HISTORIC BUILDINGS AND FLOOD PROTECTION

A GUIDE FOR OWNERS OF HISTORIC BUILDINGS

AUGUST 2017

National Trust *for* Historic Preservation™

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THE PROJECT

Farnsworth House in Plano, Illinois, after a flood in 2017.

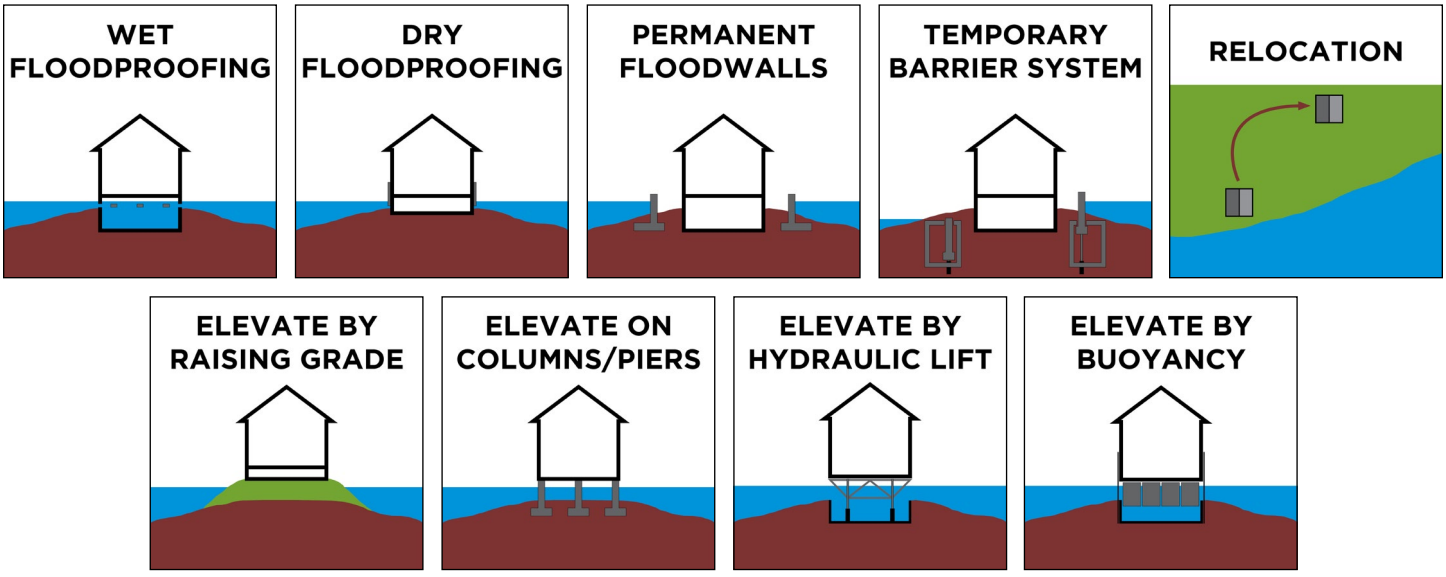
INTRODUCTION

Flooding has been increasing in areas across the country, which is forcing historic site owners to consider how to protect their historic buildings from rising water.

At the National Trust for Historic Preservation, one of the sites most greatly affected by increased flooding is Farnsworth House in Plano, IL. This modernist building, designed by Mies van der Rohe and constructed in 1951, has always experienced site flooding but flood models indicate the occurrence and severity of the flooding will increase, inundating the interior of the building and causing continual damage to the building's materials and systems.

Through the study about how to protect Farnsworth from rising floodwaters, a great deal of information about different flood protection options has been gathered. With funding provided by a National Center for Preservation Technology and Training grant, the National Trust has worked to expand what has been learned from Farnsworth to help other owners of historic buildings navigate the various flood protection options and determine which option is the best for their historic building.

FLOOD PROTECTION OPTIONS



THE PROJECT

IMPORTANT CONSIDERATIONS

The flood protection options considered here are most relevant for buildings that experience floodwaters less than 15 ft. deep. For floodwater depths greater than 15 ft. deep, the only real option is relocation.

For many of the options, the building footprint should be less than 5,000 sf. Building footprints much larger than this will require additional analysis to determine which options are viable.
For all elevation options, it is assumed that the building will be elevated at least above the highest expected flood level (typically the 500-yr flood).

For many of the flood protection options, warning time is needed to set up or mobilize the protection system. For this reason, these options are not relevant for buildings that most often experience flash flooding.

Finally, while the information in this report is meant to help guide owners of historic buildings, before definitively choosing any option, the owner should:

- Consult licensed engineers and architects to confirm the solution is appropriate and feasible.
- Consult your local building code and supplements to learn about any code restrictions.
- Determine if special permitting from the Army Corps of Engineers or other relevant government agencies will be required and can be acquired to build in the floodplain.
- If your building is historically designated, work with all relevant government agencies (Dept. of the Interior, SHPO, or local historic commission) to prevent loss of designation.

WHY USE THE 500-YEAR FLOOD LEVEL?

Currently FEMA defines the Base Flood Elevation (BFE) as the height of flooding that might be expected in a 100-year flood. The BFE for your site is determined from flood insurance rate maps (FIRMs), and this elevation plus freeboard is typically the elevation above which all new construction is built (Design Flood Elevation or DFE) and the elevation above which FEMA recommends retrofitting any buildings in the floodplain.

As preservationists, however, we think long-term. Understanding that the 100-year flood level is increasing with time and it takes FEMA years to reissue the new levels, it is our recommendation to retrofit based on the height of flooding that might be expected in a 500-year flood. If this elevation is so high that it makes all flood protection options infeasible, then the DFE should be used.

THANKS TO NCPTT

This project was made possible by the funding awarded to the Trust by the National Center for Preservation Technology and Training.

NCPTT

MORE ON THE FARNSWORTH PROJECT

For more information about the Farnsworth project led by the National Trust and supported by numerous consultants, visit farnsworthproject.org.

FARNSWORTH

THE QUIZ

INTRODUCTION

The following quiz has been developed to help owners of historic buildings narrow down their flood protection options based on a few key considerations:

» Highest expected floodwater depth
» Ability to temporarily move your building
» Amount of money you are willing to spend

After answering these questions and moving through the quiz based on the instructions on each page, you should go to the information sections about each recommended flood protection option. At the end of each information section, there is another quiz to further help owners of historic buildings determine if the flood protection option in question is right for them.

A couple of comments about the quiz. The three questions that follow are not necessarily the most important questions to ask in determining the right flood protection option for you, but the answers to these questions do help to significantly narrow down the options. Other important considerations are highlighted in the individual information sections about each flood protection option.

For owners that are willing to spend as much money as possible to protect their historic building from flood risk, elevation by a buoyancy system is not one of the recommended options. This is because there are very few situations in which elevation by a buoyancy system would be a better solution than elevation by a hydraulic lift system (compare the information sections “Elevate by Hydraulic Lift” and “Elevate by Buoyancy”).

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Under 3 feet	Between 3 and 6 feet	Over 6 feet
Go to page 6	Go to page 7	Go to page 8

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Under 3 feet

Many flood protection options require moving the building during construction.
IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?

Yes	**No**
Go to page 9	Go to page 10

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Between 3 and 6 feet

Many flood protection options require moving the building during construction.
IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?

