6 Case Studies

This chapter presents case studies based on structural and nonstructural retrofitting measures. The studies illustrate many of the procedures presented in the previous chapters and actual design practices. The cases include scenarios that examine elevation, relocation, dry and wet floodproofing, and small floodwalls and levees.

The case studies that follow are fictionalized scenarios developed to illustrate the retrofit option selection and design process. Narratives, graphics, photos, and calculations are fabricated and not based on actual individuals or structures.

6.1 Case Study #1: Residential Retrofit in Riverine Floodplain Using Elevation or Relocation

This case study examines the retrofit of a residential building in a riverine floodplain by means of elevation or relocation. Details are provided in the subsections that follow.

6.1.1 Description of Property

Harry S. Truman
55555 Cedar River Road, Mount Vernon, IA 55555

The Truman family has owned a large plot of land near Mount Vernon, Iowa, since the early 20th century. The 200+ acre plot slopes up from the Cedar River to a hilly, wooded area. Their current home, a one-story, wood-frame structure, was built in the 1960s, and is considered pre-FIRM construction. It has experienced varying levels of flooding from the Cedar River since its construction. A sunroom addition was built onto

the back of the structures in the 1980s. The structure is located in the SFHA (100-year floodplain) but, due to the sloping nature of the site, most of the rest of the plot is located outside the SFHA.

Harry Truman, the current owner, has decided that he would like to retrofit his home to resist flood damage. The local floodplain ordinance does not allow elevation on fill, and he does not like the idea of an open foundation. Mr. Truman indicated he would like to pursue retrofitting options that would allow him to obtain a reduced NFIP flood insurance rate. If possible, Mr. Truman would like to apply for HMA grant assistance.

6.1.2 Structure Information

55555 Cedar River Road is a one-story, wood-frame structure on a crawlspace and is a structure of good quality (Figure 6-1).

Other structure information includes:

- Footprint: 1,800 square feet
- Foundation:
  - Perimeter crawlspace foundation walls are reinforced and grouted CMU block, 8 inches thick, supported by a 2-foot wide x 1-foot thick reinforced concrete wall footer
  - Twelve interior piers at 10-foot spacing are reinforced and grouted double-stack CMU block, supported by 2-foot x 2-foot x 1-foot footer
  - Perimeter foundation walls and interior piers extend 2 feet below grade to the top of the footers, and 2 feet above grade
  - There are no flood vents in the above-grade portion of the perimeter foundation walls
- Structure:
  - First floor elevation of 694.2 feet (reference NAVD88), measured at the top of the lowest finished floor
  - Top of crawlspace of 692.2 feet (reference NAVD88)
  - Wood-frame structure
  - Wood siding
  - Wood-frame interior walls with gypsum board sheathing
- Roof:
  - Gable roof without overhangs over main structure (40 foot x 40 foot plan area)
  - Flat roof without overhangs over sunroom (10 foot x 20 foot area)
  - Asphalt shingle roof covering over entire roof
- Interior:
  - Wood stud interior walls with gypsum board sheathing
  - Hardwood floors

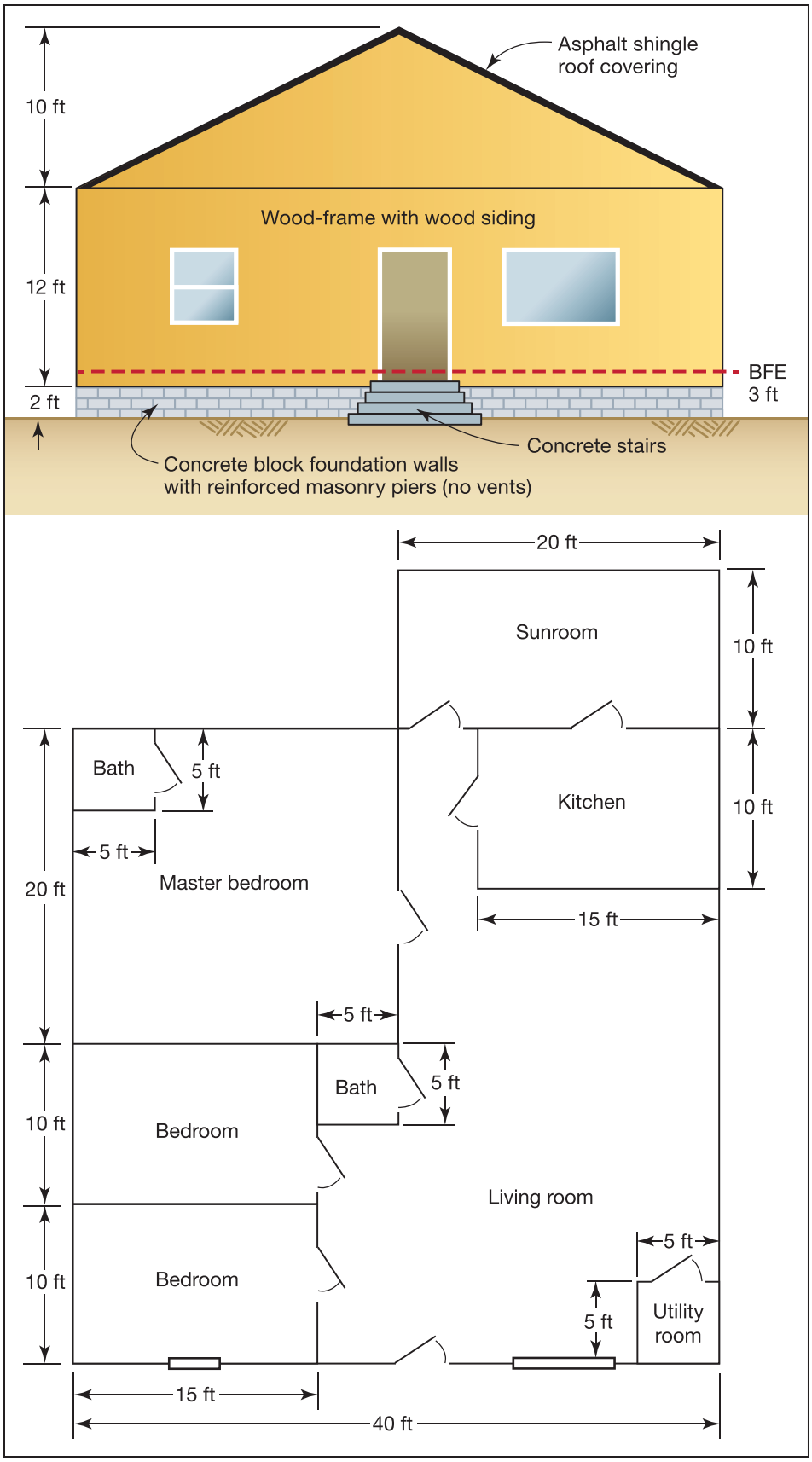


Figure 6-1.
The Truman house

Plot

The 200+ acre plot slopes from an elevation of approximately 690 feet near the river to near 730 feet in the woods. The 10-foot contour map shows the approximate size and topography of the plot and is included at the end of this case study. The site soils are primarily a mixture of silty sand and gravel (Soil Type SM).

Building Assessment

An updated tax card is included at the end of this case study as an alternate source of the building replacement value as well as to verify the building square footage data.

Additionally, an engineer's estimate is that the Truman home has a building replacement value of approximately $105.00 per square foot, based on popular cost estimating guides.

Flood Hazard Data

The local floodplain management ordinance applies to all structures in the floodplain. Elevation on fill is prohibited, and a 1-foot freeboard is required for all new construction and substantial improvements.

The structure itself sits at the low point of the property and is in the SFHA, although most of the plot is outside of the regulatory floodplain. The flood map (FIRMette) is included at the end of this case study.

The applicable excerpts from the FIS show the flood elevations and discharges for the existing structure and are included in Section 6.1.5 and summarized in Table 6-1.

Table 6-1. Summary of Flood Elevations and Discharges for the Truman House

	Streambed	10-year	50-year	100-year	500-year
Elevation (ft)	671.2	694	696.3	697.8	700
Discharge (cfs)	NA	53,500	77,900	87,900	112,900

cfs = cubic feet per second

Note: All topographic maps and flood hazard data reference NAVD88.

A licensed surveyor filled out the elevation certificate, which references NAVD88 and is included at the end of this case study.

Note that since there are no flood vents, the top of the lowest floor is considered to be the top of the crawlspace floor. In this case, the top of the crawlspace floor is equivalent to the LAG.

The flow velocity under base flood conditions is assumed to be 2.0 ft/sec.

6.1.3 Retrofit Options Selection

During an initial interview with Mr. Truman, potential retrofit options were discussed (Figure 6-2). Immediately, elevation on fill was ruled out because it is prohibited by the local floodplain ordinance. Similarly, dry floodproofing, wet floodproofing, and floodwalls and small levees were ruled out because these measures will not bring a pre-FIRM home located in a SFHA into compliance with the NFIP. Therefore, elevation and relocation are viable options for the structure and will reduce NFIP flood insurance rates.

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

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
Floodproofing Measures									
Measure Allowed or Owner Requirement		X					X	X	X
Homeowner Concerns									
Aesthetic Concerns			X	X	X				
High Cost Concerns	X		X	X	X	X			
Risk Concerns									
Accessibility Concerns	X		X	X	X				
Code Required Upgrade Concerns									
Off-Site Flooding Concerns									
Total "X's"	**2**	**NA**	**3**	**3**	**3**	**1**	**NA**	**NA**	**NA**

Instructions: Determine whether a floodproofing measure is allowed under local regulations or homeowner requirement. Put an "x" in the box for each measure that 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 that would affect its implementation. A concern is defined as a homeowner issue that, 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 6-2. Preliminary Floodproofing/Retrofitting Preference Matrix for the Truman house

Cost was a concern for all potential retrofit options. Mr. Truman was also concerned about building accessibility for an elevation project. Mr. Truman was particularly concerned about how his home might look with an open foundation.

Based on the retrofit option screening matrix, the two most viable options were elevation by extending the foundation walls and relocation. Calculations and considerations are provided for both relocation and elevation.

Relocation

The only way to completely eliminate the flood risk to Mr. Truman's home is to move the entire structure out of the SFHA. Because his plot is so large, and ample buildable space exists outside of the SFHA, relocation is a good option to consider. Refer to Table 1-2 of this document for the advantages and disadvantages of relocation. The relocation process would include:

- selecting the new structure site;
- designing, excavating for, and constructing the new foundation;
- installing new utility connections at the new site;
- disconnecting utilities at the existing site;
- lifting the existing structure on hydraulic jacks;
- transporting the structure from the original site to the new site;
- lowering the structure and securing it onto the new foundation ;
- connecting utilities; and
- demolishing and filling the old foundation.

A preliminary cost estimate shows that the cost of relocation would likely be approximately $120,000. A preliminary BCA shows a BCR of 1.18. Therefore, relocation would be cost-beneficial as well as effective at eliminating future flood damage.

Elevation by Extending the Perimeter Foundation Walls

Elevating the structure on the existing perimeter foundation walls is also a viable retrofit option. Refer to Table 1-1 of this document for the advantages and disadvantages of elevation. The elevation process would include:

- designing the extended foundation;
- disconnecting utilities;
- lifting the existing structure on hydraulic jacks;
- extending the foundation walls;

- installing flood vents;
- lowering the structure;
- reconnecting utilities; and
- constructing a new deck and stairs.

The BFE is 697.8 feet NAVD88, and the first floor elevation (i.e., the top of the lowest floor) is 694.2 feet. The elevation of the LAG is 692.2 feet. The BFE is at a depth of 697.8 feet – 692.2 feet = 5.6 feet. Therefore, the floodproofing depth H = 5.6 feet + 1 feet = 6.6 feet.

Installing NFIP-compliant flood vents in the foundation walls will ensure that the crawlspace is no longer considered the "lowest floor" and that the lowest floor elevation will actually be the top of the floor of the living area. Because the crawlspace is already 2 feet high, the perimeter walls would only need to be extended an additional 4.6 feet to place the first floor elevation 1 foot above the BFE (i.e., 6.6 feet above the LAG).

A preliminary cost estimate shows a retrofit cost of approximately $100,000. This cost yields a BCR of 1.08. Therefore, elevation would be effective and cost-beneficial.

The elevated structure would look as shown in Figure 6-3. A hydrostatic force computation worksheet is presented in Figure 6-4.

Note that the concrete staircase has been replaced with wooden stairs that allow water to flow through the base.

To ensure that the foundation is properly designed, the flood forces must be calculated and checked with applicable design loads.

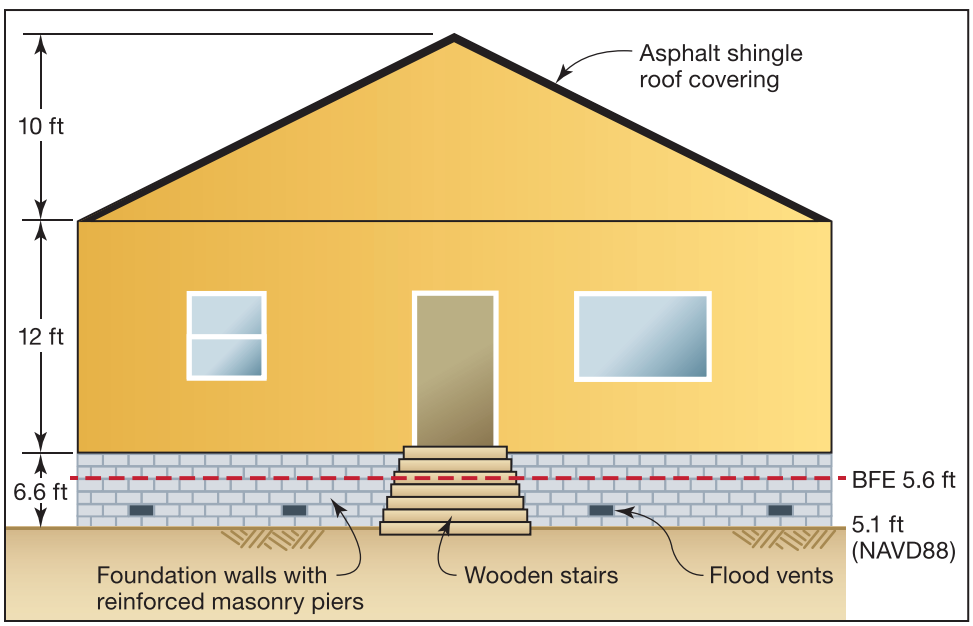


Figure 6-3. The Truman house after elevation, including extended foundation walls and flood vents

Hydrostatic Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Constants

γ_w = specific weight of water = 62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater

Variables

H = floodproofing design depth (ft) = 6.6 ft

D = depth of saturated soil (ft) = 2 ft

S = equivalent fluid weight of saturated soil (lb/ft^3) = NA

Vol = volume of floodwater displaced by a submerged object (ft^3) = 2,167 ft^{3,a}

Summary of Loads

f_{sta} = 0 lb/ft

f_{dif} = 0 lb/ft

f_{comb} = 0 lb/ft

F_{bouy} = 135,236 lb

Equation 4-4: Lateral Hydrostatic Force

$$f_{sta} = \frac{1}{2}P_h H = \frac{1}{2}\gamma_w H^2 = 0 \text{ lb/ft}$$

Equation 4- 5: Submerged Soil and Water Force

$$f_{dif} = \frac{1}{2}(S - \gamma_w)D^2 = 0 \text{ lb/ft}$$

Equation 4-6: Combined Lateral Hydrostatic Force

$$f_{comb} = f_{sta} + f_{dif} = 0 \text{ lb/ft}$$

Equation 4-7: Buoyancy Force

$$F_{buoy} = \gamma_w(Vol) = (62.4 \text{ lb/ft}^3)(2{,}167 \text{ ft}^3) = 135{,}236 \text{ lbs}$$

[a] Volume of water displaced is equal to the volume of the foundation walls, footers, floor system, and interior piers:

Walls: Perimeter = 40 ft + 40 ft + 40 ft + 10 ft + 20 ft + 10 ft + 20 ft = 180 ft; height = 4 ft (above grade) + 2 ft (below grade) = 6 ft; thickness = 16 in = 1.33 ft; 6 corners subtract 6(1.33 ft)(1.33 ft)(6 ft) = 63.7 ft^3; vents: 1 in^2 of open area for 1 ft^2 of enclosed area 1800 in^2 of open area 12.5 ft^2 of open area subtract 1.33 ft * 12.5 ft^2 = 16.6 ft^3

V_{walls} = (180 ft)(6 ft)(1.33 ft) – 6(1.33 ft)(1.33 ft)(6 ft) – (12.5 ft^2)(1.33 ft) = 1,355.7 ft^3

Footers: Perimeter = 180 ft; width = 2 ft; thickness = 1 ft; corners subtract 6(2 ft)(2 ft)(1 ft) = 24 ft^3

$V_{footers}$ = (180 ft)(2 ft)(1 ft) – 6(2 ft)(2 ft)(1 ft) = 336 ft^3

Floor: The floor joists and subfloor must be included in Zone A because the top of the lowest floor is at 4 ft. 2 in.x10 in. floor joists at 16 in. o.c (40 ft x12 in./ft)/16 in. ≈ 30 joists in main structure. Volume of one joist in main structure = 2 in. x (ft/12 in.) x 10 in. x (ft/12 in.) x 40 ft = 5.56 ft^3. In sunroom, (20 ft x 12 in./ft)/16 in. = 15 joists. Volume of one joist in sunroom = 2 in. x (ft/12 in.) x 10 in. x (ft/12 in.) x 10 ft = 1.39 ft^3. Total volume of joists = 30 x 5.56 ft^3 + 15 x 1.39 ft^3 = 187.65 ft^3. Subfloor 0.5 in. plus 0.25 in. hardwood floor volume of floor = (0.5 in. + 0.25 in.) x (1 ft/12 in.) x 1800 ft^2 = 112.5 ft^3

V_{slab} = 187.65 ft^3 + 112.5 ft^3 = 300.15 ft^3

Interior Piers: 12 piers. Each 16 in^2, 6 ft tall with a 2 ft x 2 ft x 1 ft footer.

