Protecting Manufactured Homes from Floods and Other Hazards

A Multi-Hazard Foundation and Installation Guide

FEMA P-85, Second Edition / November 2009

FEMA

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Preface

The Federal Emergency Management Agency (FEMA) first published *Manufactured Home Installation in Flood Hazard Areas* (FEMA 85) in 1985. Since then, manufactured homes have become better built, and natural hazards like flood, wind, and earthquake (seismic) events are better understood.

To benefit from the advances made in the last 24 years, FEMA 85 has been updated to reflect the requirements of the most current codes and standards and to provide a *best practices* approach in reducing damages from natural hazards. While the original version of FEMA 85 concentrated on flood and wind events, this version also addresses seismic hazards and recommends several multi-hazard resistant foundation designs. Designs are included for wood-framed foundations, conventional concrete and masonry pier foundations, and ground anchors. The ground anchor foundations are based on results from a series of first-of-its-kind saturated and dry soil anchor tests. The anchor tests were conducted with the support of the U.S. Department of Housing and Urban Development (HUD), the Manufactured Housing Institute (MHI), the Systems Building Research Alliance (SBRA, formerly the Manufactured Housing Research Alliance [MHRA]), and several ground anchor manufacturers. A detailed example showing step-by-step procedures on how to design a foundation for a manufactured home is also included.

This guidance is also valuable to designers of alternate foundations allowed by the HUD 24 CFR 3285 *Model Manufactured Home Installation Standards*, especially for homes located in Special Flood Hazard Areas (SFHAs) for which certain 24 CFR 3285 foundation designs are not applicable (24 CFR 3285.303, Table 1, Note 4, et al.).

The foundation designs discussed in Chapter 10 and shown in Appendix H of this guide are but one group of acceptable foundation solutions. They should not be considered mandatory or all inclusive. Alternative foundation systems, designed to resist equivalent loads and provide equivalent performance, should be considered equally acceptable.

Limitations of the Guide

This manual has been prepared to assist in protecting manufactured homes from floods and other hazards. Builders, installers, architects, and engineers using this guide assume responsibility for the resulting designs and the performance during a natural hazard event.

The foundation designs and analyses presented in the guide are based on load combinations contained in the American Society of Civil Engineers (ASCE 7-05) and the 2006 version of the International Residential Code® (IRC®).

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1 Introduction

This revised edition of FEMA 85 provides new recommendations for manufactured home foundation design and installation. The initial 1985 edition of FEMA 85 provided guidance on installation methods designed to make manufactured homes less susceptible to damage caused by flood and wind events. Significant advances in design and construction technologies, mitigation strategies, and regulatory requirements since 1985 have all contributed to the need for updated guidance.

1.1 Purpose and Scope of the Guide

Like the original guide, this updated version of FEMA 85 focuses primarily on the installation and foundation requirements for manufactured homes in floodplains for communities participating in the National Flood Insurance Program (NFIP). However, it also addresses other natural hazards such as high winds and earthquakes.

The purpose of the second edition of FEMA 85 is to provide guidance for the design and construction of alternative foundation systems as described in the HUD *Model Manufactured Home Installation Standards* (24 CFR 3285). It is important to recognize that both the U.S. Department of Housing and Urban Development (HUD) and the NFIP require that foundation systems for manufactured homes located in Special Flood Hazard Areas (SFHAs) prevent flotation, collapse, or lateral movement of the structure (24 CFR 3285.302 and 44 CFR 60.39(a)(3), respectively).

> The manufactured housing industry has adopted the term "community" for manufactured home developments. However, the term "park" is used in the NFIP and is also used in this publication.

With its broad and comprehensive scope, this document provides guidance on siting and installing manufactured homes in areas exposed to natural hazards. The guide is organized into 10 chapters, each covering a different aspect of manufactured homes in the United States, and 8 appendices.

Chapter 1 provides a historical overview of Federal, State, and local regulations that affect the design, construction, and installation of manufactured homes, including guidance on the NFIP and HUD installation requirements.

Chapter 2 presents and defines the characteristics of a manufactured home, the types of foundations used, typical installation techniques, and additional design considerations of attachments to manufactured homes (e.g., carports, decks, porches, and awnings).

Chapter 3 provides the regulatory requirements pertaining to the installation of manufactured homes in flood-prone areas. NFIP, HUD and model building code requirements are discussed as well as methods for mitigating manufactured homes (e.g., elevation and relocation).

Chapter 4 presents issues to consider in the siting of manufactured homes.

Chapter 5 provides a review of natural hazards that must be considered in site selection, foundation design, and installation of manufactured homes. The discussion covers flooding, including the special hazards associated with coastal flooding (e.g., storm surge, velocity flow, and wave impact), high winds, and seismic events. The combined effects of multiple hazards are also covered.

Chapter 6 contains a review of the geology and hydrology of soils and their effects on manufactured home foundation systems. Soil characteristics and the behavior of saturated soils are discussed. Recommendations are provided for soil testing criteria applicable for manufactured home installation.

Chapter 7 presents a review of the use of ground anchors with manufactured home foundations, including the results of laboratory and field tests of anchor performance in saturated soils.

Chapter 8 presents different types of manufactured home foundation systems, including their performance, installation procedures, maintenance requirements, and possible modifications. Systems discussed include pier systems that incorporate ground anchors, braced piers and piles, slabs, elevated floors or crawlspaces, and proprietary systems.

Chapter 9 discusses recommended design processes and criteria for manufactured home foundations in SFHAs. Recommended design criteria, performance requirements, and best practice recommendations are presented. Sites that fall outside of the criteria specified for recommended foundations in Chapter 10 can use the design process detailed in this chapter.

Chapter 10 provides design criteria for recommended foundations appropriate for typical installation of manufactured homes in flood zones designated A, AE, A1-A30, A0, or AH on a FEMA Flood Insurance Rate Map (FIRM). Criteria are presented regarding maximum flood depth, flow velocity, wind speed, and seismic force. The designs are shown in Appendix H.

The appendices include:

A: References

B: Sources for Flood Information

C: Flood Velocity Determination

D: Definitions

E: Acronyms and Abbreviations

F: Example Calculations

G: Wind Zone Comparisons

H: Pre-Engineered and Prescriptive Foundation Designs

The foundation designs discussed in Chapter 10 and shown in Appendix H are but one of a group of acceptable foundation solutions. They should not be considered mandatory or all inclusive. Any modifications to the foundation drawings must be designed and approved by a licensed professional engineer. Alternative foundation systems designed to resist equivalent loads and to provide equivalent performance should be considered equally acceptable.

Flowcharts, checklists, maps, formulas, and drawings are provided throughout the guide to help in understanding the issues to consider when installing a manufactured home in a floodplain. Examples are presented to demonstrate decisions and calculations designers must make to reduce the potential damage to manufactured homes from natural hazard events.

1.2 Background

1.2.1 Manufactured Homes in the United States

Manufactured homes help fill a demand for affordable housing in many parts of the United States. In 2007, the U.S. Census reported that the industry shipped 95,700 homes with an average price of $64,500. Single-section homes had an average price of $35,200, and double-section homes had an average price of $73,100. U.S. Census Bureau figures from Census 2007 show that 74 percent of new manufactured homes were located on private properties and 26 percent were located in manufactured home parks. The average floor area of a manufactured home placed in 2007 was approximately 1,600 square feet. Approximately 31 percent of the manufactured homes placed in 2007 were located in four States (Florida, California, Louisiana, and Texas).

Since 1976, the NFIP has regulated the installation of manufactured homes in floodplains. Over the years, the NFIP has strengthened the regulations by defining existing and new manufactured home parks and applying differing standards for each. The standards governing manufactured homes continue to improve; Federal, State, and local governments and the manufactured home industry strive to institute construction practices and regulations to increase the safety of manufactured homes in natural hazard environments. The following list summarizes regulations, programs, and actions that have been developed to improve the resistance of manufactured homes to natural hazards:

- On July 13, 1994, HUD adopted new structural resistance guidelines for the construction of manufactured homes to be placed in HUD Wind Zones II and III (Figure 1-1).
- Section 605 of the National Manufactured Housing Construction and Safety Standards Act of 1974 (42 U.S.C. 5401), as amended by the Manufactured Housing Improvement Act of 2000, authorized the Secretary of HUD to establish and implement a national manufactured housing installation program to include (1) installation standards, (2) the training and licensing of manufactured home installers, and (3) the inspection of manufactured home installations.

> States may choose to operate an installation program for manufactured homes in lieu of the Federal program. The State must implement standards that provide protection to its residents that equals or exceeds the *Model Manufactured Home Installation Standards* (24 CFR 3285.1(a)(1). See http://www.hud.gov/offices/adm/hudclips for more information.

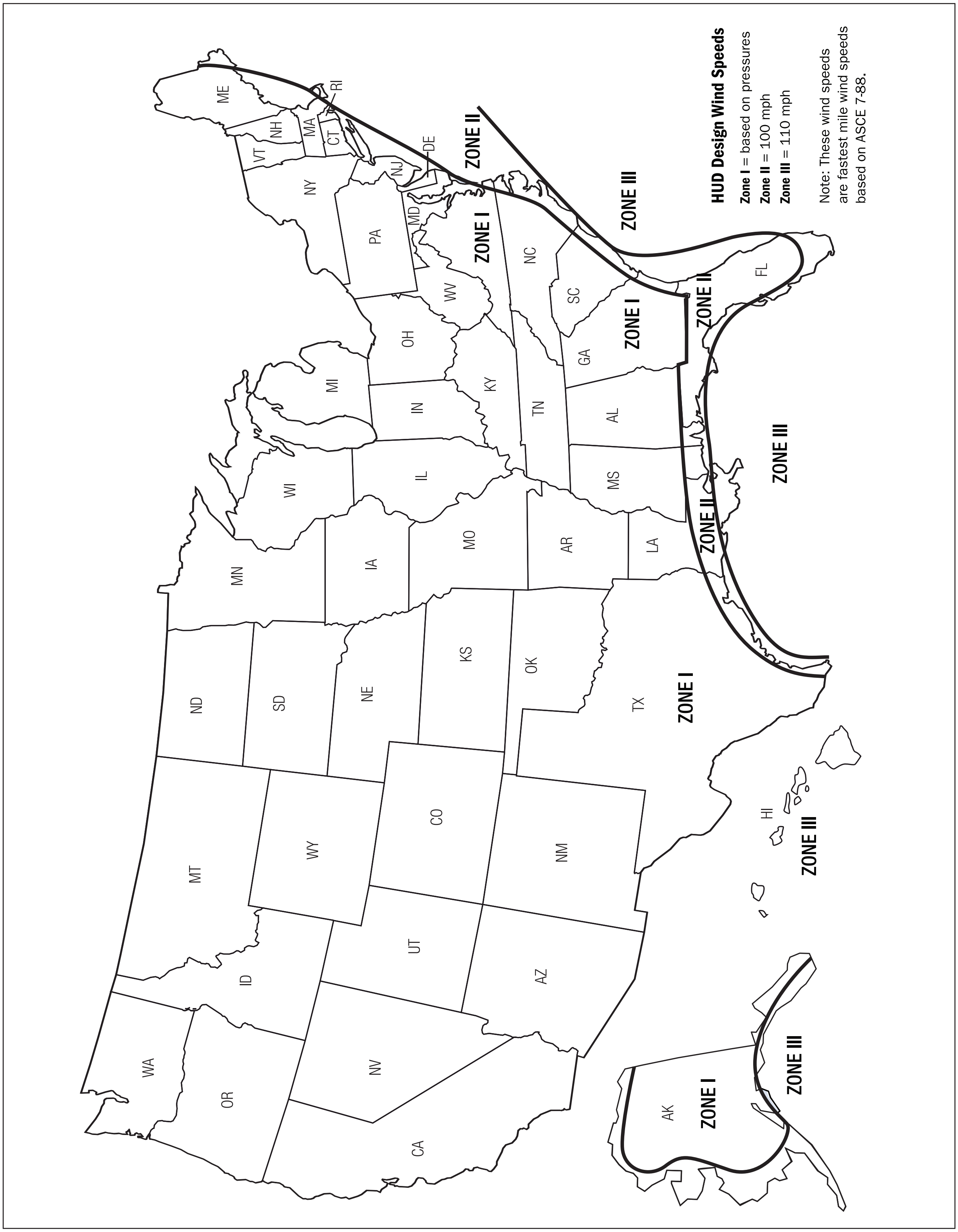


Figure 1-1. Basic wind zone map for manufactured housing.

- Installation program requirements have been established under 24 CFR 3286, *Federal Manufactured Home Installation Program* effective October 20, 2008. Compliant training and licensing programs for installation and inspections are being implemented in all States.
- The National Fire Protection Association (NFPA) has published three documents on the subject of manufactured housing:
  - NFPA 501, *Standard on Manufactured Housing*
  - NFPA 501A, S*tandard for Fire Safety Criteria for Manufactured Home Installations, Sites and Communities*
  - NFPA 225, *Model Manufactured Home Installation Standard*, which will, in adopted areas, govern installation of manufactured homes.
- The National Technology Transfer Act of 1995 included a goal that Federal agencies use technical standards developed or adopted by voluntary consensus standard bodies. Although HUD has recognized NFPA as a consensus standard developing body, HUD is not obligated to use standards developed by that body.
- Several States and localities, including Florida and North Carolina, have strong installation standards, which include requiring manufactured homes to meet State and local building code requirements; a manufactured home installer education, testing, and certification program for HUD homes; and aggressive inspection programs to ensure proper installation.

1.2.2 National Flood Insurance Program

The U.S. Congress established the NFIP with the passage of the National Flood Insurance Act of 1968, as amended. The NFIP is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages. Participation by communities in the NFIP is based on an agreement between communities and the Federal Government. If a community adopts and enforces floodplain management regulations to reduce future flood risks to new construction in floodplains, the Federal Government will make flood insurance available within the community as a financial protection against flood losses. Participation in the NFIP by communities is voluntary.

Federal flood insurance is designed to provide an alternative to disaster assistance and disaster loans for home and business owners. Disaster assistance rarely comes close to covering all of the costs to repair and cleanup. While available to qualified victims, disaster loans do not significantly ease the financial burden due to repayment terms. It is important to remember that disaster assistance is available only after floods have been declared major disasters by the President of the United States. In contrast, insurance claims will be paid any time damage from a qualifying flood event occurs.

Another important objective of the NFIP is to break the cycle of flood damage. Many buildings have been flooded, repaired, or rebuilt, and flooded again. In some parts of the country, this cycle occurs every couple of years; people rebuilt in the same flood-prone areas and used the same construction techniques that did not adequately protect the structure. By encouraging communities to guide development to lower risk areas, and by requiring the elevation of new buildings and older nonconforming buildings that are subject to flood damage, one of the long-term objectives of the NFIP can be achieved: reducing flood damage and losses. Older buildings may be removed or replaced, or they may be upgraded or modified with techniques that lead to little or no future flood damage.

The NFIP is administered by the Federal Emergency Management Agency (FEMA), which is part of the Department of Homeland Security (DHS).

In order to participate in the NFIP, communities must adopt minimum floodplain management requirements that meet or exceed the minimum requirements of the NFIP. Communities can adopt NFIP floodplain management requirements through building codes, zoning ordinances, subdivision regulations, health and safety codes, and stand-alone floodplain ordinances.

NFIP regulations have specific floodplain management requirements for manufactured homes located in a SFHA. In general, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. At sites having a base flood elevation (BFE) identified for Zones A1-30, AH, or AE on the community's FIRM, NFIP regulations generally require that manufactured homes be elevated on a permanent foundation such that the lowest floor is at or above the BFE, and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement. At sites having a BFE identified for Zone VE on the community's FIRM, NFIP regulations require that manufactured homes be elevated on pilings and columns so that the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE. More detailed information pertaining to the NFIP requirements for manufactured homes installed in flood hazard areas is provided in Chapter 3.

1.2.3 Performance of Manufactured Homes in Wind and Flood Events

1.2.3.1 Performance of Pre-1994 Manufactured Homes

In 1992, Hurricane Andrew struck Dade County, Florida, destroying 97 percent of the manufactured homes in its path. In 1994, in response to the devastating damage, HUD adopted more stringent wind design criteria for manufactured homes installed in HUD Wind Zones II and III. Provisions for doors and windows more resistant to wind pressures were required. Although numerous hurricanes have made landfall in the U.S. since 1994, none have produced winds that approached those of Hurricane Andrew. In 1998, Hurricane Georges caused damage throughout Monroe County (the Florida Keys), Florida. FEMA dispatched a Building Performance Assessment Team (BPAT) to report on the performance of manufactured housing in impacted areas. Most of the damage observed occurred to homes installed before Monroe County had adopted the NFIP regulations that required new and substantially damaged manufactured homes located in SFHAs be elevated to the BFE and anchored to resist flotation, collapse, or lateral movement.

Most of the flood damage caused by Hurricane Georges to the manufactured homes constructed before 1994 was the result of a lack of adequate elevation, the use of unreinforced piers (dry-stacked blocks) in areas exposed to moving floodwaters, inadequate anchoring, and failure of attached site-built additions (Figures 1-2 and 1-3). Anchoring failure problems included poorly attached anchors; lack of corrosion-resistant materials; homes not fastened to their support piers; and improperly attached tie-down straps.

Figure 1-2. Inadequate turnbuckle anchor installed by the homeowner on this pre-1994 manufactured home, coupled with lack of elevation and an unreinforced foundation system, led to severe damage.

Figure 1-3. The addition to this manufactured home was destroyed, causing considerable damage to the rest of the home.

1.2.3.2 Performance of Post-1994 Manufactured Homes

The lessons learned from Hurricane Andrew in Florida have resulted in manufactured homes being built stronger and installed more solidly; thus these homes are able to better resist extreme loading (in particular, flood and wind loads).

Figure 1-4 shows the success of the reinforced masonry pier foundation of a manufactured home installed after 1994. Although the area experienced moving floodwaters fast enough to displace the air conditioning compressor shown under the home and create localized erosion and scour, the reinforced masonry piers survived without damage.

The manufactured home shown in Figure 1-5, on Cudjoe Key in Monroe County, was built to the 1994 standards. It survived Hurricane Georges with only minor damage.

Figure 1-4. Reinforced masonry pier foundation system under a manufactured home installed after 1994 that performed well.

Figure 1-5. Manufactured home in Cudjoe Key, Florida, built and installed after 1994, survived Hurricane Georges with only minor damage caused by the loss of an awning. The older manufactured home on the lot next door was destroyed by high winds and coastal surge.

1.2.3.3 Performance of Manufactured Homes During Hurricane Charley (2004) in Florida

Based on field observations, the Hurricane Charley Mitigation Assessment Team (MAT) provided the following conclusions in their report as related to the performance of manufactured homes:

"Finally, performance of manufactured housing was also observed to be a function of age of the building and the regulations to which the units were designed, constructed, and installed. Widespread damage was observed to manufactured housing designed and constructed prior to the 1976 HUD regulations. The performance of units installed between 1976 when the first HUD regulations were enacted and the implementation of the 1994 HUD regulations was observed to be somewhat improved, but significant improvements in performance were observed in the units designed and installed to the HUD regulations implemented after 1994 in response to Hurricane Andrew. Although some instances of structural failure were observed, the newer manufactured housing units typically sustained minimal structural damage and remained secured to their foundations when installation followed State requirements (e.g., enforced by the Division of Motor Vehicles, Department of Highway Safety and Motor Vehicles, etc.) of unit tie-downs (anchors) at 5 feet, 4 inches on-center (if no ancillary structures were attached to the unit). Much of this improved performance was difficult to observe due to widespread damage caused by the failures of improperly designed and constructed attached structures (including screen enclosures, carports, and accessory structures). The failure of these attached structures, in many places occurring where wind speeds were below the design wind speed for the area, resulted in extensive damage to roof coverings, siding, windows, and doors of the manufactured units, and generated significant amounts of debris. Very few manufactured homes had glazing protection and, as a result, numerous unprotected windows on units along the path of the eye of the storm were damaged and broken. Had the [HUD design wind speed] Zone II and Zone III homes installed in areas where debris protection is required for site-built one- and two-family dwellings been shipped with appropriate glazing protection, these homes [within the path of Hurricane Charley] would have been protected from windborne debris."

2 Manufactured Homes

2.1 Manufactured Home Characteristics

Manufactured homes are one of several types of homes constructed entirely or partially in an off-site factory, transported over roadways, and then placed or assembled on a site-built foundation. After the home is in position, utilities (e.g., water, sewer, electric) are connected, ancillary components (e.g., siding, skirting) are installed, and the home is ready for habitation. Factory built homes include manufactured homes, modular homes, panelized homes, and pre-cut homes.

Modular, panelized, and pre-cut homes must comply with the same State and local building codes as "site stick built" codes. Manufactured homes must meet HUD regulations.

HUD regulations for manufactured homes are contained in 24 CFR 3280, *Manufactured Home Construction and Safety Standards* (MHCSS), and 24 CFR 3285, *Model Manufactured Home Installation Standards* (collectively referred to as the HUD codes). HUD regulations define manufactured housing as:

> "..a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities" (24 CFR 3280.2 and 24 CFR 3285.5)

2.1.1 Chassis Support System

Manufactured homes are constructed on a chassis consisting of main steel beams and cross members; fitted axles, leaf springs, and wheels making up the running gear; and a steel hitch assembly. After the home is sited, the chassis frame distributes the manufactured home loads to the foundation system. The hitch assembly is generally removed for appearance purposes.

There are two general chassis designs. The traditional chassis system consists of two longitudinal steel beams (between 10 and 12 inches deep); steel cross members that span between the beams; and steel "outriggers" extend beyond the beams to support exterior walls of the home (Figure 2-1). Manufactured homes designed to be placed on perimeter foundation walls often are manufactured with shorter outriggers to provide clearance for the site-built foundation walls.