Yes	**No**
Go to page 11	Go to page 12

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Over 6 feet

Many flood protection options require moving the building during construction.
IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?

Yes	**No**
Go to page 13	Go to page 14

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Under 3 feet

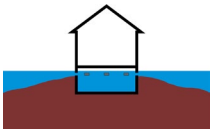
Many flood protection options require moving the building during construction.
IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?

Yes

HOW MUCH MONEY ARE YOU WILLING TO SPEND?

As little as possible

WET FLOODPROOFING



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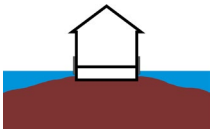
DRY FLOODPROOFING



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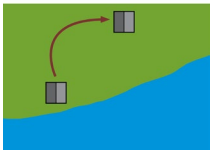
A reasonable amount

RELOCATION



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ELEVATE BY RAISING GRADE

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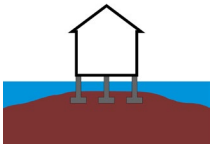
ELEVATE ON COLUMNS/PIERS



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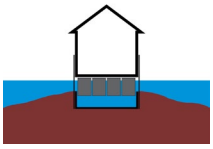
ELEVATE BY BUOYANCY



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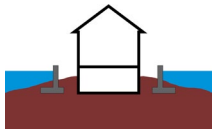
As much as it takes

PERMANENT FLOODWALLS



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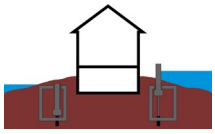
TEMPORARY BARRIER SYSTEM



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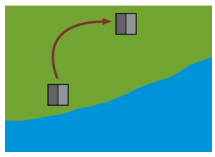
RELOCATION



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ELEVATE BY RAISING GRADE

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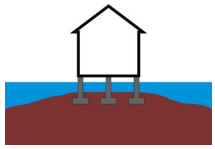
ELEVATE ON COLUMNS/PIERS



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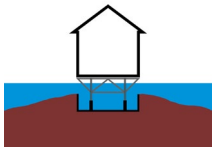
ELEVATE BY HYDRAULIC LIFT



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WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Under 3 feet

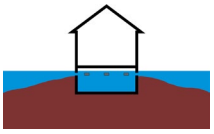
Many flood protection options require moving the building during construction.
IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?

No

HOW MUCH MONEY ARE YOU WILLING TO SPEND?

As little as possible

WET FLOODPROOFING



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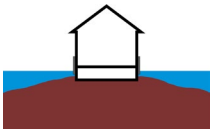
DRY FLOODPROOFING



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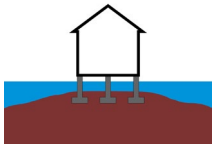
A reasonable amount

ELEVATE ON COLUMNS/PIERS



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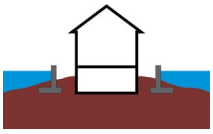
As much as it takes

PERMANENT FLOODWALLS



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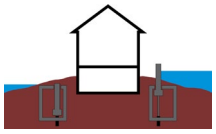
TEMPORARY BARRIER SYSTEM



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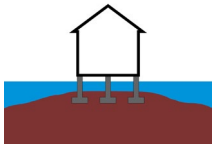

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WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Between 3 and 6 feet

Many flood protection options require moving the building during construction. **IS THERE A SPACE ON YOUR SITE/ELSEWHERE TO TEMPORARILY STORE THE BUILDING DURING CONSTRUCTION?**

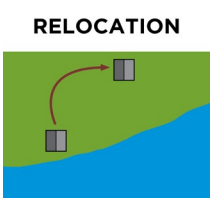
Yes

HOW MUCH MONEY ARE YOU WILLING TO SPEND?

As little as possible

There are no cheap options available based on your answers. Consider spending a little more money.

A reasonable amount



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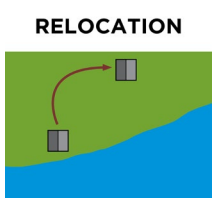

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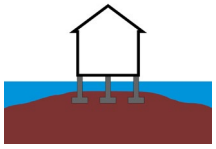

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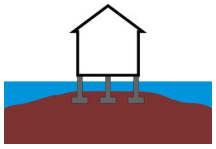

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WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Over 6 feet

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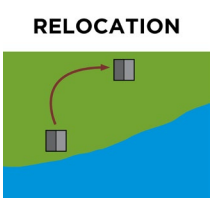
Yes

HOW MUCH MONEY ARE YOU WILLING TO SPEND?

As little as possible

There are no cheap options available based on your answers. Consider spending a little more money.

A reasonable amount



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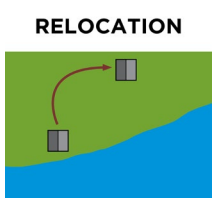
As much as it takes



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*Due to the larger floodwater depth, the building would have to be elevated on piles, which are similar to columns.

WHAT IS THE HIGHEST FLOOD LEVEL EXPECTED AT YOUR SITE?

Over 6 feet

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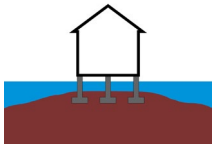

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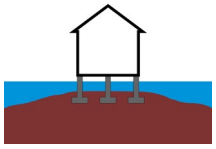

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*Due to the larger floodwater depth, the building would have to be elevated on piles, which are similar to columns.

WET FLOODPROOFING

Flood vents allow water to enter the basement, preventing excessive pressure from developing on the basement walls.

DESCRIPTION

Wet floodproofing is a flood protection option that allows floodwaters to enter the building. The spaces in which water will enter, such as the basement or ground floor, are modified to minimize damage. Modifications may include water-proofing building materials and creating or modifying openings in the exterior walls to allow water to enter. By allowing floodwaters to enter the building, you don't have to worry about the excessive build-up of pressure caused by the floodwaters on the building's exterior walls (hydrostatic pressure). Wet floodproofing is best suited for infrequent flooding and shorter duration floods, and it is typically the cheapest flood protection option.

ADVANTAGES

One of the main advantages of wet floodproofing is that it is a minimal cost and minimal effort solution.

DISADVANTAGES

The main disadvantage of wet floodproofing is that it is a short-term solution and will, therefore, result in the deterioration of building materials due to repeated exposure to floodwaters.

IMPORTANT CONSIDERATIONS

- Some aspects of the building's architecture will be modified, although these modifications are minimal.
- If there are important collection items in the spaces that may get wet during a flood, these items either need to be temporarily moved before the flood or permanently moved to avoid damage.
- Because wet floodproofing allows floodwaters to enter the building, clean-up after flood events can be substantial and may require that the building stay closed for an extended period of time.
- Utilities may need to be relocated or waterproofed if they are located in spaces that may be submerged during a flood event.

To protect outdoor utilities, such as air conditioning units, they should be elevated above the flood level.

WET FLOODPROOFING

HELPFUL LINKS

» FEMA Technical Bulletin 7 (1993), www.fema.gov/media-library/assets/documents/3503

WET FLOODPROOFING | QUIZ

1) Is flooding infrequent? ☐

2) Is the flood duration less than 24 hours? ☐

3) Does the floodwater rise slowly? ☐

4) Is the floodwater velocity low to moderate? ☐

5) Is a short-term flood protection solution sufficient? ☐

6) Can the architecture on the ground flood and/or in the basement be modified without adversely affecting the building's architectural significance? ☐

7) Everything (building materials, fixed objects, etc.) below the highest flood level will be submerged. Is this acceptable? ☐

8) Can your building be closed during and/or after a flood event? ☐

9) Can utilities be relocated above the 500-year flood elevation? ☐

10) Can you have some flood clean-up costs? ☐

11) Can you perform cyclical maintenance on sealants? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

DRY FLOODPROOFING

Flood shields in front of doors and windows should be placed before a flood event to prevent water from entering the building.