V_{piers} = 12(1.33 ft)(1.33 ft)(6 ft) + 12(2 ft)(2 ft)(1 ft) = 175.4 ft^3

$V_{water} = V_{walls} + V_{footers} + V_{slab} + V_{piers}$ = 1,355.7 ft^3 + 336 ft^3 + 300.15 ft^3 + 175.4 ft^3 = 2,167 ft^3

Figure 6-4. Hydrostatic Force Computation Worksheet for the elevated Truman house (refer to Figure 4-9)

6.1.4 Load Calculations

The following paragraphs provide calculations for flood loads, dead loads, live loads, and load combinations, as well as bearing capacity, sliding, uplift, and overturning checks associated with the elevation option.

Load Calculations: Flood Loads

The first step is to calculate hydrostatic forces. As determined above, the floodproofing depth H is 4 feet. The perimeter wall extends 2 feet underground and is supported by a 1-foot-deep footer; therefore, the saturated soil depth D (measured from the ground surface to the top of the footer) is 2 feet (see Figure 4-8). Because openings were installed in the crawlspace, there are no hydrostatic forces.

The flow velocity is 2.0 ft/sec. An equivalent hydrostatic force computation worksheet is presented in Figure 6-5.

Equivalent Hydrostatic Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Constants

γ_w = specific weight of water = 62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater

g = acceleration of gravity = 32.2 ft/sec^2

Variables

H = design floodproof depth (ft) = 6.6 ft

V = velocity of floodwater (10 ft/sec or less) = 2 ft/sec

P_{dh} = hydrostatic pressure due to low velocity flood flows = (lb/ft^2)

b = width of structure perpendicular to flow (ft) = 40 ft

Summary of Loads

f_{dh} = 40.0 lb/ft

f_{sta} = 0 lb/ft

f_{dif} = 0 lb/ft

f_{comb} = 19.38 lb/ft

Equation 4-8: Conversion of Low Velocity Flood Flow to Equivalent Head

$$dh = \frac{C_d V^2}{2g} = (1.25)(2\text{ ft/sec})^2/(2)(32.2\text{ ft/sec}^2) = 0.0776\text{ ft}$$

Develop C_d: b/H = 40 ft/4 ft = 10 From Table 4-5; C_d = 1.25

Equation 4-9: Conversion of Equivalent Head to Equivalent Hydrostatic Force

$$f_{dh} = \gamma_w (dh) H = P_{dh} H = (62.4\text{ lb/ft}^3)(0.0776\text{ ft})(6.6\text{ ft}) = 40.0\text{ lb/ft}$$

Equation 4-10: Combined Lateral Hydrostatic Force

$$f_{comb} = f_{sta} + f_{dif} + f_{dh} = 0\text{ lb/ft} + 0\text{ lb/ft} + 40.0\text{ lb/ft}$$

Figure 6-5. Equivalent Hydrostatic Force Computation Worksheet for the Truman house (refer to Figure 4-11)

The design flood depth is 4 feet; therefore, C_D = 0.75. C_B = 1.0. An impact force computation worksheet is presented in Figure 6-6.

Impact Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Variables

W = weight of the object (lb) = 1,000 lbs

V = velocity of water (ft/sec) = 2 ft/sec

C_D = depth coefficient (see Table 4-6) = 0.75

C_B = blockage coefficient (taken as 1.0 for no upstream screening, flow path greater than 30 feet; see Table 4-7 for more information)

C_{Str} = building structure coefficient

= 0.2 for timber pile and masonry column supported structures 3 stories or less in height above grade

= 0.4 for concrete pile or concrete or steel moment resisting frames 3 stories or less in height above grade

= 0.8 for reinforced concrete foundation walls (including insulated concrete forms)

Summary of Loads

F_i = 1,200 lbs

Equation 4-13: Normal Impact Loads

$$F_i = W\,V\,C_D C_B C_{Str} = (1000 \text{ lbs})(2 \text{ ft/sec})(0.75)(1)(0.8) = 1{,}200 \text{ lbs}$$

Figure 6-6. Impact Force Computation Worksheet for the Truman house (refer to Figure 4-12)

Flood Force Summary:

Horizontal Force:

f_{comb} = 40.0 lb/lf

F_i = 1,200 lbs

The total flood force acting on the front wall (perpendicular to flow) is:

F = (40.0 lb/lf)(40 ft) + 1,200 lbs= 2,800 lbs

Vertical Force:

F_{buoy} = 135,236 lbs

Load Calculations: Dead Loads

The dead load is the self-weight of the structure. Table 6-2 illustrates the dead load calculations using the conservative unit weights listed in Chapter 4 as well as a less conservative approach.

Table 6-2. Summary of Dead Load Calculations for the Truman House

Element	Area (ft^2)	Chapter 4 Unit Weight (lb/ft^2)	Chapter 4 Total Weight (lbs)
Exterior walls: drywall, 4 in. batt insulation, wood siding	(4)(40 ft)(12 ft) + (2)(10 ft)(12 ft) = 2,160	11	23,760
Interior walls: wood stud, 2 ft x 4 ft, ½ in. drywall	(12)(5+5+20+20+15+10+10+5+5+10+15 +10) = 1,560	8	12,480
Floor frame: wood frame, 2 ft x 10 ft interior, unfinished floor	1,800	10	18,000
Floor cover: hardwood	1,800	3	5,400
Ceiling: drywall	1,800	10	18,000
Roof: sloping timbers, sheathing, 10 in. batt insulation	(2)(40)(102 + 202)1/2 + (10)(20) = 1,992[a]	15	29,880
Roof cover: asphalt shingles	1,992	4	7,968
TOTAL	**Over the 1,800 ft^2 structure**	**61**	**115,488**

[a] Roof area is taken to be the area of the sloping sections of the roof, calculated as twice the area of one side of the roof. Each side of the roof is taken to be rectangular, with dimensions of 40 ft (along the base) and [(10)2 + (20)2]1/2 = 22.4 ft (the hypotenuse of the triangle formed by the vertical section of the roof structure).

[b] Foundation walls are considered to be a single layer, reinforced CMU wall (8-in. thick) with a unit weight of 75 lb/ft^2. Walls after mitigation extend 4 ft above ground and 2 ft below ground. The area is therefore [4 (40 ft)(6 ft)] – [4x(0.67 ft)(6 ft)] (to account for corners) = 944 ft^2.

[c] Foundation piers are considered to be double stack, reinforced CMU piers (16 in. x 16 in.). The unit weight of a 16-in. thick pier is taken to be twice the unit weight of an 8-in. thick reinforced CMU pier. The area is therefore 12 (1.333 ft)(6 ft) = 96 ft^2.

[d] Unit weights for reinforced concrete are given in lb/ft^3. The footing volume is taken to be [4 (40 ft)(2 ft)(1ft)] – [4 (2 ft)(1 ft)(1 ft)] = 312 ft^3.

[e] See (d). The interior footing volume is taken to be 12 (2 ft)(2 ft)(1 ft) = 48 ft^3.

Load Calculations: Live Loads

Live Load (Vertical)

Per ASCE 7-10, assume a live load of:

L = 40 lb/ft^2 x (1,800 ft^2) = 72,000 lbs

Roof Live Load (Vertical)

Per ASCE 7-10, assume a roof live load of 20 lb/ft^2. The roof live load acts on the horizontal projected area of the roof:

L_r = 20 lb/ft^2 x (1,800 ft^2) = 36,000 lbs

Snow Load (Vertical)

Assume a conservative snow load of 20 lb/ft^2, per ASCE 7-10. The snow load also acts on the horizontal projected area of the roof.

S = 20 lb/ft^2 (1,800 ft^2) = 36,000 lbs

Wind Load (Horizontal)

Appendix C contains a detailed discussion of wind load calculations, including a detailed example. Refer to Appendix C for wind load calculations; this case study uses a simplified approach. Using a simplified wind load, assuming that the structure is fully enclosed, assume a worst case scenario wind load acting perpendicular to the structure (i.e., on the entire face of the structure facing the river). Because the roof at the front (windward side) of the house is sloped and there are no overhangs, there is no vertical wind (uplift) component. Therefore, assume a wind pressure of 30 lb/ft^2 acting uniformly over the entire aboveground structure:

Area = Elevated Crawlspace area + Exterior Wall area + Vertical Roof area

$\Rightarrow A$ = (4 ft)(40 ft) + (12 ft)(40 ft) + (10 ft)(40 ft) = 160 ft^2 + 480 ft^2+ 400 ft^2 = 1040 ft^2

W = 30 lb/ft^2 x (1,040 ft^2) = 31,200 lbs

Earthquake Load

Earthquake forces are assumed to be negligible for this location. Therefore, $E = 0$.

Load Combinations

To determine the worst-case horizontal and vertical loading scenarios, ASCE 7-10 load combinations are used (Allowable Stress Design). Table 6-3 presents a summary of the horizontal and vertical load combinations.

Load Summary:

Horizontal Loads

$D = L = L_r = S = E = 0$

$F_a = F_{comb}$ = 2,800 lbs

W = 31,200 lbs

Table 6-3. Summary of Horizontal and Vertical Load Combinations for the Truman House

	Combination	Horizontal (lbs)	Vertical (lbs)
1.	D	0	115,560
2.	$D + L$	0	187,560
3.	$D + (L_r$ or S or $R)$	0	151,560
4.	$D + 0.75L + 0.75(L_r$ or S or $R)$	0	196,560
5.	$D + (0.6W$ or $0.7E) + 0.75F_a$	20,820	14,133
6a.	$D + 0.75L + 0.75(0.6W) + 0.75(L_r$ or S or $R) + 0.75F_a$	16,140	95,133
6b.	$D + 0.75L + 0.75(0.7E) + 0.75S + 0.75F_a$	2,100	95,133
7.	$0.6D + 0.6W + 0.75F_a$	20,820	-32,091
8.	$0.6D + 0.7E$	0	69,336

Vertical Loads

D = 115,560 lbs
L = 72,000 lbs
L_r = 36,000 lbs
S = 36,000 lbs
W = 0 (conservative)
E = 0
$F_a = F_{buoy}$ = 135,236 lbs

Bearing Capacity Check

$P_{max} = A_{bearing} S_{bc}$
S_{bc} = 2,500 lb/ft^2 (Table 5-2)

The bearing area is the area of the footings:

$A_{bearing}$ = [4 (40 ft)(2 ft)] - [4 (2 ft)(2 ft)] + [12(2 ft)(2 ft)] = 352 ft^2
P_{max} = (2,500 lb/ft^2)(352 ft^2) = 880,000 lbs

Maximum vertical load:

335,688 lbs < P_{max} ✓

Sliding Check

The soil type is SM; from IBC 2009 (Table 1806.2), the coefficient of friction is 0.25. Worst case horizontal load combination 7: $0.6D + 0.6W + 0.75F_a$

Horizontal Resistive Force = Foundation Resistive Force + Resistive Force from Structure Self-Weight

Foundation Resistive Force $r = (k_p)(\gamma_{soil})(d^2/2)$, where:

$k_p = \tan^2(45^o + \phi/2)$, where ϕ is the soil angle of internal friction (assume $\phi = 30^o$)
$k_p = \tan^2(45^o + 30^o/2) = 3$
γ_{soil} = 77 lb/ft^3 (Soil Type SM; see Table 4-3)
d = depth of soil from top of soil to top of footer = 2 ft
Therefore, r = (3)(77 lb/ft^3)(2 ft)^2/2 = 462 lb/ft

Assume both side walls of the main structure resist sliding, therefore,

R_H = 2(40 ft)(462 lb/ft) = 36,960 lbs
Resistive Force from Structure Self Weight = 0.25 (0.6D) = 0.25 x 0.6 (115,560 lbs) = 17,334 lbs
Total Resistive Force = 36,960 lbs + 17,334 lbs = 54,294 lbs
Horizontal Load = 0.6W + $0.75F_a$ = 20,820 lbs < 38,203 lbs ✓

Figure 6-7 presents the moment diagram for the Truman house.

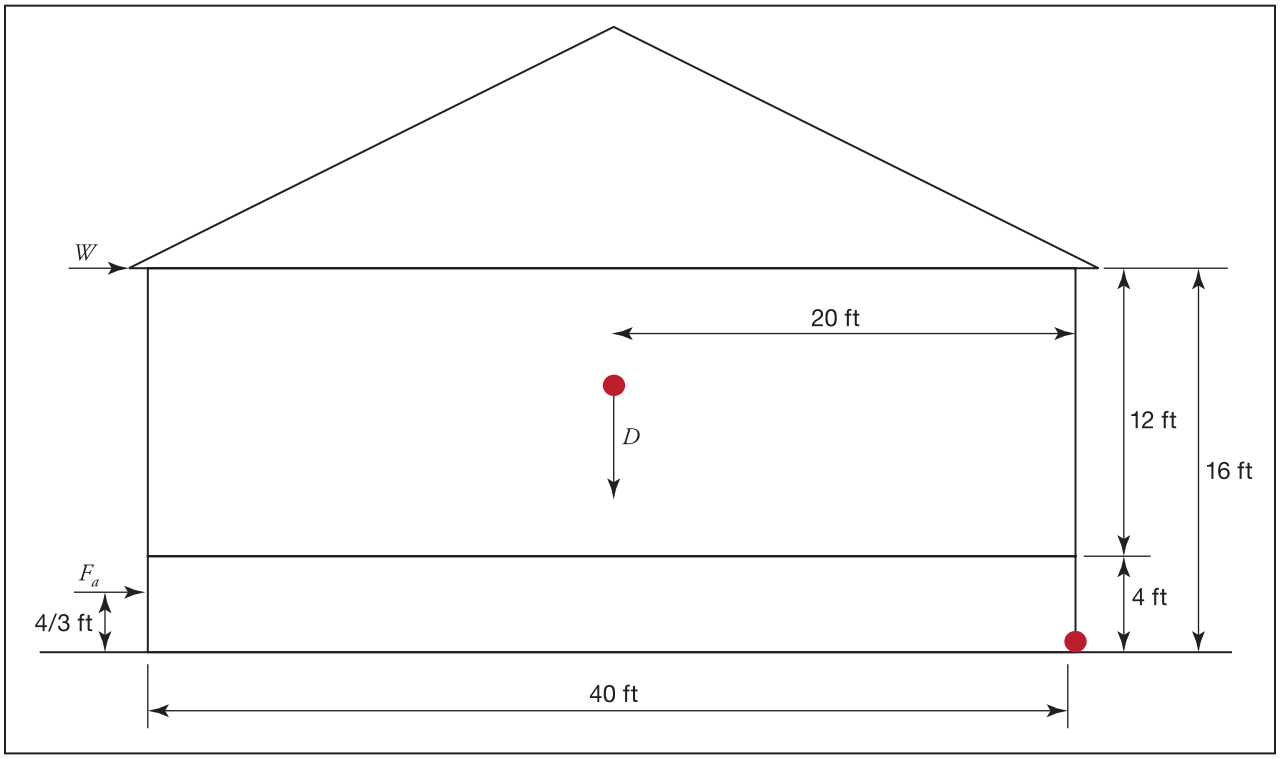


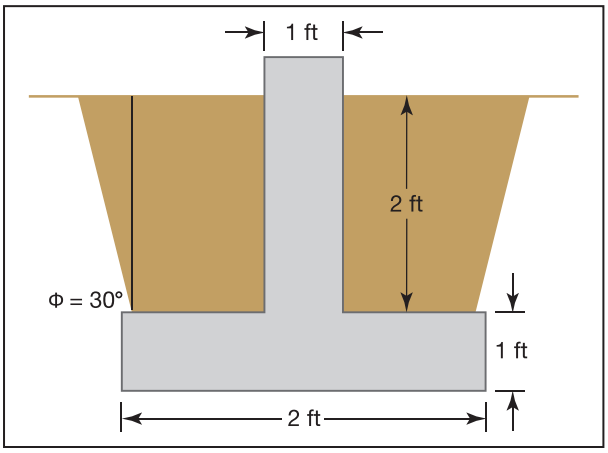
Figure 6-7. Moment diagram for the Truman house

Uplift Check

The worst case load combination for the uplift check would be $0.6D + 0.6W + 0.75F_a$.

The resistive force is equal to the weight of the concrete footer and soil above the footer that would need to be uprooted. Assuming a soil angle of internal friction of $\phi = 30^o$, a cross section of the displaced soil and footer is as follows in Figure 6-8:

Figure 6-8. Cross section of displaced soil and footer



To calculate the weight of the displaced concrete and soil, calculate the volume displaced. The perimeter of the house is given by (40 ft x 3 + 20 ft + 10 ft + 20 ft + 10 ft) = 180 ft.

The volume of the foundation walls is given by:

V_{walls} = (180 ft x 2 ft x 1 ft) – 6(2 ft x 1 ft) = 348 ft^3

The volume of the footers is given by:

V_{footer} = (180 ft x 1 ft x 2 ft) – 6(1 ft x 2 ft) = 348 ft^3

The total volume of concrete is: $V_{concrete}$ = 348 ft^3 + 348 ft^3 = 696 ft^3

The total weight of concrete is: $W_{concrete}$ = 150 lb/ft^3 x 696 ft^3 = 104,400 lbs

The cross-section of the displaced soil is given by the area of the trapezoid of soil failure minus the area of the wall. The smaller base of the trapezoid is 2 feet. The angle of internal friction is 30°, therefore the wider base of the trapezoid is 2 feet + 2[2tan(30°)] = 4.3 feet. Therefore the cross-sectional area of the displaced soil is:

A_{soil} = (2 ft + 4.3 ft) x 2 ft/2 – 2 ft x 1 ft = 4.3 ft^2

The volume of displaced soil is given by:

V_{soil} = (180 ft x 4.3 ft^2) – 6(4.3 ft^2) = 748.2 ft^3

The total weigt of soil is: W_{soil} = 77 lb/ft^3 x 748.2 ft^3.