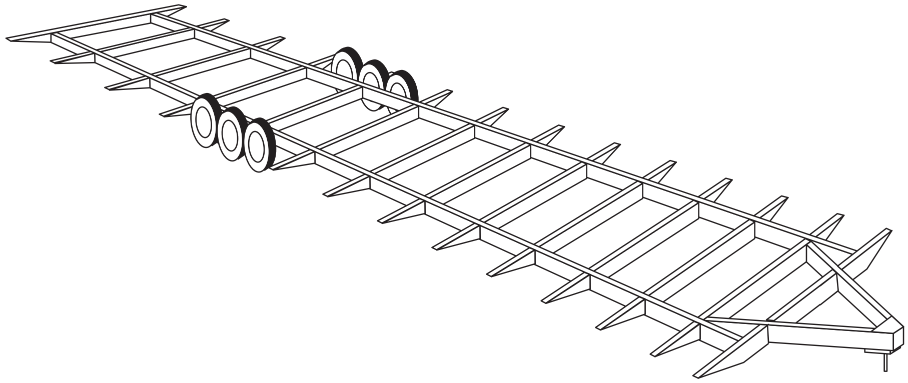


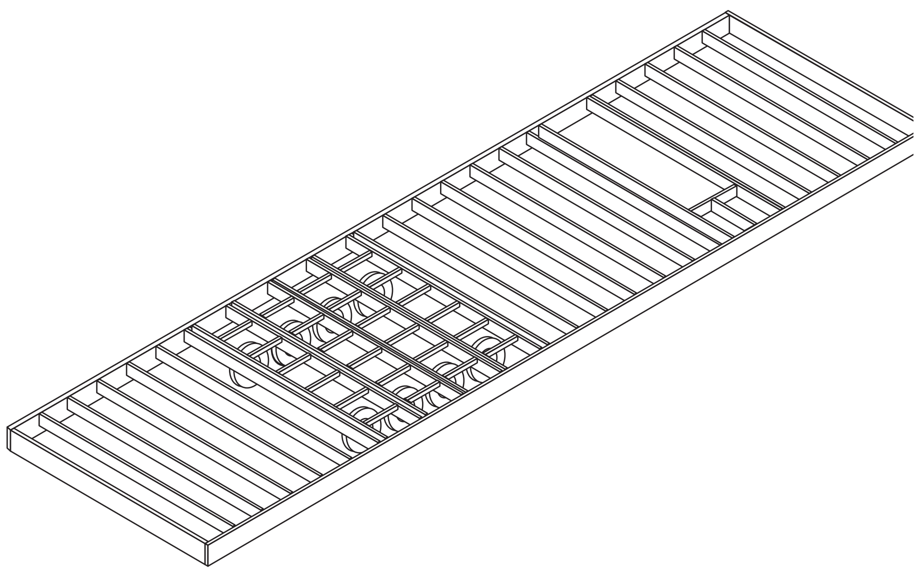
Figure 2-1. Traditional chassis system.

2.1.2 Integrated Support System

An alternative configuration relocates the steel main beams to the perimeter of the home, eliminating the cantilever “outriggers” (Figure 2-2).

Figure 2-2. Integrated floor system consisting of steel-reinforced perimeter framing.

Source: *Manufactured Home Producer's Guide to the Site-Built Market*, HUD.



2.1.3 Envelope Construction

The manufactured home envelope must be designed to meet MHCSS (24 CFR 3280) strength and rigidity requirements. The floor decking material, attached to the floor joists, is usually wood composite panels or plywood. Floor joists spanning between steel cross beams generally are spaced at 16-inch centers. Exterior wall frames generally are constructed with wood studs, and the exterior of the home is generally covered with vinyl, aluminum, or wood siding. Common wood stud dimensions used in HUD Code housing are typically 2 inches wide by 3 inches deep, or 2 inches wide by 4 inches deep based on the design vertical and lateral loads. Some designs for manufactured homes located in HUD Wind Zone III require the use of studs 2 inches wide by 6 inches deep.

Interior structural walls must have the structural capacity adequate for their intended use, with a minimum capacity to resist a horizontal load of 5 pounds per square foot (24 CFR 3280.305(f)(2). Interior wall frames typically use 2-inch by 3-inch wood studs. Interior non-structural walls can use 1-inch by 2-inch studs for framing.

The roof and ceiling system is typically constructed with prefabricated scissor trusses or other peaked trusses, sheathed with composite roof panels, underlayment, and shingles. Roof trusses typically are spaced at 24-inch centers.

Other construction features of manufactured homes include insulation, vapor barriers, gypsum wall and ceiling board, exterior roof and wall sheathing, doors and windows, and other finishing materials similarly found in site-built and modular homes. Figure 2-3 shows the main construction features of a typical manufactured home, including the envelope construction elements.

2.1.4 Double Section

A double-section manufactured home is constructed from two single floor sections and is, therefore, generally twice as wide as the normal 12- to 16-foot wide single-section unit. The design and construction of the chassis/floor system is comparable to that of the single-section unit. The double section is transported as two separate floor sections (Figure 2-4). The floor sections are then attached at the home's site. The area where the two floor sections come together is called the marriage line. Marriage beams, beam joists, and walls are properly aligned and connected at the site. The roof, walls, and floor along the marriage line must be properly aligned, sealed, and supported.

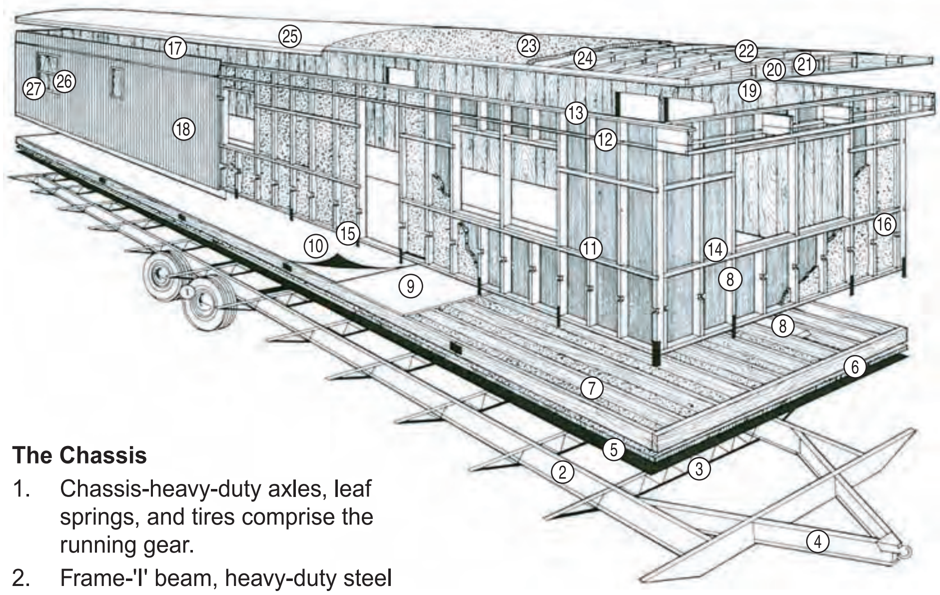
2.2 Types of Foundation Systems

Typical types of foundation systems used to support a manufactured home located in SFHAs include the following:

- Piers and ground anchors.
- Perimeter wall foundations.
- Proprietary foundation systems that transmit loads from the manufactured home to the ground using patented components or assemblies.

The HUD Codes (24 CFR 3285 Subparts D – Foundations and E – Anchorage Against Winds) provide design standards for pier foundations and anchor systems, including ground anchors. Alternative foundations must be manufactured and installed in accordance with their listings by a nationally recognized testing laboratory, based on a nationally recognized testing protocol, or be designed or tested by a registered professional engineer or architect in accordance with accepted engineering practice, and must not take the home out of compliance with the MHCSS (24 CFR 3285.301).

Figure 2-3. Main construction features of a typical manufactured home.



The Chassis

1. Chassis-heavy-duty axles, leaf springs, and tires comprise the running gear.
2. Frame-'I' beam, heavy-duty steel welded frames. 8", 10", or 12" “I” beams, depending on length of frame.
3. Rigid steel outriggers and center cross members.
4. Hitch – sturdy “I” beam hitch members optionally removable for cleaner appearance.

The Floor System

5. Bottom board tightly sealed on bottom of floor.
6. Floor insulation – all-weather insulation for temperature control, blanket fiberglass installed under entire floor for complete weatherproofing.
7. Floor joists.
8. Heat duct – aluminum-framed duct.
9. 5/8" decking particleboard glued and fastened to floor joists.
10. Roll goods-cushioned vinyl floor in non-carpeted areas.

The Wall System

11. 2" x 4" studs.
12. Dadoed belt rails for unitized sidewall construction.
13. 1" x 4" top and bottom plate.
14. Interior paneling – prefinished fire rated interior paneling glued and stapled to sidewall studs for unitized construction.
15. Rugged metal anchor bonding ties sidewalls to floor for additional strength.

16\. Sidewall insulation – heavy-density fiberglass insulation.

17\. Trim to harmonize with exterior decor.

16\. Rigid exterior metal is prefinished aluminum with baked-on enamel finish.

The Roof/Ceiling System

19. Decorative ceiling board.
20. Gusseted truss-type rafters for extra roof strength.
21. Blanket fiberglass insulation between rafters.
22. Steel straps full length of roof over rafters support insulation and galvanized roof between rafters.
23. Thick fiberglass roll insulation over rafters.
24. Vapor barrier on warm side of roof to prevent condensation buildup.
25. Galvanized steel one-piece roof.

Windows and Doors

26, Large aluminum-framed windows with screens and optional storm windows.

27\. Egress windows for emergency exit from every sleeping room.

Mechanical Service Systems

28. Electrical, plumbing, heating, and construction conform to or exceed the Federal Manufactured Home Construction and Safety Standards.

Figure 2-4. One section of a double-section manufactured home being transported.

Source: Manufactured Housing Institute.

Additional technical information on foundation systems for installation of manufactured homes is provided in Chapter 8 of this guide.

2.2.1 Typical Foundation Systems

2.2.1.1 Typical Installation

A manufactured home is typically placed on a site that has been stabilized and improved to provide adequate support for the home and anchoring system. Site and area improvements techniques vary widely across the country. Typical improvement techniques include simple ground stabilization (ground compaction), application of gravel, and/or construction of a concrete runner or slab.

Typical manufactured home foundations consist of a system of piers and ground anchors (refer to Section 2.2.1.2). Piers are typically placed beneath the two steel beams at a spacing of 8 to 10 feet along the length of the manufactured home. Frame ties are connected to the steel chassis or perimeter beams, and run to ground anchors (Figure 2-5) that are used with tie-downs and straps to secure a manufactured home in place. The frame ties and anchors provide lateral support; the piers provide vertical support.

Although typical manufactured home foundations and installation methods often address wind events, many give little consideration to the forces associated with flooding and seismic events. They generally are not designed for flood effects such as hydrodynamic and hydrostatic forces, buoyancy, erosion, and scour. Potential failure modes observed in a typical installation include:

- **Buoyancy**, particularly during rapidly rising floodwaters
- **Lateral movement**, particularly when exposed to moving floodwaters that extend above the home's steel beams

- **Pier collapse**, particularly when homes are exposed to wind and moving floodwaters simultaneously
- **Erosion and scour**, particularly when homes are exposed to high velocity floodwaters

2.2.1.2 Piers and Ground Anchors

Using both pier foundations and anchor assemblies together is the most common type of foundation system (Figure 2-6). Piers support the gravity loads of the home, and the anchors resist uplift and lateral loads. Piers are installed under the main beams of the home sections, under the marriage line of multi-section homes, and at locations designated by the home manufacturer. Common types of piers include several configurations of steel jack stands and stacked, reinforced or unreinforced hollow-core concrete masonry blocks of various configurations. Ground anchors, a specific anchoring assembly, typically consisting of auger-type (screw-in) ground anchors, are the most commonly used. The anchor is attached to the home's steel beams by steel straps. Chapter 7 discusses ground anchors in more depth.

Figure 2-5. Typical installation of a manufactured home on masonry block piers with tie-down straps.

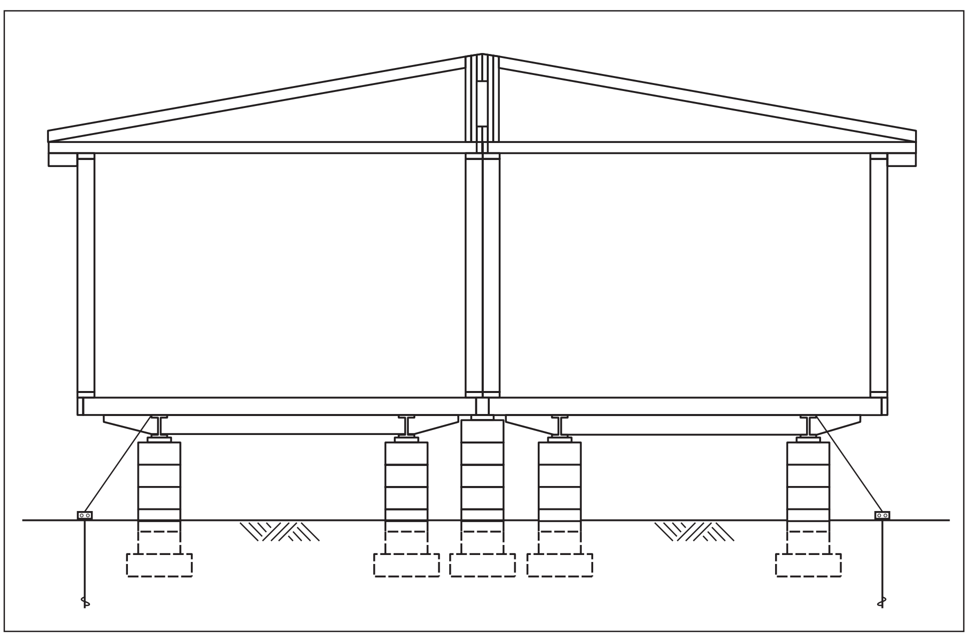


Figure 2-6. Typical installation of a double-section manufactured home on a pier and ground anchor foundation system.

The advantages of this foundation system are that it adapts easily to the site conditions, does not require much dimensional precision, is installed very quickly, and is economical to install.

2.2.1.3 Perimeter Wall Foundations

When perimeter foundations are used with a manufactured home constructed with chassis beams, the chassis beams provide support for gravity loads, and the perimeter walls resist uplift and lateral loads. When used with a manufactured home constructed with an integral floor framing system, the perimeter walls resist uplift, lateral, and gravity loads (Figure 2-7). With chassis systems, interior piers support the chassis, points along the marriage wall, and other areas of concentrated loads.

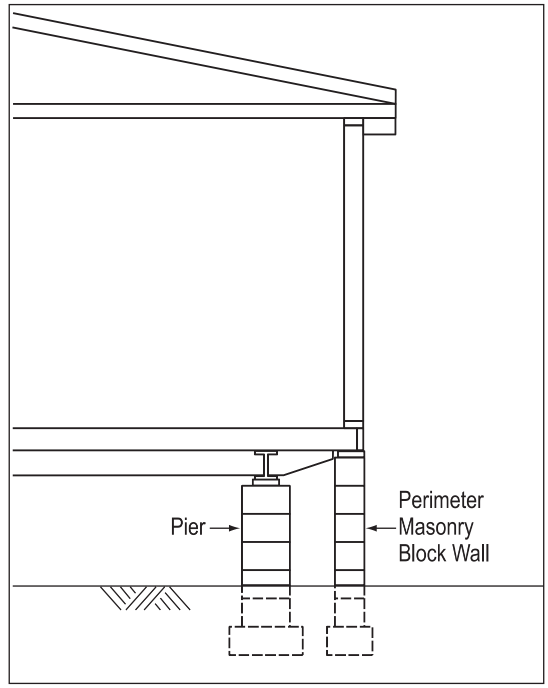


Figure 2-7. Perimeter wall foundation under a manufactured home.

Perimeter walls can be constructed with typical building materials (e.g., cast-in-place concrete, masonry, or preservative-treated wood); footings are generally cast-in-place concrete. Attaching the floor joists to the foundation wall provides resistance to horizontal and uplift forces.

Some considerations in using this system include the following:

- The system must be precisely measured and constructed before the home is delivered to the site.
- Typically, a crane or roller system will be needed to place the home onto the foundation.

The cost and construction time of this system is greater than the pier and ground anchor foundation system.

2.2.2 Proprietary Systems

A proprietary foundation is a patented system manufactured and sold only by the owner of the patent or licensee. If a proprietary system is selected for a manufactured home, it must be capable of resisting all design loads of the MHCSS, and those imposed by any site-specific natural hazards. (See the checklist on the next page for more information.)

The Systems Building Research Alliance (SBRA, formerly the Manufactured Housing Research Alliance [MHRA]) has evaluated proprietary and non-proprietary foundation systems for manufactured homes. Their publication, *Guide to Foundation and Support Systems for Manufactured Homes*, provides guidance for deciding among alternative foundation designs that are appropriate for a given site and budget. The SBRA is also continuing to conduct research foundation systems developed for use in SFHAs.

Proprietary Foundation System Checklist

- **Identify type of natural hazards for the manufactured home site.** Follow the steps in Chapter 9 of this guide.
- **Identify natural hazards design loads for the manufactured home.** Follow the steps in Chapter 9.
- **Check design loads on engineering drawings or specifications.** Design loads must be greater than or equal to the loads identified in Step 2 of Chapter 9.
- **The drawing must have a professional engineer's or architect's seal,** ensuring the system was designed by a professional.

2.3 Utilities and Mechanical Equipment

2.3.1 Utilities Placement

Care needs to be taken in the placement of utilities (such as water, sewer, and gas services) and mechanical systems. Connecting the manufactured home to these utility and mechanical systems requires them to extend from the grade beneath the home up through the floor. Their location makes them susceptible to being inundated by floodwaters and damaged by floating debris. Therefore, separating these systems to protect them is important. To minimize damage to utility lines, they should be placed in waterproof risers located adjacent to the elevated foundation member on the downstream side of the expected (or anticipated) flood flow.

State and local codes and regulations must also be followed for utility services installations and connections. These provisions may require the waterproofing of all connections, the use of certain specific waterproof materials, and backflow preventers on water and sewage service. Underground telephone and electric service should also be enclosed in a riser and protected from damage in a similar manner. If electrical and telephone service is supplied from overhead lines, the service connection to the manufactured home must be located above anticipated flooding.

Special care must be taken in running underground utilities to homes. Differential movement between the home and utility can cause failure of the home to utility connection. Failures can cause electrical shock hazard or leakage of gas, water, or raw sewage. Similar problems can occur when utilities run through uncompacted backfill around a basement excavation or when utilities are subjected to seismic loads. Installing a flexible connection in the line is one way to reduce potential line breakage.

It is possible that a home with utility services could be displaced in a design wind or a seismic event. By design, ground anchors that are used to hold down many homes will displace on the order of 2 to 3 inches. Seismic forces can cause even higher displacements to utility connections than a design wind event (Figure 2-8). Therefore, some flexibility must be provided in the utility lines to accommodate for any potential movements. Utility attachments to the manufactured home should be capable of accommodating the anticipated seismic and wind displacement of the support and anchorage system.

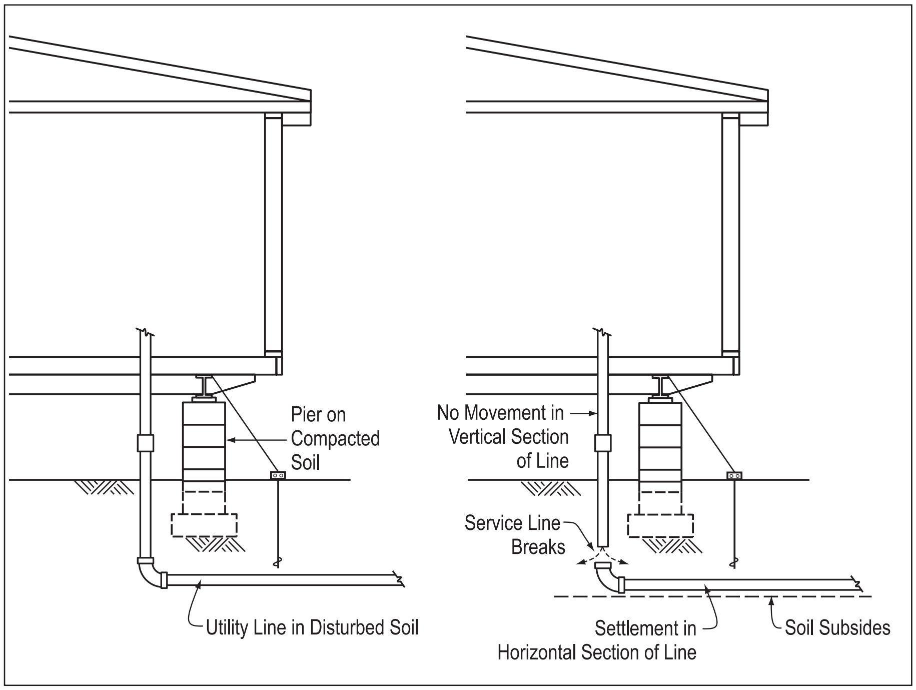


Figure 2-8. Utility line damage in unstable soils.

Propane and fuel oil tanks used to supply energy for heating or other services should be anchored against flotation or elevated above the anticipated flood level. Tank foundations should be separated from the home's foundation system. To minimize the potential for debris impact and damage, tanks and their supporting foundations should be located on the downstream side of homes. Bollards can be used to deflect floodborne debris and reduce the potential of impact damage. Additional information on utility systems for manufactured homes in the floodplain is provided in Section 3.6.7.

For manufactured homes located in seismic areas, site-installed water heaters should be provided with seismic bracing straps in accordance with the manufacturer's recommendations. Strapping a water heater to a wall to prevent it from falling over is an easy and cost-effective seismic mitigation measure. Other site-installed equipment weighing more than 100 pounds should be anchored to resist horizontal seismic forces.

2.3.2 Mechanical Access

Components of heating and air-conditioning systems installed within manufactured homes are generally located above the floor. When the home is elevated to the BFE, interior components are protected. However, components located below the floor remain vulnerable to flood damage. In particular, exterior heating and air conditioning compressors, and crossover ducts are common components that are damaged by floodwaters.

Compressor units can be elevated by placing them on platforms at the BFE; however, crossover ducts require the entire home to be elevated 1 to 2 feet above the BFE to prevent them from being damaged during the design flood.

2.4 Attachments – Carports, Decks, Porches, and Awnings

Carports, decks, porches, and awnings are often attached after the manufactured home has been installed. The HUD installation standard (24 CFR 3285.3) requires that attachments must not impose loads to the manufactured home or its foundations unless the attachments are included in the manufacturer's approved designs and installation instructions, or the attachments are designed by a registered engineer or architect consistent with the manufacturer's design. Similarly, the International Residential Code® (IRC®) requires that accessory buildings (e.g., carports, decks, porches, and awnings) shall not be structurally supported by or attached to a manufactured home unless engineering calculations are submitted to substantiate any proposed construction (IRC 2006 AE 504.1).