DESCRIPTION

Dry floodproofing a building involves sealing the portion of the building below the highest expected flood level to make it watertight and as impermeable to floodwaters as possible. In other words, the goal is to keep the water out of the building, which is achieved through a combination of sealant systems, like wall coatings and waterproofing compounds, and closing openings, such as doors and windows, with permanent or removable shields. Dry floodproofing is best suited for infrequent flooding and shorter duration floods.

ADVANTAGES

One of the main advantages of dry floodproofing is that it is a minimal cost and minimal effort solution.

DISADVANTAGES

The main disadvantage of dry floodproofing is that it is a short-term solution and will, therefore, result in the deterioration of building materials due to repeated exposure to floodwaters.

IMPORTANT CONSIDERATIONS

- Some aspects of the building's architecture will be modified, although these modifications are minimal.
- The floodwater on the exterior walls of the building can cause an immense amount of pressure (hydrostatic pressure). For this reason, dry floodproofing is not a good option for wood frame buildings or buildings with a basement.
- Maintaining the sealant systems is essential to the success of this flood protection option.
- Although the goal of dry floodproofing is to keep water out of the building, it is not a fail-safe system and water may enter the building due to sealant failures. Consequently, after flood events, there may be some clean-up costs and the building may need to be closed for an extended period of time.
- The exterior wall surfaces in the flood zone likely will be coated with waterproofing which will change the appearance.

DRY FLOODPROOFING

HELPFUL LINKS

» Southern Tier Central Regional Planning and Development Board, Floodproofing Info #4, www.stcplanning.org/usr/Program_Areas/Flood_Mitigation/Floodproofing/FProof_04_Dry_Floodproof.pdf

Exterior vents and utilities should be protected either by relocating them or by installing flood shields.

DRY FLOODPROOFING | QUIZ

1) Is flooding infrequent? ☐

2) Is the flood duration less than 24 hours? ☐

3) Does the floodwater rise slowly? ☐

4) Is the floodwater velocity low to moderate? ☐

5) Is a short-term flood protection solution sufficient? ☐

6) Can you alter your building's without adversely affecting the building's architectural significance? ☐

7) Is your building constructed of masonry (CMU, brick, or stone) or other strong building materials? ☐

8) Dry floodproofing is typically not suitable for buildings with a basement. Does your building NOT have a basement? ☐

9) Can your building be closed during a flood event? OR Is your entrance elevated above the highest expected flood level so that the building can be occupied during flood events? ☐

10) Is there enough warning time before flood events to set up temporary barriers for windows and doors? ☐

11) Do you have people available to set up temporary barriers for windows and doors? ☐

12) Can you have some flood clean-up costs? ☐

13) Are you willing to test and maintain the flood shields and sealants? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

PERMANENT FLOODWALLS

An example of a permanent brick floodwall designed and constructed by Carl Canty at his home in Bubwith, England, along the River Derwent.

A swing-hinged flood gate provides access along this permanent brick floodwall.

A concrete floodwall permanently protects the community of East Park in the City of Rosevill, California, from flooding along the Dry Creek.

DESCRIPTION

Permanent floodwalls are permanent barriers constructed on your site to prevent water from coming into contact with your building. Floodwalls must be specially designed to resist the pressure caused by the floodwater acting on one side of the wall. While floodwalls are often constructed of reinforced concrete, they can be faced with more attractive building materials or integrated into the landscaping of the site to be more attractive and less conspicuous.

ADVANTAGES

One of the main advantages of permanent floodwalls is that the building does not have to be disturbed at all.

DISADVANTAGES

The main disadvantage of permanent floodwalls is that you need sufficient extra land around your building on which to build the walls.

IMPORTANT CONSIDERATIONS

- Some localities restrict the construction of individual floodwalls. It is important to check your local zoning/building code to determine if it is possible to build floodwalls on your property.
- If the water levels rise above the highest expected flood level, floodwalls can overturn and fail.
- Floodwalls that are constructed close to property lines can negatively impact local drainage patterns, which may increase flooding for your neighbors.
- Depending on how floodwater encroaches on your site, you may only need to construct floodwalls in a certain area, rather than around your entire building.
- Any access openings in the floodwall need to be closed by temporary barriers during a flood event.
- An option similar to a permanent floodwall is a levee, which is a barrier constructed out of soil, but levees typically need special permits to be constructed and take up much more space than floodwalls.

PERMANENT FLOODWALLS

HELPFUL LINKS

» Louisiana State University Agricultural Center, Floodwalls: www.lsuagcenter.com/NR/rdonlyres/7A01F7C8-703B-47D1-BCCD-63CD0A57721F/2995/pub2745Floodwall6.pdf
» Floodwalls and Flood Embankments: evidence.environment-agency.gov.uk/FCERM/Libraries/Fluvial_Documents/Fluvial_Design_Guide_-_Chapter_9.sflb.ashx
» Homeowner's Guide to Retrofitting, Chapter 8: Barriers: www.fema.gov/media-library-data/1404150139578-ee3a6bc655a236dceba367adcfb8c982/FEMA_P312_Chap_8.pdf

A small stone floodwall that protects the house from a local creek.

PERMANENT FLOODWALLS | QUIZ

1) Is there extra land available around your building? ☐

2) Is it okay to erect a permanent wall to protect the building from floodwaters? ☐

3) Can you construct a permanent wall without adversely affecting the visitor/aesthetic experience of the site? ☐

4) Do you have people available to set up temporary barriers in the floodwall's access openings? ☐

5) Floodwalls can leak at joints. Is it acceptable for some water to enter the protected area? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

TEMPORARY BARRIER SYSTEM

An example of a water-filled temporary barrier system by Aqua Dam.

DESCRIPTION

Temporary barrier systems are barriers that are erected temporarily just before a flood event. There are several kinds of temporary barrier systems. There are temporary barrier systems that are permanently constructed on-site but are only lifted temporarily during a flood event and stored in-situ during normal activities. These systems can be more expensive and include hydraulic-actuated concrete barriers, inflatable barrier systems, and flip-up or placed-in flood barriers. There are also temporary barrier systems that must be placed just before a flood event and then are stored nearby during normal activities. These systems include water-filled temporary barriers, air-filled temporary barriers, and gravel-filled containers. In general, these temporary barrier systems are less expensive than the temporary barrier systems constructed on-site.

ADVANTAGES

One of the main advantages of temporary barrier systems is that they are not visible during normal activities on your site. Additionally, the building is not disturbed at all.

DISADVANTAGES

There are several disadvantages to temporary barrier systems. First, you need sufficient extra land around your building on which to erect the barriers. Second, you must get enough warning time before a flood event to set up the barriers. Third, these systems are not fail-safe systems and do not guarantee complete flood protection.