Therefore, the total resistive force is: R_v = 104,400 lbs + 57,611 lbs = 162,011 lbs

Vertical uplift = $0.6W + 0.75F_a$ = 101,427 lbs < 162,011 lbs ✓

Overturning Check

M_W = (16 ft)W = 499,200 ft-lbs

M_F = –(20 ft)F_V + –(4/3 ft)F_H= –2,708,453 ft-lbs

$0.6M_W + 0.75M_F$ = (0.6)(+499,200 ft-lbs) + (0.75)(– 2,708,453) = –1,731,820 ft-lbs

M_D = (20 ft)D = 2,311,200 ft-lbs

$0.6M_D$ = 1,386,720 ft-lbs

M_{Rv} = (20 ft)R_V = 3,240,220 ft-lbs

$0.6M_W + 0.75M_F < 0.6M_D + M_{Rv}$ ✓

6.1.5 Supporting Documentation

This section includes additional information about the Truman house. The following maps and documents provide backup documentation for the values used in the Case Study 1 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-9);
- FIRMette showing the location of the plot relative to the SFHA (Figure 6-10);
- summary of discharges, excerpted from the FIS, showing the 10-, 50-, 100-, and 500-year discharges at the Truman house (Figure 6-11);
- flood profile showing the 10-, 50-, 100-, and 50-year flood elevations at the Truman house (Figure 6-12);

- elevation certificate showing the first floor elevation (Figure 6-13);
- tax card providing building value and square footage (Figure 6-14); and
- BCA report excerpt summarizing the cost-effectiveness of elevation and relocation (Figure 6-15).

Figure 6-9. Topographic map showing the location of the Truman plot (in red). Please note these are 10-foot contours.

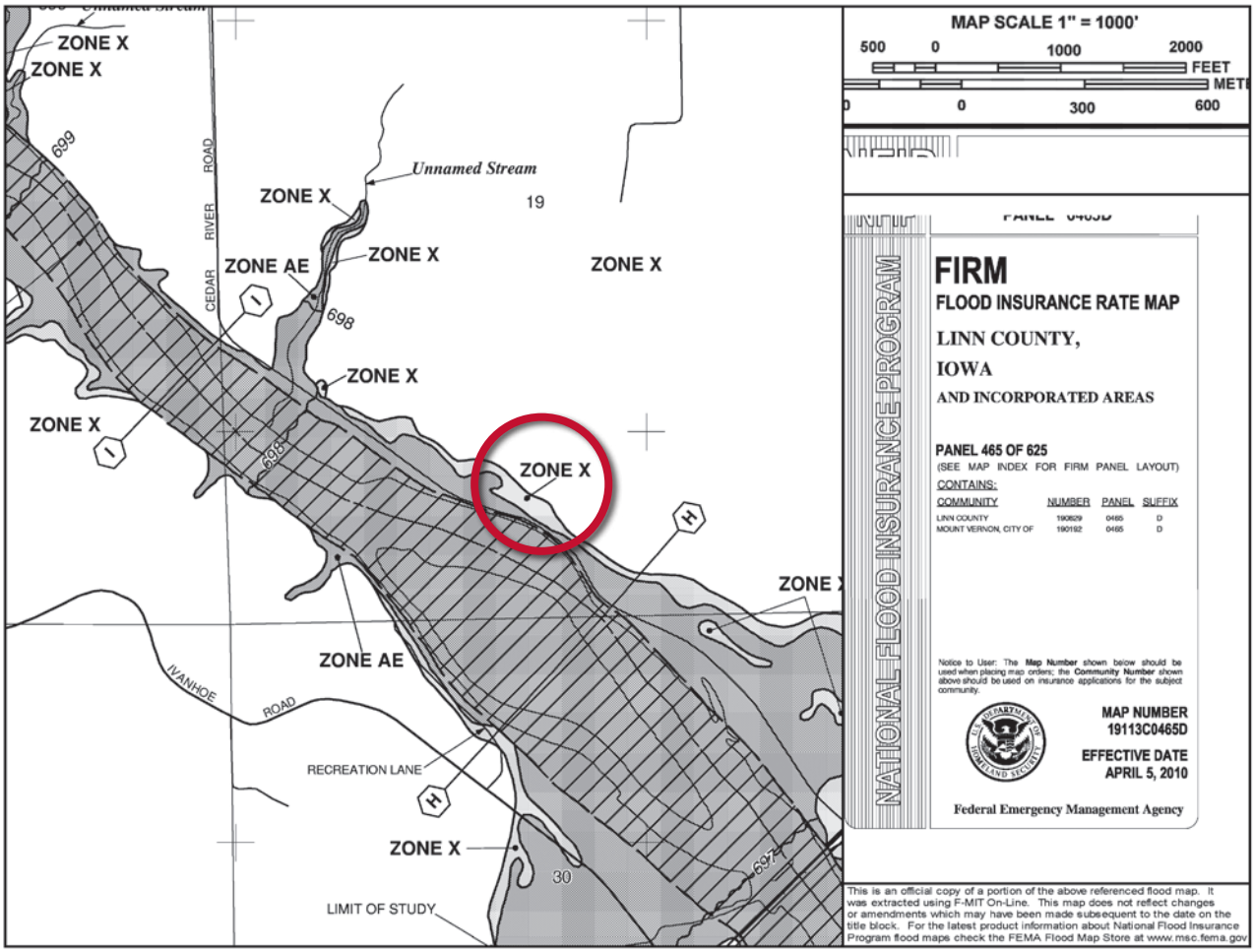


Figure 6-10. FIRM showing the location of the Truman plot (circled in red)

TABLE 3 – SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area Sq. Miles	Peak Discharges (CFS) 10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CEDAR CREEK					
At south county boundary	6997	53800	78000	88000	112000
At State Highway 1 bridge	6974	53500	77900	87900	112900
Just upstream of confluence of Big Creek	6844	53200	77700	87700	112700
Just upstream of confluence of Morgan Creek	6458	53500	78100	88100	113100
At the gaging station in Cedar Rapids at 7th Avenue SW	6510	53000	77000	87000	112000
Just upstream of confluence of Otter Creek	6381	53700	78400	88400	113400
Just upstream of confluence of Opossum Creek	6243	53800	78500	88600	113600
WAPSIPINICON RIVER					
At south county boundary	1324	18350	30520	36000	49220
Just above confluence of Heatons Creek	1294	18090	30080	35480	48500
Just above confluence of Waltons Creek	1242	17810	29620	34940	47760
MARTINS CREEK					
At mouth	4.2	1255	2485	3152	4995
Just upstream of small tributary in the northwest quarter of Section 14, T83N, R6W	3.5	1225	2410	3055	4830
Just upstream of small tributary in the northwest quarter of Section 11, T83N, R6W	2.2	1010	2010	2565	4105

Figure 6-11. FIS Excerpt: Discharge table for the Truman house (applicable discharges circled in red)

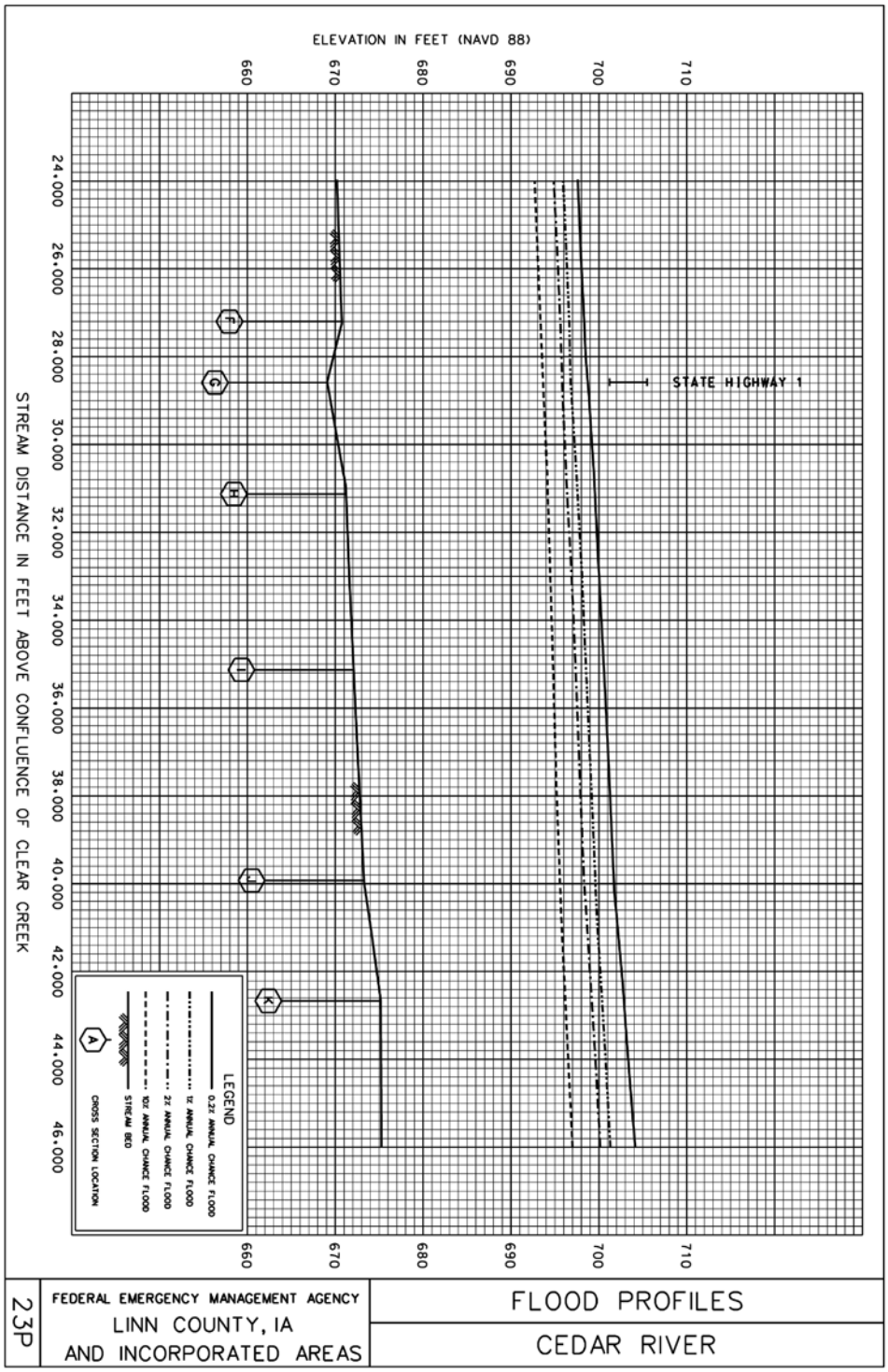


Figure 6-12.
FIS excerpt: Flood profile for the Truman house

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name Samuel Klayman

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
55555 Cedar River Road
City Mount Vernon State IA ZIP Code 55555

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)
NA

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential
A5. Latitude/Longitude: Lat. NA Long. NA Horizontal Datum: ☐ NAD 1927 ☐ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number 8
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) 1800 sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade 0
c) Total net area of flood openings in A8.b 0 sq in
d) Engineered flood openings? ☐ Yes ☒ No

A9. For a building with an attached garage:
a) Square footage of attached garage _____ sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A9.b _____ sq in
d) Engineered flood openings? ☐ Yes ☐ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
19113C	Linn County	IA

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
465	D	April 5, 2010	April 5, 2010	AE	697.8

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☒ FIS Profile ☐ FIRM ☐ Community Determined ☐ Other (Describe) _____
B11. Indicate elevation datum used for BFE in Item B9: ☐ NGVD 1929 ☒ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☒ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized _____ Vertical Datum NAVD 88
Conversion/Comments _____

Check the measurement used.

a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	694.2	☒ feet ☐ meters (Puerto Rico only)
b)	Top of the next higher floor	696.2	☒ feet ☐ meters (Puerto Rico only)
c)	Bottom of the lowest horizontal structural member (V Zones only)	_____.____	☐ feet ☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	_____.____	☐ feet ☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	696.2	☒ feet ☐ meters (Puerto Rico only)
f)	Lowest adjacent (finished) grade next to building (LAG)	694.2	☒ feet ☐ meters (Puerto Rico only)
g)	Highest adjacent (finished) grade next to building (HAG)	694.5	☒ feet ☐ meters (Puerto Rico only)
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	694.2	☒ feet ☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available.I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☐
Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☐ Yes ☒ No

Certifier's Name Jane Q. Engineer License Number 5555555
Title Project Engineer Company Name Engineering Co, Inc
Address 555 Main Street City Springfield State IA ZIP Code 55555
Signature Date Telephone 555-555-5555

STATE OF IOWA
JANE Q. ENGINEER
NO. 55555
NOT LICENSED
PROFESSIONAL ENGINEER

FEMA Form 81-31, Mar 09 See reverse side for continuation. Replaces all previous editions

Figure 6-13. Elevation certificate excerpt for the Truman house

LINN COUNTY ASSESSOR

Pin	55555-55555-55555
Deed	TRUMAN HARRY S
Property Address	55555 CEDAR RIVER RD MT VERNON
Class	RESIDENTIAL

Current Value Information			
Land Value	Dwelling Value	Improvement Value	Total Value
1,434,098	163,795	0	1,597,893

Prior Year Value Information				
Year	Land Value	Dwelling Value	Improvement Value	Total Value
2011	1,434,098	163,795	0	1,597,893
2010	1,434,098	163,795	0	1,597,893
2009	1,434,098	163,795	0	1,597,893
2008	1,434,098	163,795	0	1,597,893
2007	1,434,098	163,795	0	1,597,893

Residential Building Information			
Occupancy	Style	Year Built	Total Living Area
Single-Family/Owner Occupied	1 Story Frame	1964	1,800

Yard Extra Information		
Description	Item Count	Year Built
NA		

Land Information		
Lot Basis	Square Feet	Acres
Lump Sum	9,280,000	213

Tax History Information				
Tax Year	Assessed Value	Taxable Value	Gross Tax	Net Tax
2009	1,597,893	748,564	23,363	23,363
2008	1,597,893	728,462	20,791	20,600
2007	1,597,893	704,354	20,244	19,200
2006	1,356,789	618,145	17,533	17,000

Figure 6-14. Truman house tax card

16 Sep 2011 Project: **Case Study 1** Pg 1 of 21

Total Benefits: **$246,241** Total Costs: **$220,000** BCR: **1.12**

Project Number: Disaster #: Program: Agency: **City of Mount Vernon**

State: **Iowa** Point of Contact: Harry Truman Analyst:

Project Summary:

Project Number: Disaster #:

Program: Agency: City of Mount Vernon

Analyst:

Point of Contact: Harry Truman Phone Number:

Address: 55555 Cedar River Rd, Mount Vernon, Iowa, 55555

Email:

Comments:

Structure Summary For:

1-Elevation, 55555 Cedar River Road, Mount Vernon, Iowa, 55555, Linn

Structure Type: Building Historic Building: No Contact:

Benefits: $105,211 Costs: $100,000 BCR: 1.05

Mitigation	Hazard	BCR	Benefits	Costs
Elevation	Flood	1.05	$105,211	$100,000

2-Relocation, 55555 Cedar River Road, Mount Vernon, Iowa, 55555, Linn

Structure Type: Building Historic Building: No Contact:

Benefits: $141,030 Costs: $120,000 BCR: 1.18

Mitigation	Hazard	BCR	Benefits	Costs
Acquisition	Flood	1.18	$141,030	$120,000

Figure 6-15. Sample BCA report excerpt for the Truman house elevation and relocation projects

6.1.6 Real World Examples

Although the Truman house is fictional, elevation and relocation are both commonly used flood mitigation measures. Figures 6-16 and 6-17 are examples of real structures that have been protected using the mitigation measures discussed in this case study.

This structure was relocated to another property.

Figure 6-16.
Relocation of an existing building to another location

This home was elevated on solid foundation walls in Louisiana.

Figure 6-17.
Elevation of an existing home above the BFE

6.2 Case Study #2: Residential Retrofit in Coastal A Zone Using Elevation or Acquisition

This case study exercise examines the retrofit of a residential building in a coastal floodplain by means of elevation or acquisition. Details are provided in the subsections that follow.

6.2.1 Description of Property

Abe and Bea Chester
1234 Bay Street, Norfolk, VA 12345

Abe and Bea Chester built their home in the 1960s before flood maps were developed for the area. The one-story, wood-frame structure does not have a basement. They live on Bay Street, close to the beach, in Norfolk, VA. Although they live outside of Zone V, they are still in the SFHA (Zone A) and would like to protect their home from flooding. They are not interested in moving the house itself, but they may be willing to move out of the neighborhood if they can get money to purchase another house. Because they live in Zone A and are subject to coastal flooding, they are interested in elevation on an open foundation. The local floodplain ordinance prohibits elevation on fill. The effective BFE is 4 feet above the first floor elevation.

The Chesters indicated they would like to pursue retrofitting options that would allow them to obtain a reduced NFIP flood insurance rate. If possible, the Chesters would like to apply for HMA grant assistance.

6.2.2 Structure Information

1234 Bay Street is a one-story, wood-frame structure and is a structure of average quality (Figure 6-18). See Section 6.2.5 for a tax card, including a floor plan of the structure.