Carports, decks, porches, and awnings should only be built as stand-alone units. Additionally, if a stand-alone deck or porch is going to be added, design criteria for vertical foundation members on the addition should be equivalent to those for the foundation system of the main structure to prevent damage to the main structure from adjacent structures.

During the Hurricane Charley post-event assessment (2004), engineers noted the failure of these attached structures (in many places, occurring where wind speeds were below the design wind speed for the area), resulting in extensive damage to roof coverings, siding, and windows of the manufactured units, and generating significant amounts of debris.

3. Regulatory Requirements

Federal, State, and local regulatory requirements must be identified and assessed as an initial step in the installation of manufactured housing. The following discussion provides a summary of the applicable NFIP minimum requirements for the installation of manufactured homes in floodplains. In addition, HUD MHCSS and model building code requirements are summarized. Appendix A provides a list of publications for further guidance for the installation and placement of manufactured homes in hazard-prone areas.

3.1 Introduction to the NFIP

The NFIP has three main elements:

1. Flood insurance that provides financial protection for property owners to cover flood-related damage to buildings and contents.
2. Floodplain management requirements within the mapped flood hazard areas that are designed to prevent new development from increasing the flood threat and to protect new and existing buildings from anticipated flood events.
3. Hazard identification and mapping under which engineering studies are conducted and flood maps are prepared to delineate areas that are predicted to be subject to flooding under certain conditions.

Federal flood insurance is designed to provide an alternative to disaster assistance and disaster loans for home and business owners. Disaster assistance rarely comes close to covering all of the costs to repair and cleanup. While available to qualified victims, disaster loans do not significantly ease the financial burden due to repayment terms. It is important to remember that disaster assistance is available only after floods have been declared major disasters by the President of the United States. In contrast, insurance claims will be paid any time damage from a qualifying flood event occurs.

The NFIP is intended to encourage States and local governments to recognize and incorporate flood hazards in land use and development decisions. In some communities, this is achieved by guiding development to areas with lower risk. When decisions result in development within floodplains, application of the criteria set forth in 44 CFR 59.1 and 60.3 is intended to minimize exposure and flood-related damage. These are the minimum requirements that a community must adopt in order to participate in the NFIP. In general, the NFIP minimum floodplain management regulations require that new residential structures or substantially improved or substantially damaged existing residential buildings in A zones must have their lowest floor (including basement) elevated to or above the BFE. Non-residential structures in A zones can be either elevated or dry-floodproofed to the BFE. In V zones, the building must be elevated on piles and columns such that the bottom of the lowest horizontal structural member of the lowest floor of all new construction or substantially improved existing buildings must be elevated to or above the BFE.

Any community may exceed the minimum NFIP requirements by adopting more restrictive regulations. Communities often do this when they have access to information or knowledge of conditions that require, particularly for human safety, higher standards than the minimum NIFP requirements. Therefore, any floodplain management regulations that are more restrictive than the NFIP requirements shall take precedence.

By encouraging communities to guide development to lower risk areas, and by requiring the elevation of new construction and existing buildings that have been substantially improved or substantially damaged, one of the long-term objectives of the NFIP can be achieved: reducing flood damage and losses.

In addition to providing flood insurance and reducing flood damages through floodplain management regulations, the NFIP identifies and maps the nation's floodplains. Mapping flood hazards creates a broad-based awareness of the flood hazards and provides the data needed for floodplain management programs and to actuarially rate new construction for flood insurance.

3.2 Identifying and Mapping Flood Hazards

FEMA is required by statute to identify and map the nation's flood-prone areas and to establish flood-risk zones in these areas. Since the inception of the NFIP, FEMA has complied with this statutory requirement by performing engineering studies of flood-prone communities and producing flood maps. The flood maps are used by mortgage lenders, insurers, real estate agents, map determination companies, community officials, land developers, engineers and surveyors, State and local emergency response officials, and property owners. The flood maps are also used by States and communities for emergency management, land use planning, and water resources planning and by Federal agencies implementing Executive Order 11988, Floodplain Management for Federal actions proposed in or affecting floodplains.

The NFIP would not be able to offer insurance at affordable rates without the existence of risk management (floodplain management) to reduce flood losses. To assess and manage the flood risk, a national standard was needed. The 1-percent annual chance flood was chosen on the basis that it provides a higher level of protection while not imposing overly stringent requirements or the burden of excessive costs on property owners. The 1-percent annual chance flood (or 100-year flood) represents a magnitude and frequency that has a statistical probability of being equaled or exceeded in any given year or, stated alternatively, the 100-year flood has a 26 percent (or 1 in 4) chance of occurring over the life of a 30-year mortgage.

FEMA performs a Flood Insurance Study (FIS) and creates FIRMs delineating the extent of the flood that has a 1-percent chance of being equaled or exceeded in any given year. The delineated area is designated an SFHA, which is the area in which development must be regulated by NFIP floodplain management regulations. Under the NFIP, a floodplain is defined as any land area susceptible to being inundated by floodwaters from any source.

When producing a new FIS and FIRMs or updating existing ones, FEMA typically uses a combination of the two study approaches (approximate and detailed) in identifying a community's flood hazards. Detailed study methods typically employ the use of engineering models and, at a minimum, result in the determination of BFEs or flood depths and floodways that will be displayed on the flood map. Approximate study methods are used to identify flood hazards, but they use more simplified engineering methods to determine the floodplain boundaries; however, BFEs and floodways are not identified or mapped.

In general, the decision on whether to use approximate or detailed study methods is based on existing and anticipated development in and near the floodplain in the community. Flood hazard information for flooding sources that affect developed or developing areas are based on detailed studies whenever possible; approximate study methods generally are used for undeveloped or sparsely developed areas.

When a new or updated detailed FIS is performed, the following information is usually generated:

- BFEs are presented as either water-surface elevations or average depths of flow above the ground surface. These elevations and depths were historically referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). However, as a result of advances in technology, an updated vertical datum – the North American Vertical Datum of 1988 (NAVD 88) – was created and has been officially adopted by the Federal Government as a new basis for measuring heights. Newly updated maps and BFEs are now generally referenced to NAVD 88.
- Water-surface elevations for the 10-year (10-percent annual chance), 50-year (2-percent annual chance), 100-year (1-percent annual chance), and 500-year (0.2-percent annual chance) floods.
- Boundaries of the regulatory floodway. The regulatory floodway is defined as the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the entire base flood (1-percent annual chance flood) discharge can be conveyed with no greater than a 1.0-foot increase in the BFE.
- Boundaries of the 1- and 0.2-percent annual chance floodplains. The 1-percent annual chance floodplain is referred to as the SFHA. The 0.2-percent annual chance flood is the flood that has a 0.2 percent chance of being equaled or exceeded in any given year and is also known as the 500-year flood.

The results of the FIS are presented on the FIRM. An example of a FIRM showing the map and title box is shown in Figure 5-1. FIRMs are now being prepared as a digital product, known as a Digital Flood Insurance Rate Map (DFIRM), which may involve converting an existing manually produced FIRM to digital format, or creating a product from new digital data sources using a Geographic Information System (GIS) environment. A sample DFIRM is shown in Figure 3-1.

Figure 3-1. Sample DFIRM.

The results of the FIS are also presented in a report that accompanies the FIRMs or DFIRMs. The FIS report contains a narrative that describes the flooding conditions in the community, and the types of studies that were performed. The report also contains tables and Flood Profiles. For determining a BFE at a building site, communities should use the Flood Profiles rather than the BFE on the FIRM. A sample FIS summary of discharges is shown in Figure 3-2(a), a sample FIS floodway data table is shown in Figure 3-2(b), and a sample FIS flood profile is shown in Figure 3-2(c). Refer to Section 5.1 for additional details on obtaining FIRM and FIS data. The NFIP FISs and FIRMs can be viewed and ordered online at http://store.msc.fema.gov.

Flood risk zones are shown on the FIRM or DFIRM for the 1-percent annual chance flood as Zone A, Zone A1-30 (on older FIRMs), Zone AE, Zone AO, Zone AH, Zone AR, Zone A99, Zone AR/A, Zone AR/AE, Zone AR/A1-30 (on older FIRMs), Zone AR/AH, Zone AR/AO, Zone V, Zone V1-30 (on older FIRMs), or Zone VE. Table 3-1 provides a general description of the most common flood zone designations for riverine flood areas and inland flood zones in coastal areas. Table 3-2 provides a general description of the most common flood zone designations for coastal flood areas. The zone designations presented on the FIRM or DFIRM depend on the type of flood hazard and type of study performed. The 0.2-percent annual chance floodplain is labeled as Zone B (on older FIRMs) or Zone X (shaded). Areas outside of the SFHA are labeled as Zone C or Zone X (unshaded). Definitions and descriptions of the flood insurance risk zones can be found at: http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/flood_zones.shtm.

Table 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
TENMILE RIVER					
At the downstream corporate limits	210.0	7,500	13,660	16,850	26,280
At South Dover Bridge	194.5	6,930	12,410	15,260	23,470
Downstream from the confluence of the Swamp River	189.0	6,730	11,970	14,710	22,500
Upstream from the confluence of the Swamp River	141.0	4,980	8,300	10,070	14,590
At the upstream corporate limits	130.0	4,580	7,490	9,060	12,940
WELLS BROOK					
At its confluence with the Tenmile River	6.1	610	1,010	1,270	1,960
At a point approximately 0.8 mile upstream of its confluence with the Tenmile River	2.6	430	750	930	1,380

Figure 3-2(a). Sample FIS Summary of Discharges table.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Tenmile River (continued)								
x	49,320[1]	260	1,992	4.8	374.3			
Y	52,410[1]	120	1,035	9.2	377.2			
Z	54,310[1]	250	1,746	5.5	382.4			
AA	57,590[1]	275	1,664	5.8	387.9			
AB	58,470[1]	301	2,386	4.0	390.2			
Wells Brook								
A	725[2]	115	270	4.1	375.6			
B	1,980[2]	28	168	6.6	380.2			
C	4,280[2]	69	270	4.1	391.3			

[1]Feet above corporate limits
[2]Feet above concluence with Tenmile River
[3]Elevation computed without consideration of backwater effects from Tenmile River

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF DOVER, NY

(DUTCHESS CO.)

FLOODWAY DATA

TENMILE RIVER AND WELLS BROOK

Figure 3-2(b). Sample FIS Floodway Data.

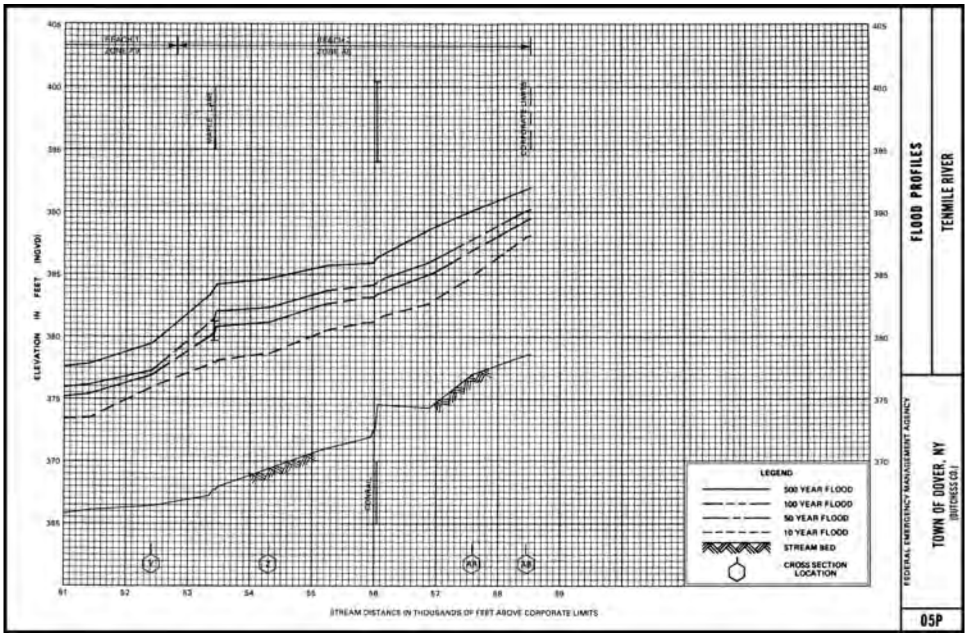


Figure 3-2(c). Sample FIS Flood Profile.

Table 3-1. Common SFHA Designations for Riverine or Inland Flood Zones

Zone	Description
Flood Risk Zones	
A	Areas subject to inundation by the 1-percent annual chance flood event. Because detailed hydraulic analyses are not used, no BFE or depths are shown.
AE and A1-30[1]	Areas subject to inundation by the 1-percent annual chance flood event determined by detailed methods. BFEs are shown.
AH and AO	Areas subject to inundation from the 1-percent annual chance flood that have flood depths of between 1 and 3 feet. AO zones can be either ponding areas or sheet flow and are assigned a base flood depth measured in feet above the ground. AH zones are generally ponding areas and are assigned a BFE.

[1] Zone designations found on older FIRMS have been replaced by the designation listed in the same box above them.

Table 3-2. Common SFHA Designations for Coastal Flood Areas

Zone	Description
Flood Risk Zones	
V	Areas subject to inundation from the 1-percent annual chance flood in coastal areas where there is a velocity hazard due to wave action and, by definition, the entire Primary Frontal Dune. No BFEs have been determined.
VE V1-30[1]	Areas subject to inundation from the 1-percent annual chance flood in coastal areas where there is a velocity hazard due to wave action. BFEs have been determined and are shown on the FIRM.

[1] Zone designations found on older FIRMs have been replaced by the designation listed in the same box above them.

In addition to the SFHAs labeled as V zones, there are some A zones, generally located landward of and contiguous to V zones, where flooding characteristics may include wave action, high velocity flows, and erosion or scour. These are referred to as Coastal A zones, and they are further described below and in Section 3.7.

Along rivers, streams, and lakes within the U.S., FEMA computes BFEs using computer models, statistical techniques, or both. These elevations are a function of the amount of water expected to enter a particular system by means of precipitation and runoff. The SFHAs along rivers, streams, and lakes are labeled as A zones.

Along the coast, FEMA determines SFHAs by an analysis of storm surge, wind direction, wind speed, wave heights, and other factors. FEMA designates these areas along the coast as both V and A zones on the FIRM or DFIRM.

FEMA applies the VE zone designation to those areas along the coast where water depth and other conditions would support at least a 3-foot wave height. FEMA also considers other factors in identifying VE zones, such as wave runup and the existence of a Primary Frontal Dune. FEMA usually designates AE zones in coastal areas landward of the VE zone. Coastal flood hazard areas mapped as AE zones can be subject to storm surge and damaging waves; however, the waves are less than 3 feet in height.

Currently, NFIP regulations make no distinction between the design and construction requirements for coastal AE zones and riverine AE zones. However, evidence suggests that design and construction requirements in some portions of coastal AE zones should be more like VE zone requirements. One of the hazard identification criteria for VE zone designation is where wave heights are estimated to be equal to or greater than 3 feet. Unfortunately, post-storm investigations have shown that typical AE zone construction techniques (e.g., wood frame, light gauge steel, or masonry walls on shallow footings or slabs, etc.) are subject to damage when exposed to waves less than 3 feet in height. Laboratory tests and post-disaster field investigations confirm that wave heights as small as 1.5 feet can cause failure of the above-listed wall types. Other flood hazards associated with coastal waves (e.g., floating debris, high velocity flow, erosion, and scour) also damage AE zone-type construction in these coastal areas.

As a result, for all new detailed coastal studies starting in 2009, FEMA will delineate the landward limit of waves 1.5 feet in height on the FIRMs and include this information in the DFIRM database as an informational layer. The landward limit of the area affected by waves greater than 1.5 feet is called the Limit of Moderate Wave Action (LiMWA). The LiMWA will be included on the preliminary FIRM; however, if a community does not want to delineate the limit on its final FIRMs, the community may provide a written request to FEMA with justification for such a request. There are no NFIP floodplain management requirements that communities must adopt or special insurance ratings associated with the designation of the LiMWA. However, communities are encouraged to adopt higher standards than the minimum NFIP requirements in these areas to address the increased risks associated with waves and velocity action.

3.3 The NFIP's Community Rating System (CRS)

The NFIP's Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.

As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS:

1. Reduce flood losses
2. Facilitate accurate insurance rating
3. Promote the awareness of flood insurance

For CRS participating communities, flood insurance premium rates are discounted in increments of 5 percent; a Class 1 community would receive a 45 percent premium discount, while a Class 9 community would receive a 5 percent discount (a Class 10 is not participating in the CRS and receives no discount). The CRS classes for local communities are based on 18 creditable activities, organized under four categories:

1. Public Information
2. Mapping and Regulations
3. Flood Damage Reduction
4. Flood Preparedness

3.4 NFIP Definitions Related to Manufactured Homes

In addressing the NFIP floodplain management requirements for manufactured homes, it is useful to define key terms. The following definitions are found in the NFIP floodplain management regulations at 44 CFR 59.1 unless noted otherwise. Several NFIP definitions can also be found in Appendix D. The definition for "manufactured home" does not include a recreational vehicle.

- "Manufactured home" means a structure, transportable in one or more sections built on a chassis and designed for use with/without a permanent foundation when attached to utilities.
- "Manufactured home park or subdivision" means a parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.
- "Existing manufactured home park or subdivision" means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be

Permanent Foundations

A permanent foundation is a foundation constructed of durable materials that may include masonry, reinforced concrete, corrosion resistant steel, or pressure treated timber. The foundation designs provided in Appendix H are considered permanent foundations in accordance with this definition.

affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by the community.

- “New manufactured home park or subdivision” means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of the floodplain management regulations adopted by a community.
- “Expansion to an existing manufactured home park or subdivision” means the preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).
- “Substantial damage” means damage of any origin sustained by a structure whereby the cost of restoring the structure to the condition before damage would equal or exceed 50 percent of the market value of the structure before the damage occurred.
- "Substantial improvement" means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the “start of construction” of the improvement. This term includes structures that have incurred “substantial damage,” regardless of the actual repair work performed. The term does not, however, include either (1) any project for improvement of a structure to correct existing violations of State or local health, sanitary, or safety code specifications that have been identified by the local code enforcement official and that are the minimum necessary to ensure safe living conditions, or (2) any alteration of a “historic structure,” provided that the alteration will not preclude the structure’s continued designation as a “historic structure.”

3.5 General NFIP Floodplain Management Requirements for Manufactured Homes

Under the NFIP, participating communities are required to regulate all development in SFHAs. “Development” is defined in the NFIP regulations as:

> “Any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials.” [44 CFR 59.1]

Before a property owner can undertake any development in the SFHA, a permit must be obtained from the community. The community is responsible for reviewing all permit applications to determine whether development complies with the community’s floodplain management regulations. Communities are also required to review proposed development in SFHAs to ensure that all necessary permits have been received from those government agencies from which approval is required by Federal or State law, such as 404 wetland permits from the U.S. Army Corps of Engineers (USACE) or permits under the Endangered Species Act.

The NFIP requires manufactured homes to meet the same basic regulatory requirements that are required for residential structures in the floodplain. The following general NFIP minimum standard applies to all residential structures in the floodplain in which communities are to:

> "Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding." [44 CFR 60.3(a)]

The NFIP also requires that new manufactured home parks and subdivisions meet the same basic requirements as all other subdivision proposals in which communities are to:

> "Review subdivision proposals and other proposed new development, including manufactured home parks or subdivisions, to determine whether such proposal will be reasonably safe from flooding. If a subdivision proposal or other proposed development is in a flood-prone area, any such proposals shall be reviewed to assure that:
>
> (i) all such proposals are consistent with the need to minimize flood damages within the flood-prone area,
>
> (ii) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located and constructed to minimize or eliminate flood damage, and
>
> (iii) adequate drainage is provided to reduce exposure to flood hazards." [44 CFR 60.3(a)(4)]

3.6 NFIP Requirements for Manufactured Homes in Riverine and Inland Flood Zones

Generally, manufactured homes must meet the same flood protection requirements as a "stick built" or typical housing. The general requirement for manufactured homes like typically built residential structures is that they must be elevated so that the lowest floor is above the BFE. This applies to new or substantially improved or substantially damaged manufactured homes.

BFE and DFE

Base flood elevation (BFE) – The water surface elevation resulting from the base, or 100-year (1 percent annual chance) flood.

Design flood elevation (DFE) – The elevation to which development in the regulatory floodplain is built. At a minimum, the DFE is equivalent to the BFE. However, in some areas, the DFE includes an additional freeboard height above the BFE as shown in the formula below.

DFE = BFE + Freeboard

Freeboard – An additional elevation requirement some height (1, 2, or more feet) above the BFE that provides a margin of safety above the estimated BFE.

As indicated above, the minimum DFE requirement for NFIP communities is the BFE. However, in communities where a higher degree of protection is promoted or required, the DFE includes a freeboard height above the BFE. This freeboard provides a margin of safety above the estimated BFE and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties. The NFIP encourages participating communities to adopt and enforce freeboard requirements as part of their local floodplain management ordinance. This is shown in 44 CFR 60.1(d); which states, "Any floodplain management regulations adopted by a State or a community which are more restrictive than the criteria set forth in this part are encouraged and shall take precedence."

3.6.1 Approximate A Zones

Approximate A zones are not studied using detailed methods; therefore, BFEs have not been developed. When a manufactured home is proposed on an approximate A zone site, the community must make every effort to obtain any BFE data and floodway data in order to achieve a reasonable measure of flood protection.

> "Obtain, review, and reasonably utilize any base flood elevation and floodway data available from a Federal, State, or other source…." [44 CFF 60.3(b)(4)]

BFE data may be available from a variety of sources such as local hydrologic and hydraulic (H&H) studies, State Departments of Natural Resources, or from Federal agencies such as the USACE. Several other sources of BFE data are identified in FEMA 265, *Managing Floodplain Development in Approximate Zone A Areas, A Guide for Obtaining and Developing Base (100-year) Flood Elevations.*

If BFE or floodway data cannot be obtained from these sources, the community should consider conducting, or requiring the applicant to conduct, a site-specific engineering analysis to determine a BFE. Guidance for developing a BFE is available in FEMA 265.

If no BFE data are available, communities must ensure that building sites will be reasonably safe from flooding for proposed developments. A simplified method for estimating a BFE as well as other methods for ensuring a building site is reasonably safe from flooding can also be found in FEMA 265.