IMPORTANT CONSIDERATIONS

» A temporary barrier system erected close to property lines can negatively impact local drainage patterns, which may increase flooding for your neighbors.
» Depending on how floodwater encroaches on your site, you may only need to have a temporary barrier system erected on a portion of your site instead of around your entire building.
» Temporary barrier systems are difficult to test between flood events, but training and drills for erecting the temporary barriers are important to ensure that they are installed correctly during flood events.
» The temporary barriers should be cleaned after use.

TEMPORARY BARRIER SYSTEM

HELPFUL LINKS

» inflater: inflater.eu/inflater/technology-watch/
» Flood Control International: www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/flood-barriers.php

(Left) Temporary barrier wall laid flat during normal activities, and (right) before a flood event, the temporary barrier wall flips up.

An example of an air-filled temporary barrier system called the NOAQ Tubewall.

TEMPORARY BARRIER SYSTEM | QUIZ

1) Is the floodwater velocity low to moderate? ☐

2) Is there extra land available around your building? ☐

3) Is it okay to erect a temporary wall to protect the building from floodwaters? ☐

4) Barriers can leak at joints. Is it acceptable for some water to enter the protected area? ☐

5) Is there enough warning time before flood events to set up barriers before water encroaches? ☐

6) Do you have people to help set up/remove temporary barriers? ☐

7) Are you willing to maintain the sealants/components of the barrier system? ☐

8) Do you have nearby storage for the temporary barrier system? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

RELOCATION

An 1800s farmhouse is moved 300 feet in Elizabeth Township to get out of the floodplain.

DESCRIPTION

Relocating a building is an option that can provide complete flood protection, as long as there is an appropriate site available that is above the 500-year flood level. The technology used to move buildings is well established and readily available. Relocation is the best option for buildings that experience frequent and large flood events.

ADVANTAGES

The biggest advantage of relocation is that the building is completely protected from flood risks and normal operations do not have to be interrupted.

DISADVANTAGES

The main disadvantage of relocation is that the building is severed from its original location.

IMPORTANT CONSIDERATIONS

- Many types and sizes of structures can be moved, although smaller, lighter structures are easier and less expensive to move. Still, larger, masonry buildings can be moved. Some general building footprint size limits are 5,000 sf for masonry structures and 10,000 sf for wood frame structures.
- Moving a building can become expensive if you have to purchase another plot of land to place the building.
- Moving a building becomes more expensive as the distance increases between the sites, as well as if there are obstacles between the sites, such as narrow roads, bridges and power lines.
- Wherever the building is moved to—somewhere else on the current site or to a different site—the site has to be prepared for the building, including the construction of a new foundation and potentially adding utilities to the site.
- Particularly for relocation, if your building is designated to the National Register or a state or local register, it is important to consult with any relevant government and preservation agencies before and during the construction process.

RELOCATION

HELPFUL LINKS

» FEMA's Selecting Appropriate Mitigation Measures for Floodprone Structures, Chapter 9: Relocation: www.fema.gov/media-library-data/20130726-1608-20490-8941/fema551_ch_09.pdf
» Southern Tier Central Regional Planning and Development Board: www.stcplanning.org/usr/Program_Areas/Flood_Mitigation/Floodproofing/FProof_03_Relocate.pdf
» NOAA's Out of Harm's Way: Relocation Strategies to Reduce Flood Risk: coast.noaa.gov/digitalcoast/training/kinston-flood-risk.html

The National Czech and Slovak Museum and Library is moved 200 feet in Cedar Rapids to move away from the Cedar River.

The Otis Mason house is relocated in Alexandria, Virginia, due to a highway project.

RELOCATION | QUIZ

1) Is there land available for relocation of your building above the 500-year flood level? ☐

2) Is your building small enough to be moved (under 5,000 sf footprint)? ☐

3) Can the building's relationship to the landscape/landscape features be changed without adversely affecting the site's cultural and architectural significance? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

ELEVATE BY RAISING THE GRADE

After the 1900 Galveston Hurricane hit Galveston, Texas, much of the town was elevated on new fill. In this image, part of the town has been covered in fill, while the rest of the town is only elevated by posts.

Another view of Galveston, Texas.

DESCRIPTION

Raising the grade below and around a building involves moving the structure temporarily while fill that is designed to be stable under conditions of flooding is transported onto the site and graded to a height above the floodplain.

ADVANTAGES

The primary advantages of elevating a building by raising the grade are that the building remains in its original location and the building is completely protected from flood risks. Raising the grade is also a fairly maintenance-free solution, although the new landscape must be maintained and monitored to make sure there is not any severe erosion.

DISADVANTAGES

Although the building remains in its original location, the building's relationship to the surrounding landscape and any significant landscape features is changed.

IMPORTANT CONSIDERATIONS

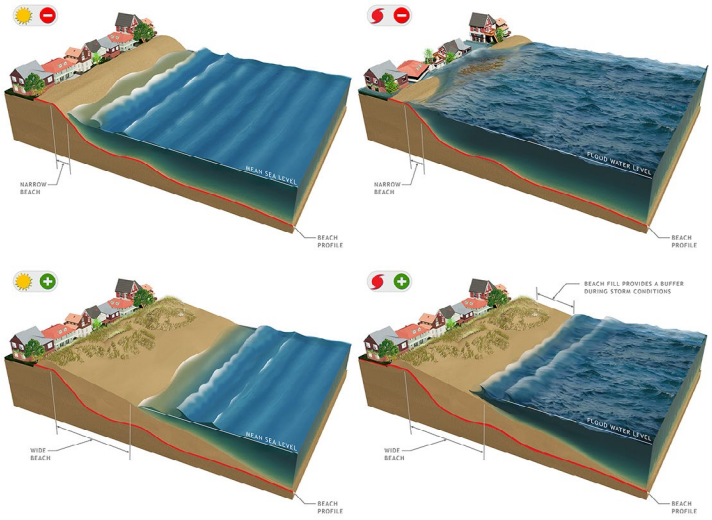
- While fill is brought on to the site and compacted and a new foundation for the building at the higher elevation is constructed, the building must be moved temporarily.
- While not a lot of fill may be necessary to raise the building the required amount above the floodplain, additional fill is needed to create slope stability between the new grade and the old grade. Moreover, if you don't want the change in grade to be extremely obvious, even more fill is needed to create a more gradual slope between the new grade and old grade. The area over which fill must be spread may become quite large. If there is not sufficient area to do this, retaining walls may be required, which can be ugly, expensive, and obtrusive to neighbors.
- Fill can be challenging to acquire and trucking costs can be very expensive.
- To raise a building with a 25 ft x 25 ft footprint 3 feet above the current grade, with the maximum slope around the building for slope stability, approximately 12 truckloads of fill are required (12 cubic yards of fill per truckload).
- Raising the grade close to property lines can negatively impact local drainage patterns, which may increase flooding for your neighbors.
- FEMA does not permit elevation of buildings on fill in V zones.

ELEVATE BY RAISING THE GRADE

HELPFUL LINKS

» Challenge for Sustainability: Elevation of Building on Fill: challengeforsustainability.org/resiliency-toolkit/elevation-building-fill/
» Southern Tier Central Regional Planning and Development Board: www.stcplanning.org/usr/Program_Areas/Flood_Mitigation/Floodproofing/FProof_02_Elevate.pdf
» Farnsworth Flood Mitigation Project: farnsworthproject.org/option-a-elevate/#.WYNajIQrK00

In La Crosse, fill was added on Charles Street to elevate new homes above the floodplain.