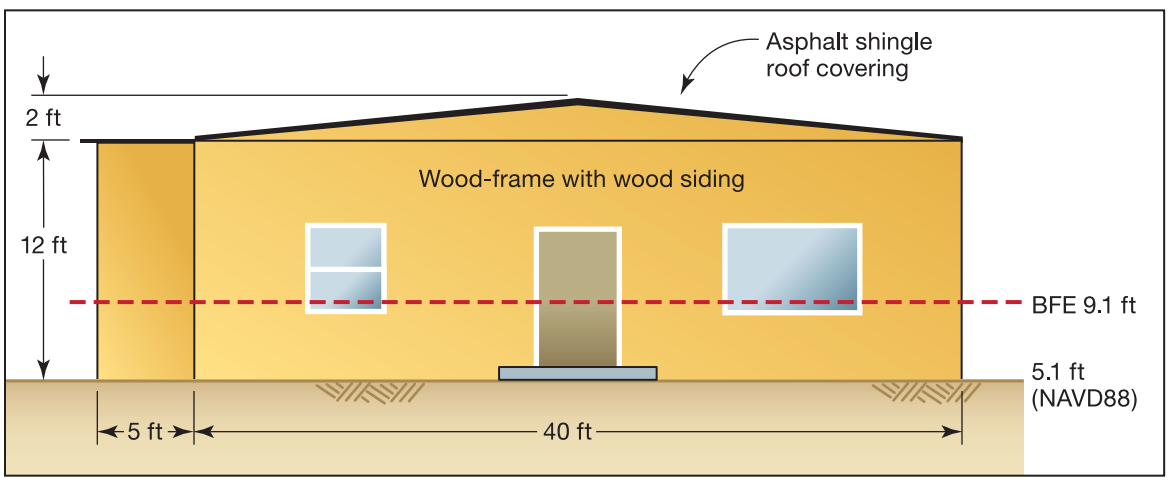


Figure 6-18. The Chester house, before mitigation

Other structure information includes:

- Footprint:
  - 1,025 square feet (see section 6.2.5)
- Foundation:
  - 6-inch-thick concrete slab on a 2-foot-wide x 1-foot-thick concrete wall footer
- Structure:
  - First floor elevation of 5.1 feet NAVD88, measured from the top of the lowest finished floor
  - Wood-frame structure
  - Wood siding
  - Wood-frame interior walls with gypsum board sheathing
- Roof:
  - Gable roof without overhangs over main structure (35-foot x 25-foot plan area)
  - Flat roof without overhangs over side areas (two 5-foot x 15-foot areas)
  - Asphalt shingle roof covering over entire roof
- Interior:
  - Wood stud interior walls with gypsum board sheathing
  - Hardwood floor coverings

Plot

The Chesters' plot is essentially flat and relatively small. The entire plot is in the SFHA. The ground elevation is between 5.1 feet and 5.3 feet (NAVD88) over the entire plot. The site soils are primarily a mixture of silty sand and gravel (Soil Type SM).

Building Assessment

An updated tax card is included at the end of this case study as an alternate source of the building replacement value as well as to verify the building square footage data.

Additionally, an engineer's estimate is that the Chesters' home has a building replacement value of approximately $80 per square foot, based on popular cost estimating guides.

Flood Hazard Data

The local floodplain management ordinance applies to all structures in the SFHA. Elevation on fill is strictly prohibited, and a 1-foot freeboard is required for all new construction and substantial improvements. The flood map (FIRMette) is included in Section 6.2.5 to document the flood hazard data used below.

The applicable excerpts from the FIS show the flood elevations and the BFE for the existing structure and are included in Section 6.2.5. Table 6-4 shows the stillwater elevations and BFE of the property.

Table 6-4. Stillwater Elevations for the Chester House

Stillwater Elevations (ft)				
BFE	10-year	50-year	100-year	500-year
9.1	5.5	6.9	7.6	8.9

Note: All topographic maps and flood hazard data reference NAVD88.

A licensed surveyor filled out the elevation certificate, which references NAVD88 and is included at the end of this case study.

The base flood flow velocity is assumed to be 3.0 feet per second.

6.2.3 Retrofit Options Selection

During an initial interview with the Chesters, potential retrofit options were discussed (Figure 6-19). Immediately, elevation on fill was ruled out because it is prohibited by the local floodplain ordinance. Similarly, dry floodproofing, wet floodproofing, and floodwalls and small levees were ruled out because these measures will not bring a pre-FIRM home located in a SFHA into compliance with the NFIP. Therefore, acquisition (not included in matrix) and elevation were viable options for the structure and will reduce NFIP flood insurance rates.

Cost was a concern for all potential retrofit options. The Chesters were also concerned about building accessibility for an elevation project.

Based on the retrofit option screening matrix, the two most viable options were elevation on piers and acquisition/demolition.

Acquisition

The only way to completely eliminate the risk to the Chesters' home is to move the entire structure out of the SFHA. Because the Chesters aren't interested in this, but are willing to move, acquiring the house and demolishing it may be a viable option. The acquisition process would include:

- Using HMA or other funds to purchase the home from the Chesters
- Demolishing the existing structure
- Restoring the site to green space
- Maintaining the site as green space

Owner Name: Abe and Bea Chester Prepared By: Jane Q. Engineer

Address: 1234 Bay Street Date: 9/1/2011

Property Location: Norfolk, VA

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
Floodproofing Measures									
Measure Allowed or Owner Requirement		X				X	X	X	X
Homeowner Concerns									
Aesthetic Concerns	X		X	X	X				
High Cost Concerns			X	X	X				
Risk Concerns	X		X	X					
Accessibility Concerns	X		X	X	X				
Code Required Upgrade Concerns									
Off-Site Flooding Concerns	X								
Total "X's"	**4**	**NA**	**4**	**4**	**3**	**NA**	**NA**	**NA**	**NA**

Instructions: Determine whether a floodproofing measure is allowed under local regulations or homeowner requirement. Put an "x" in the box for each measure that 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 that would affect its implementation. A concern is defined as a homeowner issue that, 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 6-19. Preliminary Floodproofing/Retrofitting Preference Matrix for the Chester house

A preliminary cost estimate shows that the cost of acquisition would be approximately equal to the market value of the structure, plus $15,000 for demolition and title fees. Based on the tax card (at the end of this case study), the 2011 market value of the structure and land is $127,461. Based on a total cost of $142,461, the BCR is 1.25 (see Section 6.2.5). Therefore, acquisition and demolition would be a cost-beneficial retrofit option.

Elevation on Pile Foundation

If the Chesters decide that they are not interested in moving, elevating on timber piles may be a viable retrofit option. Because the Chesters live in a Coastal A Zone, piers and columns may not be appropriate because of hydrodynamic forces. Refer to Table 1-1 for the advantages and disadvantages of elevation. The elevation process would include:

- Designing the new pile foundation system
- Disconnecting utilities
- Lifting the existing structure on hydraulic jacks and moving it to install piles
- Demolishing the existing foundation
- Driving new piles
- Moving the structure back, lowering the structure, and connecting it to the piles
- Reconnecting utilities

The BFE is 9.1 feet, and the LAG and top of the finished first floor are both 5.1 feet. Including the required 1 foot of freeboard, the floodproofing depth H is (9.1 – 5.1 + 1.0) = 5 feet. Because the Chesters may want to use the empty space below their newly elevated house for parking, building access, or storage, they may choose to elevate the first floor to 8 feet rather than 5 feet.

A preliminary cost estimate shows a retrofit cost of approximately $175,000. Therefore, the BCR is 0.86 (see Section 6.2.5). Consequently, elevation on piles as designed is not cost effective. The Chesters may decide not to pursue this option, or they may decide to alter the elevation design to lower costs. For illustrative purposes, load calculations for elevation on piles (as described) are shown in the following sections.

The elevated structure would look as shown in Figure 6-20.

The timber pile plan for the elevated structure is shown in Figure 6-21.

To ensure that the foundation is properly designed, the flood forces must be calculated and checked with other applicable loads.

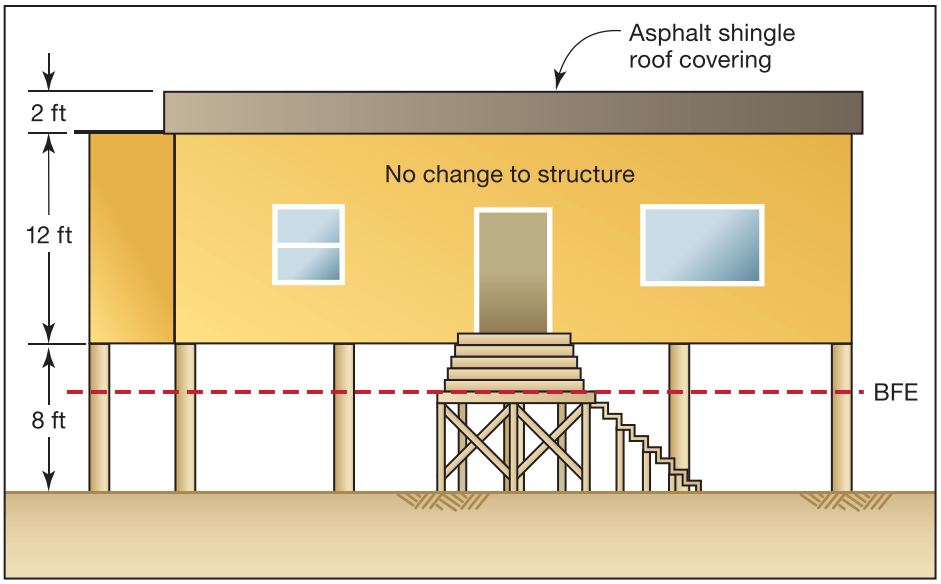


Figure 6-20.
The Chester house, after mitigation

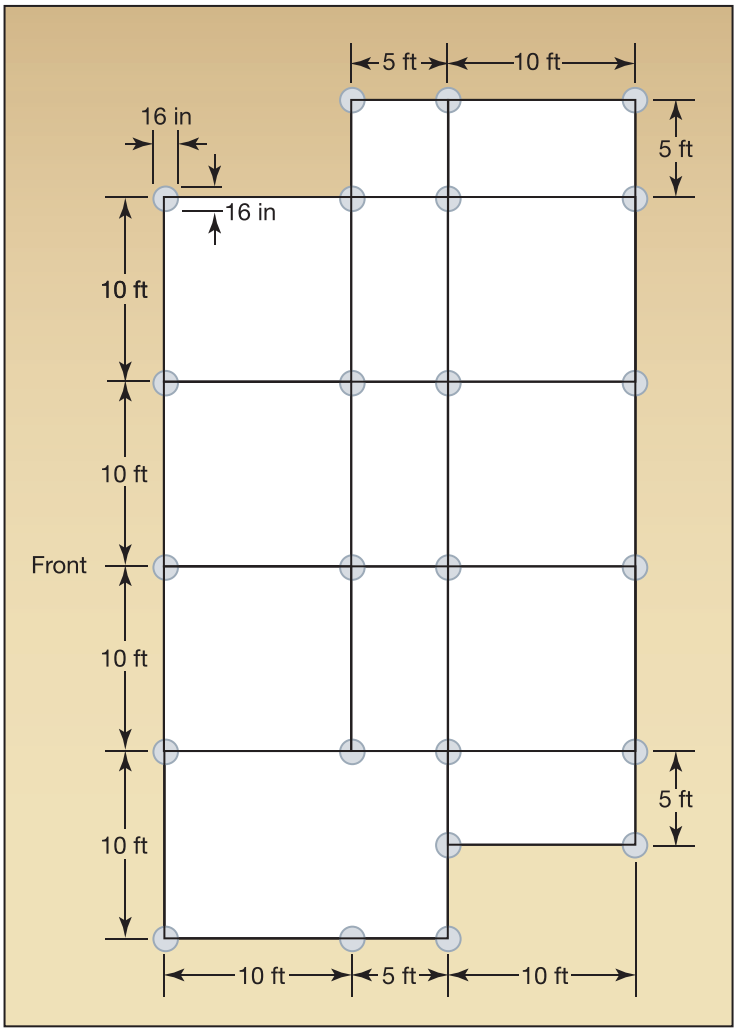


Figure 6-21.
Timber pile plan for the elevated Chester house

6.2.4 Load Calculations

The paragraphs that follow provide calculations for flood loads, dead loads, live loads, and load combinations associated with the elevation option.

Load Calculations: Flood Loads

The first step is to calculate hydrostatic forces. As determined above, the floodproofing depth H is 5 feet. Because the home is being elevated on an open foundation, the saturated soil depth is 0 feet. Because the home is being elevated on an open foundation, and because it is being supported on piles, no lateral hydrostatic or hydrodynamic forces are acting on the structure. Further, vertical hydrostatic (buoyancy) forces will be negligible.

The design flood depth is 5 feet, therefore C_D = 1.00. Assume C_B = 1.0. An impact force computation worksheet is presented in Figure 6-22.

Hydrostatic Force Computation Worksheet

Owner Name: Abe and Bea Chester Prepared By: Jane Q. Engineer

Address: 1234 Bay Street Date: 9/1/2011

Property Location: Norfolk, VA

Variables

W = weight of the object (lbs) = 1,000 lbs

V = velocity of water (ft/sec) = 3 ft/sec

C_D = depth coefficient (see Table 4-6) = 1.00

C_B = blockage coefficient (taken as 1.0 for no upstream screening, flow path greater than 30 ft; see Table 4-7 for more information)

C_{Str} = building structure coefficient

= 0.2 for timber pile and masonry column supported structures 3 stories or less in height above grade

= 0.4 for concrete pile or concrete or steel moment resisting frames 3 stories or less in height above grade

= 0.8 for reinforced concrete foundation walls (including insulated concrete forms)

Summary of Loads

f_i = 600 lb

Equation 4-13: Normal Impact Loads

$$F_i = W\,V\,C_D C_B C_{Str} = (1{,}000 \text{ lbs})(3 \text{ ft/sec})(1.0)(1.0)(0.2) = 600 \text{ lbs}$$

Figure 6-22. Impact Force Computation Worksheet for the Chester house (Refer to Figure 4-12)

Flood Force Summary:

Horizontal Force:

f_{comb} = 0 lb/lf

F_i = 600 lbs

The total flood force acting on the six piers of the front wall (perpendicular to flow) is:

F = 600 lbs

Vertical Force:

F_{buoy} = 0 lbs

Load Calculations: Dead Loads

The dead load is the self-weight of the structure. Case Study #1 illustrates a detailed calculation of the dead load. For this case study, assume a dead weight of approximately 50 lb/ft^2 over 1,025 square feet.

D = 50 lb/ft^2 x (1,025 ft^2) = 51,250 lbs

Load Calculations: Live Loads

Live Load (Vertical)

Per ASCE 7-10, assume a live load of:

L = 40 lb/ft^2 x (1,025 ft^2) = 41,000 lbs

Roof Live Load (Vertical)

Per ASCE 7-10, assume a roof live load of 20 lb/ft^2. The roof live load acts on the horizontal projected area of the roof:

L_r = 20 lb/ft^2 x (1,025 ft^2) = 20,500 lbs

Snow Load (Vertical)

Assume a conservative snow load of 20 lb/ft^2, per ASCE 7-10. The snow load also acts on the horizontal projected area of the roof.

S = 20 lb/ft^2 (1,025 ft^2) = 20,500 lbs

Wind Load (Horizontal)

Appendix C contains a detailed discussion of wind load calculations, including a detailed example. Refer to Appendix C for wind load calculations; this case study uses a simplified approach. Using a simplified wind load, assuming that the structure is fully enclosed, assume a worst case scenario wind load acting perpendicular to the structure (i.e., on the entire face of the structure facing the river). Because the roof at the front (windward side) of the house is sloped and there are no overhangs, there is no vertical wind (uplift) component on the roof. There may be some uplift on the bottom of the structure, but it is not considered here. Therefore, assume a wind pressure of 30 lb/ft^2 acting uniformly over the entire aboveground structure:

Area = Pier surface area (6 piers) + Exterior Wall area + Vertical Roof area

$\Rightarrow A$ = (6)(16 in./(12 in./ft))(5ft) + (45 ft)(16 ft) + (1/2)(2 ft)(40 ft) = 40 ft^2 + 720 ft^2 + 40 ft^2 = 800 ft^2

W = 30 lb/ft2 x (800 ft2) = 24,000 lbs

Earthquake Load

Seismic forces are not considered for this example. Therefore, $E = 0$.

Load Combinations

IBC section 1810.1 requires that deep foundations be designed on the basis of a detailed geotechnical analysis. For that reason, failure modes are not analyzed here. For illustrative purposes, ASCE 7-10 load combinations (Allowable Stress Design) are presented in Table 6-5.

Table 6-5. Summary of Horizontal and Vertical Load Combinations for the Chester House

	Combination	Horizontal (lbs)	Vertical (lbs)
1.	D	0	51,250
2.	$D + L$	0	92,250
3.	$D + (L_r$ or S or $R)$	0	71,750
4.	$D + 0.75L + 0.75(L_r$ or S or $R)$	0	97,375
5.	$D + (0.6W$ or $0.7E) + 0.75F_a$	14,850	51,250
6a.	$D + 0.75L + 0.75(0.6W) + 0.75(L_r$ or S or $R) + 0.75F_a$	11,250	97,375
6b.	$D + 0.75L + 0.75(0.7E) + 0.75S + 0.75F_a$	450	97,375
7.	$0.6D + 0.6W + 0.75F_a$	14,850	30,750
8.	$0.6D + 0.7E$	0	30,750

Load Summary:

Horizontal Loads

$D = L = L_r = S = E = 0$

$F_a = F_{sta}$ = 600 lbs

W = 24,000 lbs

Vertical Loads

D = 51,250 lbs

L = 41,000 lbs

L_r = 20,500 lbs

S = 20,500 lbs

W = 0 (conservative)

$E = 0$

$F_a = F_{buoy} = 0$

6.2.5 Supporting Documentation

This section includes additional information about the Chester house. The following maps and documents provide backup documentation for the values used in the Case Study 2 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-23);
- DFIRM excerpt showing the location of the Chester house relative to the SFHA (Figure 6-24);
- elevation certificate showing the first floor elevation and BFE (Figure 6-25);
- tax card providing building value and square footage (Figure 6-26); and
- BCA report excerpt summarizing the cost effectiveness of elevation and acquisition (Figure 6-27).

