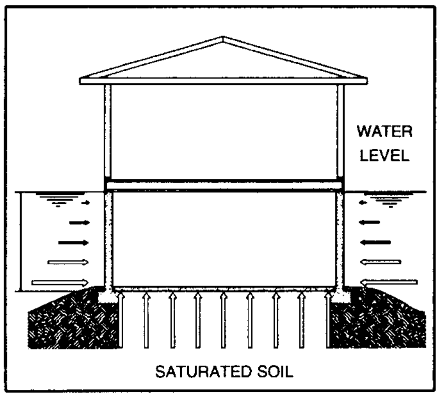


Figure III-9: Buoyancy Forces Resulting From Saturated Soil

> Contact the local office of the Natural Resources Conservation Service (NRCS) or a local geotechnical engineering firm to obtain guidance on the permeability or consolidation features of soils native to the area. Because the site may have been backfilled with non-native materials during original construction, NCRS data should be used carefully.

Soil Type

Permeable soils, such as sand and gravel, are those which allow groundwater flow. In flooding situations, these soils may allow water to pass under floodwalls and levees unless extensive seepage control measures are employed as part of the retrofitting measures. Saturated soil pressure may build up against basement walls and floors. These conditions cause seepage, disintegration of certain building materials, and structural damage. Levees, floodwalls, sealants, shields, and closures may not be effective in areas with highly permeable soil types.

Saturated soils subject horizontal surfaces, such as floors, to uplift forces, called buoyancy. Like lateral hydrostatic forces, buoyancy forces increase in proportion to the depth of water/saturated soil above the horizontal surface. Figures III-8 and III-9 illustrate the combined lateral saturated soil and buoyancy forces.

For example, a typical wood-frame home without a basement or proper anchoring may float if floodwaters reach three feet above the first floor. A basement without floodwater in it could fail when the ground is saturated up to four feet above the floor. Uplift forces occur in the presence of saturated soil. Therefore, well-designed, high-capacity subsurface drainage systems with sump pumps may be an effective solution and may allow the use of dry floodproofing measures.

Other problems with soil saturated by floodwaters need to be considered. If a building is located on unconsolidated soil, wetting of the soil may cause uneven (differential) settlement. The building may then be damaged by inadequate support and subject to rotational, pulling, or bending forces. Some soils, such as clay or silt, may expand when exposed to floodwaters, causing massive forces against basement walls and floors. As a result, buildings may sustain serious damage even though floodwaters do not enter or even make contact with the structure itself.

QUESTION III-9

If a levee is built to protect a house from floodwaters, but the soil the house is built upon is highly permeable, describe other measures which may be taken to ensure that house is adequately protected.

ANSWER III-9

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

The following steps may be taken:

- increase the distance between the house and the levee to lower the phreatic surface;
- install sump pump to lower the phreatic surface;
- install a foundation drainage system (drain tile and/or sump pump) to remove any seepage which gets to the house;
- construct an impermeable subsurface cut-off beneath the levee to cutoff underseepage.

BUILDING CHARACTERISTICS

Ideally, a building consists of three different components: substructure, superstructure, and support services. While the substructure consists of the foundation system, the superstructure consists of the portion of the building envelope above the foundation system. The support services are those elements that are introduced into a building to make it habitable.

These components are integrally linked together to help a building maintain its habitability and structural integrity. Any action that considerably affects one may have a minimal or sometimes drastic effect on the others. An understanding of building characteristics and types of construction involved is therefore an important consideration in deciding upon an appropriate retrofitting measure.

Substructure

> A cracked foundation is one indication of a weak foundation. The use of floodwalls and levees may be the easiest and most practical approach to retrofitting a structure with a poor foundation. Another solution may be an entire relocation of the building's superstructure on a new foundation.

The substructure of a building supports the building envelope. It includes components found beneath the earth's surface, as well as above-grade foundation elements. This system consists of both the vertical foundation elements such as walls, posts, piles, and piers, which support the building loads and transmit them to the ground, and the footings that bear directly on the soil.

At any given time, there are a number of different kinds of loads acting on a building. The foundation system transfers these loads safely into the ground. In addition to dead and live loads, retrofitting decisions must take into account the buoyant uplift thrust on the foundation, the horizontal pressure of floodwater against the building, and any loads imposed by multiple hazards such as wind and earthquake events.

The ability of a foundation system to successfully withstand these and other loads or forces, directly or indirectly, is dependent to a large extent on its structural rigidity. A designer should determine the type and condition of a building's foundation system early in the retrofitting evaluation.