When a new manufactured home park or subdivision is being planned on a site that is greater than 50 lots or 5 acres (whichever is less), BFE data must be developed for approximate A zones through the use of detailed study methodologies similar to those used in creating the FIS. Under this requirement, the community must:

> "Require that all new subdivision proposals and other proposed development (including proposals for manufactured home parks and subdivisions) greater than 50 lots or 5 acres, whichever is the lesser, include within such proposals base flood elevation data." [44 CFR 60.3(b)(3)]

The community can perform a study to determine these elevations or require the developer to fund or complete the study. When the 50-lot, 5-acre threshold is surpassed and the development includes one or more lots that lie at least partially within the floodplain, BFE data must be developed through detailed study methodologies. If the developer completes the study, it is subject to approval by the community.

For manufactured home sites that are below the 50-lot/5-acre threshold and BFE data for those sites are not available from other sources, communities should consider conducting or requiring the permit applicant to develop a BFE in an approximate A zone. In addition to reducing flood damages, there are other advantages of developing a BFE. For example, flood insurance policies obtained in approximate A zones that are rated using a BFE developed using a detailed study methodology will often qualify for significantly lower insurance rates than policies that are rated without a BFE. The difference in flood insurance premiums could be substantial.

If a manufactured home is proposed in an approximate A zone where BFE data are not available from a Federal, State, or other source, the community must require that:

> "…all manufactured homes to be placed within Zone A on a community FHBM or FIRM shall be installed using methods and practices which minimize flood damage. For the purpose of this requirement, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include, but are not limited to, the use of over-the-top frame ties to ground anchors. This requirement is in addition to applicable State and local anchoring requirements for resisting wind forces." [44 CFR 60.3(b)(8)]

This minimum standard requires that manufactured homes be elevated and anchored to resist flood and wind forces. If elevation data are not available from a Federal, State, or other source, FEMA advises communities to require manufactured homes under this provision to be elevated at a minimum of 3 feet or higher from the highest adjacent grade to minimize flood damages. Guidance for anchoring is further addressed in Section 3.6.5 and in Chapter 7. The areas below the 3-foot elevation must be constructed with flood-resistant materials and utilities, and mechanical equipment must be elevated to the 3-foot elevation. Any utility and mechanical components that must be below the BFE must be made watertight to the 3-foot elevation as described in 3.6.7.

When BFEs or floodway data are obtained for manufactured home sites, the manufactured home must meet the elevation and floodway standards described in Sections 3.6.2 and 3.6.9.

3.6.2 Elevation in A, A1-30, AE, and AH Zones

Most manufactured home placements are subject to the same performance standards as typically built residential structures. The performance standard for the placement of these manufactured homes is addressed in this section. An exception has been made for the placement of manufactured homes in existing manufactured home parks or subdivisions which is addressed in Section 3.6.3.

The NFIP requires that manufactured homes placed or substantially improved in Zones A1-30, AH, or AE on the community's FIRM on sites:

> (i) "Outside of a manufactured home park or subdivision,
>
> (ii) In a new manufactured home park or subdivision,
>
> (iii) In an expansion to an existing manufactured home park or subdivision, or
>
> (iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood,
>
> be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement." [44 CFR 60.3(c)(6)]

This requirement establishes the basic elevation and anchoring standards that apply to most manufactured home placements, including those outside of manufactured home parks and subdivisions and in new manufactured home parks and subdivisions. These manufactured homes must have their lowest floors elevated to or above the BFE. These requirements also apply to manufactured homes placed in expansions to existing manufactured home parks and on lots where manufactured homes are substantially damaged by flood. Once a manufactured home in an existing manufactured home park or subdivision is substantially damaged by flood, from that point on all manufactured homes placed on that lot must be elevated to or above the BFE.

The best way to meet the elevation requirement described above is to elevate the bottom of the manufactured home steel frame to the BFE. The manufactured home must be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement. Section 3.6.5 and Chapter 7 address anchoring in more detail.

> This guide recommends for A zones the best practice of placing the bottom of the manufactured home's steel frame at the BFE and not the lowest floor of the manufactured home in order to prevent flood damage to the floor and other interior finishes and contents (Figure 3-3).

As with stick built housing, all parts of the manufactured home below the BFE must be constructed with flood damage-resistant materials and utility systems must either be elevated or made watertight to the BFE.

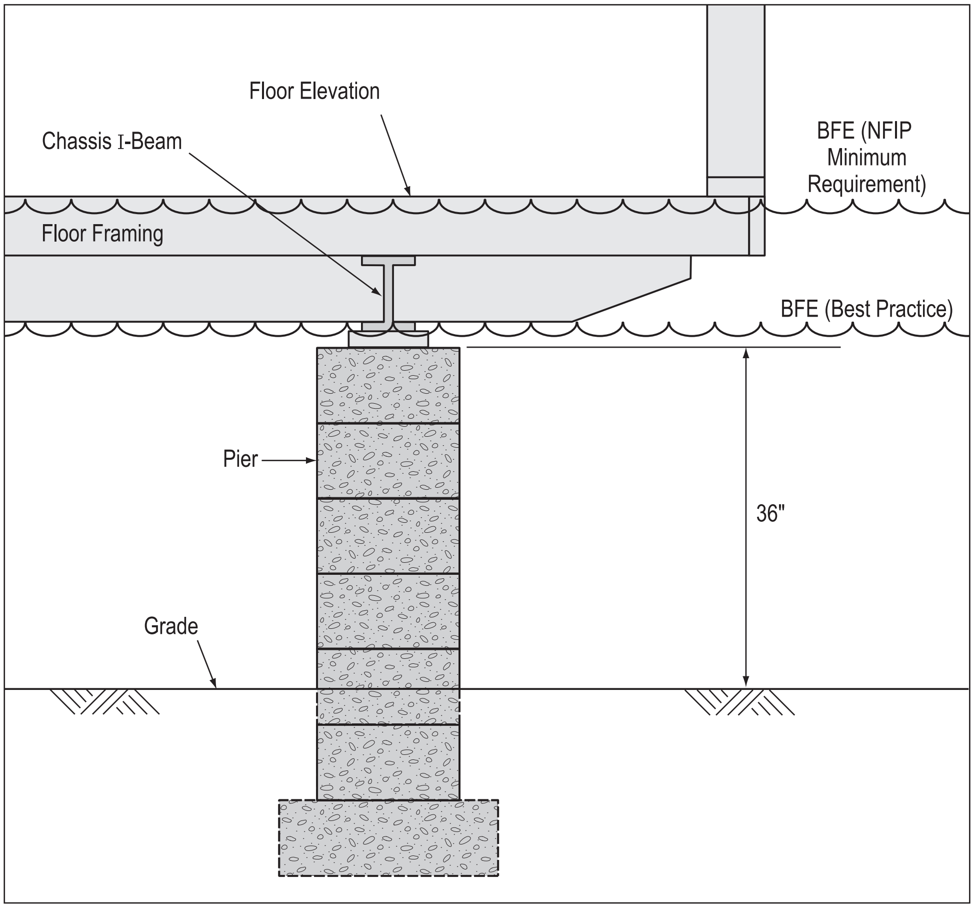


Figure 3-3. Manufactured home with lowest floor elevated to the BFE.

3.6.3 3-Foot Pier Foundation

The NFIP allows for a limited exemption to elevating to the BFE by allowing elevating to no less than 36 inches in height above grade for lots in existing manufactured home parks in Zones A1-30, AE, or AH on the community's FIRM. A manufactured home placed in an existing manufactured home park must meet either of the following requirements:

"(1) The lowest floor of the manufactured home is at or above the base flood elevation; or

(2) The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement." 44 CFR 60.3(c)(12).

The elevation requirements above apply in existing manufactured home parks or subdivisions established before the date of the community's initial floodplain management regulations when:

1) A manufactured home is being placed or replaced with a new model in an existing community or subdivision, or

2) A manufactured home is being replaced in an existing manufactured home park or subdivision when the previous home had sustained substantial damage due to reasons other than a flood.

The selection of the 36-inch pier foundation does not apply to the repair or replacement of a manufactured home on a site in an existing manufactured home park where a manufactured home has been substantially damaged by flood.

The option of allowing elevating 36 inches in height above grade is a compromise to balance the flood hazard against the economic impacts on some manufactured park owners that would result if elevation to the BFE were required. There are often practical difficulties in elevating manufactured homes to the BFE in many older parks due to small lot sizes and the split ownership of the manufactured home and the lot itself.

3-Foot Pier Foundation

The 3-foot pier foundation is one option for manufactured homes installation in existing manufactured home parks or subdivisions. However, the NFIP strongly encourages elevating to the level of the BFE or higher for increased safety and property protection and reduced flood insurance premiums.

It is important to note that, when the 36-inch pier foundation is selected, the manufactured home may not be protected to the level of the BFE. For this reason, care must be exercised in using the 36-inch pier foundation option. This option may not be appropriate in communities where the flood hazard may be so severe, such as deep floodplains and high velocity areas, that it would place lives and property at too great a risk. Some communities may find placement of a manufactured home in an existing manufactured home park can accommodate elevation to the BFE.

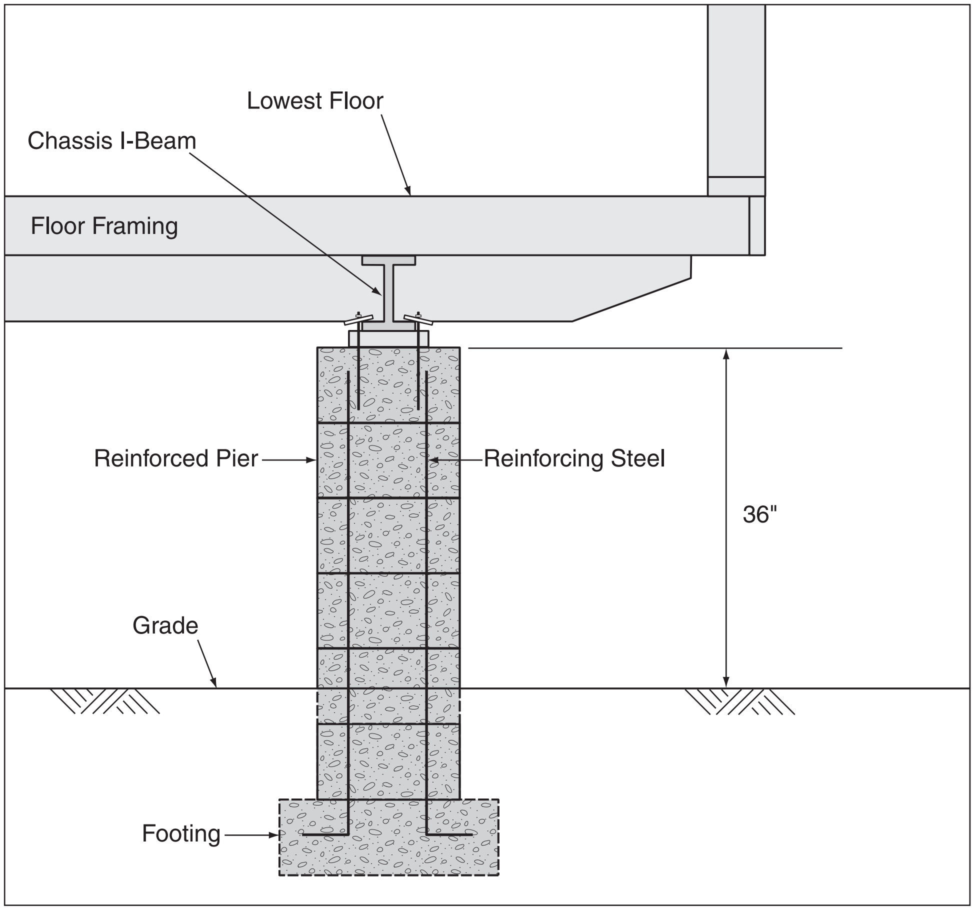
If the option of elevating the manufactured home to 36 inches above grade is chosen, the strength of the anchoring system must be increased in order to resist the additional flood forces that will be exerted upon the foundation since it is possible that water will reach or exceed the level of the home's floor. Therefore, under this scenario, the use of typical manufactured home installation methods such as foundations using dry-stack blocks and ground anchors would preclude the use of the other foundation designs in this guide.

No matter which option is chosen for elevating a manufactured home in an existing manufactured home park, the manufactured home must be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement.

As with stick built housing, all parts of the manufactured home below the BFE must be constructed with flood-resistant materials and utility systems must either be elevated or made watertight to the BFE. The best way to meet the requirement for flood resistance is to elevate the bottom of the manufactured home steel frame to the BFE.

Figure 3-4 shows a typical example of a foundation used on manufactured housing per the 36-inch pier foundation alternative. The pier, footing, and connection between the pier and the home must be designed to resist flotation, collapse, or lateral movement.

Figure 3-4. Manufactured home on reinforced pier foundation 36 inches high.



3.6.4 Elevation in Zone AO

A Zone AO is an area of shallow flooding with flood depths between 1 and 3 feet with no clearly defined channel. FIRMs indicate a flood height above grade that is based on an average depth to which structures must be raised for Zone AO.

Manufactured homes placed or substantially improved in Zone AO must meet the same standards as other residential structures and have their lowest floor elevated above the highest adjacent grade at least as high as the depth number specified on the FIRM.

HUD manufactured home standard 24 CFR 3285.305 requires a minimum clearance of 12 inches between the lowest member of the main frame and the ground surface, and the manufactured home main frame is typically 0.5 feet to 1 feet deep; therefore, the lowest floor level is typically 1.5 to 2 feet above grade. Under this scenario, meeting the NFIP elevation requirement for Zone AO may already be met or require a relatively small additional elevation of up to 1.5 feet. This additional elevation can be accomplished using installation techniques found in this guide, such as placing the home on piers and securing it with ground anchors.

Standard installation techniques provide a foundation that is typically elevated at least 3 feet above grade, and flood depths in Zone AO are typically 3 feet or less. Therefore, the placement or substantial improvement of manufactured homes in Zone AO are typically elevated to or above the base flood level, even if they are being placed in an existing manufactured home park or subdivision. However, the recommended best practice is to elevate the bottom of the steel frame to the BFE in Zone AO.

As in the other A zones, manufactured homes in Zone AO must be anchored to resist flotation, collapse, or lateral movement. The areas below the Zone AO flood depth must be made with flood damage-resistant materials, and utilities and mechanical equipment must be elevated to the flood depth specified on the FIRM. Any utility and mechanical components that must be below the BFE must be made watertight to the Zone AO flood depth. Refer to Sections 3.6.6 and 3.6.7 and Chapter 7 for additional details on these requirements.

3.6.5 Anchoring

In addition to the elevation requirement, manufactured homes are required to be securely attached to an adequately anchored foundation system to resist flotation, collapse, or lateral movement:

> "[Manufactured homes must] …and be securely anchored to an adequately anchored foundation to resist flotation, collapse and lateral movement." [44 CFR 60.3(c)(6) and (c)(12)]

"Adequately anchored" is considered to be a system of ties, anchors, and anchoring equipment that will withstand flood and wind forces.

Anchor and Tie-down Systems

Anchor and tie-down systems must meet load requirements stipulated in locally adopted installation ordinances. Many communities across the country have adopted or are in the process of adopting the International Code Council's (ICC's) model building codes, which include the International Residential Code® of 2009 (IRC® 2009). IRC 2009 stipulates working load requirements of 3,150 pounds with a 50 percent overload or 4,725 pounds for manufactured home anchoring systems.

Florida's manufactured home installation requirements, *Rules of Department of Highway Safety and Motor Vehicles Division of Motor Vehicles, Chapter 15C-1*, for homes manufactured before July 14, 1994, have the same loading standards for anchor systems as those found in the IRC 2009, a working load of 3,150 pounds with an ultimate load of 4,725 pounds. However, for homes manufactured after July 14, 1994, the system must be able to resist a working load of 4,000 pounds with an ultimate load of 6,000 pounds.

Additional guidance on anchoring manufactured homes can be found in Chapter 7.

3.6.6 Flood Damage-Resistant Materials

When a manufactured home is elevated, it is important that all parts exposed to floodwaters be made of flood damage-resistant materials. This includes all portions of the manufactured home such as foundation elements and any enclosures below the BFE.

> "[Community must] Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a floodprone area, all new construction and substantial improvements shall…(ii) be constructed with materials resistant to flood damage…" [44 CFR 60.3(a)(3)]

"Flood [damage]-resistant material" is described in FEMA Technical Bulletin 2 as "any building product [material, component or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage." The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than cosmetic repair. "Cosmetic repair" includes cleaning, sanitizing, and resurfacing (e.g., sanding, repair of joints, repainting) of the material.

For further information on flood-resistant materials refer to FEMA Technical Bulletin 2, *Flood Damage-Resistant Material Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program.*

3.6.7 Utilities and Mechanical Equipment

The manufactured home's utilities and mechanical equipment need to be protected. Their location below the BFE can make them susceptible to being inundated by floodwaters and damaged by floating debris. Utilities and mechanical equipment must:

> "…be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding." [44 CFR 60.3(a)(3)(iii)]

Essentially, utility systems and mechanical equipment must be elevated to or above the BFE. Elevating utilities and mechanical equipment such as furnaces, hot water heaters, and heating, ventilation, and air conditioning equipment (HVAC) is the best protection. With most outdoor HVAC compressors, the main issues presented by floodwaters are inundation, velocity flow, and debris impact. The control and power circuits and mechanical parts in HVAC equipment, even when they are designed for outdoor installations, are not designed to withstand inundation by floodwaters. The most effective flood-resistant design for outdoor HVAC compressors is to strap or bolt the equipment onto a platform above the BFE.

Utility and mechanical components that must be below the BFE must be made watertight to the BFE. Examples of this include sealing on-site water well casings to prevent water intrusion or enclosing HVAC equipment in a flood-resistant enclosure so that it is protected to the BFE.

The NFIP does not recommend locating ductwork below the BFE for manufactured homes located in SFHAs. There is no known or cost-effective technique for designing air ducts to keep floodwaters from entering or accumulating within the systems components during inundation by floodwaters. If ductwork must be installed below the BFE, it should be minimized as much as possible. Placing the bottom of the steel frame at the BFE as recommended enhances protection of utility and mechanical equipment. The exception would be installation of cross-over duct work for manufactured housing that needs to pass under chassis frame members. If cross-over ducts are used, elevating the manufactured home 1 to 2 feet above the BFE will prevent them from being damaged during flood events.

Additional guidance for protecting utility and mechanical systems can be found in FEMA 348, *Protecting Building Utilities From Flood Damage, Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems.*

3.6.8 Enclosed Areas

Generally, the space beneath the lowest floor of manufactured home is covered by some type of skirting or screening. Manufactured homes are also often installed on an enclosed foundation (see Chapter 8) when the BFE is several feet above grade.

When an enclosed area below the lowest floor of a manufactured home is created, special attention is needed for two reasons:

- The walls of enclosed areas are subject to flood damage from hydrostatic and hydrodynamic forces.
- People are tempted to convert enclosures that are intended to flood into areas that can sustain damage in a flood.

To protect enclosed areas below the lowest floor, the community must:

> "Require, for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters." [44 CFR 60.3(c)(5)]

The NFIP allows only certain uses of the enclosed area below the lowest floor of an elevated manufactured home. These spaces can only be used for parking of vehicles, building access, or storage.

Additionally, the enclosure must be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. To protect the enclosure, the NFIP minimum requirements are:

- A minimum of two openings in walls of the enclosure having a total net area of not less than 1 square inch for every square foot of enclosed area subject to flooding.
- The bottom of all openings must not be higher than 1.0 foot above the higher of the exterior or interior grade or floor immediately below the opening.
- Openings must permit the automatic entry and exit of floodwaters. The openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they meet this requirement.
- Alternative designs are allowed but must be certified by a registered professional engineer or architect as meeting the requirement to automatically equalize forces on exterior walls by allowing for the entry and exit of floodwaters.

To further minimize flood damages, mechanical, electrical, plumbing equipment, and other service facilities must be designed and/or located so as to prevent damage during conditions of flooding (see Section 3.6.7). Enclosures below the BFE must also be constructed with flood damage-resistant materials.

If the area below the manufactured home is enclosed with rigid skirting that is less likely to be dislodged by wind or flood loads, openings are required to equalize hydrostatic pressure in accordance with NFIP regulations.

For further information on enclosed areas refer to FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program.*

3.6.9 Floodways

If a community receives a proposal for the development in the SFHA, the community must ensure that the proposal will not impose flood problems on other properties. To prevent this, communities must adopt floodways to designate those areas where flood flows are most sensitive to changes brought on by development. The NFIP defines the floodway as:

> "….the channel of a river or other watercourse and adjacent land area that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height." [44 CFR 59.1]

A floodway is the central portion of a riverine floodplain needed to carry the deeper, faster moving water. A floodway is included with most riverine Flood Insurance Studies and will generally be shown on the FIRM or DFIRM as indicated in Figure 3-5. A floodway schematic is provided in Section 4.4.1.1 (Figure 4-2). The area chosen for the regulatory floodway must be designed to carry the waters of the 1-percent annual chance flood without increasing the water surface elevation of that flood more than 1 foot at any point.

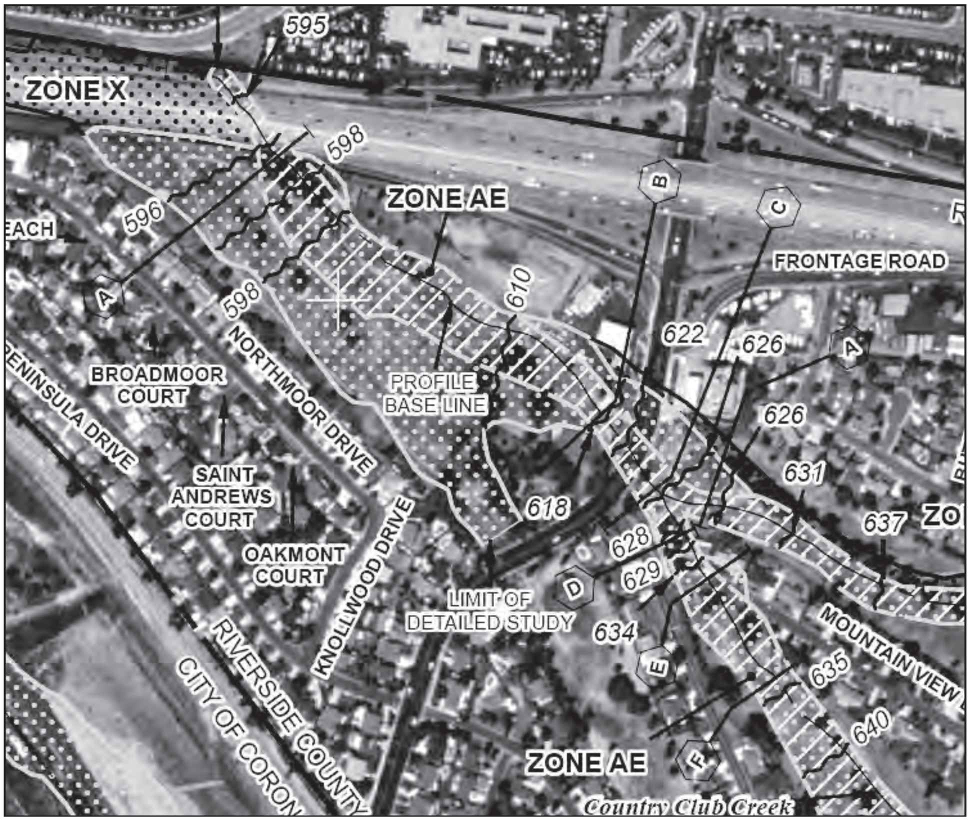


Figure 3-5. DFIRM showing the floodway (cross-hatched area in Zone AE).