Figure 6-23. Topographic map for the Chester house (general location in red circle)

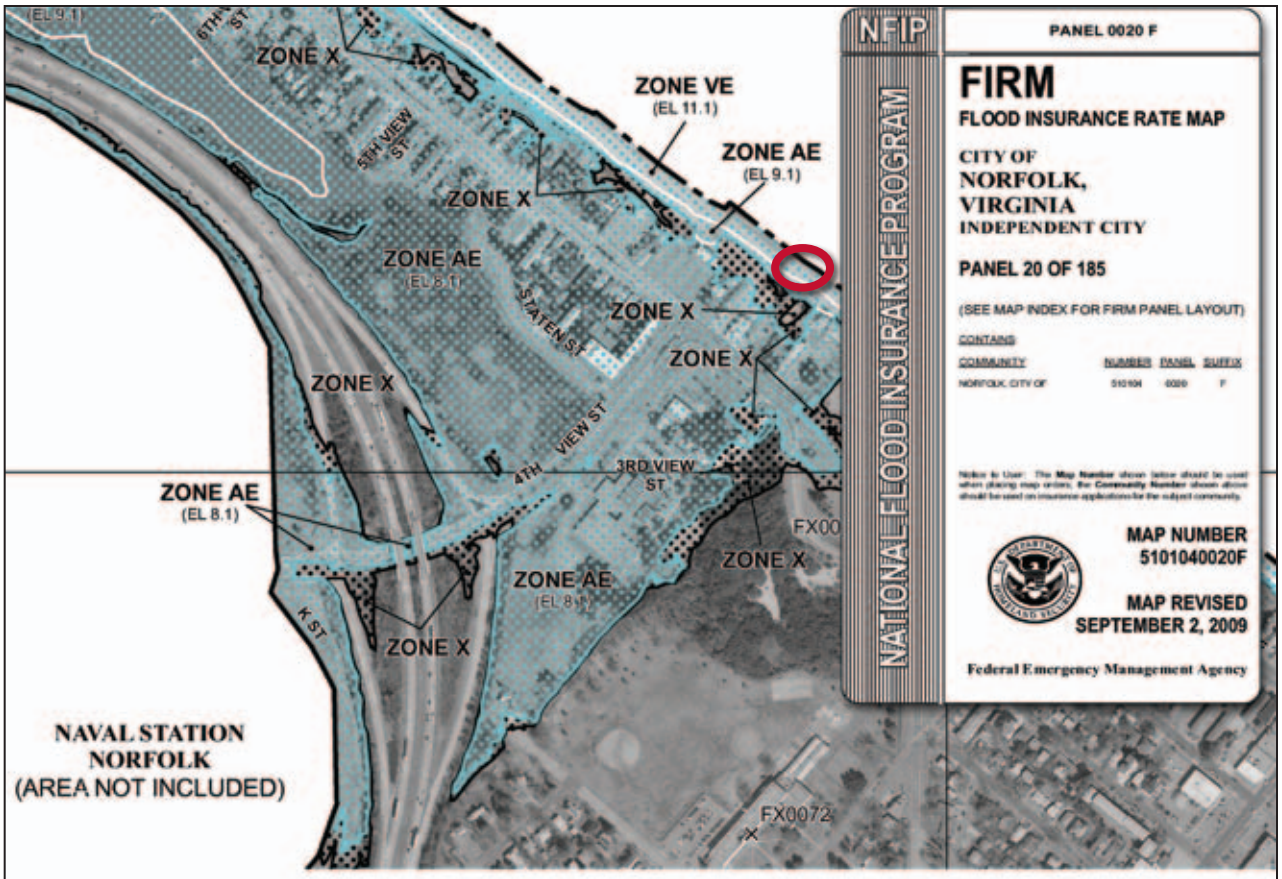


TABLE 1 - SUMMARY OF STILLWATER ELEVATIONS

Flood Source and Location	Elevation (Feet) NAVD 88 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Chesapeake Bay and Tributaries				
Entire shoreline within community	5.5	6.9	7.6	8.9
Little Creek				
From the east corporate limits to approximately 0.3 mile west of the east corporate limits	5.6	7.2	7.8	9.2
From approximately 0.3 mile west of the east corporate limits and remaining shoreline	5.5	6.9	7.6	8.9
Mason Creek				
Entire shoreline	4.5	5.6	6.1	7.4

Figure 6-24. DFIRM excerpt and FIS excerpt: Summary of stillwater elevations for the Chester house

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name Abe and Bea Chester

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
1234 Bay Street
City Norfolk State VA ZIP Code 1234

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) _____
A5. Latitude/Longitude: Lat. _____ Long. _____ Horizontal Datum: ☐ NAD 1927 ☐ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number _____
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

A9. For a building with an attached garage:
a) Square footage of attached garage _____ sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A9.b _____ sq in
d) Engineered flood openings? ☐ Yes ☐ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Norfolk, VA 510104	NA	VA

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0020	F	9/2/2009		AE	9.1

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☒ FIS Profile ☒ FIRM ☐ Community Determined ☐ Other (Describe) _____
B11. Indicate elevation datum used for BFE in Item B9: ☐ NGVD 1929 ☒ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☒ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized _____ Vertical Datum NAVD88
Conversion/Comments _____

Check the measurement used.

a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	-4.1	☒ feet	☐ meters (Puerto Rico only)
b)	Top of the next higher floor	5.1	☒ feet	☐ meters (Puerto Rico only)
c)	Bottom of the lowest horizontal structural member (V Zones only)	_____.____	☐ feet	☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	_____.____	☐ feet	☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	-4.1	☒ feet	☐ meters (Puerto Rico only)
f)	Lowest adjacent (finished) grade next to building (LAG)	4.8	☒ feet	☐ meters (Puerto Rico only)
g)	Highest adjacent (finished) grade next to building (HAG)	5.3	☒ feet	☐ meters (Puerto Rico only)
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	_____.____	☐ feet	☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☐
Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☐ Yes ☐ No

Certifier's Name Joseph Kavalier License Number 12345
Title Surveyor Company Name Surveyors Inc
Address 1234 Survey Street City Richmond State VA ZIP Code 54321
Signature Date Telephone

STATE OF IOWA
JANE Q. ENGINEER
NO. 55555
NOT LICENSED
PROFESSIONAL ENGINEER

FEMA Form 81-31, Mar 09 See reverse side for continuation. Replaces all previous editions

Figure 6-25. Elevation certificate excerpt for the Chester house

CITY OF NORFOLK ASSESSOR

Pin	12345-67898-76543
Deed	CHESTER ABRAHAM
Property Address	1234 BAY STREET NORFOLK, VA 12345
Class	RESIDENTIAL

Current Value Information

Land Value	Dwelling Value	Improvement Value	Total Value
25,461	102,000	0	127,461

Prior Year Value Information

Year	Land Value	Dwelling Value	Improvement Value	Total Value
2011	25,461	102,000	0	127,461
2010	25,461	102,000	0	127,461
2009	27,508	105,333	0	132,841
2008	27,508	105,333	0	132,841
2007	27,508	105,333	0	132,841

Residential Building Information

Occupancy	Style	Year Built	Total Living Area
Single-Family/Owner Occupied	1 Story Frame	1983	1,275

Yard Extra Information

Description	Item Count	Year Built
NA		

Land Information

Lot Basis	Square Feet	Acres
Lump Sum	5,400	0.124

Tax History Information

Tax Year	Assessed Value	Taxable Value	Gross Tax	Net Tax
2009	127,461	58,108	9,404	9,400
2008	132,841	53,136	8,502	8,540
2007	132,841	60,223	10,022	10,001
2006	132,841	61,132	11,276	11,200

Figure 6-26. Tax card for the Chester house (page 1)

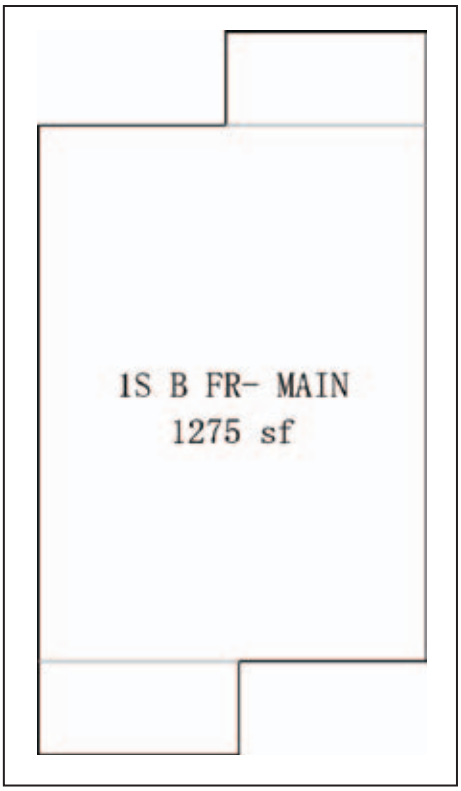


Figure 6-26 (concluded). Tax card for the Chester house (page 2)

16 Sep 2011 Project: **Case Study 2** Pg 1 of 21

Total Benefits: **$497,269** Total Costs: **$292,461** BCR: **1.70**

Project Number: Disaster #: Program: Agency: **City of Norfolk**

State: **Virginia** Point of Contact: Analyst:

Project Summary:

Project Number: Disaster #:

Program: Agency: City of Norfolk

Analyst:

Point of Contact: Phone Number:

Address: Virginia

Email:

Comments:

Structure Summary For:

1-Elevation, 1234 Bay Street, Norfolk, Virginia, 12345, Norfolk City

Structure Type: Building Historic Building: No Contact:

Benefits: $227,014 Costs: $150,000 BCR: 1.51

Mitigation	Hazard	BCR	Benefits	Costs
Elevation	Flood	1.51	$227,014	$150,000

2-Acquisition, 1234 Bay Street, Norfolk, Virginia, 12345, Norfolk City

Structure Type: Building Historic Building: No Contact:

Benefits: $270,255 Costs: $142,461 BCR: 1.90

Mitigation	Hazard	BCR	Benefits	Costs
Acquisition	Flood	1.90	$270,255	$142,461

Figure 6-27. Sample BCA Report excerpt for the Chester house elevation and acquisition

6.2.6 Real World Examples

Although the Chester house is fictional, elevation and acquisition are both commonly used flood mitigation measures. Figures 6-28 and 6-29 are examples of real structures that have been protected using the mitigation measures discussed in this case study.

These homes were elevated on timber piles.

Figure 6-28.
House elevated on timber piles

Figure 6-29.
Elevation on timber piles

6.3 Case Study #3: Residential Retrofit Outside of the Floodplain Using Dry or Wet Floodproofing

This case study exercise examines the retrofit of a residential building outside the floodplain by means of dry floodproofing or wet floodproofing. Details are provided in the subsections that follow.

6.3.1 Description of Property

Jorge Luis Borges
18 Chai Avenue
Memphis, TN 36549

The Borges family built their home in 1992. It is a one-story structure with a walkout-on-grade basement that serves as a garage. It is not in the floodplain but, due to the sloping terrain and the development in the area, water tends to collect in their backyard. Since living in the house, they've had water in their garage nearly every time it rains. On four occasions, they have had to conduct some repairs and replacements to damaged items and building materials. Mr. Borges estimated the amount of damage he incurred during each event (see Table 6-6). The main level does not have any flooding problems.

The Borges family does not live in the SFHA and, therefore, does not have flood insurance. However, the damage they incurred in 2011 encouraged them to retrofit their home to protect it against further damages.

6.3.2 Structure Information

18 Chai Avenue is a good quality, 1-story masonry house with a walkout-on-grade garage (see Figures 6-30 and 6-31).

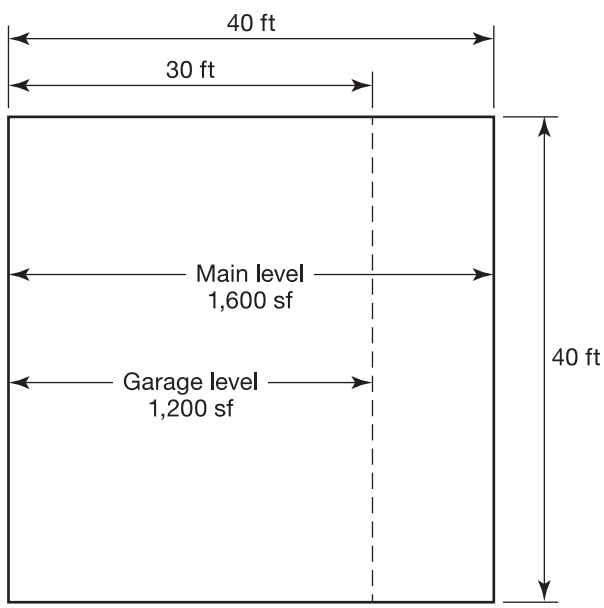


Figure 6-30. Plan drawing for the Borges house

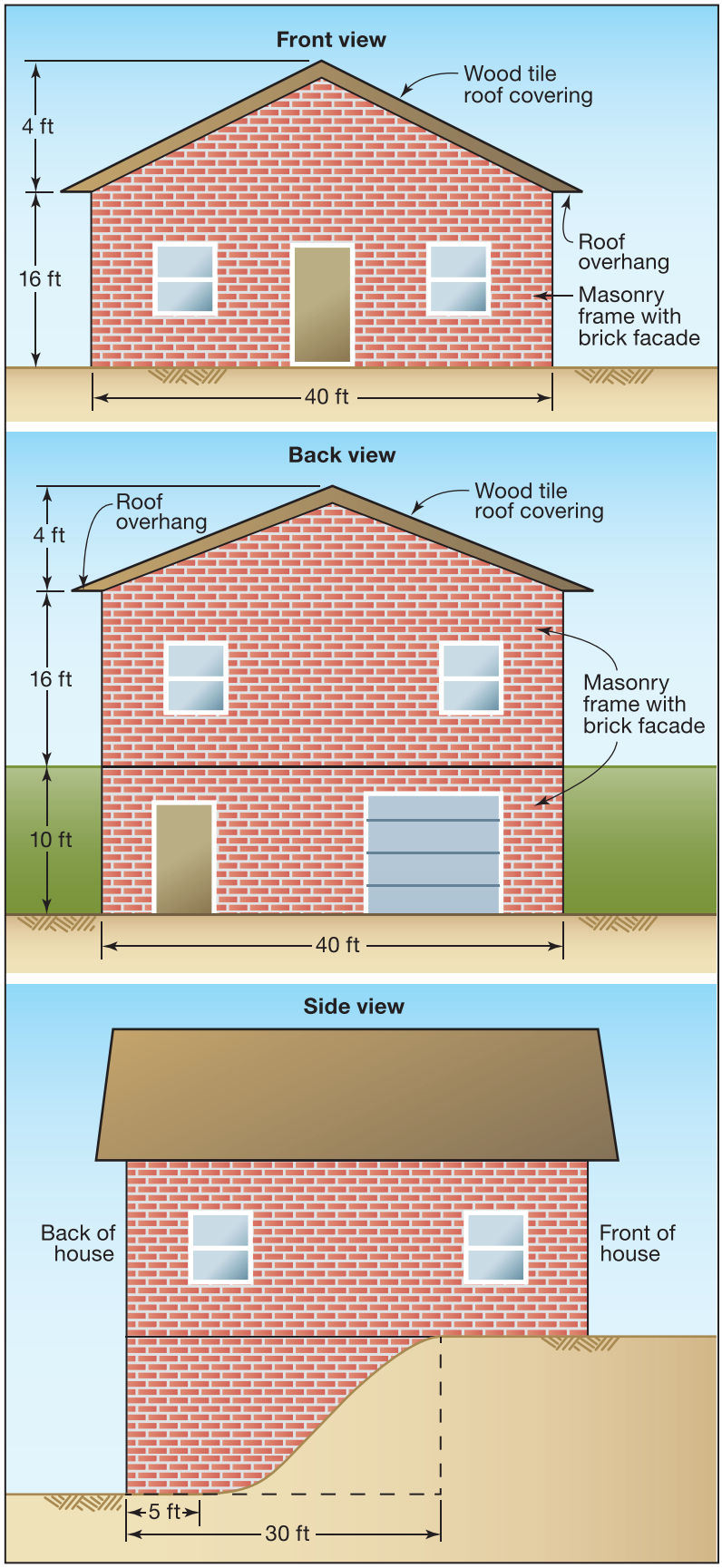


Figure 6-31. Elevation drawings from the front, back, and side of the Borges house

Other structure information includes:

- Main floor (footprint): 1,600 square feet (40 feet x 40 feet)
- Garage: 1,200 square feet (30 feet x 40 feet)
- Foundation:
  - Garage walls are reinforced and grouted CMU block, 8 inches thick, supported by a 2-foot-wide x 1-foot-thick concrete wall footer with a 6-inch-thick interior concrete slab.
  - Main floor over garage is supported on 2-inch x 8-inch joists spaced at 16 inches on center. Main floor not over garage is 4-inch-thick concrete slab supported by a 2-foot-wide x 1-foot-thick concrete wall footer.
  - Approximately 5 feet of the side garage walls are exposed at grade level.
  - Below-grade walls have an existing drainage system to control hydrostatic pressures below ground.
- Structure:
  - Main structure: Concrete block with common brick veneer
  - Garage: Concrete block with common brick veneer
  - Wood-frame interior walls with gypsum board sheathing
- Roof:
  - Gable roof with 1-foot overhangs over main structure
  - Asphalt shingle roof covering over entire roof
- Interior:
  - Wood stud interior walls with gypsum board sheathing
  - Hardwood floor coverings
- Entrances:
  - The garage has two entrances: a single pedestrian door (3-feet wide) and a standard garage door (8-feet wide)
  - There are no other windows or entrances in the garage

Plot

No part of the Borges' plot is in the floodplain. The site soils are primarily poorly graded gravel (Soil Type GP).

Building Assessment

An updated tax card is included at the end of this case study as an alternate source of the building replacement value as well as to verify the building square footage data.

Additionally, an engineer's estimate is that the Borges' home has a building replacement value of approximately $100.00 per square foot, based on popular cost estimating guides.

Flood Hazard Data

Because 18 Chai Avenue is not in the floodplain, there is no BFE for the structure. However, Mr. Borges has kept records of flood events that required some repairs. Flood depths are in inches from the top of the garage floor (see Table 6-6).