Retrofitting of structures with basements is not covered in this manual.

All foundations are classified as either shallow or deep. Shallow foundations consist of column and wall footings, slab-on-grade, crawl space, and basement substructures; deep foundations include piles. Even though each of these foundation types may be utilized either individually or in combination with others, most residential buildings located outside coastal high hazard areas are supported on shallow foundations. Each type has its own advantages and limitations when retrofitting measures are being evaluated. Whichever is used in a building, a designer should carefully check for the structural soundness of the foundation system.

Basement walls may be subject to increased hydrostatic and buoyancy forces; thus, retrofitting a building with a basement is often more involved and costly.

Superstructure

The superstructure is the portion of the building envelope above the foundation system. It includes walls, floors, roof, ceiling, doors, and other openings. A designer should carefully and thoroughly analyze the existing conditions and component parts of the superstructure to determine the best retrofitting options available. Flood- and non-flood-related hazard effects should also be considered; the uplift, suction, shear, and other pressures exerted on building and roof surfaces by wind and other environmental hazards may be the only reasons needed to rule out elevation as a retrofitting measure.

Support Services

These are elements that help maintain a human comfort zone and provide needed energy, communications, and disposal of water and waste. For a typical residential building, the combination of the mechanical, electrical, telephone, cable TV, water supply, sanitary, and drainage systems provides these services. An understanding of the nature and type of services used in a building is necessary for a designer to be able to correctly predict how they may be affected by retrofitting measures.

For example, the introduction of new materials or the alteration of a building's existing features may require resizing existing services to allow for the change in requirements. Retrofitting may also require some form of relocated duct work and electrical rewiring. Water supply and waste disposal systems may have to be modified to prevent future damage. This is particularly true when septic tanks and groundwater wells are involved. If relocation is being considered, the designer must consider all these parameters and weigh the cost of repairs and renovation against the cost of total replacement.

QUESTION III-10

1. Mark the following descriptions with the appropriate building characteristic of

   a. superstructure,

   b. substructure, or

   c. support services.

_________1. above grade building envelope components

_________2. supports the building envelope

_________3. footings that bear directly on the soil

_________4. sanitary and drainage systems

_________5. building envelope support components both below and above grade

_________6. includes roofs, ceilings, and doors

_________7. helps maintain a human comfort zone

_________8. vertical foundation elements

ANSWER III-10

1. superstructure
2. substructure
3. substructure
4. support services
5. substructure
6. superstructure
7. support services
8. substructure

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Building Construction

For general consideration of retrofitting measures, all construction should be classified as wood material unless all walls and foundations are concrete and masonry.

Modern buildings are constructed with a limitless palette of materials integrated into various structural systems. A building may be constructed with a combination of various materials. Thus, the suitability of applying a specific retrofitting measure may be difficult to assess.

Concrete and masonry construction may be considered for all types of retrofitting measures, whereas other materials may not be structurally sound or flood-damage resistant and therefore not suitable for some measures. When classifying building construction as concrete and masonry, it is important that all walls and foundations be constructed of this material. Otherwise, there may be a weak link in the retrofitting measure, raising the potential for failure when floods exert hydrostatic or hydrodynamic forces on the structure.

Masonry-veneer-over-wood-frame construction must be identified since wood-frame construction is less resistant to lateral loading than a brick-and-block wall section.

QUESTION III-11

What two categories describe the materials of which the building is constructed? When should the designer apply each category?

ANSWER III-11

Masonry-and-concrete and wood. A building should be classified as wood unless all walls and foundations are concrete and masonry.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Building Condition

Typically, a designer will begin a retrofitting project with an initial analysis of the present conditions. Decisions based on early findings may be revised after a more detailed analysis.

A building's condition may be difficult to evaluate, as many structural defects are not readily apparent. However, careful inspection of the property should provide for a classification of "excellent to good" or "fair to poor." This classification is only for the reconnaissance phase of selecting appropriate retrofitting measures. More in-depth planning and design may alter the initial judgment regarding building condition, thereby eliminating some retrofitting measures from consideration at a later time.

Analysis of a building's substructure, superstructure, and support services may be done in two stages--an initial analysis, usually based on visual inspection, and a detailed analysis, which is often more informative, involves greater scrutiny, and usually requires detailed engineering calculations.