Once a community has adopted a floodway, it must prohibit development in the floodway unless it has been demonstrated through H&H analyses performed using standard engineering practice that the development will not result in any increase in flood levels during the base flood. This "encroachment analysis" is required under the following NFIP provision:

> "Prohibit encroachments in the floodway, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during occurrence of the base flood discharge." [44 CFR 60.3(d)(3)]

FEMA defines "any increase" as meaning a zero increase (greater than 0.00 feet). This analysis is usually called a "no-rise" or "zero-rise" analysis and results in a "no-rise" or "zero-rise" certification by a qualified registered professional engineer. Remember that considerable encroachment into the floodplain was already allowed when the floodway was designated by the community. Although some communities or States perform the H&H analyses themselves, most require the permit applicant to obtain the services of a qualified registered professional engineer to perform the analysis and provide the certification. Generally, very little development or disturbance is permitted in the floodway because even minor encroachments in the floodway lead to increases in the BFE. Unless the engineering analysis demonstrates that there will not be an increase in the BFE as a result of the development, the permit must be denied.

For streams and other watercourses where FEMA has provided BFEs, but no floodway has been designated, the community must review developments on a case-by-case basis to ensure that these increases do not occur, as stated in 44 CFR 60.3(c)(10), in which communities must:

> "Require until a regulatory floodway is designated, that no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1–30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community." [44 CFR 60.3(c)(10)]

3.7 NFIP Requirements for Manufactured Homes in Coastal Flood Areas

Flood hazard areas along coastlines that are subject to flooding from storm surge and wave impacts during coastal storms and hurricanes are designated on the FIRMs as Zones V1-30, VE, and V. In general, different standards than those in riverine floodplains apply in V zones to help manufactured homes withstand wave impacts. Many V zones are also subject to erosion and scour, which can undercut manufactured home foundations.

In addition, some A zones near the coast, generally located landward of and contiguous to V zones, experience V zone flooding characteristics, including wave action, high velocity flows, and erosion or scour. These are referred to as Coastal A zones. While the forces in Coastal A zones are not as severe as those in V zones, they can still cause damage to manufactured housing and foundations.

> **Coastal A Zones**
>
> NFIP regulations do not differentiate between Coastal and non-Coastal A zones. However, this guide recommends that manufactured housing in Coastal A zones be installed to be more resistant to flood forces found in coastal flood areas, including wave effects, velocity flows, erosion, and scour.

Although there are no distinct NFIP floodplain management regulations for Coastal A zones, this guide recommends that V zone regulations be followed within Coastal A zones where flood forces are generally stronger and more destructive than those in non-Coastal A zones.

44 CFR 60.3(e) outlines the NFIP requirements for manufactured homes in coastal flood hazard areas in relation to elevation and anchoring, fill, enclosed areas and breakaway walls, and setbacks. Each of these requirements will be addressed in Sections 3.7.1 through 3.7.4, respectively.

In addition to these requirements, manufactured homes in coastal flood areas are required to meet many of the same requirements as manufactured homes constructed in riverine and inland flood areas, such as the use of flood damage-resistant materials below the BFE (Section 3.6.6) and protection of utilities and mechanical equipment (Section 3.6.7).

3.7.1 Elevation and Anchoring

Manufactured homes placed or substantially improved in V zones must be elevated so that the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE in sites:

> "(i) Outside of a manufactured home park or subdivision, (ii) In a new manufactured home park or subdivision, (iii) In an expansion to an existing manufactured home park or subdivision, or (iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood, meet the standards of paragraphs (e)(2) through (e)(7) of 44 CFR 60.3." [44 CFR 60.3(e)(8)]

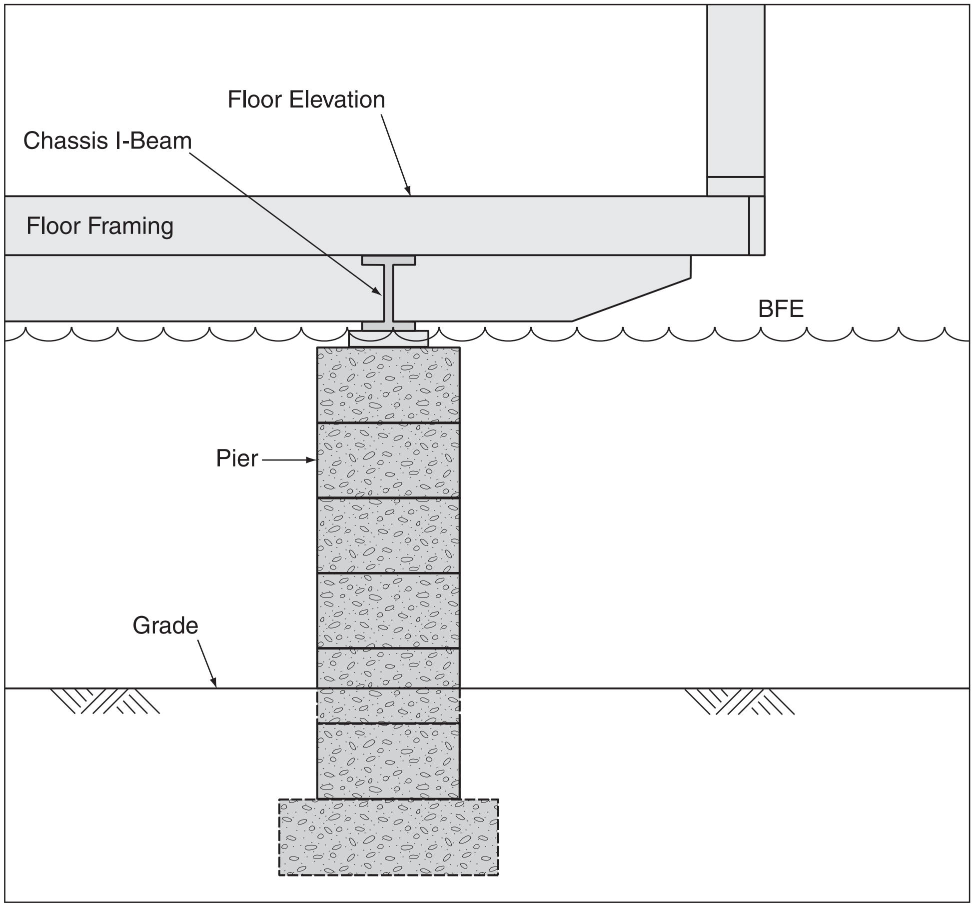
Elevation requirements for structures in the V zones differ from those in the A zones. In A1-30, AE, A, and AO zones, the finished floor elevation (i.e., top of floor) must be elevated to or above the BFE. Structures in V zones must be elevated so that *"the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE."* For manufactured homes, the lowest horizontal structural member would generally be the chassis main steel beams. Having the bottom of the lowest horizontal structural member to or above the BFE minimizes flood damages due to wave action. Figure 3-6 illustrates the reference level requirement.

44 CFR 60.3 (e)(4) requires the community to:

> "Provide that all new construction and substantial improvements in Zones V1-30, VE, and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that (i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and (ii) the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design, specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e)(4)(i) and (ii) of this section."

Satisfying 44 CFR 60.3(e)(4)(ii) means that flood and wind loads are to be considered acting simultaneously in the design of elevated portions of the building, its foundation, and its attachment to the structure, so that the building will not be subject to flotation, collapse,

Figure 3-6.
Manufactured home with the bottom of the lowest horizontal structural member elevated to the BFE.



displacement, or other structural damage. Design wind loads are to comply with State or local building standards.

Manufactured homes to be placed or substantially improved on sites in an existing manufactured home park or subdivision in V zones must be elevated so that the bottom of the lowest horizontal structural member of the lowest floor is to or above the BFE or meet the 3-foot pier foundation addressed in Section 3.6.3. In the case of the 3-foot foundation, it is important to note that structures in V zones are subject to wave action, intense hydrodynamic pressures, and generally deeper flood depths than riverine areas. Foundations in V zones need to be designed to withstand flood forces from breaking waves and greater flood depths from storm surge. The 3-foot foundation should not be expected to withstand these forces. For these reasons, the NFIP recommends that all manufactured homes in V zones be elevated to or above the BFE. FEMA's *Coastal Construction Manual* (FEMA 55) recommends that the lowest horizontal structural members in coastal areas should be perpendicular to the expected wave crest.

As discussed in Section 3.2, post-storm investigations have indicated that typical AE Zone constructed buildings along the coast are subject to considerable damage when exposed to waves less than 3 feet and as small as 1.5 feet in height. Evidence from these post-storm investigations suggests that design and construction requirements in some portions of Coastal AE zones should be more like the VE zone requirements to minimize damages.

To help communities identify those Coastal AE zone areas subject to damaging wave heights, FEMA will delineate the landward limit of the area affected by waves greater than 1.5 feet in height on the FIRMs and include this information in the DFIRM database as an informational layer. As indicated in Section 3.2, FEMA refers to this limit as the LiMWA. Communities are encouraged but not required to adopt the coastal AE Zone area defined by the LiMWA and adopt and enforce higher building standards than the minimum NFIP requirements in these areas.

Furthermore, the 2009 International Building Code® (IBC®) references the American Society of Civil Engineers (ASCE) 24-05 *Flood Resistant Design and Construction* standard, which has specific design requirements, similar to Zone VE construction, that apply to areas that may be affected by waves greater than 1.5 feet (which ASCE 24 refers to as Coastal A zones). In addition, every FEMA coastal construction publication since the issuance of FEMA 55, *Coastal Construction Manual*, dated June 2000, has recommended the use of Zone VE construction practices in areas subject to wave heights greater than 1.5 feet. The NFIP's CRS provides credits for communities that adopt and enforce more stringent floodplain management requirements in these areas.

3.7.2 Fill

Due to the wave action and more intense hydrodynamic forces experienced in coastal flood areas that lead to erosion and scour, elevating on structural fill is not permitted in V zones. Under the NFIP, the use of fill is prohibited for structural support.

> "[The community must] Prohibit the use of fill for structural support of buildings within Zones V1-30, VE, and V on the community's FIRM."[44 CFR 60.3(e)(6)]

While fill is not allowed for structural support, a limited amount of fill is allowed for landscaping, local drainage needs, and to smooth out a site for an unreinforced concrete pad. Fill must not divert floodwaters or deflect floodwaters and waves beneath elevated buildings. Fill must also not divert floodwaters or deflect waves such that increased flood damages is sustained by adjacent and nearby buildings.

For further information on fill in coastal flood areas refer to FEMA Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program.*

3.7.3 Enclosed Areas and Breakaway Walls

The preferred method of constructing a V zone building is to leave the area below the elevated floor free of obstruction or to enclose the area only with latticework or insect screening. That way waves can freely flow under the building without placing additional loads on the foundation. The only solid foundation walls allowed below the lowest floor of a manufactured home in a V zone area are breakaway walls that will give way under wind and water loads without causing collapse, displacement, or other damage to the elevated portion of the manufactured home or supporting to the piles. The NFIP requirements for enclosures below an elevated building are:

> "[The community must] Provide that all new construction and substantial improvements within Zones V1-30, VE, and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purpose of this section, a breakaway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of breakaway walls which exceed a design safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions….."
> [44 CFR 60.3(e)(5)]

Just as in A zones, the space enclosed by walls is to be used solely for parking of vehicles, building access, or storage, and must be constructed with flood-resistant materials. Solid breakaway walls are allowed, as are garage doors that meet the same breakaway requirements. Solid breakaway walls are intended to collapse under the force of wave impacts without damaging the building's foundation or the elevated portion of the building. All solid breakaway walls should have their designs certified by a registered professional engineer or architect. The area enclosed by solid breakaway walls should be limited to less than 300 square feet because flood insurance rates increase dramatically for enclosures larger than 300 square feet.

For further information on enclosed areas and breakaway walls in coastal flood areas, refer to FEMA Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program* and Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program.*

3.7.4 Setbacks

44 CFR 60.3 (e)(3) requires the community to "provide that all new construction within Zones V1-30, VE, and V on the community's FIRM is located landward of the reach of mean high tide."

In coastal areas, there is a mean high tide line used for regulatory purposes. This means that the high tide line is physically shifting over time as beach and coastal areas are dynamic. However, the community, region, or State will have a regulatory line defined. The NFIP does not allow any development or construction to occur seaward of this line. Figure 3-7 illustrates how the mean high tide line defines the area of no development in coastal regions. Figure 3-8 shows coastal development in an area where setback requirements are enforced.

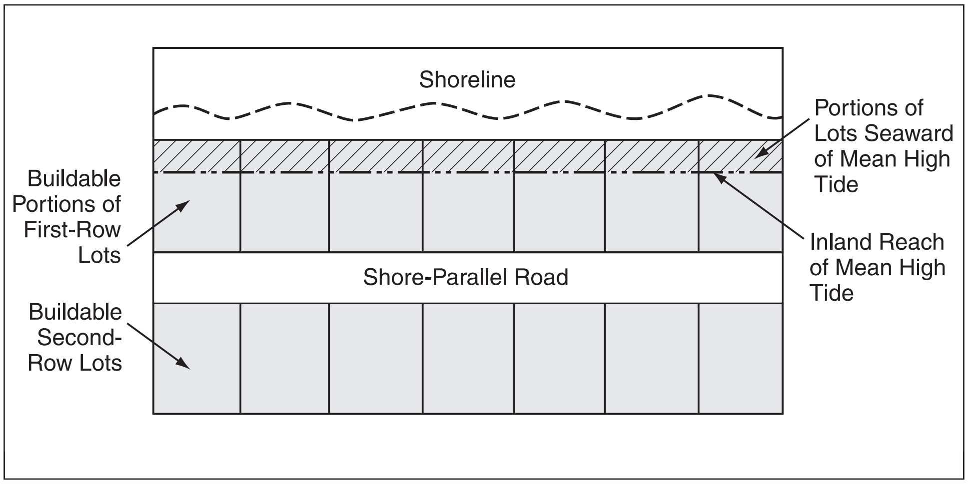


Figure 3-7. Mean high tide line development restriction.

Figure 3-8. Coastal development well-suited to the land: generous setbacks, in combination with deep lots and avoidance of dune areas, should afford protection from erosion and flooding for years to come.

3.8 Existing Manufactured Homes in Flood Hazard Areas

3.8.1 Relocation

The best way to prevent damage to manufactured homes and to prevent loss of life and injury during a flood is to install manufactured homes outside of flood-prone areas. For existing manufactured homes, relocation of the manufactured home out of the floodplain may be a viable option to minimize damages.

Manufactured homes are relatively easy to transport and can be moved from areas prone to flooding to sites located outside of the flood hazard area. This not only allows the homeowner to prevent damage to the manufactured home, but also provides peace of mind concerning safety risks and property damages due to flooding.

Some issues to consider when evaluating relocation as a mitigation option include:

- Will it be cost-effective (cost of incurring damages versus cost of preventing damages)?
- Is the home in good enough condition for transporting?
- Is the removal of existing utility connections easily done prior to transportation?
- Is there a suitable new site for relocation?
- Are utilities with similar connections available at the new site?
- Is there a route that will provide adequate clearance for transporting the manufactured home?

The relocation process consists of nine steps that are fairly clear, but include many design considerations:

Step 1. Select a manufactured home moving contractor

Step 2. Analyze the existing site and manufactured home conditions

Step 3. Select, analyze, and design foundation for the relocated home at the new site

Step 4. Prepare the existing site

Step 5. Evaluate and plan the moving route

Step 6. Prepare the manufactured home for relocation

Step 7. Move the manufactured home

Step 8. Prepare the new site

Step 9. Restore the old site

More information on relocation as a retrofitting technique can be found in Chapter 7 of FEMA 312, *Homeowner's Guide to Retrofitting* (2nd Edition, 2009), and FEMA 259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures* (2nd Edition, 2001).

3.8.2 Evacuation

Evacuation of a manufactured home from a site when there is a flood threat can result in extensive flood damages being avoided to the home. Communities may have procedures in place for evacuating homes when there is a flood threat and may provide assistance to the occupant of the manufactured home to remove the manufactured home to a protected site. The NFIP will pay up to $1,000 for the reasonable expenses incurred to move an insured manufactured home to a place other than the described location that contains the manufactured home in order to protect it from flood or the imminent danger of flood. Any insured manufactured home moved to a place other than the described location must be placed outside of the Special Flood Hazard Area or above ground level.

Communities may allow the evacuation of manufactured homes in Zones A1-30, AH, and AE only in the following cases:

- Evacuation of a manufactured home from an existing manufacture home park or subdivision; or
- Evacuation of a manufactured outside of a manufactured home park or subdivision.

After the threat of flooding from a specific event has passed, these manufactured homes can be returned to their original site without being elevated in accordance with the requirements at either 44 CFR 60.3(c)(6) or (c)(12) provided the manufactured home was not subject to the elevation requirements in these two paragraphs when first installed on the site.

Communities that allow existing manufactured homes to be removed to avoid flooding should have some type of permitting and tracking system in place to ensure that the same home is being returned to the original permanent site or pad. Communities may require a permit to ensure that utility reconnections meet local codes. If a community has developed a plan that pre-identifies manufactured homes that would be removed in the event of a flood, the plan should include procedures for determining which manufactured homes are to be removed and which ones are to be returned to their original site or pad. If a community has not developed a plan or individual manufactured homeowners initiate removal of their home on their own, the community is still responsible for determining whether the same home is being returned to the original site or pad. Since much can go wrong in trying to evacuate a manufactured home, evacuation is not a substitute for permanently protecting the manufactured home by elevating it to or above the BFE.

The community should issue some type of re-occupancy permit for owners who want to return the home to the original site or pad as a record to distinguish these from new or substantially improved manufactured homes that must meet the community's floodplain management regulations. A variance under the NFIP floodplain management regulations at 44 CFR 60.6(a) is not required for returning a manufactured home that was evacuated to the original site or pad because it is not a new placement, a replacement of, or substantial improvement.

3.8.2.1 Manufactured Home Substantially Improved or Returned to a Different Site or Pad in an Existing Manufactured Home Park

If the manufactured home that was evacuated due to the threat of flooding is placed on a different site or pad in the existing manufactured home park or subdivision or is substantially improved on the original site or pad, it would have to meet the requirements at 44 CFR 60.3(c)(12) in all A zones (the manufactured home would have to be elevated to the BFE or be elevated at 36 inches in height above grade).

3.8.2.2 Manufactured Home Placed in a New Manufactured Home Park or Subdivision

If the manufactured home that was evacuated due to the threat of flooding is placed in a new manufactured home park or subdivision or in the expanded part of an existing manufactured home park or subdivision, or is placed on a different site outside a manufactured home park or subdivision, it would have to meet the elevation requirements of 44 CFR 60.3(c)(6) in Zones A1-30, AE, and AH and elevate to the BFE or 44 CFR 60.3(e)(8) in Zones V1-30, VE, and V and elevate to the BFE.

3.9 HUD Manufactured Home Construction and Safety Standards

Prior to 1975, there were no Federal mandatory regulations or standards governing the design and construction of manufactured homes. Since 1976, HUD's Manufactured Home Construction and Safety Standards (MCHSS), or "HUD codes," have regulated the design and construction of factory-built manufactured housing.

After Hurricane Andrew in 1992, the HUD codes underwent many improvements regarding design and construction of manufactured homes. The lateral (wind) load provisions were updated to a modified American National Standards Institute/American Society of Civil Engineers (ANSI/ASCE) 7-88 design standard.

The HUD codes were revised to include three wind zones (Figure 1-1). Zone II homes are designed to resist a 100-mph (fastest mile) wind event; Zone III homes are designed for 110 mph. The design wind speed for Zone I homes is not specified. Rather, HUD I homes are designed to resist specified lateral and uplift wind pressures. Also, as point of interest, the HUD codes' energy design requirements were updated around this time frame. HUD codes program standards are found in 24 CFR 3280.

HUD's MHCSS include provisions for support and anchoring systems based on HUD Wind Zones I, II, and III. HUD's standards specify design requirements for the body and frame of the manufactured home. However, the HUD standards do not take seismic loading into account for the design of foundations and attachments.

The program has been in effect since 1976, and all manufactured homes built on or after June 15, 1976, are subject to HUD requirements. Although building codes are usually regulated at a local level, an exception is made with manufactured housing because it is most often built outside of the locality where it is eventually sited for use. Prior to the MHCSS, the quality of manufactured housing was unreliable, which resulted in the severe restriction or banning of the housing within several localities.

Under the program, manufacturers who build manufactured homes for sale in the U.S. are required to follow HUD-mandated design and construction standards. The standards are enforced either through HUD or approved Primary Inspection Agencies (either private firms or State administrative agencies) that perform reviews of manufacturers' designs and inspect the homes during construction to ensure compliance with the standards.

According to 24 CFR 3280, the purpose of the MHCSS is to establish standards for "all equipment and installations in the design, construction, transportation, fire safety, plumbing, heat-producing and electrical systems of manufactured homes which are designed to be used as dwelling units."

A manufactured home designed and constructed in accordance with the MHCSS standards will have a data plate and a certification label attached to it. The data plate will be affixed in a permanent manner near the main electrical panel or other readily accessible and visible location. The data plate contains the following information:

- The name and address of the home's manufacturing plant
- The serial number and model designation of the unit
- The date it was manufactured
- A list of the certification label numbers that are affixed to each transportable section
- A list of factory-installed equipment, including the manufacturer's name and the model number for each appliance
- Reference to the roof and wind load zones for which the home is designed

The certification label will be a 2-inch by 4-inch aluminum plate. The plate will be permanently attached to the home on the tail light end of the home, approximately 1 foot from the floor and 1 foot in from the road side. Figure 3-9 is a certification plate for homes built after June 15, 1976.