Table 6-6. Summary of Damages for the Borges House

Damage Year	Flood Depth (inches)	Damages (2011 dollars)
1994	6	$2,500
1999	1	$500
2003	2	$800
2011	8	$5,000

Based on this history of flooding, Mr. Borges would like to protect his house from up to 2 feet of flooding.

6.3.3 Retrofit Options Selection

During an initial interview with the Borges family, potential retrofit options were discussed (Figure 6-32). Initially, relocation was quickly ruled out because the Borges family was not willing to move. Floodwalls and levees were also ruled out, because there is not sufficient space on the property to undertake those methods. Although elevation was considered, it is not required and the costs were unreasonably high for the required level of protection.

Based on the retrofit option screening matrix, the two most viable options are dry floodproofing and wet floodproofing.

Dry Floodproofing

The purpose of dry floodproofing is to keep the water out of the garage. Refer to Table 1-3 for the advantages and disadvantages of dry floodproofing. This would involve:

- applying a waterproof sealant to the exterior of the CMU block walls, approximately $12/linear foot for a 2-foot flood depth (note that the sealant need only be applied to exposed walls because there is an existing drainage system for below-grade walls); and
- installing metal flood shields over the two doors, approximately $250/linear foot for a 2-foot flood depth.

Note that other dry floodproofing measures such as check valves, sump pumps, and drainage are not considered because there is no plumbing in the garage.

Preliminary Floodproofing/Retrofitting Preference Matrix

Owner Name: Jorge Juis Borges Prepared By: Jane Q. Engineer

Address: 18 Chai Avenue Date: 9/1/2011

Property Location: Memphis, TN

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
Floodproofing Measures									
Note the measures NOT allowed						X			X
Homeowner Concerns									
Aesthetic Concerns	X	X	X	X	X				
High Cost Concerns	X	X	X	X	X				
Risk Concerns	X	X					X	X	
Accessibility Concerns	X	X	X	X					
Code Required Upgrade Concerns									
Off-Site Flooding Concerns	X	X					X		
Total "X's"	**5**	**5**	**3**	**3**	**3**	**NA**	**2**	**1**	**NA**

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 that would affect its implementation. A concern is defined as a homeowner issue that, 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 6-32. Preliminary Floodproofing/Retrofitting Preference Matrix for the Borges house

The exposed areas of the CMU wall are:

Back wall: 40 ft – 3 ft – 8 ft = 29 ft

Side walls: 2 x 5 ft = 10 ft

Therefore, the total cost of sealant is (10 ft + 29 ft) x $12/lf = $468

Refer to Figure 5D-3 in Chapter 5D for details of sealant systems.

Metal closures would require 3 ft + 8 ft = 11 ft of closure.

Therefore, the total cost of closures is (11 ft) x $250/lf = $2,750

Refer to Figures 5D-5 and 5D-6 in Chapter 5D for closure details.

The total cost of dry floodproofing is $3,218. Additionally, an additional $75 per year will be needed to maintain the floodproofing sealants and shields.

Using this cost estimate, a preliminary BCA yields a BCR of 1.39. Therefore, this project would be cost effective.

This technique may be effective for a few inches of water, but it could lead to far more significant damages for greater levels of flooding. Dry floodproofing may not work for water levels that are sufficient to cause uplift against the underside of the garage slab, leading to cracking and water intrusion into the garage. See Section 6.3.4 for calculations related to the slab of the house. The hydrostatic forces associated with 2 feet or more of water on the slab would likely cause the slab to crack, allowing water into the garage and resulting in severe damage to the foundation of the house. This option is included here to illustrate its use; however, it is strongly recommended that the wet floodproofing option be used over the dry floodproofing option. Refer to the buoyancy check calculations in Section 6.3.4 for further information.

Wet Floodproofing

The purpose of wet floodproofing would be to allow water into the garage to equalize hydrostatic forces. Refer to Table 1-4 for the advantages and disadvantages of wet floodproofing. This would involve:

- elevating all stored contents above the floodproofing depth (2 feet);
- elevating all utilities above the floodproofing depth (2 feet); and
- installing flood vents along back wall and sides of house (see Figure 5E-15).

Note that wet floodproofing often includes replacing interior finishes with flood damage-resistant materials. Because the wet floodproofed area is a garage, there are no interior finishes. Additionally, concrete block walls and floors are considered to be flood damage-resistant under NFIP Technical Bulletin 2-08, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (FEMA, 2008a).

It is expected that the cost of wet floodproofing will be approximately $3,600, with an additional $50 a year budgeted to maintain the project, including clearing flood vents. A preliminary BCA yields a BCR of 1.41. Therefore, this project would also be cost effective.

6.3.4 Load Calculations

The paragraphs that follow provide calculations for flood loads, dead loads, live loads, and load combinations, as well as bearing capacity, sliding, uplift, and overturning checks associated with the dry and wet floodproofing options.

Load Calculations: Flood Loads

The first step is to calculate hydrostatic forces (Figure 6-33). As determined above, the floodproofing depth *H* is 2 feet. The house is slab-on-grade, so the saturated soil depth is 0 feet (again, these calculations are for the exposed walls only; there is an existing drainage system for the buried walls). Note that, for dry floodproofing, the hydrostatic forces act on the house in both the horizontal and vertical directions. For wet floodproofing, however, the hydrostatic forces are equalized, so the equivalent hydrostatic force (vertical and horizontal) is 0 pounds.

Because the source of flooding is surface runoff rather than a water body, the flow velocity is considered to be 0 ft/sec and there are no hydrodynamic or flood-borne debris impact forces.

Flood Force Summary:

Horizontal Force:

f_{comb} = 124.8 lb/lf
F_i = 0 lbs

The total flood force acting on the back wall is:
F_{sta} = (124.8 lb/lf x 40 ft) = 4,992 lbs (dry floodproofing)

Vertical Force:

F_{bouy} = 149,760 lbs (dry floodproofing)

Load Calculations: Dead Loads

The dead load is the self-weight of the structure. Case Study #1 illustrates a detailed calculation of the dead load. For this case study, assume a dead weight of approximately 40 lb/ft^2 over 1,600 square feet for the main level, plus approximately 40 lb/ft^2 over 1,200 ft^2 for the garage.

D = 40 lb/ft^2 x (1,600 ft^2) + 40 lb/ft^2 x (1,200 ft^2) = 112,000 lbs

Load Calculations: Live Loads

Live Load (Vertical)

Per ASCE 7-10, assume a live load of:
L = 40 lb/ft^2 x (1,600 ft^2 + 1,200 ft^2) = 112,000 lbs

Hydrostatic Force Computation Worksheet

Owner Name: Jorge Juis Borges Prepared By: Jane Q. Engineer

Address: 18 Chai Avenue Date: 9/1/2011

Property Location: Memphis, TN

Constants

γ_w = specific weight of water = 62.4 lb/ft³ for fresh water and 64.0 lb/ft³ for saltwater

Variables

H = floodproofing design depth (ft) = 2 ft

D = depth of saturated soil (ft) = 0 ft

S = equivalent fluid weight of saturated soil (lb/ft³) = 75 lb/ft³

Vol = volume of floodwater displaced by a submerged object (ft³) = 1,200 ft² x 2 ft = 2,400 ft³

P_h = hydrostatic pressure due to standing water at a depth of H (lb/ft²), $P_h = \gamma_w H$ = 124.8 lb/ft²

Summary of Loads

f_{sta} = 124.8 lb/ft

f_{dif} = 0 lb/ft

f_{comb} = 124.8 lb/ft

F_{bouy} = 149,760 lbs

Equation 4-4: Lateral Hydrostatic Force

$$f_{sta} = \frac{1}{2}P_h H = \frac{1}{2}\gamma_w H^2 = (1/2)(62.4 \text{ lb/ft}^3)(2 \text{ ft})^2 = 124.8 \text{ lb/ft}$$

Equation 4- 5: Submerged Soil and Water Force

$$f_{dif} = \frac{1}{2}(S - \gamma_w)D^2 = 0 \text{ lb/ft}$$

Equation 4-6: Combined Lateral Hydrostatic Force

$$F_{buoy} = \gamma_w (Vol) = 124.8 \text{ lb/ft} + 0 \text{ lb/ft} = 124.8 \text{ lb/ft}$$

Equation 4-7: Buoyancy Force

$$dh = \frac{C_d V^2}{2g} = (62.4 \text{ lb/ft}^3)(2{,}400 \text{ ft}^3) = 149{,}760 \text{ lbs}$$

Figure 6-33. Hydrostatic Force Computation Worksheet for the Borges house (Refer to Figure 4-9)

Roof Live Load (Vertical)

Per ASCE 7-10, assume a roof live load of 20 lb/ft². The roof live load acts on the horizontal projected area of the roof:
L_r = 20 lb/ft² x (1,600 ft²) = 32,000 lbs

Snow Load (Vertical)

Assume a conservative snow load of 20 lb/ft², per ASCE 7-10. The snow load also acts on the horizontal projected area of the roof.
S = 20 lb/ft² x (1,600 ft²) = 32,000 lbs

Wind Load (Horizontal)

Appendix C contains a detailed discussion of wind load calculations, including a detailed example. Refer to Appendix C for wind load calculations; this case study uses a simplified approach. Using a simplified wind load, assuming that the structure is fully enclosed, assume a worst case scenario wind load acting perpendicular to the structure (i.e., on the entire face of the structure facing the river). Therefore, assume a wind pressure of 30 lb/ft^2 acting uniformly over the entire aboveground structure:

Area = Exterior Wall area + Vertical Roof area

$\Rightarrow A$ = (40 ft)(10 ft) + (40 ft)(16 ft) + (1/2)(4 ft)(40 ft) = 1,120 ft^2

W_H = 30 lb/ft^2 x (1,120 ft^2) = 33,600 lbs

Wind Load (Vertical)

With a 1-foot overhang, assume that the only vertical wind force is acting upwards on the horizontal projected area of the overhangs (a simplification).

The horizontal projected area is taken to be 1 foot as a conservative estimate.

The upward wind force acts on the length of the overhang (40 feet) on each side of the house. Therefore, the total horizontal area is:

$\Rightarrow A$ = 2 x 1 ft x 40 ft = 80 ft^2

Assuming a vertical wind load of 20 lb/ft^2, the total vertical wind load is:

W_V = 20 lb/ft^2 x (80 ft^2) = 1,600 lbs

Earthquake Load

Earthquake forces are assumed to be negligible for this location, because the project is located far from the New Madrid fault. Therefore, for the purposes of this case study, E = 0.

Load Combinations

To determine the worst-case horizontal and vertical loading scenarios, ASCE 7-10 load combinations are used (Allowable Stress Design).

Load Summary:

Horizontal Loads

$D = L = L_r = S = E = 0$

$F_a = F_{sta}$ = 4,992 lbs (dry floodproofing); F_a = 0 lbs (wet floodproofing)

W = 33,600 lbs

Vertical Loads

D = 112,000 lbs (↓)

L = 112,000 lbs (↓)

L_r = 32,000 lbs (↓)

S = 32,000 lbs (↓)

W = 1,600 lbs (↑)

E = 0

$F_a = F_{buoy}$ = 149,760 lbs (↑) (dry floodproofing), F_a = 0 (wet floodproofing)

Table 6-7 presents a summary of the horizontal and vertical loads for the Borges house.

Table 6-7. Summary of Horizontal and Vertical Load Combinations for the Borges House Combination

	Horizontal (lbs)	Vertical (lbs)
1. D	0	112,000
2. $D + L$	0	224,000
3. $D + (L_r$ or S or $R)$	0	144,000
4. $D + 0.75L + 0.75(L_r$ or S or $R)$	0	220,000
5. $D + (0.6W$ or $0.7E) + 0.75F_a$	23,904 (dry) 20,160 (wet)	-1,280 (dry) 111,040 (wet)
6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r$ or S or $R) + 0.75F_a$	18,864 (dry) 15,120 (wet)	106,960 (dry) 219,280 (wet)
6b. $D + 0.75L + 0.75(0.7E) + 0.75S + 0.75F_a$	3,744 (dry) 0 (wet)	107,680 (dry) 220,000 (wet)
7. $0.6D + 0.6W + 0.75F_a$	23,904 (dry) 20,160 (wet)	-46,080(dry) 66,240 (wet)
8. $0.6D + 0.7E$	0	67,200

Bearing Capacity Check

$P_{max} = A_{bearing} S_{bc}$

S_{bc} = 2,500 lb/ft^2 (see Table 5-2)

The bearing area is taken to be the area of the footer under the garage:
$A_{bearing}$ = 2 ft x (2x40 ft + 2x30 ft) – (4 ft x 2 ft) = 272 ft^2
P_{max} = (2,500 lb/ft^2)(272 ft^2) = 680,000 lbs

Maximum vertical load:
436,000 lbs < P_{max} ✓

Sliding

Lateral forces are resisted by the walls of the structure, buried footers, and the slab. An analysis of resistance to sliding on foundation walls is included in Case Study 1. Additional sliding resistance will be provided by the slab.

Note that, although the home is unlikely to slide, the garage walls are susceptible to cracking due to lateral hydrostatic forces.

Uplift and Overturning

Resistance to uplift and overturning will be provided by the footers, the slab, and the soil below grade. An analysis of uplift resistance provided by footers is included in Case Study 1, and that additional resistance is provided by the slab. Note that, although the structure is unlikely to float out of the ground, the slab is susceptible to cracking (see below).

Slab Check

For dry floodproofing, it is necessary to check that the slab can resist the vertical and horizontal flood forces. This is done by checking the uplift forces against the dead load of the slab, as well as by checking the bending moment at the slab-to-wall connection. This analysis is a simplified comparison of vertical forces to the dead weight of the slab and does not account for steel reinforcement inside the slab. A slab that is both bottom- and top-reinforced may be able to resist uplift forces without cracking.

For this check, the dead load is the weight of the slab only (not including the rest of the structure):

D = 1,200 ft^2 x 6 in. x 1 ft/12 in. x 150 lb/ft^3 = 90,000 lbs

The vertical and horizontal flood forces are the same:

F_V = 149,760 lbs
F_H = 4,992 lbs

The worst case loading scenario for both the uplift and moment checks will be $0.6D + 0.75F_a$.

Uplift:

0.6D = 0.6(90,000 lbs) = 54,000 lbs
$0.75F_V$ = 0.75(149,760 lbs) = 112,320 lbs > 54,000 lbs **NOT ACCEPTABLE (dry floodproofing)**

The buoyancy forces are greater than the resisting force of the slab, causing the slab to crack or even rise out of the ground.

Bending:

For this check, the pivot point is the connection of the slab to the back wall and only the flood and slab weight forces are included, as shown in Figure 6-34.

$0.6M_D$ = 0.6(15 ft)(90,000 lbs) = 810,000 ft-lbs

$0.75M_{Fa}$ = 0.75(15 ft)(149,760 lbs) + 0.75(2/3 ft)(4,992 lbs) = 1,687,296 ft-lbs > 810,000 ft-lbs
NOT ACCEPTABLE (dry floodproofing)

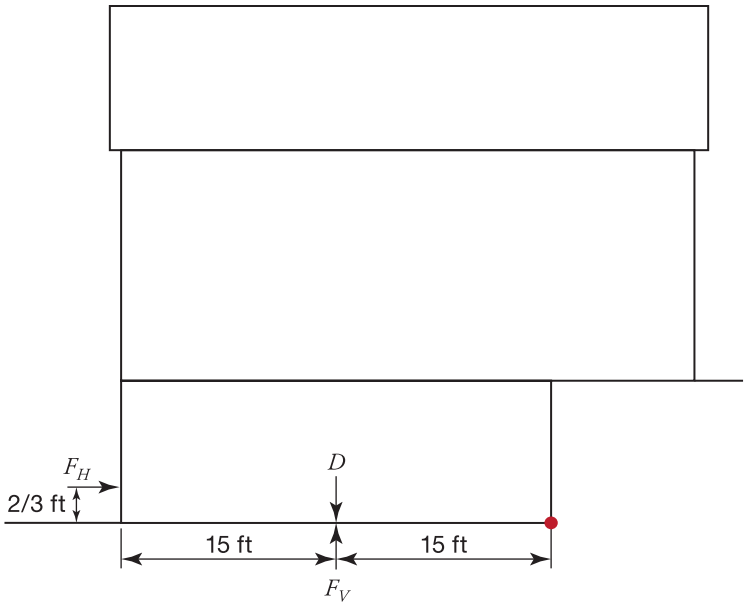


Figure 6-34. Moment diagram for the Borges house, slab only

The moment resulting from the flood forces is significantly greater than the resistive force of the slab, causing the slab to crack.