To mitigate flooding along the shore, sandy fill is added to the beach as a part of beach restoration. The fill creates a wider beach and, therefore, a buffer during storm conditions.

ELEVATE BY RAISING THE GRADE | QUIZ

1) Is the floodwater velocity low to moderate? ☐

2) Is your lot big enough to add fill without adding retaining walls? ☐

3) Do you have access to a lot of fill? ☐

4) Do you have truck access to deliver the fill to your site? (It takes approximately 18 truck-loads to elevate a 1-story, 1000 sf building 3 feet) ☐

5) Can the building's relationship to the landscape/landscape features be changed without adversely affecting the site's cultural and architectural significance? ☐

6) Are you willing to design and maintain the new landscape? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

ELEVATE ON COLUMNS/PIERS

A historic residence in Mandeville, Louisiana, is raised on columns.

DESCRIPTION

Permanently elevating a building by placing it on columns involves temporarily lifting the structure and installing wood, steel, or precast reinforced concrete columns into pre-dug holes. The columns are typically anchored or embedded into concrete pads to accommodate any large loads. Bracing the columns may be required to help the columns act as a unit and to resist horizontal loads, such as wind.

Elevating a building on piers is similar to elevating a building on columns. Piers are typically constructed of reinforced concrete or concrete masonry units (CMU), and they are supported by concrete footings. Piers are a little different from columns in that they act individually, and care must be taken to ensure that the piers can sustain both the necessary vertical loads from the building and horizontal loads caused by flooding.

For floodwaters deeper than six feet or for buildings that experience higher wind velocities/stronger floodwater flows, a building should be elevated onto piles. The piles, which are driven into bedrock or driven deep enough to develop the necessary friction forces, are constructed of wood, steel, micro-piles, or reinforced concrete. There does need to be sufficient space around the building to accommodate the construction machinery required to drive the piles.

ADVANTAGES

The main advantages of elevating a building on columns/piers/piles are that the building has complete protection from flood risk, the building remains in its original location, and the construction methods are fairly simple and well established.

DISADVANTAGES

Some of the disadvantages include the building's appearance is altered, as well as its relationship to the ground, and the vertical access to the building is changed, which will require constructing new stairs, ramps, and/or an elevator.

IMPORTANT CONSIDERATIONS

- For floodwaters deeper than six feet or for buildings that experience higher wind velocities/ stronger floodwater flows, a building should be elevated onto piles.
- A geotechnical investigation must be performed to determine if the soil under and around the building is susceptible to erosion and/or appropriate for this type of construction.
- Lighter (i.e. wood frame) and smaller structures are easier and less expensive to elevate, although more robust and larger structures can also be elevated.
- Masonry structures that are elevated on columns/piers may be more susceptible to cracking.
- Before construction begins, it is important to determine if the land beneath your building has the potential to yield archaeology that is important to history or prehistory.

ELEVATE ON COLUMNS/PIERS

HELPFUL LINKS

» Challenge for Sustainability: Elevation of Building on Piles: challengeforsustainability.org/resiliency-toolkit/elevation-building-piles/
» Southern Tier Central Regional Planning and Development Board: www.stcplanning.org/usr/Program_Areas/Flood_Mitigation/Floodproofing/FProof_02_Elevate.pdf
» FEMA's Foundation Requirements and Recommendations for Elevated Homes: www.fema.gov/media-library-data/1386073605870-56034eb27952e04bd44eb84b72032840/SandyFS2OpenFoundation_508post2.pdf
» Floodlists's Elevation of Buildings in Flood-Prone Locations: floodlist.com/protection/elevation-buildings-flood-prone-locations

In Louisiana, there has been a long tradition of building houses on open brick pier foundations, as seen here at this French Louisiana Cottage from the early 1800s in Gramercy, Louisiana.

A small wood-frame house elevated on piles.

Almost the entire town of Galveston, Texas, was elevated after the 1900 Galveston Hurrican devastated the town and caused severe damage.

ELEVATE ON COLUMNS/PIERS | QUIZ

1) Is the floodwater velocity low to moderate? ☐

2) Can you change the relationship between the building and the ground without adversely affecting its architectural significance? ☐

3) Can you change the access to the building by adding stairs/elevator/ramp? ☐

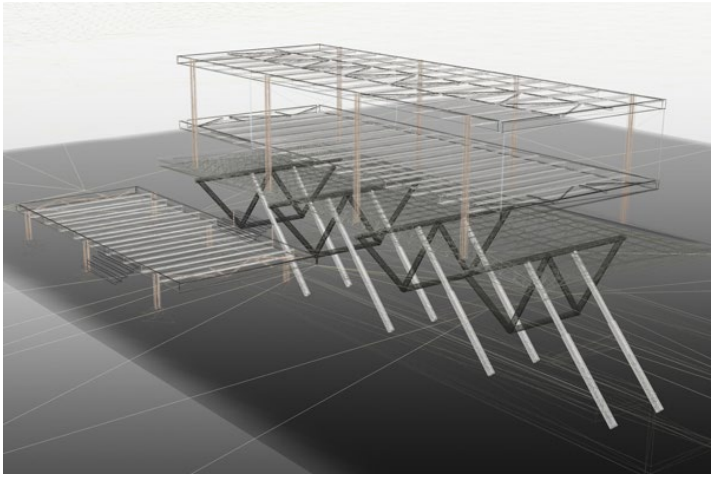
4) If you have a basement or crawlspace, is it okay to abandon it? ☐

5) Can you elevate the utilities with the building? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

ELEVATE BY HYDRAULIC LIFT



Model of the hydraulic lift system proposed for Farnsworth House in Plano, IL.

DESCRIPTION

Elevating a building by placing it on a hydraulic lift system involves moving the structure temporarily, constructing a pit under the building, installing the hydraulic equipment and necessary structural supports, and placing the building back over the pit. During flood events, the building is temporarily elevated via hydraulic lifts and truss supports, which resist lateral forces caused by wind and floodwaters. During normal operations the building is lowered back over the pit, making the flood protection invisible during normal operations.

ADVANTAGES

There are several advantages to elevating a building by hydraulic lift. First, the hydraulic lift system is essentially invisible during normal activities and, therefore, the building's relationship to the landscape and any significant landscape features remains unchanged. Second, the system can be tested before flood events occur to ensure that it is working properly, and the rate at which the building is raised and lowered can be controlled, which minimizes the amount of warning time needed to mobilize the system. Finally, the hydraulic lift can be mobilized remotely at the push of a button and by a single person, making this an ideal solution for a site that has a very small staff. Hydraulic lifts can work in all weather conditions, including freezing temperatures, and the system works even when submerged under water.

DISADVANTAGES

The major disadvantage of elevating a building by hydraulic lift is that it is an expensive solution and creates more building systems to maintain. Additionally, regular maintenance and inspection of the system must be performed to ensure that it is working correctly.

IMPORTANT CONSIDERATIONS

- Smaller, lighter buildings are the best candidates for elevation by a hydraulic lift system.
- Buildings that have a regularly-shaped footprint are much easier to raise and lower by hydraulic lifts. Buildings that have an irregular footprint may require multiple hydraulic lift systems, which increases the cost and complexity of the flood protection system.
- Excavating the pit required to hold the hydraulic lift equipment becomes much more difficult and expensive if there is bedrock near the ground surface.
- To make room for the pit and hydraulic lift equipment, any below-grade spaces (like a crawlspace or basement) may be lost.
- A redundant power source (like a generator at higher ground), as well as regular maintenance and inspection, is essential to make this a fail-safe solution.
- The building's utilities must be waterproofed and flexible connections must be installed.
- Before construction begins, it is important to determine if the land beneath your building has the potential to yield archaeology that is important to history or prehistory.