In the course of an analysis, a designer should visually inspect the walls, floors, roof, ceiling, doors, windows, and other superstructure and substructure components. Walls should be examined for type of material, structural stability, cracks, and signs of distress. A crack on a wall or dampness on concrete, plaster, wood siding, or other wall finishes may be a sign of concealed problems. Doors, windows, skylights, and other openings should be checked for cracks, rigidity, structural strength, and weather resistance.

Metal-clad wood doors or panel doors with moisture-resistant paint, plastic, or plywood exterior finishes may appear fine even though the interior cores may be damaged. Aluminum windows may be checked for deterioration due to galvanic action or oxidation from contact with floodwater. Steel windows may be damage-free if they are well protected against corrosion. Wood windows require inspection for shrinkage and warping, and for damage from moisture, mold, fungi, and insects.

Flooring in a building covers a vast range of treatments. It involves the use of virtually every material that can be walked upon, from painted concrete slabs to elegant, custom-designed wood parquet floors. A designer should investigate the nature of both the floor finishes and the underlying subfloor. Vinyl or rubberized plastic finishes may appear untouched due to their resistance to indentations and water; however, the concrete or wood subfloor may have suffered some damage. Likewise, a damage-free subfloor may be covered with a scarred finish.

An initial analysis of the conditions of the roof and ceiling of a building can be done by observation during the early decision-making stage. An understanding of the materials and construction methods will be necessary at a later date to evaluate fully the extent of possible damage and need to retrofit. The roofs over most residential buildings consist of simple to fairly complex wood framing that carries the ceilings below and plywood roof decks above, over which the roof finishes are placed. Finish materials include asphalt, wood, metal, clay and concrete tile, asbestos, and plastic and are available in various compositions, shapes, and sizes. In some cases, observation may be enough to determine the suitability, structural rigidity, and continuing durability of a roof system. However, it may be necessary to pop up a ceiling tile, remove some shingles, slate, or roof tiles, or even bore into a roof to achieve a thorough inspection.

The inspection also determines if the building materials and component parts are sound enough for the building to undergo either elevation, relocation, or wet or dry floodproofing easily. If not, floodwalls or levees around the structure may be the best alternative if allowable.

Figure III-10 presents a template that a designer can use to document findings during the initial building condition survey.

Owner Name: ______________________	**Prepared By:** __________________
Address: __________________________	**Date:** _________________________
Property Location: ____	

Preliminary Building Condition Evaluation Worksheet

Building Components	Condition		Notes and Materials
	Excellent to Good	Fair to Poor	
Substructure Footings Foundation Foundation Walls Other ____________			
Superstructure Floors Walls Ceilings Doors Windows Roof Other ____________			
Support Services Heating System Plumbing System Air Conditioning System Water Supply Sewage Other ____________			
Comments			

Figure III-10: Preliminary Building Condition Evaluation Worksheet

QUESTION III-12

1. List components of a building which a designer should check during the initial inspection of the structure's condition.

2. What are four indications of strength or weakness of the components that a designer should look for?

ANSWER III-12

1. Walls, doors, windows, flooring, and roof

2. Cracks, rigidity, structural strength, and weather resistance

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

BALANCING HISTORIC PRESERVATION INTERESTS WITH FLOOD PROTECTION

Many historic building features were developed, either deliberately or intuitively, as responses to natural and environmental hazards, and to local climate or topography. Recognizing how and why these features were intended to work can help in designing a program of preventive measures that is historically appropriate and that minimizes incongruous modifications to historic residential properties.

There are retrofitting steps that will not have a negative or even significant impact upon the historic character of a site or its particular features. Preventive measures can be carried out without harming or detracting from historic character, as long as design and installation are carefully supervised by a professional knowledgeable in historic preservation.

There may well be instances, however, when a measure that best protects the site also may result in some loss of historic character. In such a case, the designer and the owner will have to weigh the costs of compromising character or historic authenticity against the benefits of safeguarding the site or a particular site feature against damage or total destruction. One example of such a choice is the decision whether to elevate a historic structure located in a flood hazard area, relocate it out of the area, retrofit it with wet or dry floodproofing techniques, or leave it in its existing state to face the risks of damage or loss. It is difficult to prescribe a formula for such a decision, since each situation will be unique, considering location, structural or site conditions, the variety of preventive alternatives available, cost, and degree of potential loss of historic character. Here are some questions the designer may wish to pose in deliberating such a decision:

- What is the risk that the historic feature or the entire site could be totally destroyed or substantially damaged if the preventive measure is not taken? If the measure is taken, to what degree will this reduce the risk of damage or total destruction?