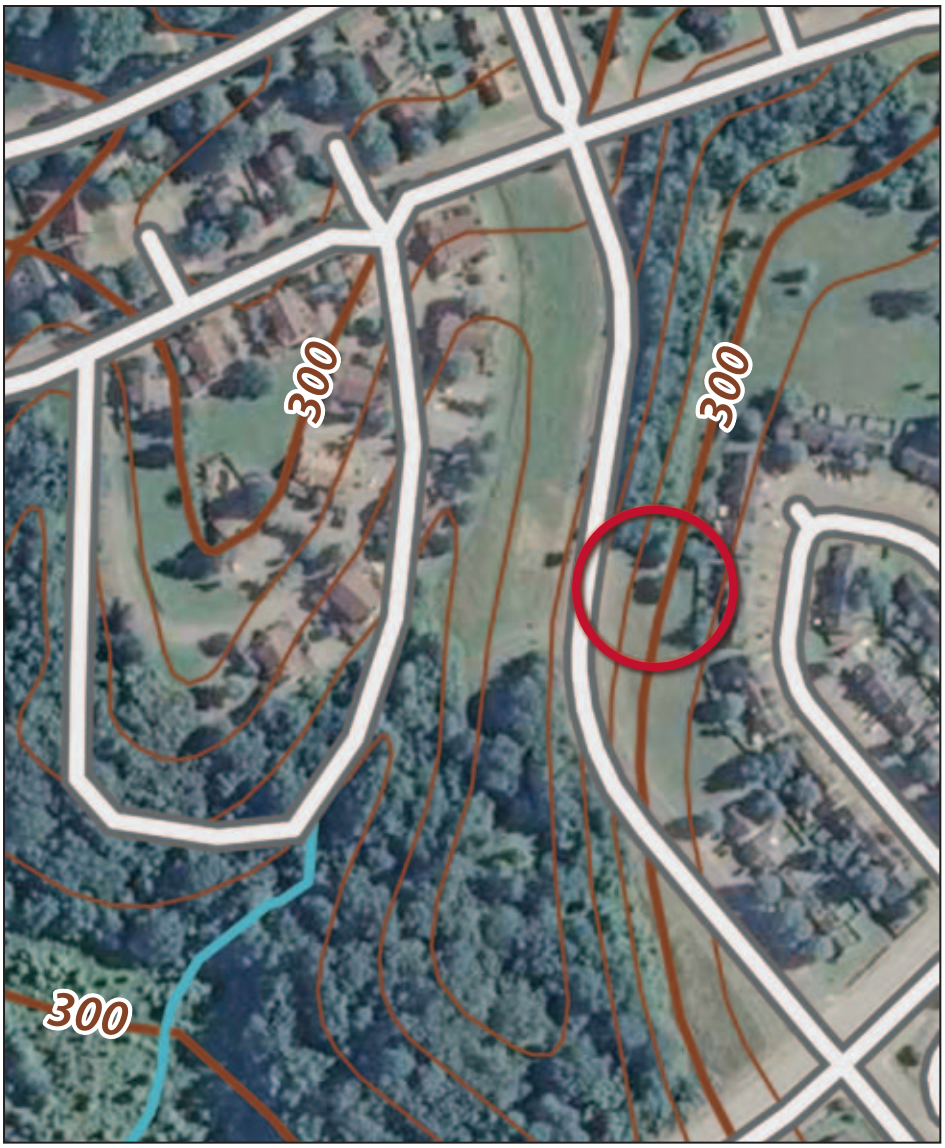
Dry floodproofing the existing garage is therefore not an option, because a flood depth of 2 feet would cause the slab to fail, allowing water into the house and requiring expensive repairs. The Borges family can either opt to use wet floodproofing, or they can install a thicker, better reinforced slab.

6.3.5 Supporting Documentation

This section includes additional information about the Borges house. The following maps and documents provide backup documentation for the values used in the Case Study 3 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-35);
- FIRM excerpt showing the location of the Borges house, outside of the 100-year floodplain (Figure 6-36);
- elevation certificate showing the first floor elevation (Figure 6-37);
- tax card providing building value and square footage (Figure 6-38); and
- BCA report excerpt summarizing the cost effectiveness of dry and wet floodproofing (Figure 6-39).

Figure 6-35. Topographic map showing the location of the Borges house (circled in red). Please note these are 10-foot contours.



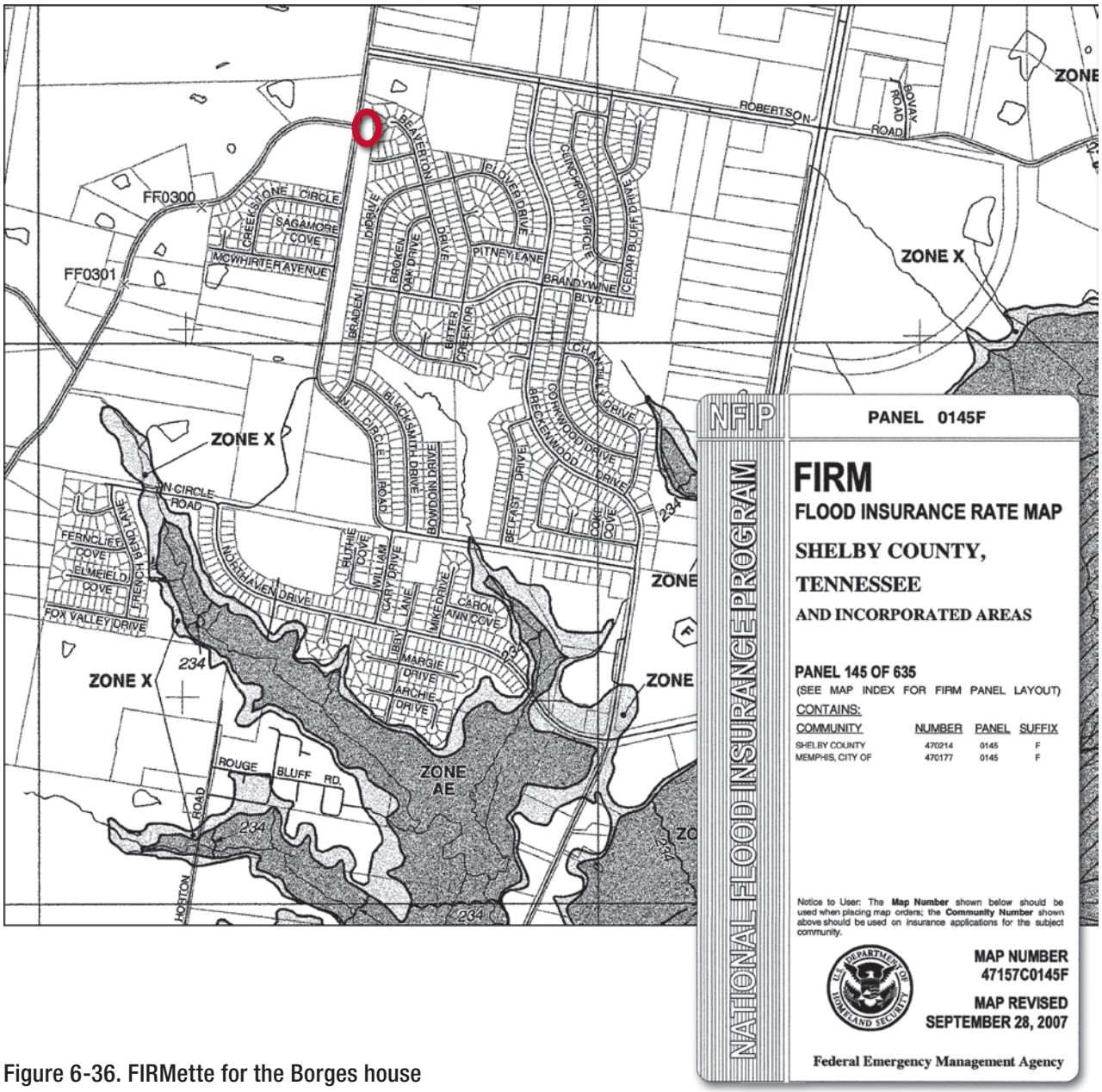


Figure 6-36. FIRMette for the Borges house

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name Jorge Luis Borges

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
18 Chai Avenue

City Memphis State TN ZIP Code 36549

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential
A5. Latitude/Longitude: Lat. _____ Long. _____ Horizontal Datum: ☐ NAD 1927 ☐ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number _____
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☐ No

A9. For a building with an attached garage:
a) Square footage of attached garage 1200 sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade 0
c) Total net area of flood openings in A9.b 0 sq in
d) Engineered flood openings? ☐ Yes ☐ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Memphis, 47147	Shelby	TN

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0145	F	9/28/2007		NA	NA

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☐ FIS Profile ☐ FIRM ☐ Community Determined ☒ Other (Describe) NA
B11. Indicate elevation datum used for BFE in Item B9: ☐ NGVD 1929 ☐ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☐ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized _____ Vertical Datum _____
Conversion/Comments _____

Check the measurement used.

a) Top of bottom floor (including basement, crawlspace, or enclosure floor) 250.3 ☒ feet ☐ meters (Puerto Rico only)
b) Top of the next higher floor 260.3 ☒ feet ☐ meters (Puerto Rico only)
c) Bottom of the lowest horizontal structural member (V Zones only) _____.____ ☐ feet ☐ meters (Puerto Rico only)
d) Attached garage (top of slab) _____.____ ☐ feet ☐ meters (Puerto Rico only)
e) Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments) 254.2 ☒ feet ☐ meters (Puerto Rico only)
f) Lowest adjacent (finished) grade next to building (LAG) 250.0 ☒ feet ☐ meters (Puerto Rico only)
g) Highest adjacent (finished) grade next to building (HAG) 260.0 ☒ feet ☐ meters (Puerto Rico only)
h) Lowest adjacent grade at lowest elevation of deck or stairs, including structural support _____.____ ☐ feet ☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available.I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☐
Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☐ Yes ☐ No

Certifier's Name Jane Q. Engineer License Number 183654
Title Project Engineer Company Name Engineering, Inc.
Address 72 McSwarley Street City Memphis State TN ZIP Code 36547
Signature Date Telephone

STATE OF TENNESSEE
PLACE
JANE Q.
ENGINEER
HERE
NO. 183654
NOT LICENSED
PROFESSIONAL ENGINEER

FEMA Form 81-31, Mar 09 See reverse side for continuation. Replaces all previous editions

Figure 6-37. Elevation certificate excerpt for the Borges house

Property Location and Owner Information		2011 Appraisal and Assessment Information	
Parcel ID:	D0134 L00000	Class:	RESIDENTIAL
Property Address:	18 Chai Avenue	Land Appraisal:	$50,900
Municipal Jurisdiction:	UNINCORP	Building Appraisal:	$150,338
Neighborhood Number:	0000000	Total Appraisal:	$201,238
Land Square Footage:	6795		
Acres:	0.1560	Total Assessment:	$50,700
Lot Dimensions:	61.55/66.43X110/85		
Subdivision Name:	BRECKENWOOD SEC F	Greenbelt Land:	$0
Subdivision Lot Number:	000	Homesite Land:	$0
Plat Book and Page:	00-00	Homesite Building:	$0
Number of Improvements:	0	Greenbelt Appraisal:	$0
Owner Name:	BORGES JORGE LUIS	Greenbelt Assessment:	$0
In Care Of:			
Owner Address:	18 Chai Avenue		
Owner City/State/Zip	Memphis, TN 36549		

Dwelling Construction Information			
		Heat:	CENTRAL A/C AND HEAT
Stories:	1.5	Fuel:	NA
Exterior Walls:	Brick Veneer	Heating System:	NA
Land Use:	Single Family		
Year Built:	1991	Fireplace Masonry:	0
Total Rooms:	6	Fireplace Pre-Fab:	0
Bedrooms:	3		
Bathrooms:	2	Ground Floor Area:	1600
Half Baths:	0	Total Living Area:	1600
Basement Type:	Slab		
		Car Parking:	Garage

Figure 6-38. Tax card for the Borges house

16 Sep 2011 Project: **Case Study 3** Pg 1 of 9

Total Benefits: **$11,700** Total Costs: **$9,191** BCR: **1.27**

Project Number: Disaster #: Program: Agency: **City of Memphis**

State: **Tennessee** Point of Contact: Analyst:

Project Summary:

Project Number: Disaster #:

Program: Agency: City of Memphis

Analyst:

Point of Contact: Phone Number:

Address: Memphis, Tennessee

Email:

Comments:

Structure Summary For:

1-Dry Floodproofing, 18 Chai Ave, Memphis, Tennessee, 36549, Shelby

Structure Type: Building Historic Building: No Contact:

Benefits: $5,757 Costs: $4,971 BCR: 1.16

Mitigation	Hazard	BCR	Benefits	Costs
Dry Flood Proofing	Damage-Frequency Assessment	1.16	$5,757	$4,971

2-Wet Floodproofing, 18 Chai Ave, Memphis, Tennessee, 36549, Shelby

Structure Type: Building Historic Building: No Contact:

Benefits: $5,943 Costs: $4,220 BCR: 1.41

Mitigation	Hazard	BCR	Benefits	Costs
Other flood proofing measures	Damage-Frequency Assessment	1.41	$5,943	$4,220

Figure 6-39. Sample BCA report excerpt for dry and wet floodproofing of the Borges house

6.3.6 Real World Examples

Although the Borges house is fictional, wet- and dry-floodproofing are both commonly used flood mitigation measures outside of the 100-year floodplain. Figures 6-40 through 6-43 are examples of real structures that have been protected using the mitigation measures discussed in this case study.

Figures 6-40 and 6-41 show flood shields installed in dry floodproofed buildings.

Figure 6-40.
Example of a flood shield over a door

Figure 6-41.
Example of a flood shield over a door

Figures 6-42 and 6-43 show typical flood openings in exterior walls:

Figure 6-42.
Example of flood vents

Figure 6-43.
Example of flood vents

6.4 Case Study #4: Residential Retrofit Outside of the Floodplain Using Floodwalls or Levees

This case study exercise examines the retrofit of a residential building outside the floodplain by means of floodwalls or levees. Details are provided in the subsections that follow.

6.4.1 Description of Property

Atticus Finch
Valley House
2908 Valley Drive
Bismarck, ND 87421

Atticus Finch is a collector of historic properties. He recently acquired Valley House, which is a historic brick home in Bismarck, North Dakota. The exact construction date is not known, but the structure is presumed to have been built in the late nineteenth or early twentieth century. The structure has been very well maintained over the years and is not in the floodplain. However, changing hydrology, saturated grounds, and recent flooding have meant that the building has been subject to up to 2 feet of flooding several times in recent years.

Mr. Finch would like to protect the building from flooding. However, the building is on the National Register of Historic Places and, therefore, any alterations to the structure that would affect that designation are not permissible.

6.4.2 Structure Information

Valley House is a two-story, brick house on a large plot of land (Figure 6-44). The structure sits on an unreinforced concrete footer. The building footprint is 2,500 square feet. Valley House has a complex roof system—some parts are gable, some are hip, and some are flat (multiple roof renovations have been made over the years).

The interior of the house has hardwood floors and wood-frame and plaster walls.

Plot

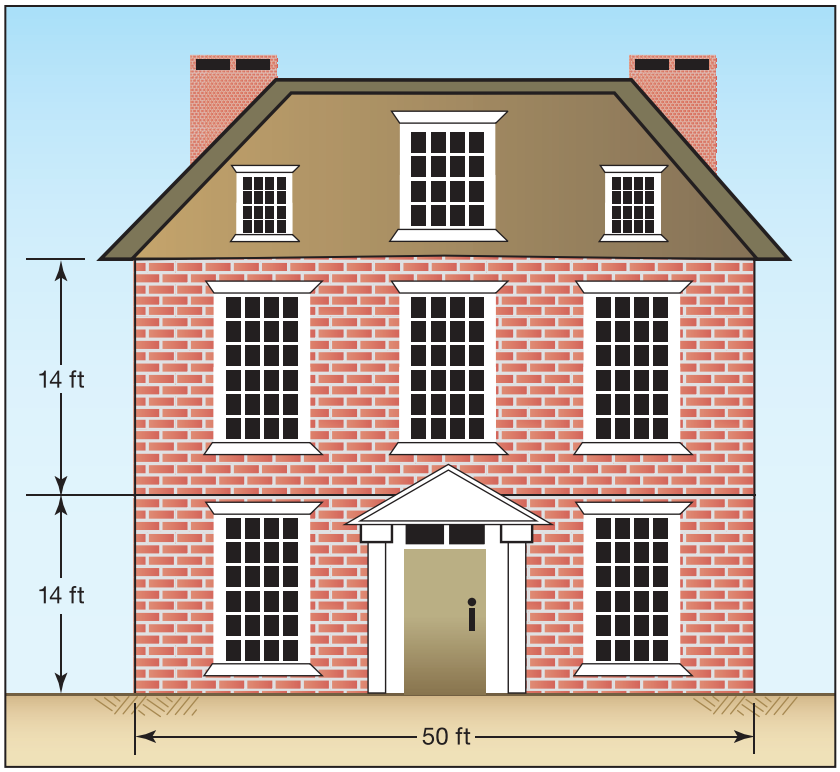
Valley House sits on a large plot of land. The plot itself is relatively flat, but sits at the bottom of a large valley. The soil type is poorly graded sand with silt (Soil Type SM-SP).

Building Assessment

An updated tax card is included at the end of this case study as an alternate source of the building replacement value as well as to verify the building square footage data.

Mr. Finch bought Valley House for $5.8 million in 2005.

Figure 6-44.
Valley house



Flood Hazard Data

Because Valley House sits at the bottom of the valley, there is no single source of flooding, and floodwater can inundate the house from any direction. The maximum rainfall intensity is approximately 1 inch/hour. Since 2005, Mr. Finch has recorded the following damages as shown in Table 6-8.

Mr. Finch would like to protect Valley House from up to 2 feet of flooding plus a 1-foot freeboard.

Table 6-8. Summary of Damages for Valley House

Damage Year	Flood Depth (in.)	Damages (2011 Dollars)
2006	6	$3,000
2008	12	$14,000
2009	8	$8,500
2011	24	$20,000

6.4.3 Retrofit Options Selection

Because Valley House is a historic building, no changes can be made to the structure itself that would affect its designation. Therefore, floodwalls and levees are considered the only viable options (Figure 6-45).