ELEVATE BY HYDRAULIC LIFT

HELPFUL LINKS

» Farnsworth Flood Mitigation Project: farnsworthproject.org/option-c-hydraulics/#.WYNadIQrK00

ELEVATE BY HYDRAULIC LIFT | QUIZ

1) Is the floodwater velocity low to moderate? ☐

2) Are winds at your site expected to be below 75 mph (hurricane-force winds)? ☐

3) Does your building have a regular footprint? ☐

4) Are you okay with altering your building's below-grade structure? ☐

5) If you have a basement or crawlspace, is it okay to abandon it? ☐

6) Can your building be closed during a flood event? ☐

7) Do you have or are you willing to install a redundant power source? ☐

8) Do you have some ground on higher elevation to place a generator? ☐

9) Do you have room in your yearly budget for systems maintenance? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

ELEVATE BY BUOYANCY

Schematic of what a buoyancy system looks like beneath a shotgun house.

DESCRIPTION

Elevating a building by placing it on a buoyant system involves moving the structure temporarily, constructing a pit under the building, installing the buoyant system, and placing the building back over the pit. The building can then be elevated temporarily above the floodplain during flood events and lowered during normal operations. The buoyant system may be visible during normal operations, although minimally. The buoyant system can consist of buoyancy (or flotation) blocks or buoyancy tanks. A sump pump should be installed to remove water from the pit after the flood event. Generally, this solution is most effective for small, light-weight structures, such as small, wood frame structures, with limited glass and plaster.

ADVANTAGES

The main advantage of elevating a building by buoyancy is that the floodwater is doing the work to raise the building. Additionally, during normal operations, the system is minimally visible.

DISADVANTAGES

There are several disadvantages to elevating a building by buoyancy. First, deployment of the system cannot be controlled and will be activated even during minor floods. Second, the rate at which the building rises and lowers cannot be controlled and there is the potential that the building will not remain level. Third, the buoyant system must be regularly maintained to ensure that it is functioning properly.

IMPORTANT CONSIDERATIONS

- Guiderails must be installed to ensure the building stays in the same position, and they must extend several feet above the ground and are, therefore, visible.
- Cleaning the pit in which the buoyant system is stored can be challenging, and debris that gets in the pit cannot be removed without jacking the house up during normal operations.
- Excavating the pit required to hold the buoyant system becomes much more difficult and expensive if there is bedrock near the ground surface.
- To make room for the pit and buoyant system, any below-grade spaces (like a crawlspace or basement) may be lost.
- The building's utilities must be waterproofed and flexible connections must be installed.
- Before construction begins, it is important to determine if the land beneath your building has the potential to yield archaeology that is important to history or prehistory.

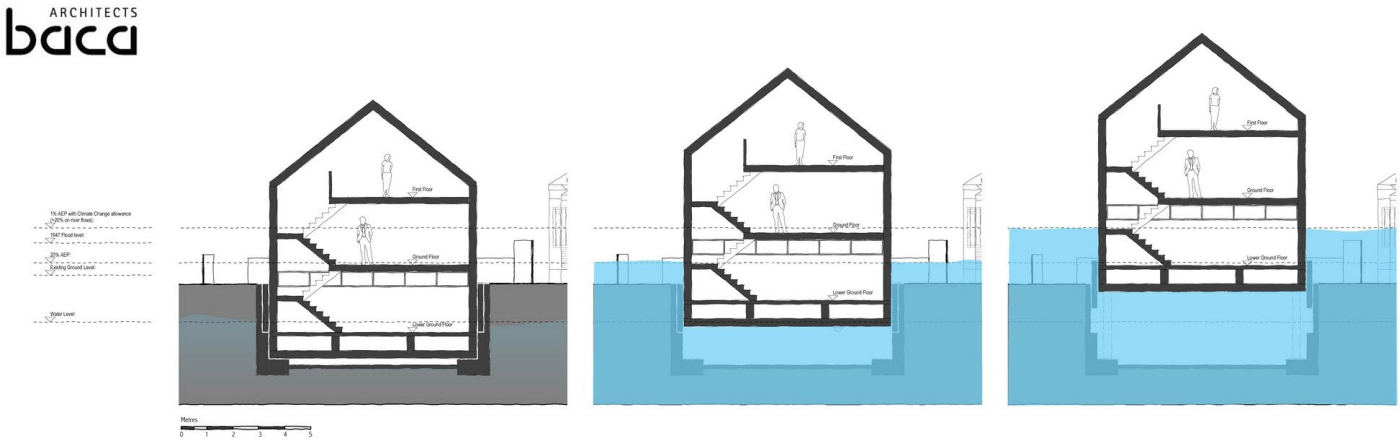
ELEVATE BY BUOYANCY

HELPFUL LINKS

» Buoyant Foundation Project: buoyantfoundation.org/
» Shoal Creek Conservancy: www.shoalcreekconservancy.org/water/flood-showcase/buoyant/
» A Local Solution to a Global Flooding Problem: www.therecord.com/news-story/7140672-a-local-solution-to-a-global-flooding-problem/
» Water-Resistant Home Floats During a Flood: www.designindaba.com/articles/creative-work/water-resistant-home-floats-during-flood

An entire community near the Mass River dyke in the Netherlands has been built to be buoyant during floods. Each house sits on hollow concrete foundations, which are attached to iron piers to guide the houses as they rise and lower with the water.

This trailer home in Louisiana has been placed on foam blocks to make the home buoyant during floods. Four steel guideposts will keep the home in place during a flood event.



BACA Architects designed the United Kingdom's first amphibious house.

ELEVATE BY BUOYANCY | QUIZ

1) Is the floodwater velocity low to moderate? ☐

2) When your site floods, does the water rise slowly? ☐

3) Are winds at your site expected to be below 75 mph (hurricane-force winds)? ☐

4) Is your building wood frame or light metal frame? ☐

5) Is the ground floor of the building on one level? ☐

6) If you have a basement or crawlspace, is it okay to abandon it? ☐

7) Are you okay with altering your building's below-grade structure? ☐

8) To keep the building in its original position, tall guiderails are needed. Will guiderails adversely affect the significance of the building? ☐

9) Can you change the access to your building during flood events? ☐

10) Are you okay with the potential that your building may not stay level as floodwaters rise and recede? ☐

11) This system is deployed during minor flood events. Are you okay if the system starts elevating as soon as there is standing water? ☐

12) Are you okay with not being to control the speed at which the building rises and lowers? ☐

13) Are you okay with not being able to test the system between flood events? ☐

If you can check all of the boxes above, then this flood protection option could be the option for you and your historic building!

If you cannot check all of the boxes above, then you should either reconsider those points that you did not check or explore one of the other flood protection options recommended based on the results of the first quiz.

OTHER OPTIONS

LEVEES

Another barrier option is to create levees around your historic building. Levees are created by digging a trench around the building and then filling the trench with a mound of compacted fill to a height at least one foot over the 500-year flood level. Because levees are made of fill, and the slope of the fill has to be shallow enough to ensure slope stability, this flood protection option requires a lot of extra land around the building. It also requires access to a lot of fill, which can be challenging to acquire and expensive to transport. Typically, levees are not suitable for flood levels over six feet deep.