Figure 3-9. Certification plate for manufactured homes built after June 15, 1976.

Siting and installation requirements for manufactured homes are generally a State or local regulatory responsibility, where such regulatory authority exists. Some State and local regulations require licensed or registered installers, and/or require permits to be obtained prior to installation. Inspections are often required in conjunction with the permits, to ensure correct installation. The new installation standards in Part 3285 dictate that manufacturers' installation instructions be approved by a Design Approval Primary Inspection Agency (DAPIA) and the protections contained therein meet or exceed all requirements of HUD's model installation standards. This requirement is to ensure that the purchaser has the correct procedures available for installing the manufactured home.

As part of the 1994 changes, the provisions for "Windstorm protection" in 24 CFR 3280.306 that address anchoring systems were also modified to be consistent with the revisions made for wind design requirements for manufactured housing in high-wind areas. This section of the standard requires that the manufacturer provide instructions, including drawings and specifications, detailing at least one acceptable system of anchoring the manufactured home that has been approved by a registered professional engineer or architect (24 CFR 3280.306(b)). Requirements are detailed in 24 CFR 3280.306 for the instructions and stipulate wind loading requirements for design. At this time, the standards do not instruct the designer to consider the forces of floodwaters or seismic loads when designing the foundation system.

3.10 HUD Model Manufactured Home Installation Standards

Siting and installation requirements for manufactured homes are generally a State or local regulatory responsibility, where such regulatory authority exists. Some State and local regulations require licensed or registered installers, and/or require permits to be obtained prior to installation. Inspections are often required in conjunction with the permits, to ensure correct installation. The new installation standards in Part 3285 dictate that manufacturers' installation instructions be approved by a Design Approval Primary Inspection Agency (DAPIA) and the protections contained therein meet or exceed all requirements of HUD's model installation standards. This requirement is to ensure that the purchaser has the correct procedures available for installing the manufactured home.

State Manufactured Home Installation Programs

As of January 2009, according to HUD's Office of Manufactured Housing Programs, the following States have Approved or Conditionally Approved Manufactured Home Installation Programs: Alabama, Arizona, Arkansas, California, Kentucky, Ohio, Pennsylvania, South Carolina, Tennessee, Washington, and West Virginia.

The following States have submitted applications for Manufactured Home Installation Programs: Georgia, Idaho, Indiana, Kansas, Maine, Michigan, Minnesota, Mississippi, Nevada, New Jersey, New York, North Carolina, North Dakota, Oklahoma, Texas, and Virginia.

The Manufactured Housing Improvement Act of 2000 required that HUD establish minimum National Model Installation Standards (which were published in 24 CFR 3285 in October 2007). The Act also set out requirements that States must meet in order to continue to regulate manufactured home installation in their State. To be eligible, States must meet certain requirements as indicated in HUD's Installation Program published in June 2008, including a requirement that State Standards meet or exceed HUD's Model Installation Standards.

The installation standards in 24 CFR 3285 include requirements for pre-installation and installation considerations, site preparation, foundations, and home installation procedures. Additionally, standards on installation, preparation, and/or testing of optional features, appliances, utility system connections, and life safety features have been incorporated. The standard is designed for adoption and use by authorities who are responsible for the safety and health of manufactured home users. The standards address natural hazards (wind, flooding, and freezing) by incorporating the following requirements:

- A section on Installation of Manufactured Homes in Flood Hazard Areas states that FIRMs must be consulted prior to installation to determine a property's flood risk and identify whether floodplain development permits may be necessary.
- In areas prone to flooding, elevation and anchoring techniques are required, as well as consultation with a registered professional engineer and local authorities to ensure installation conforms to all applicable codes and regulations.
- Piers, anchoring, and support systems of the foundation in flood hazard areas must be capable of resisting loads associated with design flood and wind events.
- Oil storage tanks in flood hazards areas must be protected from damage by anchoring and elevation or other design.
- Appliances located on the outside of the manufactured home and air inlets must be elevated to or above the design flood elevation (DFE), which is defined in Appendix D.
- Special requirements for footings and foundations for manufactured home placement in freezing climates apply.
- The installer is required to secure the manufactured home against the wind according to the HUD codes.
- Anchor type requirements (longitudinal) for manufactured homes subject to higher winds (Wind Zones II and III) apply.
- Provisions for maximum diagonal tie-down strap spacing, dependent on the wind zone in which the property is located, apply.

The standard can be viewed online at http://www.nfpa.org/assets/files/PDF/CodesStandards/MHCCHUD/MHCCInstallationStandardsFinalRule.pdf.

In October 2007, HUD issued 24 CFR 3285 *Model Manufactured Home Installation Standards*, which regulates manufactured home installations.

The new standard creates a baseline standard for manufactured housing installation; it presents the minimum requirements for installation that must be equaled or exceeded by States and are also a minimum requirement for manufacturers' installation instructions.

Manufactured Home Installation Standards for Flood Hazard Areas

24 CFR 3285.302 also requires manufacturers to indicate in the installation instructions if the foundation specifications have been designed for flood-resistant considerations and, if so, the conditions of applicability for velocities, depths, or wave action; or to indicate if the foundations are not designed to address flood loads.

Model Manufactured Home Installation Standards 24 CFR 3285.302 – Flood Hazard Areas requires:

> "…foundations, anchoring and support systems must be capable of resisting loads associated with design flood and wind events, or combined wind and flood wind events, and homes must be installed on foundation supports that are designed and anchored to prevent flotation, collapse, or lateral movement of the structure"

3.11 Model Building Code Requirements

Model building codes can be adopted and enforced by localities and States to specifically address manufactured housing installation. Two major building codes within the U.S. are the ICC's International Code Series, and NFPA 5000, Building Construction and Safety Code (2006). The International Code Series includes the IRC for 2006 (IRC 2006), which applies to one- and two-family dwellings. In addition, the IRC for 2009 (IRC 2009) is now available.

3.11.1 IRC 2006

The IRC 2006 is a comprehensive residential building code that includes provisions for development in the SFHAs that meet the minimum requirements of the NFIP. Appendix E of the IRC 2006 contains a section dedicated to "Manufactured Housing Used as Dwellings." Section 502 of this appendix describes requirements for foundation systems, which, in part, refer to the general provisions of the code. Under the IRC Appendix E, all footings for manufactured housing shall be as follows:

- Extend below the frost line
- Be constructed of materials specified by the code, including masonry and concrete
- Be made of solid material (concrete and masonry footings)
- Be designed in accordance with seismic specifications, including minimum reinforcements near the bottom of the footing, and specifications on joints between footings and stem walls if located in a Seismic Design Category D1 or D2 area
- Be elevated to the DFE for new and replacement manufactured homes

Appendix E, Section AE604.1 of the IRC 2006 also details requirements for anchorage installation. The code ground anchor requirements are:

- The load carrying portion of the ground anchors shall be installed to the full design depth and shall extend below the established frost line into undisturbed soil.
- The manufacturer's installation directions should provide preload requirements and load capacities for various soil types.
- Approved ground anchors must be capable of resisting an allowable working load 3,150 pounds in the direction of the tie plus a 50 percent overload or 4,725 pounds without

failure. Failure is considered to have occurred when the anchor moves more than 2 inches at a load of 4,725 pounds.

- Ground anchors designed to be installed so that loads on the anchors are other than direct withdrawal must be designed and installed to resist an applied design load of 3,150 pounds at 40 to 50 degrees from vertical without displacing the end of the anchor more than 4 inches horizontally.

Appendix E, Section AE605 of the IRC 2006 establishes performance requirements for ties, materials, and installation. The requirements include:

- Ties must be attached to ground anchors with turnbuckles or other adjustable tensioning devices, and
- Ties must be capable of resisting a working load of 3,150 pounds with less than a 2 percent elongation, and a 50 percent overload of 4,725 pounds.

FEMA has evaluated the IRC 2006 and has determined that it is consistent with NFIP regulations. The IRC 2009 has also been determined to be consistent with NFIP regulations.

3.11.2 NFPA 5000

NFPA 5000's Chapter 39 (Flood-Resistant Design and Construction) includes many of the minimum NFIP requirements. According to the code, manufactured housing located in the flood hazard area must adhere to the following requirements:

- Foundations must be designed and constructed as required by Structural Engineering Institute (SEI)/ASCE 24, *Flood Resistant Design and Construction.*
- In flood areas subject to high velocity wave action, structural fill, slabs-on-ground, and foundation walls are prohibited.
- The lowest floor of the structure must be elevated to or above the DFE (see Appendix D for DFE description).
- Manufactured homes must be installed using methods that minimize flood damage and shall be securely anchored to a foundation (meeting the requirements of SEI/ASCE 24). These requirements are in addition to the manufacturer's specifications and State and local anchoring requirements for resistance to wind.
- Where temporary structures are proposed, the authority having jurisdiction must consider flood warning time as well as the location of the structure in relation to any floodways, alluvial fan areas, or high velocity wave action areas before granting a permit.

NFPA 5000 also dictates that ASCE 7 is to be used to determine the design loads associated with environmental loads, including wind, seismic, snow, and ice events. The code states that all buildings and other structures shall be designed to resist these design loads.

3.11.3 NFPA 501

NFPA 501, *Standard on Manufactured Housing*, addresses the design, manufacture, and transportation of manufactured homes and adopts, by reference, ASCE 7-2002. NFPA 501 also added some seismic provisions by requiring all homes placed in seismic areas to have their water heaters braced to prevent falling or horizontal movement.

3.11.4 NFPA 225

NFPA 225, *Model Manufactured Home Installation Standard*, is the first multi-hazard installation standard for manufactured homes. NFPA specifies wind provisions (ASCE 7-02), includes provisions for homes sited in SFHAs, and contains the latest National Earthquake Hazards Reduction Program (NEHRP) criteria for homes susceptible to earthquake damages.

FEMA has evaluated the 2005 edition of NFPA 225 and has determined it is consistent with NFIP regulations. In addition, the 2009 edition of NFPA 225 is now available and has also been determined to be consistent with NFIP regulations.

4 Site and Development Options

Site evaluation is a critical step in the decision-making process of installing a manufactured home. Decisions are sometimes made without accurately assessing or considering a property's vulnerability to flooding and other hazards. By conducting a thorough site assessment, a property owner or developer can mitigate the following types of losses, damage, and associated problems:

- Injuries and loss of life
- Damage or loss to buildings and contents
- Damage to attendant infrastructure
- The need for emergency evacuation

A complete and detailed understanding of the advantages and disadvantages of potential sites for manufactured home installation helps lead to informed decisions; not all sites are suitable for development.

A thorough evaluation of property for development purposes is completed through a five-step process:

1. Compile lot/parcel information for one or more candidate properties.
2. Determine if local, regional, State, and Federal regulatory requirements allow the development and installation of a manufactured home and, if so, determine the requirements.
3. Identify the hazards present at the site (e.g., wind, flooding, seismic, etc.).
4. Determine whether potential effects from hazards could be avoided through siting, design, and construction and whether the residual risks to the site and the building are acceptable.
5. Proceed either with the purchase or development of a property, or reject the candidate site, and find and evaluate alternative sites.

Basic information about the property (e.g., lot size, zoning and land use requirements, and utility and infrastructure availability) enables the potential property owner or developer to assess if the site is suitable for development as a manufactured home site. If development is feasible, the potential property owner should conduct Steps 3 and 4 of the process to assess the property's hazard vulnerability. Based on the assessment findings, the property is determined to be either suitable or unsuitable for the installation of a manufactured home. The following sections provide additional information for the recommended assessment process.

4.1 Step 1: Compiling Site Information

After a site for possible purchase and/or development has been identified, basic information about the site is collected for a development analysis. It is vital that all pertinent information is collected in order to complete a thorough analysis.

Community building permitting or planning and zoning offices are helpful in steering potential property buyers toward information they need to evaluate a property. This is true of individuals looking at isolated lots or lots within existing manufactured housing subdivisions. A checklist of information to be collected is provided in Table 4-1. Not all of this information will be available for all sites and properties.

Although much of the information listed in Table 4-1 will need to be obtained locally, State and Federal government resources are also useful. Table 4-2 presents a partial listing of the most likely resources (i.e., local, regional, or State government) for obtaining specific information.

Table 4-1. Information Checklist

Property Location	
• Municipal, township, county, or other local jurisdiction	• Flood-prone area designation
• Street address	• Seismic hazard area designation
• Parcel designation (e.g., tax map ID)	• High-wind area designation
• Subdivision information	• Other hazards areas
• Special zoning or land use districts	• Natural resource protection area designation
Property Dimensions	
• Total acreage	• Acreage outside of designated floodplain area or other hazard-prone area
• Property shape	• Acreage landward/outside of natural, physical, or regulatory construction or development limits (i.e., usable acreage)
• Property elevations and topography	
• Location relative to adjacent properties; configuration of adjacent properties	

Table 4-1. Information Checklist (continued)

Legal and Regulatory Information	
• Land use designation at property and adjacent properties • Zoning classification and resulting restrictions on use • Building codes and local amendments • Floodplain management requirements • Erosion hazard area: construction setback and regulations • Natural resource protection area: siting, construction, or use restrictions • Easements and rights-of-way on property (including beach access locations for nearby properties or the general public) • Local/State siting and construction regulations • Regulatory front, back, and side setbacks	• Local/State permitting procedures and requirements • Local/State regulations regarding use, construction, and repair of erosion control measures • Riparian rights • Local/State restrictions on cumulative repairs or improvements • Conditions or other requirements attached to building or zoning permits • Subdivision plat covenants and other restrictions imposed by developers and homeowners' associations • Hazard disclosure requirements for property transfer, including geologic hazard reports
Physical and Natural Characteristics	
• Soils, geology, and vegetation – site and region • Site drainage – surface water and groundwater • Storm, erosion, and hazard history of property • Development/potential flood debris upstream and adjacent to property • Erosion control structure on site: type, age, condition, and history	• Proximity to inlets and navigation structures • Previous or planned community/regional beach/dune restoration projects (coastal) • Relative sea-level/water-level changes – land subsidence or uplift (coastal) • Wind missile hazards – utility poles, trees
Infrastructure and Supporting Development	
• Access road(s) • Emergency evacuation route(s) • Electric, gas, water, telephone, and other utilities – on-site or off-site lines and hookup	• Sewer or septic • Limitations imposed by utility, infrastructure locations on property use
Financial Considerations	
• Intended use: owner-occupied or rental property • Real estate taxes • Development impact fees • Permit fees • Hazard insurance: availability, premiums, deductibles, and exclusions • Property management fees	• Special assessments for community/association projects (e.g., private roads and facilities) • Maintenance and repair of private erosion control structures • Increased building maintenance and repairs in areas subject to high winds or wind-driven rain • Building damage costs (insured and uninsured) from previous storms, floods, and other hazard events

Table 4-2. Partial Listing of Local, Regional, and State Responsibilities

Local	Regional	State
Deeds and Property Records	Deeds and Property Records	Building Codes and Standards
Emergency Management	Emergency Management	Emergency Management
Environmental Protection	Environmental Protection	Coastal Zone Management
Building Codes and Permitting	Geographic Information Systems	Geologic Survey
Floodplain Management	Health	Floodplain Management
Planning and Zoning	Planning and Zoning	Natural Resource Management
Municipal Engineering	Post-storm Damage Assessments	Post-storm Damage Assessments
Soil and Geology	Soil and Geology	
Subdivision Review	Subdivision Review	
Tax Assessor	Tax Assessor	
Utilities	Utilities	

4.2 Step 2: Reviewing Basic Siting Information

After collecting pertinent site information, a thorough review of the information is necessary to ensure that development of the site is feasible. Particularly, building codes and planning and zoning codes requirements should be reviewed early in the evaluation process to verify that development of the property with the installation of a manufactured home is allowable. If installation is allowable, a review of requirements will assist in location of the manufactured home on the site.

4.3 Step 3: Hazard Analysis and Risk Assessment

A hazard analysis and risk assessment should be performed to determine what hazards exist for a particular area or site, and then the risk level for that site should be evaluated. It is important to consider flooding in this analysis as well as other hazards such as dam failure, land subsidence, seismic hazards, and severe wind.

For community-wide assessments, there are several FEMA tools available for use to conduct a Hazards Analysis and Risk Assessment, including the FEMA software Hazards U.S.–Multi-Hazard (HAZUS-MH) and *Mitigation Planning How-to Guides* (FEMA 386). Under the Disaster Mitigation

Act of 2000, communities are required to complete hazard mitigation plans, which include a hazard identification and risk assessment section, should they wish to remain eligible for post-disaster mitigation funding. As a result, many regional and local governments have already used tools like HAZUS-MH and the *How-to Guides* to conduct their own risk assessments, which may be available for public review.

4.3.1 Flooding

Table 4-3 presents a list of the types of hazards that can result from flooding and the flood sources or types of flood-prone areas where they are generally of concern.

Table 4-3. Flood Hazards

Flood Hazard	Associated Flood Hazard Areas or Property Characteristics
Long duration flooding	• Large water bodies (rivers, bays) • Water bodies with slow drainage (lakes, ponds)
Inadequate storm drainage	• Flat or poorly graded land • Land located directly adjacent to a flood source
Impact forces	• Coastal areas subject to wave action flooding • Riverine flooding areas subject to high velocity flooding
High velocity flows	• Coastal areas subject to wave action • Steeply-sloped riverine flooding areas or areas otherwise subject to high velocity flood flows
Erosion	• Coastal areas subject to wave action • Steeply-sloped riverine areas with high velocity flood flows or areas otherwise subject to high velocity flood flows
Sediment deposition	• Coastal overwash areas
Movable stream beds	• Dynamic river systems
Flood depth	• Areas adjacent to the flood source • Areas with poor capacity for drainage

Two of the best sources to research a property's susceptibility to flooding are the community's FIRM and FIS. The FIRM shows the extent of the 1-percent annual chance flood, and might also include flooding corresponding to the 0.2-percent annual chance flood (also known as the 500-year flood). For areas where detailed studies have been performed, FIRMs will also show BFEs along streams and may provide delineations of floodways.

An FIS summarizes the methods used to develop the hydrologic and hydraulic studies, which together determine the extent of the 1-percent annual chance floodplain. The FIS also presents a summary of results of the study, including information about floodwater surface elevations and velocities for detailed study areas. Figure 4-1 shows portions of an FIS and a FIRM.

The FIRM is used in conjunction with the FIS to determine the flood risk for a given area or property. For detailed study areas, while the FIRM shows the extent of the base flood and the BFEs, the FIS includes flood profiles that show flood elevations for various frequency events as well as the channel bottom elevation (for riverine flooding) over the length of a given waterway. If the property is located in the base floodplain where a detailed study has been performed, the FIRM and FIS will provide the following valuable information:

- The elevation of a base flood at a site as well as elevations for the 10-, 50- and 500-year floods, which can be found on the flood profiles within the FIS
- The average velocity of floodwaters within the floodway for a base flood (where a floodway study was performed)
- Areas of coastal wave action flooding
- Riverine flooding areas
- Areas susceptible to ponding
- Areas susceptible to sheet flow or alluvial fan flooding
- Areas protected by levees

Information about an area's susceptibility to flooding can also be gathered from community officials and past storm event records and reports. Such reports usually provide information about what types of damage were inflicted on structures. For coastal areas, there may be information about beach and shoreline erosion.

A field assessment for a particular site is a way to collect information for a hazard analysis. Information gathered during a field visit (ideally conducted by a geologist or an engineer) can be used to assess what type of impact such forces will have on a manufactured home located on a particular site. This is determined by assessing what type of structures and potential debris are located upstream and adjacent to the property that could impact the manufactured home during a flood event. A field assessment can also be conducted to estimate the erosion potential for a site by investigating existing land slopes on the site as well as vegetation cover. Finally, the site's grading/topography should be evaluated. As part of the assessment, it should be determined whether or not the site will drain in a reasonable amount of time in order to prevent long duration flooding. This issue is generally only relevant for smaller storm events or more localized flooding for which floodwaters have somewhere to drain.

4.3.1.1 Accessibility

The flood risk to both the manufactured home and access routes should be assessed. Inhabitants of manufactured homes in flood-prone areas should prepare to evacuate an area should a flood watch be issued by the local or State government and should not wait for flood conditions

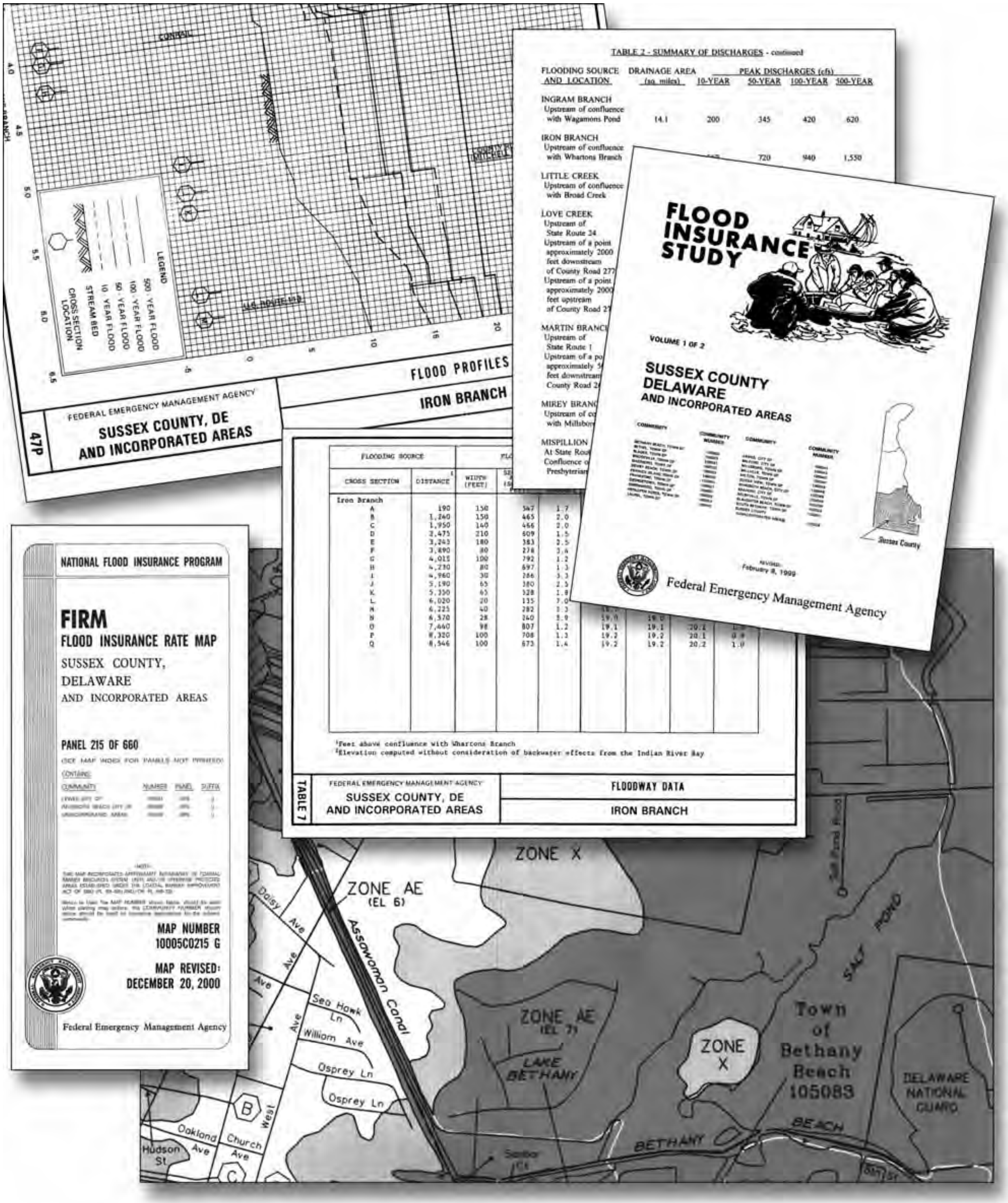


Figure 4-1. Portions of an FIS and a FIRM.

to begin before evacuating the area. In fact, drowning in vehicles is the number one cause of flood-related deaths and often happens when victims mistakenly think that a washed-out roadway or bridge is still open. Therefore, access to the manufactured home during flood events needs to be considered during the siting process.