Preliminary Floodproofing/Retrofitting Preference Matrix

Owner Name: Atticus Finch Prepared By: Jane Q. Engineer

Address: 2908 Valley Drive Date: 9/1/2011

Property Location: Bismarck, ND 87421

	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
Note the measures NOT allowed	X	X	X	X	X	X	X	X	
Homeowner Concerns									
Aesthetic Concerns									X
High Cost Concerns									
Risk Concerns									
Accessibility Concerns									X
Code Required Upgrade Concerns									
Off-Site Flooding Concerns									X
Total "x's"	NA	NA	NA	NA	NA	NA	NA	NA	3

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 that would affect its implementation. A concern is defined as a homeowner issue that, 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 6-45. Preliminary Floodproofing/Retrofitting Preference Matrix for Valley house

Floodwall

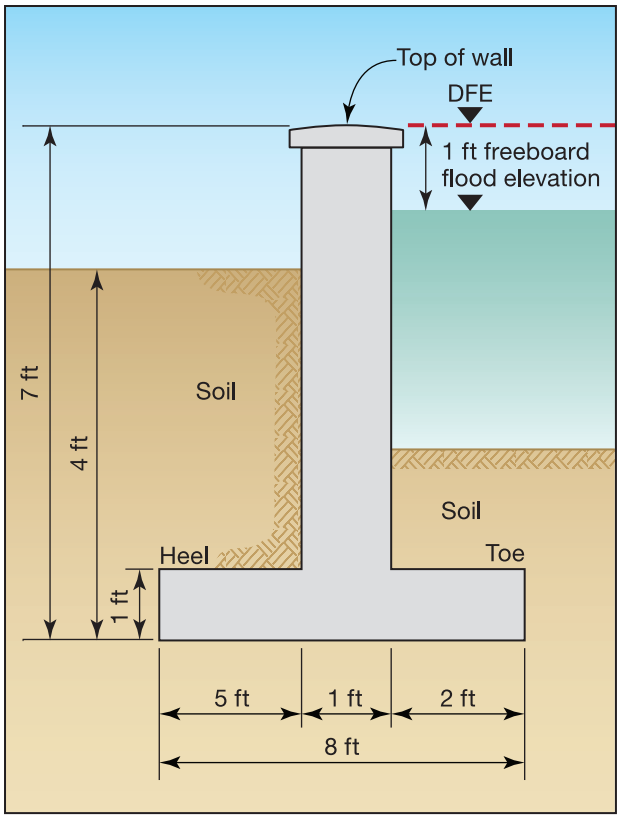
To protect the entire structure, a floodwall should be built around all four sides of the house (Figure 6-46). Refer to Table 1-5 for the advantages and disadvantages of floodwalls. This would involve:

- selecting the site and extent of the floodwall, including distance from the structure;
- excavating for footings;
- installing reinforcing steel and pouring concrete;
- designing and installing drainage system;
- designing and installing access points:
  - one set of stairs for pedestrian access; and
  - one gate with a slide-in closure for vehicle access; and
- backfilling.

Using the simplified design process in Chapter 5F, for Soil Type SM-SP, and to achieve an above-grade floodwall height of 3 feet, the dimensions required for the floodwall can be seen in Figure 6-46.

One way to install an aesthetically pleasing floodwall is to use a brick facing. Figure 5F-8 shows a detail of a brick-faced concrete floodwall.

Figure 6-46. Floodwall dimensions for the Valley house floodwall



Assuming the centerline of the floodwall should be 50 feet from the house on all sides, a floodwall or levee plan would look as shown in Figure 6-47.

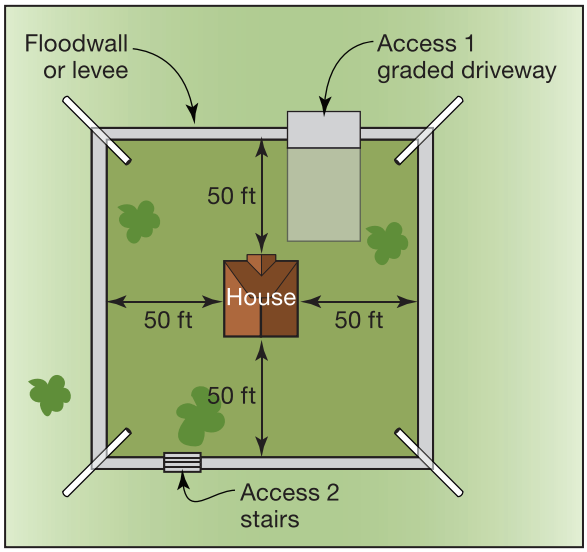


Figure 6-47. Plan drawing for Valley house floodwall or levee

Refer to the previous case study and Chapter 5D for details on closures.

A preliminary cost estimate suggests that the cost of the floodwall would be approximately $55,000. Running a BCA on this project does not result in a BCR of greater than 1, because the only recorded damages over the 100 year (or more) life of the structure were recorded in the last few years. However, this project has benefits beyond merely pure economic benefits; it will protect a historic asset. Furthermore, because this project is being conducted outside of the floodplain and thus not being used to bring a structure into compliance with the NFIP, FEMA funding will not be used to complete the project and a BCA is not required.

Levee

A levee would serve the same purpose as a floodwall, but would require significantly more space to install. Refer to Table 1-5 for the advantages and disadvantages of levees. Installing a levee would involve:

- selecting the site and extent of the levee, including distance from the structure;
- grubbing and clearing levee area;
- excavating for cutoff trench;
- laying and compacting fill;
- designing and installing drainage system;
- designing and installing access points:
  - one set of stairs for pedestrian access; and
  - one graded driveway for vehicle access; and
- seeding.

Using the minimum prescriptive requirements outlined in Chapter 5F, the following dimensions are required for a levee (Figure 6-48).

A ring levee would follow the same plan as the floodwall. However, because the required base width is 27 feet, the levee would take significantly more space to implement.

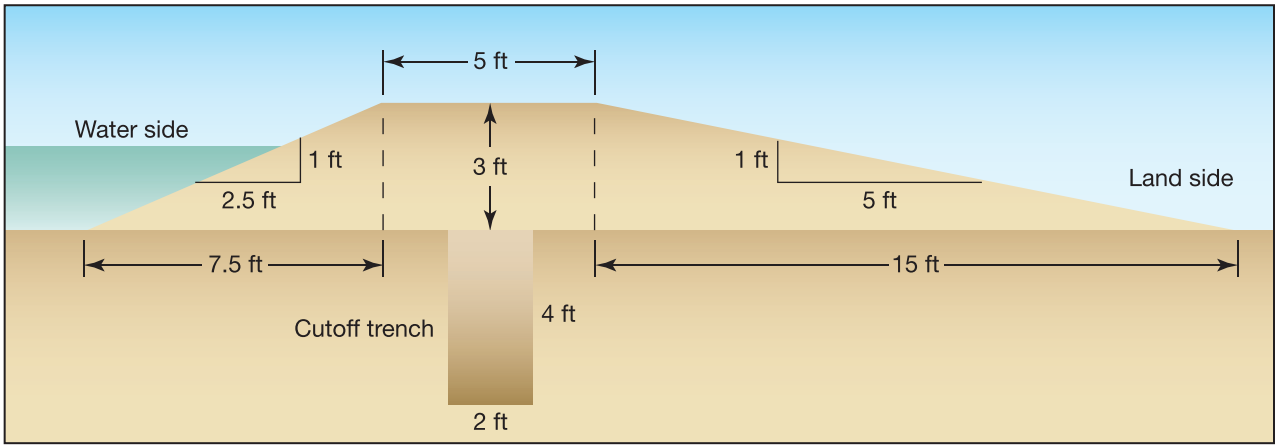


Figure 6-48. Valley House levee cross-sectional dimensions

Running a BCA on such a levee (with an assumed cost of approximately $60,000) yields similar results to the floodwall BCA, and for the same reasons.

6.4.4 Load Calculations

Because requirements for floodwalls and levees are prescriptive, load calculations are not required (however, a detailed floodwall analysis can be found in Chapter 5F). Further, because no change is being made to the existing structure itself, it is not necessary to conduct load calculations on the structure to ensure that it can resist sliding, uplift, and overturning.

6.4.5 Drainage Requirements

All floodwalls and levees require a drainage system. Figure 6-49 demonstrates drainage requirements for a floodwall or levee.

A review of various national cost guides indicates a pump with a capacity of 161.5 gpm or greater would add an additional $2,000 to the project cost of the floodwall or levee project.

Interior Drainage Computation Worksheet

Owner Name: Atticus Finch Prepared By: Jane Q. Engineer

Address: 2908 Valley Drive Date: 9/1/2011

Property Location: Bismarck, ND

Constants

0.01 = factor converting the answer to gpm

Variables

A_a = is the area enclosed by the floodwall or levee (ft^2) = 150 ft x 150 ft = 22,500 ft^2

A_b = area discharging to the area partially enclosed by the floodwall or levee (ft^2) = 0 ft^2 (fully enclosed levee/floodwall system)

c = residential terrain runoff coefficient of 0.7

i_r = intensity of rainfall (in./hr) = 1 in./hr

s_r = seepage rate (gpm) per foot of floodwall/levee = 2 gpm/300 ft (levee); 1 gpm/300 ft (floodwall)

l = length of the floodwall/levee (ft) = 4 x 150 ft = 600 ft

Summary of Loads

Q_{sp} = 161.5/159.5 gpm

Q_a = 157.5 gpm

Q_b = 0 gpm

Q_c = 4/2 gpm

Equation 4-14: Runoff Quantity in an Enclosed Area

$Q_a = 0.01 c i_r A_a$ = 0.01(0.7)(1)(22,500) = 157.5 gpm

Equation 4-15: Runoff Quantity From Higher Ground into a Partially Enclosed Area

$Q_b = 0.01 c i_r A_b$ = 0 gpm

Equation 4-16: Seepage Flow Rate Through a Levee or Floodwall

	Levees	Floodwalls
$Q_c = sr(l)$ =	(2/300)(600) = 4 gpm;	= (1/300)(600) = 2 gpm

Equation 4-17: Minimum Discharge for Pump Installation

$Q_{sp} = Q_a + Q_b + Q_c$ = length of the floodwall/levee (ft) = 4 x 150 ft = 600 ft

Figure 6-49. Interior Drainage Computation Worksheet for Valley House floodwall or levee

6.4.6 Supporting Documentation

This section includes additional information about Valley House. The following maps and documents provide backup documentation for the values used in Case Study 3 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-50);
- DFIRM excerpt showing the location of Valley House, outside of the 100-year floodplain Figure 6-51);
- elevation certificate showing the first floor elevation and base flood elevation (Figure 6-52); and
- tax card providing building value and square footage (Figure 6-53).

Figure 6-50. Topographic map showing location of Valley house (red circle). Please note these are 10-foot contours.

Levees and floodwalls are generally not cost effective; for that reason, no BCA report is included. However, floodwalls and levees may be the most effective way to protect structures like Valley House.

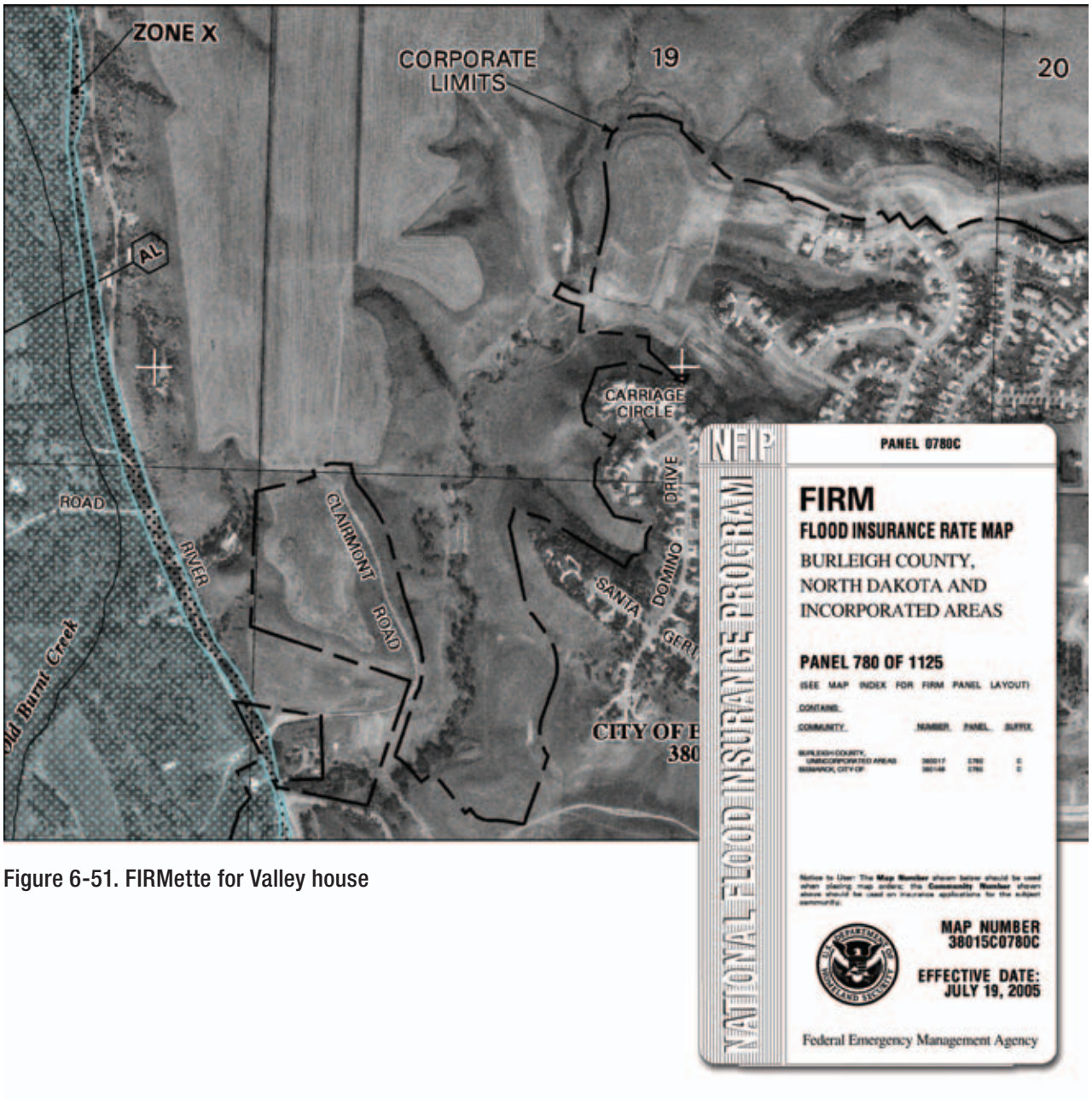


Figure 6-51. FIRMette for Valley house

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name Atticus Finch

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
2908 Valley Drive

City Bismarck State ND ZIP Code 87421

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential-Historic
A5. Latitude/Longitude: Lat. _____ Long. _____ Horizontal Datum: ☐ NAD 1927 ☐ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number _____
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☐ No

A9. For a building with an attached garage:
a) Square footage of attached garage _____ sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade 0
c) Total net area of flood openings in A9.b 0 sq in
d) Engineered flood openings? ☐ Yes ☐ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Bismarck 380149	Burleigh	ND

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0780	C	7/15/2005		NA	NA

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☐ FIS Profile ☐ FIRM ☐ Community Determined ☒ Other (Describe) NA
B11. Indicate elevation datum used for BFE in Item B9: ☐ NGVD 1929 ☐ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☐ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized _____ Vertical Datum _____
Conversion/Comments _____

Check the measurement used.

a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	1730.3	☒ feet ☐ meters (Puerto Rico only)
b)	Top of the next higher floor	1740.3	☒ feet ☐ meters (Puerto Rico only)
c)	Bottom of the lowest horizontal structural member (V Zones only)	_____.____	☐ feet ☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	_____.____	☐ feet ☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	1730.3	☒ feet ☐ meters (Puerto Rico only)
f)	Lowest adjacent (finished) grade next to building (LAG)	1730.0	☒ feet ☐ meters (Puerto Rico only)
g)	Highest adjacent (finished) grade next to building (HAG)	1732.1	☒ feet ☐ meters (Puerto Rico only)
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	1730.0	☐ feet ☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available.I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☐
Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☐ Yes ☐ No

Certifier's Name Jane Q. Engineer License Number 183654
Title Project Engineer Company Name Engineering, Inc.
Address 72 McSwarley Street City Memphis State TN ZIP Code 36547
Signature Date Telephone

STATE OF NORTH DAKOTA
JANE Q. ENGINEER
NO. 183654
NOT LICENSED
PROFESSIONAL ENGINEER

FEMA Form 81-31, Mar 09 See reverse side for continuation. Replaces all previous editions

Figure 6-52. Elevation certificate excerpt for Valley house

Property Location and Owner Information		2011 Appraisal and Assessment Information	
Parcel ID:	D0122 L00000	Class:	RESIDENTIAL-HIST
Property Address:	2908 VALLEY DR	Land Appraisal:	$143,566
Municipal Jurisdiction:	UNINCORP	Building Appraisal:	$607,443
Neighborhood Number:	0000000	Total Appraisal:	$751,009
Land Square Footage:	90,000		
Acres:	2.07	Total Assessment:	$750,000
Lot Dimensions:			
Subdivision Name:	VALLEY HILLS	Greenbelt Land:	$0
Subdivision Lot Number:	000	Homesite Land:	$0
Plat Book and Page:	00-00	Homesite Building:	$0
Number of Improvements:	0	Greenbelt Appraisal:	$0
Owner Name:	FINCH ATTICUS	Greenbelt Assessment:	$0
In Care Of:			
Owner Address:	5674 Main St		
Owner City/State/Zip	Bismarck, ND 87542		

Dwelling Construction Information			
		Heat:	CENTRAL A/C AND HEAT
Stories:	2	Fuel:	NA
Exterior Walls:	BRICK	Heating System:	NA
Land Use:	Historic		
Year Built:	1900 (est)	Fireplace Masonry:	1
Total Rooms:	12	Fireplace Pre-Fab:	0
Bedrooms:	4		
Bathrooms:	3	Ground Floor Area:	2500
Half Baths:	1	Total Living Area:	5000
Basement Type:	Slab		
		Car Parking:	Garage

Figure 6-53. Tax card for Valley House

6.4.7 Real World Examples

Although Valley House is fictional, floodwalls and levees are both commonly used flood mitigation measures outside of the 100-year floodplain. The following photos are examples of real structures that have been protected using the mitigation measures discussed in this case study.

Figures 6-54 and 6-55 show residential floodwalls.

Figures 6-56 and 6-57 show residential levees.

Figure 6-54. Interior sump pump for a residential floodwall

Figure 6-55. Brick-faced residential floodwall and access stairs

Figure 6-56.
Residential levee

Figure 6-57.
Driveway access over a residential levee