Other important considerations include how constructing levees close to property lines can negatively impact local drainage patterns, which may increase flooding for your neighbors. Levees can also fail or be overtopped during large or long flood events, and the levees, as a new part of the site's landscape, must be maintained. Finally, as a conspicuous addition to the landscape, levees can adversely affect the historic building's relationship to certain landscape features.

Levee around a single home and property.

A levee constructed of soil and sand protects a single home in Vicksburg, Mississippi along the Yazoo River.

OTHER OPTIONS

A home is elevated on extended poured concrete foundation walls.

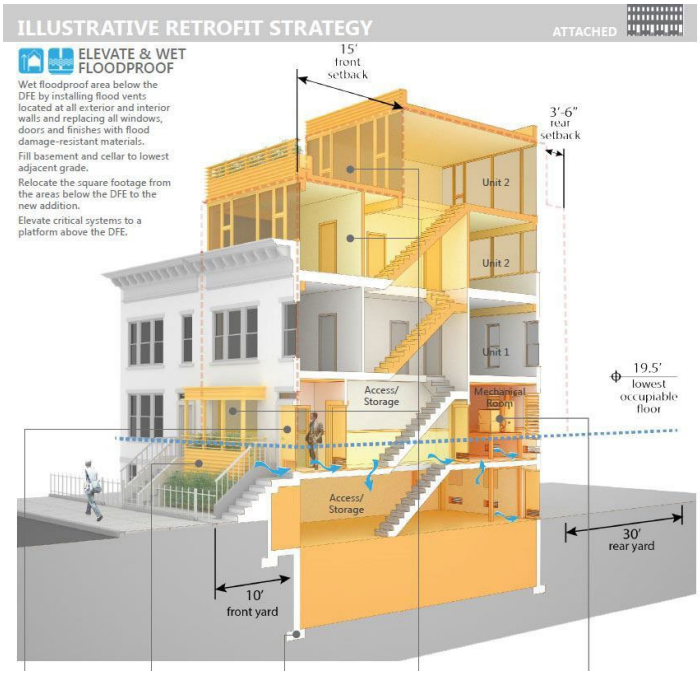
ELEVATE ON CLOSED FOUNDATION

Similar to elevating a building on columns or piers, historic buildings can also be raised on solid perimeter foundation walls. Typically, the building is raised in place and then the foundation walls are extended from the current foundation using concrete masonry units (CMU) or cast-in-place concrete. Consequently, the existing foundation walls must be analyzed to confirm that they have sufficient capacity to accept the additional load, and, if the existing foundation system does not, it should be strengthened. The existing foundation system may also need to be strengthened to accommodate the lateral loads expected on the extended foundation walls. To reduce the lateral pressure on the extended foundation walls, openings, such as flood vents, can be installed to allow water to enter the space beneath the structure, which allows the hydrostatic pressure to equalize on either side of the foundation walls. Elevation on a closed foundation is most suited for floodwaters that are expected to be low to moderate in depth and velocity.

A Greek Revival home in the Village of Owego's historic district in upstate New York before being elevated.

The same home after being elevated onto an extended poured concrete foundation.

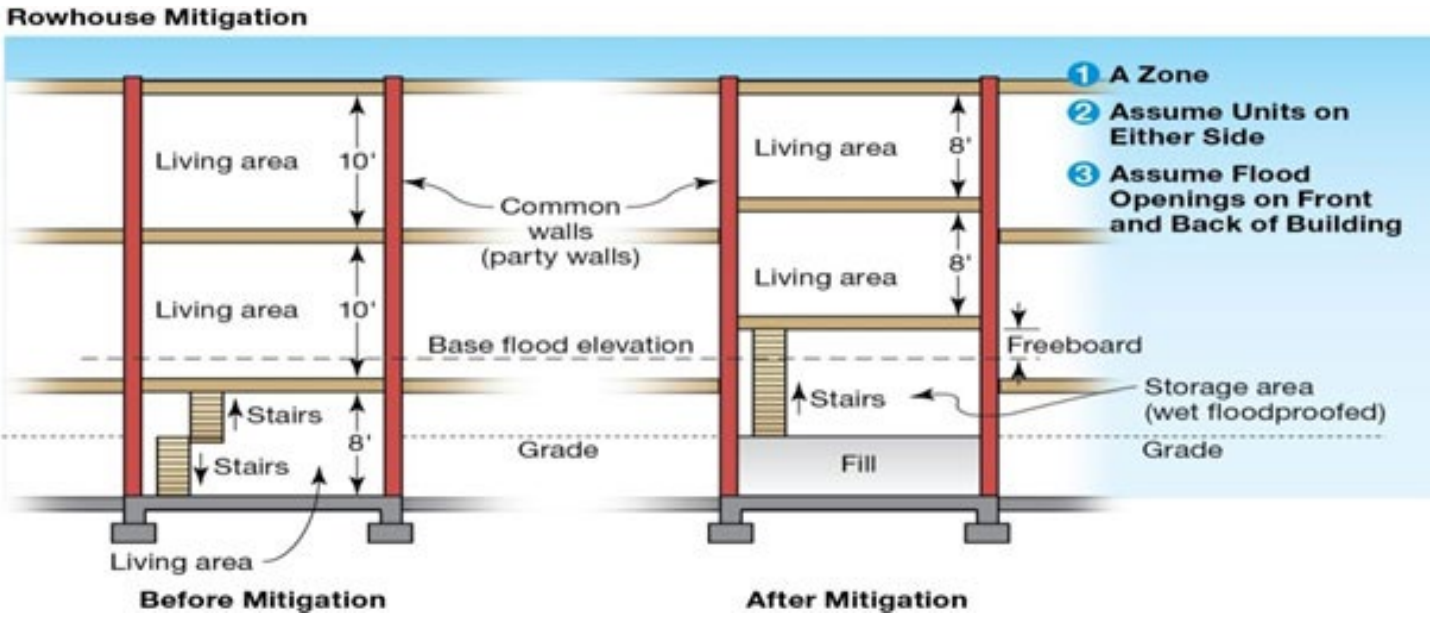
OTHER OPTIONS



Schematic to illustrate how the areas below the highest expected flood level can be abandoned and wet floodproofed to raise the lowest habitable space of the building to be above the expected flood level. Additional floors can be added to compensate for loss of habitable space.

ELEVATE BY RAISING LOWEST LEVEL INSIDE THE BUILDING

There are a couple of different ways to raise the lowest level of the building. One method is to construct a new floor several feet above the existing floor. This method is most appropriate for buildings constructed out of masonry or concrete masonry units with floodwater depths less than four or five feet. The construction process involves removing the roof, raising the window and door openings, adding new rows of masonry units to extend the height of the building, and constructing a new floor system. The floor system, which should be elevated above the 500-year flood level, can either be a new wood frame system or a new concrete slab on grade. For the new concrete slab on grade, fill must be placed and compacted on the existing slab before the new slab is poured. Another method is to abandon the lowest level of the building as a habitable space and construct another story on top of the building. The abandoned level should be wet floodproofed to prevent the failure of the existing walls. Again, this method is most appropriate for buildings constructed of masonry or concrete masonry units.



Schematic to illustrate how a new floor constructed on fill placed over the existing lowest level can raise the lowest inhabited level of the building above the highest expected flood level.