Inhabitants of manufactured homes in flood-prone areas should *never* remain within the home during a flood, regardless of the home's elevation level above the BFE. They should always evacuate when a flood warning is issued by the local or State government and not wait for flood conditions to begin before evacuating the area.

Actual damage to roadways during flood events, as well as high-wind, seismic, and land subsidence events, can leave roads impassable for several days or for weeks after a major disaster. Even roadways that are located outside of, but adjacent to, flood-prone areas can be undermined by severe erosion along stream banks. Therefore, even if a home is adequately protected from incurring major damage due to a flood event, its location within (or surrounded by) a flood-prone area could either force occupants to repeatedly evacuate or become stranded for several days if access and egress routes are blocked.

A clear access and egress path during a flood event ensures that building occupants can evacuate and that emergency and critical services can continue to be provided. Both access and egress should be addressed while evaluating a potential site to ensure that feasible alternatives exist. Necessary considerations may also include bridges, walkways, and areas of refuge for safe evacuation.

Similarly, accessibility to potential sites after major wind and seismic events should be considered. After wind and seismic events, roadways can be blocked by debris and remain unusable for several days while cleanup efforts are underway. Potential property buyers or property owners should consider possible evacuation routes from the property in all cases.

It is important to note that accessibility is more than ingress and egress in an emergency. Frequent and long duration flooding can cause major problems for occupants of flood-prone structures; a site is not a good location for a manufactured home if its occupants are forced to evacuate several times a year due to a flood threat, or must stay out of their homes for days or weeks at a time when they do evacuate. Frequent and/or long-term displacement often results in significant financial hardships and emotional distress for flooding victims.

4.3.2 Other Hazards

In addition to flooding, there are a variety of other hazards that should be considered during the manufactured home siting process. Table 4-4 presents some of these hazards, their associated hazard-prone areas, and sources to use to determine an area's susceptibility. Historical storm or hazard event records are additional resources for this hazard analysis; they provide details on how hazards have previously affected a given area.

Table 4-4. Hazard-Prone Areas

Hazards	Associated Hazard Areas	Source for Determination
Dam failure	• Dam failure inundation areas located downstream of dam structures	• Dam failure inundation maps usually created at the State, regional, or local level
Land subsidence	• Steeply sloped land	• United States Geological Survey (USGS) Landslide Overview Map of the Conterminous United States (national level) • State Geologist • Local Public Works Director
Seismic	• Area within 6 miles of a known fault	• USGS Seismic Maps (as found in FEMA 450 and ASCE 7) • Building Codes
Wind/Debris	• Coastal areas • Tornado-prone areas • Alluvial fans	• Wind Zone Maps (as found in FEMA 320 and ASCE 7) • Building Codes

Dam failure inundation maps provide the best tool for determining the risk from a dam failure event and are usually available at the State or local level. Every State has a Dam Safety Officer responsible for coordinating its Dam Safety Program. State-specific information about State dam safety regulations is available at the Association of State Dam Safety Officials' web site: http://www.damsafety.org.

To avoid damage that can be caused in areas subject to land subsidence, manufactured homes should be sited away from steep slopes and areas where land subsidence has been known to occur in the past. While the USGS Landslide National Map indicates relative risk on a national basis, State geologists and local public work directors can provide better community-specific information about landslide risk. A listing of State geologists is available at the Association of American State Geologists web site: http://www.stategeologists.org.

USGS seismic maps as well as local officials are the best sources for determining the seismic risk for a site. The types of soils present on the site should also be taken into consideration. Poor soils, often found in flood-prone areas, can greatly amplify ground motions and seismic forces.

During wind events, large structures or items such as trees and telephone poles can be damaged and either collapse or become separated from their anchoring to the ground to become sizable pieces of debris. Manufactured homes should be sited away from or in a manner that provides protection from such items since airborne debris can act as missiles during a wind event.

Generally, coastal areas are susceptible to high winds from storm and/or hurricane events. A good reference to determine the susceptibility of a property to wind and seismic hazards is ASCE 7, which provides maps that show the risk of wind and seismic activity for the entire United States and detail design considerations for areas based on the risk posed by these hazards.

4.4 Step 4: Protecting Properties In and Near Hazard-Prone Areas

The best way to avoid damage to a manufactured home is to site the home away from areas susceptible to hazards. If the home is to be sited in or near a hazard-prone area, the developer must establish that the risk for the site is acceptable by ensuring that the home can be installed on the proposed site in accordance with applicable hazard-resistant codes and standards. In addition, mitigation techniques can be used during the installation process to further reduce the hazard risk.

NFIP floodplain requirements and HUD installation standards exist to lessen manufactured home vulnerability to flood hazards. Two aspects to consider during this process include the following:

- Placement options
- Design and construction techniques

4.4.1 Placement Options

One way to reduce the risk of damage to manufactured housing and attendant infrastructure is to select a site outside the limits of the hazard areas. This option is most applicable to areas subject to flooding and landslides where hazard areas can be reasonably well defined. Flood and landslide hazards are often localized so that all or a portion of the proposed site development can be located outside of the hazard-prone area. Note that this method is best suited for land that is initially subdivided or in the overall design of a manufactured home park.

4.4.1.1 Flood-Prone Areas

Within floodplain areas, portions of an individual site may be outside the defined floodplain. Portions of the site outside the identified floodplain typically have higher ground elevations and are less susceptible to flooding. Locating the manufactured home outside the identified flood hazard area reduces the home's exposure to the hazard. For individual sites located entirely within the flood-prone area, this method is not an option. Another option for siting in flood-prone areas is to determine if there are portions of the property that, while susceptible to flooding, are not exposed to some of the more destructive characteristics of flooding such as long duration flooding, high flood levels, and high velocity flows.

Generally, the farther a manufactured home is sited from the flood source, the less likely it is to be exposed to high velocity flows. Within riverine flooding areas, the highest velocity flows are usually recorded within and near the floodway. In areas vulnerable to coastal flooding, wave action and/or storm surge can cause floodwaters to be particularly destructive. These types of forces are the strongest in FEMA high hazard coastal zones labeled as V zones on FIRMs and the portions of A zones adjacent to V zones.

Similarly, flood levels usually decrease as the distance from the flood source increases. Setbacks from the flood source help to keep structures out of areas most susceptible to high velocity and high depth flooding. Damage to structures is directly related to the depth of floodwaters to which they are exposed.

Additionally, floodwaters can make access to and from manufactured homes difficult both during and after a flood event and greatly increase the safety hazards of flooding. For this reason, manufactured home installation in the floodplain is strongly discouraged within areas of increasing flood depths (greater than 2 to 3 feet) and high velocity flood flow (greater than 5 fps).

The duration of flooding is generally dependent on the flood source (size of the watershed), the slope of the stream, and the type of flood event (e.g., hurricane, snow melt event).

Figure 4-2 shows a floodplain/floodway schematic. The floodway is generally the area where floodwaters are deepest and have the fastest flow rate for most waterways. Development in the floodway is restricted through floodplain management regulations and, in some communities, it is prohibited. Under minimum NFIP regulations, in order to place a new structure within the floodway, a floodplain development permit applicant must show that the development will not result in any increase to the 1-percent annual chance flood elevation. In most situations, development in the floodway is not permitted by communities because it almost always leads to a water surface elevation increase.

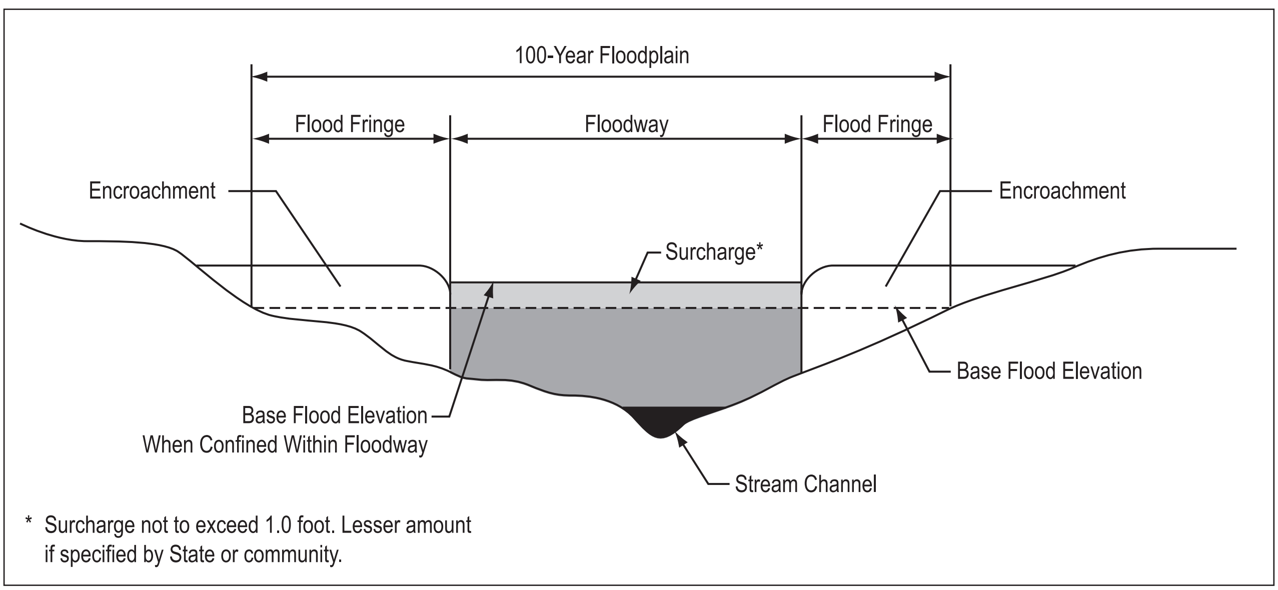


Figure 4-2. Floodplain/floodway schematic.

4.4.1.2 Areas Subject to Landslides

In areas subject to landslides, placing manufactured housing away from steeply sloped portions of a site, including relatively flat areas at the bottom of steep slopes, reduces exposure of the structure to damage. This is an option where landslides occur as the result of increased stresses from natural or manmade conditions. Some of the events or activities that can cause increased stresses include heavy rainfall, rapid snowmelts, melting of permafrost, groundwater withdrawal, soil liquefaction, and land development.

4.4.2 Design and Construction Techniques

A thorough review of design and construction techniques (as they relate to manufactured housing) and their applicability and feasibility is another consideration in the evaluation of site alternatives. A site located in a hazard-prone area cannot be deemed suitable for manufactured home installation if mitigation methods cannot be implemented at the site.

4.4.2.1 Flood-Prone Areas

Ideally, all manufactured homes should be located outside of the SFHA; however, if that is not possible, manufactured homes located in the SFHA must be installed to resist damage from flooding. Some questions for consideration in determining if design and construction techniques that prevent flood damage are feasible for a particular site follow:

- What are the flood risks for manufactured home installation at the site?
- Can structural fill be placed to elevate the site? If fill is placed, will it withstand forces from velocity flows?
- If long-duration flooding is an issue at the site, can the foundation be designed and constructed to resist long-duration floodwaters?
- Can the foundation be designed and constructed to withstand the expected design velocity flows?
- Can adequate storm drainage be provided?

Chapters 9 and 10 of this guide present methods for the design and construction of manufactured home foundations installed in flood-prone areas.

4.4.2.2 Dam Failure Inundation Areas

In dam failure inundation areas, the decision to install a manufactured home at the site will depend on assessment of the inundation risk. In higher risk areas where dam failures can trigger high flood depths and/or velocities, manufactured homes should be located elsewhere. High velocity flood surges can overwhelm typical residential foundation systems, including those used to support manufactured homes. However, in lower risk areas where relatively small flood depths and velocities are anticipated, the developer should determine if a foundation can be constructed that will provide adequate protection from expected inundation forces.

As with all hazards, safety issues such as warning times are also of vital importance.

4.4.2.3 Areas Subject to Landslides

Although it is preferable to site housing outside of areas vulnerable to damage from landslides, it might be feasible to undertake a grading project to reduce the risk of landslides. A developer must determine if this is feasible and consider whether it would be cost-effective. Licensed professionals specializing in earth movement (geotechnical, structural, and/or civil engineering) should be consulted.

4.4.2.4 Areas Subject to Seismic Events

For manufactured housing being placed in areas subject to seismic events, it is important to consider whether or not the foundation can be economically designed and constructed to withstand the expected forces for a design seismic event. Additionally, the property owner must consider the cost and effort of securing non-structural items in the manufactured home to prevent them from being damaged or dislodged. Relatively heavy items like domestic water heaters and HVAC units are particularly vulnerable to seismic events. Sewer, water, and gas lines should be sufficiently flexible to allow the home to move without damaging them. Inspections of manufactured homes after seismic events reveal that homes can be destroyed by broken utility connections (particularly natural gas connections) even where only minor damages occur to the home's structure.

4.4.2.5 Areas Subject to Wind/Debris Hazards

Manufactured housing being placed in areas subject to wind/debris events need to have a foundation that is designed and constructed to withstand the expected forces associated with a design wind event. In areas subject to seismic activity and wind, the design standard for the hazard requiring the most resistance should be used. Even if the design of a foundation to meet this requirement is cost- effective, the developer still must consider whether or not the manufactured home can withstand the forces expected from a design wind event and debris impact.

4.5 Step 5: Deciding on Property Development: Proceed or Reject

After reviewing the results of the data/information in Steps 1 through 4, deciding whether property development continues is the last step. Is the property suitable for development and for the installation of a manufactured home? If the siting evaluation shows that development of the property is feasible, and a hazard analysis and risk assessment also indicates development may be feasible, the proposed installation must be designed and constructed to adequately resist the hazard threat. If the proposed site satisfactorily addresses all of the conditions listed above, the site can be considered suitable for manufactured home installation.

5 Natural Hazards – Design Considerations

Many regions in the U.S., such as coastal areas, are subjected to severe flooding and wind events at the same time. Other areas are simultaneously subjected to snow and seismic loads. Manufactured homes can be subjected to more than one hazard at the same time and should be designed to appropriate concurrent loading (or load combinations) based on ASCE 7 design standards. However, *Manufactured Home Construction and Safety Standards* (24 CFR 3280) do not require that designs include simultaneous flood and earthquake loads. The MHCSS specifies that snow loads shall not be considered as simultaneously acting with the wind loads. HUD standards also require that foundations for manufactured homes be designed to resist loads for combined wind and flood events.

The first part of this chapter describes what kind of information is provided in FIRMs and FIS reports. The remainder of this chapter describes the characteristics of several natural hazards (flood, wind, and earthquake) that must be considered when making decisions about siting and selecting a foundation system for a manufactured home.

5.1 Flood Data

FIRMs and FIS reports are two sources that can provide vital information about flooding characteristics. Both of these tools are generally available for viewing at community permitting offices such as Zoning and Planning Departments or Building Permit Offices. The local permit official can go over these tools and help to explain floodplain development requirements. These tools are also available from FEMA's Map Service Center and can be accessed online at http://store.msc.fema.gov.

FIRMs provide key information about a property's flood vulnerability by showing the extent of the floodplain, the flood zone, the floodway (when floodway studies are performed), and the BFE (for detailed studies). Figure 5-1 shows an example of a FIRM. For example, Point 1 (white box) is located in the AE zone and has a BFE of 9 feet. For rivers and streams, FIS reports contain stream profiles that provide more accurate BFE data and should be used when determining BFEs for manufactured home installations or other types of development.

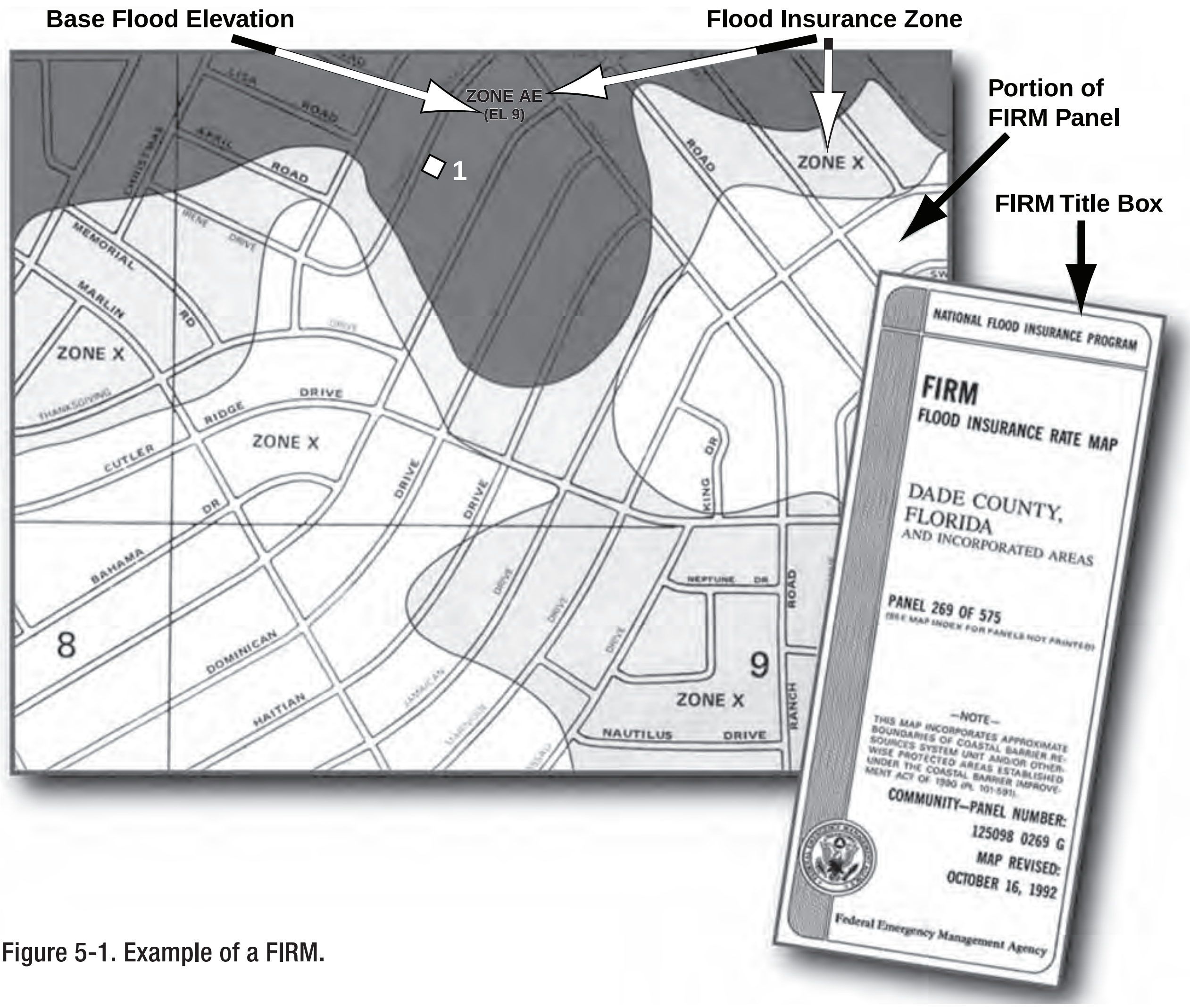


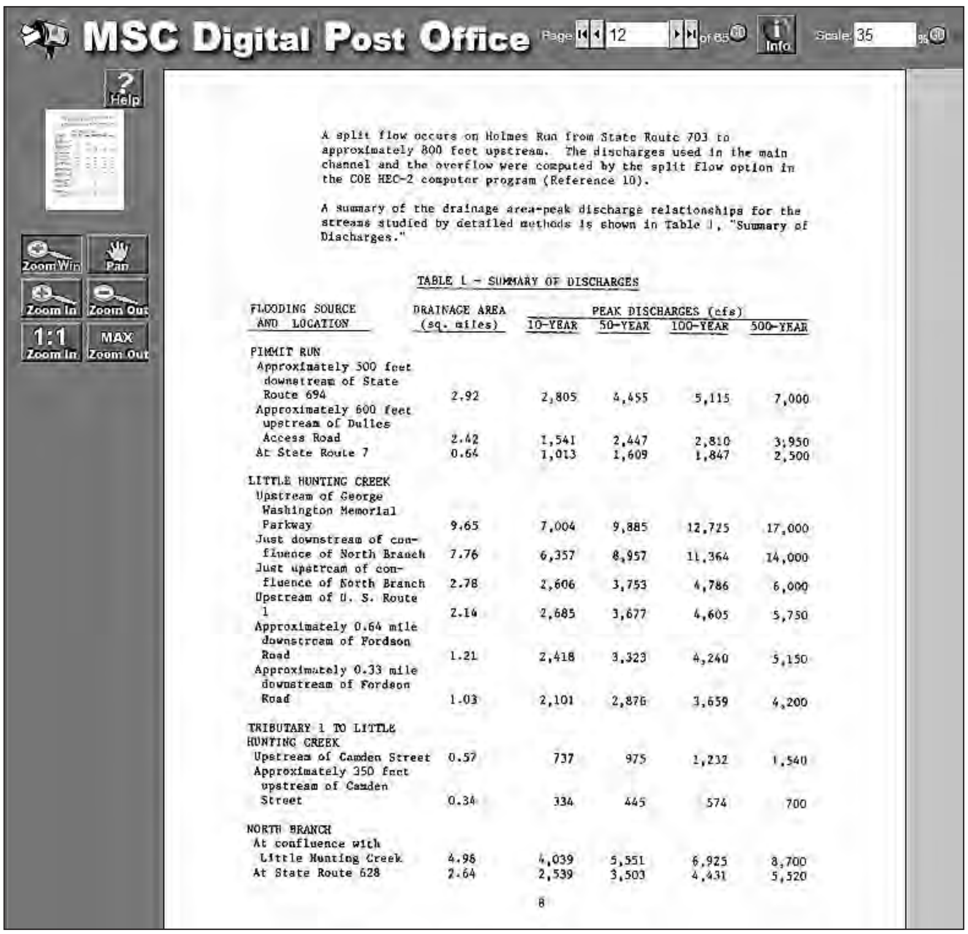
Figure 5-1. Example of a FIRM.