- Are there preventive alternatives that provide less protection from flood damage but also detract less from historic character? What are these, and what is the trade-off between protection and loss of character?

- Is there a design treatment that could be applied to the preventive measure to lessen detraction of historic character?

QUESTION III-13

What important trade-off do designers face when working with retrofitting historic buildings? How might this be overcome?

ANSWER III-13

The trade-off is between historical character and protection of the structure. This could be overcome by opting not to retrofit the building or by adopting design elements which will maintain the historical character.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

MULTIPLE HAZARDS

> It is important to consider these multiple hazards when screening and selecting a retrofitting measure. However, the designer should be aware that structures can be engineered to withstand these multiple hazards, and the existence of these hazards alone may not justify the elimination of specific homeowner-preferred retrofitting methods. The local building codes normally contain additional guidance concerning natural hazard-resistant design and construction practices.

The selection of a retrofitting method may expose the structure to additional non-flood environmental hazards that could jeopardize the safety of the structure. These multiple hazards can be accommodated through careful design of the retrofitting measures or may necessitate selection of a different retrofitting method. Multiple hazards include both flood-related and non-flood-related hazards.

The significant flood-related hazards to consider include ice and debris flow, impact forces, erosion forces, and mudslide or alluvial fan impacts. The major non-flood-related hazards to consider include earthquake and wind forces. Less significant hazards include land subsidence, fire hazards, snow loads, movable bed streams, and closed basin lakes. Multihazards may affect a structure independently, as with flood and earthquakes, or concurrently, as with flood and wind in a coastal area.

Flood-Related Hazards

IMPACT FORCES – ICE AND DEBRIS FLOW

In colder climates, floodwaters may carry chunks of ice that can act as a battering ram on a structure. During a flood, ice can also form around the structure. Rising floodwaters can lift a structure, resulting in severe damage. Flash and high-velocity floodwaters often carry debris such as cars, sheds, boulders, rocks, and trees that can destroy most retrofitting measures as well as the structure itself.

Retrofitting measures suitable for areas of ice and debris flow may include elevation on fill, relocation, levees, and armored floodwalls.

EROSION FORCES

If a soil is highly erodible, fast-moving floodwaters can undermine foundations and cause building, levee, or floodwall failures. The consideration of soil erosion is critical when retrofitting a building located in the floodplain. With the exception of deep foundation systems such as piles, shallow foundation systems generally do not provide sufficient protection against soil erosion without some type of protection or armoring measure of below-grade elements. The local office of the Natural Resources Conservation Service (NRCS) will generally have information concerning the erodibility of the soils native to a specific site.

ALLUVIAL FANS

Because of the potential for high flood velocities, significant debris flow, and varying channel locations, alluvial fans present many unique challenges. In the upper portions of the fan the only feasible retrofitting technique may be relocation. However, on lower portions of the fan where the flood velocities and depths are low, several options may be available.

FEMA is currently involved in an interagency task force developing earthquake-resistant design standards in the wake of recent disasters. For additional information contact FEMA's Mitigation Directorate or the appropriate Regional FEMA office.

Non-Flood-Related Hazards

EARTHQUAKE FORCES

Earthquake protection steps can be divided into two categories: steps that deal with the building structure itself, and steps that can be taken with other parts of the building and its contents.

Strengthening an existing masonry block foundation wall can be complicated and normally requires the expertise of a designer knowledgeable in this type of work. The local building codes may contain additional guidance concerning earthquake-resistant design and construction materials.

The most important step for the structure is making sure that it is properly bolted down onto its foundation so it will not slide off in an earthquake. Another important step, especially if the foundation is being raised to place the structure above flood levels, is to make sure the foundation can withstand an earthquake. For masonry block foundations, this usually means strengthening key portions of the wall by installing reinforcing bars in the blocks and then filling them with concrete grout.

WIND FORCES

High winds impose forces on a home and the structural elements of its foundation. Damage potential is increased when the wind forces occur in combination with flood forces. In addition, as a structure is elevated to minimize the effects of flood forces, the wind loads on the elevated structure may be increased.

A conventional structure is normally built to resist vertical downward loads (its own weight) plus live loads (contents, people) on the floor as well as appropriate snow and wind loads on the roof. Occasionally, structural elements are laid on top of each other with minimal fastening. However wind forces can be upwards, or from any direction exerting considerable pressure on structural components such as walls, roofs, connections, and anchorage. Therefore, wind loads should be considered in the design process at the same time as hydrostatic, hydrodynamic, and impact dead and live loads as prescribed under the applicable codes.