IMAGE SOURCES

WET FLOODPROOFING

» Flood vents allow water to enter the basement, preventing excessive pressure from developing on the basement walls. (Image source: floodflaps.com/new-construction/)
» To protect outdoor utilities, such as air conditioning units, they should be elevated above the flood level. (Image source: floodsavvy.com/options-in-flood-proofing-3/)

DRY FLOODPROOFING

» Flood shields in front of doors and windows should be placed before a flood event to prevent water from entering the building. (Image source: www.psfloodbarriers.com/wp-content/uploads/sites/4/2016/09/Flood-Plank-21.jpg)
» Exterior vents and utilities should be protected either by relocating them or by installing flood shields. (Image source: www.psfloodbarriers.com/product/lift-out-flood-barrier/)

PERMANENT FLOODWALLS

» An example of a permanent brick floodwall designed and constructed by Carl Canty at his home in Bubwith, England, along the River Derwent. (Image source: www.dailymail.co.uk/news/article-3380743/Why-wait-ministers-built-20-000-flood-defence-Engineer-fitted-walls-gates-pumps-cottage-realise-dream-living-river.html)
» A swing-hinged flood gate provides access along this permanent brick floodwall. (Image source: www.allianz.com/en/about_us/open-knowledge/topics/environment/articles/130625-13-ways-to-protect-your-property-from-floods.html/#!m9e9f7f0d-1392-4218-9048-7761c372a361)
» A concrete floodwall permanently protects the community of East Park in the City of Rosevill, California, from flooding along the Dry Creek. (Image source: hazardmitigation.calema.ca.gov/hazard_mitigation_success_stories/flood_walls)
» A small stone floodwall that protects the house from a local creek. (Image source: www.fprlandscaping.co.uk/projects/flood-defence-morebath)

TEMPORARY BARRIER SYSTEM

» An example of a water-filled temporary barrier system by Aqua Dam. (Image source: www.layfieldgroup.com/Environmental-Containment/Product-Finder/Aqua-Dam-Flood-Control-Systems.aspx)
» (Left) Temporary barrier wall laid flat during normal activities, and (right) before a flood event, the temporary barrier wall flips up. (Image source: www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/flip-up.html)
» An example of an air-filled temporary barrier system called the NOAQ Tubewall. (Image source: www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/noaq-tubewall.html)

RELOCATION

» An 1800s farmhouse is moved 300 feet in Elizabeth Township to get out of the floodplain. (Image source: www.wolfehousebuildingmovers.com/news/moving-house-floodwaters-reach-berks-county-pa/)
» The National Czech and Slovak Museum and Library is moved 200 feet in Cedar Rapids to move away from the Cedar River. (Image source: 42n.blogspot.com/2011/06/national-czech-slovak-museum-library.html)
» The Otis Mason house is relocated in Alexandria, Virginia, due to a highway project. (Image Source: courtesy of the National Trust for Historic Preservation)

IMAGE SOURCES

ELEVATE BY RAISING THE GRADE

» After the 1900 Galveston Hurricane hit Galveston, Texas, much of the town was elevated on new fill. In this image, part of the town has been covered in fill, while the rest of the town is only elevated by posts. (Image source: www.mitchellhistoricproperties.com/history/galveston/)
» Another view of Galveston, Texas. (Image source: www.bldgblog.com/2013/05/on-the-rise/)
» In La Crosse, fill was added on Charles Street to elevate new homes above the floodplain. (Image source: lacrossetribune.com/news/local/city-forms-floodplain-relief-program-to-help-elevate-north-side/article_3f9ed4c4-d239-53bb-aaac-ec2ac828f992.html)
» To mitigate flooding along the shore, sandy fill is added to the beach as a part of beach restoration. The fill creates a wider beach and, therefore, a buffer during storm conditions. (Image source: www.nad.usace.army.mil/CompStudy/)

ELEVATE ON COLUMNS/PIERS

» A historic residence in Mandeville, Louisiana, is raised on columns. (Image source: www.nj.gov/dep/hpo/Index_HomePage_images_links/FEMA/FEMA%20historic_structures.pdf)
» In Louisiana, there has been a long tradition of building houses on open brick pier foundations, as seen here at this French Louisiana Cottage from the early 1800s in Gramercy, Louisiana. (Image source: www.oldhousedreams.com/2015/08/13/1815-french-colonial-gramercy-la/)
» A small wood-frame house elevated on piles. (Image source: www.treehugger.com/green-architecture/built-stilts-karrie-jacobs-strange-new-kind-house-being-built.html)
» Almost the entire town of Galveston, Texas, was elevated after the 1900 Galveston Hurrican devastated the town and caused severe damage. (Image source: www.treehugger.com/sustainable-product-design/galveston-on-stilts.html)

ELEVATE BY HYDRAULIC LIFT

» Model of the hydraulic lift system proposed for Farnsworth House in Plano, IL. (Image source: farnsworthproject.org/option-c-hydraulics/#.WZGntFV9600)

ELEVATE BY BUOYANT SYSTEM

» Schematic of what a buoyancy system looks like beneath a shotgun house. (Image source: www.metropolismag.com/cities/building-for-change/)
» An entire community near the Mass River dyke in the Netherlands has been built to be buoyant during floods. Each house sits on hollow concrete foundations, which are attached to iron piers to guide the houses as they rise and lower with the water. (Image source: www.niftyhomestead.com/blog/floating-homes/)
» This trailer home in Louisiana has been placed on foam blocks to make the home buoyant during floods. Four steel guideposts will keep the home in place during a flood event. (Image source: www.niftyhomestead.com/blog/floating-homes/)
» BACA Architects designed the United Kingdom's first amphibious house. (Image source: www.architectsjournal.co.uk/revealed-the-first-ever-amphibious-house/8626324.article)

IMAGE SOURCES

OTHER - LEVEES

» Levee around a single home and property. (Image source: www.popularmechanics.com/home/how-to/a6715/how-to-build-a-homemade-levee/)
» A levee constructed of soil and sand protects a single home in Vicksburg, Mississippi along the Yazoo River. (Image source: info.themicroeffect.com/2011/05/20/extraordinary-pictures-of-homeowners-saving-their-homes-with-homemade-levees/)

OTHER - ELEVATE ON CLOSED FOUNDATION

» A home is elevated on extended poured concrete foundation walls. (Image source: www.liftandvent.com/)
» A Greek Revival home in the Village of Owego's historic district in upstate New York before being elevated. (Image source: www.pressconnects.com/story/news/2015/12/04/above-flood-historic-owego-house-raised-first-ny/76641234/)
» The same home after being elevated onto an extended poured concrete foundation. (Image source: wnbf.com/historic-owego-home-gets-a-lift/)

OTHER - ELEVATE BY RAISING LOWEST LEVEL INSIDE THE BUILDING

» Schematic to illustrate how the areas below the highest expected flood level can be abandoned and wet floodproofed to raise the lowest habitable space of the building to be above the expected flood level. Additional floors can be added to compensate for loss of habitable space. (Image source: www.jlconline.com/business/new-york-city-issues-guidance-for-flood-zone-building-retrofits_o)
» Schematic to illustrate how a new floor constructed on fill placed over the existing lowest level can raise the lowest inhabited level of the building above the highest expected flood level. (Image source: www.fema.gov/frequently-asked-questions-building-science)