QUESTION III-15

Identify the following statements as true or false.

1. Along with hydrostatic, hydrodynamic, impact, and dead and live loads, wind and seismic forces should be considered in the design process. Certain retrofitting measures, such as elevation, can cause wind and earthquake forces to have greater influence on the structure.

2. Uplift forces resulting from ice forming around a building and rising on floodwaters is one way in which ice can damage a building, while floating ice floes are not as important to consider.

3. The high velocity of floodwaters in the upper part of an alluvial fan necessitates elevation as a retrofitting measure.

ANSWER III-15

1. True

2. False

3. False

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SUMMARY QUESTIONS

Congratulations! You have completed the text review of Chapter III, Parameters of Retrofitting. All that remains to complete this segment of the Independednt Study Course is to answer and check the Summary Questions that follow.

1. Toward the beginning of the retrofitting process, the designer meets with the homeowner, then conducts a site visit. What are two aspects of the structure about which the designer should gather information during the site visit? How will identifying these help the designer?

2. Describe a local code requirement which may require expensive structural modifications or necessitate a change in the retrofitting measure selected.

3. How do flood velocity, depth, onset of flooding, and duration affect retrofitting choices? Which specific options does each point to or rule out and why?

4. After conducting the first site visit, the designer will want to research characteristics of the land around the structure. Relate these characteristics to flood velocity and depth.

5. The three main components of a building are subject to different aspects of weather and flooding forces. For each component, indicate the flood-related or non-flood related hazards which affect each and how they do so.

SUMMARY QUESTION ANSWERS

Your answers should contain the key points in the answers below.

1. Knowing the *Low Point of Entry* allows the base designer to find the flood protection elevation which, with the potential base flood elevation, indicates the vulnerability of the building. Finding the elevation of the lowest floor, a part of the Lowest Point of Entry Determination, will allow the designer to assess the flood threat. Openings to be protected through dry floodproofing will be identified as well. The *overall condition of the structure* will give the designer an idea about how easily the building might be relocated or elevated.

2. The NFIP substantial improvement/substantial damage requirement to bring a structure into compliance with current floodplain management regulations can have a significant impact on the cost and selection of a retrofitting measure.

3. Flood depth: if the flood is deeper than three feet, hydrostatic forces often rule out dry floodproofing. Elevation and relocation are probably the wisest choices although levees and floodwalls might also be viable.

   Flood velocity: the lateral movement of floodwaters introduces hydrodynamic forces. Elevation on an open system, one designed to withstand such forces, is a better selection than dry floodproofing or levees (which can be eroded more quickly). Elevation on walls running parallel to the direction of the flow can also be used.

   Onset of flooding: long duration can eliminate dry floodproofing or levees and floodwalls because of significant seepage and underseepage.

   Flood duration: in flash flood situations human intervention is usually not feasible, but elsewhere it may be an appropriate choice.

4. The location and the soil surrounding the structure are important factors in the design process. If the structure is located in the floodway, the floodwaters are often be relatively deep and fast. Elevation on an open foundation with strong supports and relocation are therefore most likely the best options. In the floodway fringe shallower and slower floodwater

is more common so that elevation on either an open or closed foundation may be possible. Relocation would still be an option, as might wet floodproofing.

Permeable soil plays a role in the decision-making process, particularly where soils are inundated by floodwater for a long duration. Floodwalls and levees are not appropriate choices when the surrounding soil is permeable to such a degree that seepage and/or underseepage is significant. Buoyancy forces from permeated soil could eliminate the use of dry floodproofing, even more so in cases where there is no adequate drainage system to relieve hydrostatic pressure.

5. Earthquakes can have a strong impact if the soil beneath or near the house is moved so that the foundation is cracked or damaged. Erosion around a substructure can leave the building vulnerable to more damage by floods, particularly if fast floodwaters carry away the soil around a slab-on-grade building and the foundation shifts or slides. Ice forming around the structure and lifting it can inflict costly and destabilizing damage on the substructure.

   The superstructure is more susceptible to wind forces than is the substructure. Uplift, shear, and suction are just some of the possible pressures that wind can place on the superstructure. Uplift from ice can cause cracks and splits, and twisting from a floating foundation may do significant damage to the superstructure as well.

   The support services can be affected by any number of flood-related and non-flood related hazards. External services, such as an air conditioner, may be damaged by wind forces or impact forces from floating debris.