There are two principal digital options for using flood maps. The simplest option is FIRM Scan data. These are simply digital images of a map and are available everywhere FEMA has a published FIRM. FEMA provides tools to view these maps and create a FIRMette, which is a printout of the area of interest, along with FIRM title block, scale bar, and north arrow. There is an online FIRMette tool that allows you to find, view, and print any map when you need it. There is also a Desktop FIRMette tool that can be faster and easier to use if you frequently use the maps for one area or need to use them without an internet connection. You can download or order the FIRMette Desktop and FIRM Scans you need.

The second digital option is flood data in GIS format. GIS technology provides powerful abilities to create custom maps and perform sophisticated analyses. It also requires the user to have specialized skills and software to use. FEMA now produces a GIS product called the DFIRM Database for use with all map updates. Beginning on or after October 1, 2009, FEMA will provide a single paper flood map and FIS to each mapped community. FEMA will convert all other distribution of maps and FIS reports for digital delivery. FEMA will continue to provide free digital map products and data to Federal, State, Tribal, and local NFIP stakeholders.

FIS Reports

Several key components of an FIS report can help users identify specific flooding characteristics. For example, summary of discharge tables report the flow rate of water within streams for a given frequency storm (Figure 5-2). These values can be used with updated topography and cross-section information to conduct hydraulic modeling and to estimate updated flood elevations.[1] FISs generally generate water surface elevations for the 10-year (10-percent annual chance), 50-year (2-percent annual chance), 100-year (1-percent annual chance), and 500-year (0.2-percent annual chance) floods (Figure 5-3). Floodway data tables provide cross-section specific information, including the width of the floodway, mean floodway velocity, and the BFE where there is no encroachment in the flood fringe (or the regulatory BFE) and where there is full encroachment in the flood fringe (Figure 5-4). However, these tables are only available when a floodway study has been performed. See Appendix C for additional information.



A split flow occurs on Holmes Run from State Route 703 to approximately 800 feet upstream. The discharges used in the main channel and the overflow were computed by the split flow option in the COE HEC-2 computer program (Reference 10).

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 1, "Summary of Discharges."

TABLE 1 – SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
PIMMIT RUN					
Approximately 500 feet downstream of State Route 694	2.92	2,805	4,455	5,115	7,000
Approximately 600 feet upstream of Dulles Access Road	2.42	1,541	2,447	2,810	3,950
At State Route 7	0.64	1,013	1,609	1,847	2,500
LITTLE HUNTING CREEK					
Upstream of George Washington Memorial Parkway	9.65	7,004	9,885	12,725	17,000
Just downstream of confluence of North Branch	7.76	6,357	8,957	11,364	14,000
Just upstream of confluence of North Branch	2.78	2,606	3,753	4,786	6,000
Upstream of U. S. Route 1	2.14	2,685	3,677	4,605	5,750
Approximately 0.64 mile downstream of Fordson Road	1.21	2,418	3,323	4,240	5,150
Approximately 0.33 mile downstream of Fordson Road	1.03	2,101	2,876	3,659	4,200
TRIBUTARY 1 TO LITTLE HUNTING CREEK					
Upstream of Camden Street	0.57	737	975	1,232	1,540
Approximately 350 feet upstream of Camden Street	0.34	334	445	574	700
NORTH BRANCH					
At confluence with Little Hunting Creek	4.96	4,039	5,551	6,925	8,700
At State Route 628	2.64	2,539	3,503	4,431	5,520

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Figure 5-2. FIS Summary of Discharges table.

1 Hydraulic modeling can be performed to estimate updated flood elevations where new or more accurate topography data are available. However, if the modeling shows lower flood elevations, they cannot be used for regulatory purposes unless a map revision (e.g., Letter of Map Amendment (LOMA) or Letter of Map Revision [LOMR]) is granted.

Figure 5-3. FIS Stream Flood Profile.

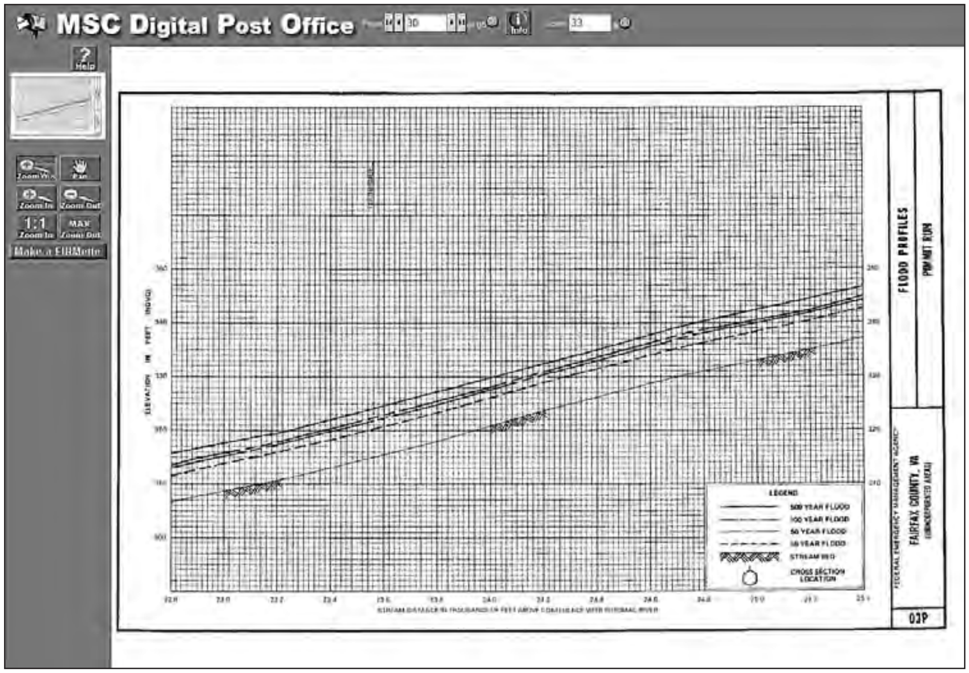
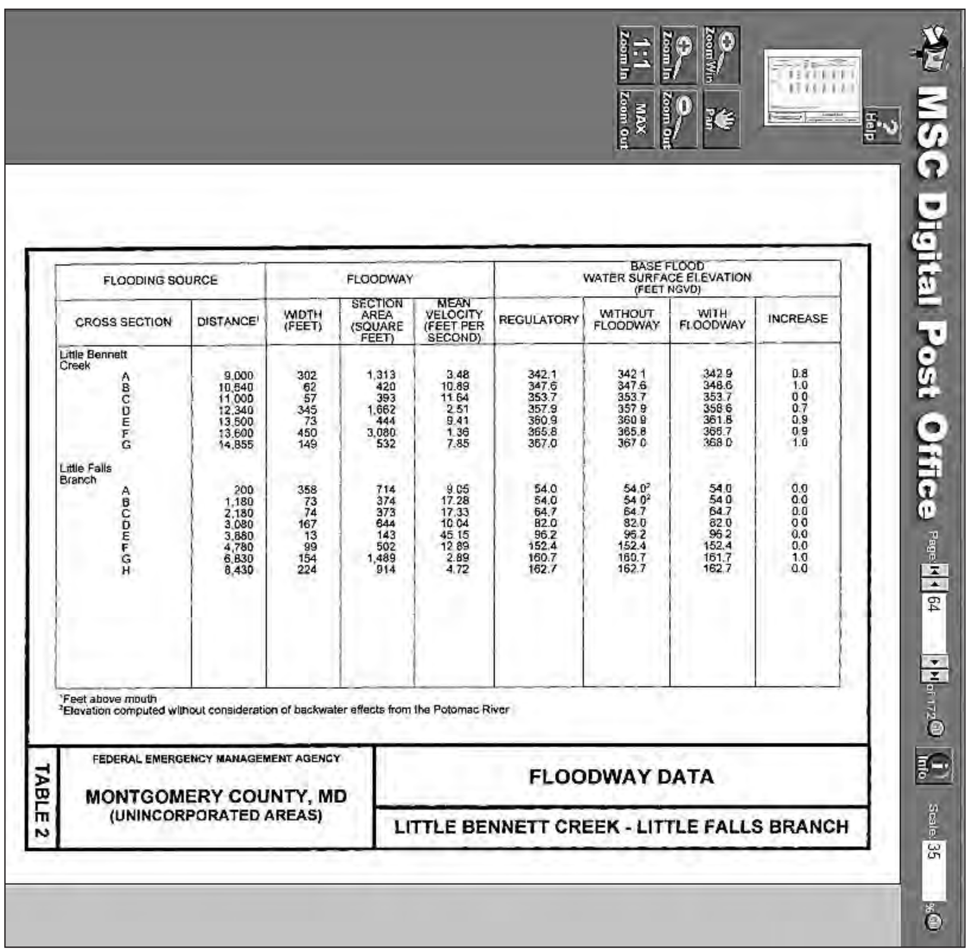


Figure 5-4. FIS Floodway Data table.



FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NGVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Little Bennett Creek								
A	9,000	302	1,313	3.48	342.1	342.1	342.9	0.8
B	10,640	62	420	10.89	347.6	347.6	348.6	1.0
C	11,000	57	393	11.64	353.7	353.7	353.7	0.0
D	12,340	345	1,662	2.51	357.9	357.9	358.6	0.7
E	13,500	73	444	9.41	360.9	360.9	361.8	0.9
F	13,600	450	3,080	1.36	365.8	365.8	366.7	0.9
G	14,855	149	532	7.85	367.0	367.0	368.0	1.0
Little Falls Branch								
A	200	358	714	9.05	54.0	54.0[2]	54.0	0.0
B	1,180	73	374	17.28	54.0	54.0[2]	54.0	0.0
C	2,180	74	373	17.33	64.7	64.7	64.7	0.0
D	3,080	167	644	10.04	82.0	82.0	82.0	0.0
E	3,880	13	143	45.15	96.2	96.2	96.2	0.0
F	4,780	99	502	12.89	152.4	152.4	152.4	0.0
G	6,830	154	1,489	2.89	160.7	160.7	161.7	1.0
H	8,430	224	914	4.72	162.7	162.7	162.7	0.0

[1]Feet above mouth
[2]Elevation computed without consideration of backwater effects from the Potomac River

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY
MONTGOMERY COUNTY, MD
(UNINCORPORATED AREAS)

FLOODWAY DATA

LITTLE BENNETT CREEK - LITTLE FALLS BRANCH

5.2 Flood Characteristics

A variety of factors contribute to the type and strength of flood forces. For instance, structures and their foundations are subject to different forces if they are flooded by standing or slowly moving floodwater versus high velocity or wave action flooding. Similarly, factors such as the duration of flooding and flood depth help to define how structures and foundations will be affected by flood events.

5.2.1 Frequency, Duration, and Rate of Rise

Frequency of flooding is the rate of flood occurrence at a particular location. This frequency is the probability, expressed as a percentage, that a flood of a specific size will be equaled or exceeded in any year. For example, the flood that has a 1-percent probability (1 in 100) of being equaled or exceeded in any given year is referred to as the "base flood" and sometimes called the "100-year flood;" the latter term is simply a convenient way to express probability. The base flood is particularly important for homeowners because it is used by the NFIP to determine flood insurance rates and define regulatory floodplain management requirements.

A 1-percent annual chance flood is a probability term and does not mean that a flood will happen approximately once every 100 years. Nor does it imply that once a 1-percent annual chance flood occurs there is little chance of another 1-percent annual chance flood occurring in the near future. To the contrary, changes in climatic conditions, such as those caused by El Niño or La Niña, often result in a cluster of floods that occur over relatively short periods of time at the same location.

Manufactured homes located within the 100-year floodplain on a FIRM might also be in the 10- or 5-year floodplain and subject to even more frequent flooding. Although more frequent floods such as the 10- or 20-percent annual chance flood (10- or 5-year flood) cause less damage to the manufactured home than the 1-percent annual chance flood, the repetitive damages can result in significant financial loss to the homeowner. Data describing the extent of more frequent but less intense flooding is also important in determining the foundation system most appropriate for resisting forces imposed by the smaller floods.

Information about the base flood can be found in the FIS and the FIRM, including the flood elevation and the extent of flooding. In areas where detailed studies have been performed, flood elevation information may also be available for the more frequent 10- or 2-percent annual chance flood as well as the less frequent 0.2-percent annual chance flood (500-year flood).

For historical flood events, flood frequency estimations are sometimes found in the FIS under the Principal Flood Problems section. Documentation of past flood events is sometimes available from other Federal sources as well as State and local agencies. Table 5-1 lists such sources and agencies.

Table 5-1. Sources for Information About Past Flood Events

Other Federal Sources	State Agencies	Local or Regional Agencies
USACE Floodplain Information Reports	Departments of Environmental Conservation/Protection	Flood Control Districts
USGS Water Resources Investigations	State Floodplain Management Office	Levee Improvement Districts
Natural Resources Conservation Service (NRCS) Watershed Studies	Departments of Natural Resources	Local Planning Commissions
Federal Highway Administration (FHWA) Floodplain Studies	Departments of Transportation	Local Public Works Departments
Tennessee Valley Authority (TVA) Floodplain Studies	Departments of Water Resources	Municipal Utility Districts
	Geologic Surveys	River Basin Commissions
		Water Control Boards

Flood duration is the time from the inundation to the recession of floodwaters. Flood duration provides an estimate of how long a manufactured home's foundation (not the home itself, assuming the home is properly elevated) will be subjected to pressures and forces exerted by floodwaters, the degree of floodwater seepage, and the length of time that a structure may be inaccessible and/or inhabitable for the occupants. For identical flood characteristics, long duration flooding is usually much more destructive than short duration flooding.

The rate of rise is a measure of how rapidly water depths increase during flooding. A slow rise of floodwaters will allow seepage of water into a manufactured home (only if it is not elevated above the flood level) and may prevent buoyancy forces from acting on a home. When water rises rapidly, however, there may be insufficient time for seepage, exposing the home to buoyancy forces. The buoyancy forces could result in failure of the foundation, the floor, or the framing of the home.

The rate of rise (and fall) also affects the amount of warning for an impending flood. For example, homeowners in the floodplains of large rivers like the Mississippi may know days in advance of upstream flooding that will eventually reach their homes. But in the floodplains of streams with high rates of rise, homeowners may have only a few hours' notice (or none at all) of an approaching flood.

The rate of rise and fall is important in planning emergency evacuations and determining the feasibility of emergency loss mitigation procedures. Although surrounding and upstream terrain is a good indicator of the rate, flooding duration for particular areas is best determined from historical data and accounts of past flood events. This information might be available locally from accounts given by homeowners and local emergency management staff, or it may be documented in the FIS or local, State, or Federal studies. See Table 5-1 for a list of potential sources of information.

5.2.2 Flood Elevation and Depth

The BFE is the elevation of the flooding, including wave height, if applicable (in V zones), having a 1-percent chance of being equaled or exceeded in any given year. The elevation of the flooding is the floodwater's height above or below an established reference datum. Ground elevation is the height of the ground surface also above or below an established reference datum. The standard datum used by most Federal agencies and many State and local agencies are the NGVD 29, and the NAVD 88; however, other datum are used. Ground elevations are established by topographic surveys; flood elevations are calculated for a particular flood event. BFEs can be found on FIRM panels where a detailed study has been performed, and should be estimated using the flood profile in the corresponding FIS.

BFE and DFE

Base flood elevation (BFE) – The water surface elevation resulting from the base, or 100-year (1 percent annual chance) flood.

Design flood elevation (DFE) – The elevation to which development in the regulatory floodplain is built. At a minimum, the DFE is equivalent to the BFE. However, in some areas, the DFE includes an additional freeboard height above the BFE as shown in the formula below.

DFE = BFE + Freeboard

Freeboard – An additional elevation requirement some height (1, 2, or more feet) above the BFE that provides a margin of safety above the estimated BFE.

As indicated above, the minimum DFE requirement for NFIP communities is the BFE. However, in communities where a higher degree of protection is promoted or required, the DFE includes a freeboard height above the BFE. This freeboard provides a margin of safety above the estimated BFE and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties. The NFIP encourages participating communities to adopt and enforce freeboard requirements as part of their local floodplain management ordinance. This is shown in 44 CFR 60.1(d); which states, "Any floodplain management regulations adopted by a State or a community which are more restrictive than the criteria set forth in this part are encouraged and shall take precedence."

Some flood zones are delineated by approximate methods without BFEs determined. When a manufactured home is proposed on an approximate A zone site, the community must make every effort to obtain, review, and reasonably utilize BFE data and floodway data from a Federal, State, or other source in order to provide a reasonable measure of flood protection in accordance with 44 CFR 60.3(b)(4). If BFE or floodway data cannot be obtained from available sources, the community should consider conducting or requiring the applicant to conduct a site-specific engineering analysis to determine a BFE or floodway. FEMA has developed *Quick-2: Computation of Water Surface Elevations in Open Channels*, which is useful in developing a BFE. *Quick 2* is available from the FEMA web site http://www.fema.gov/plan/prevent/fhm/dl_qck22.shtm. If no BFE data are available through Federal, State, or other sources, communities must ensure that building sites will be reasonably safe from flooding for proposed developments. A simplified method for estimating BFEs as well as other methods for ensuring a building site is reasonably safe from flooding can be found in FEMA 265, *Managing Floodplain Development in Approximate Zone A Areas, A Guide for Obtaining and Developing Base (100-year) Flood Elevations*. Additional guidance on approximate A zones and requirements for developing BFEs in subdivision proposals and other proposed developments can be found in Section 3.6.1.

Flood depth is the difference between the water surface elevation and the grade elevation of the flooded area (Figure 5-5). Any differences in datum between the flood elevation and the grade elevation must be taken into account when calculating flood depths.

Many communities have adopted more stringent requirements for an additional elevation (e.g., 1 foot, 1.5 feet, etc.) above the BFE. The additional height (or freeboard) is used to establish the DFE. Freeboard provides a margin of protection above the estimated base flood.

5.2.3 Hydrostatic (Buoyancy) Forces

For manufactured homes that are not elevated to above the BFE or DFE, hydrostatic forces can cause significant damages. Hydrostatic pressures are also a concern for enclosed areas underneath elevated manufactured homes.

When a body or a structure is immersed in water, the body is subjected to forces exerted by the surrounding water. These forces are called hydrostatic forces and act perpendicular to the surface on which they are applied. For example, hydrostatic forces exert lateral forces on vertical walls and vertical forces on horizontal floors.

The total vertical force (also called buoyancy force) on a submerged structure is equal to the weight of the displaced volume of water. For each foot of fresh water submersion, a buoyancy force of 62.4 psf is created. Salt water, with a greater density than fresh water, creates 64 psf for each foot of submersion. That is

$$F_{buoy} = \gamma \times V_{OL}$$

Where: γ = specific weight of water (62.4 pcf for fresh water; 64 pcf for salt water)

V_{OL} = volume of water displaced by the submergence object (ft^3)

The lateral force of water acting against a surface is related to the water's depth (d) and specific weight (γ). Hydrostatic forces create a triangular loading on vertical surfaces with zero psf on the water surface to a force equal to γ (pcf) multiplied by d (feet).

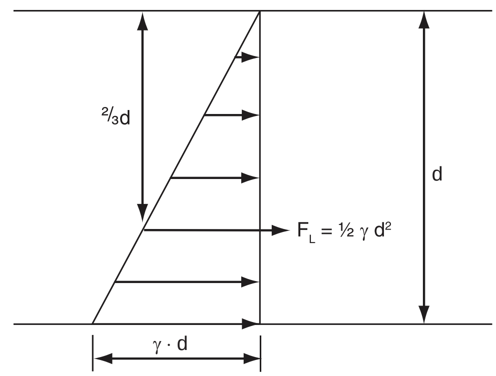
$$F_L = \frac{1}{2} \gamma d^2$$

Where: F_L = lateral force

γ = specific weight of water (pcf)

d = depth (ft)

F_L is applied at a distance 2/3 d from the water's surface.



Hydrostatic Force Distribution

Hydrostatic forces act perpendicular to submerged surfaces. If the water depth is the same on both sides of a wall, the lateral component of hydrostatic forces are equal such that the resultant force is zero.

If floodwater rises above the lowest floor, hydrostatic forces can lift an inadequately anchored manufactured home off its foundation. If buoyancy forces exceed the weight of a manufactured home, the home will float off its foundation if it is not securely fastened to the foundation. Floods do not need to be deep to displace a home. Flood depths of only 4 to 5 inches above the lowest floor can be capable of floating unsecured manufactured homes off their foundations.

The walls and floors of manufactured homes are not typically designed to resist hydrostatic forces, which can cause extensive structural damage. Floodwaters in contact with a home generally seep into it through openings around doors, windows, vents, and utility entrances. Floodwaters inside the structure add weight to the structure, thus reducing the net buoyancy force of the structure. Figure 5-5 shows hydrostatic forces acting on the walls and lowest floors below the flood level. As illustrated in Figure 5-5, an effective method of avoiding damage from hydrostatic forces is to elevate the home above the flood levels.

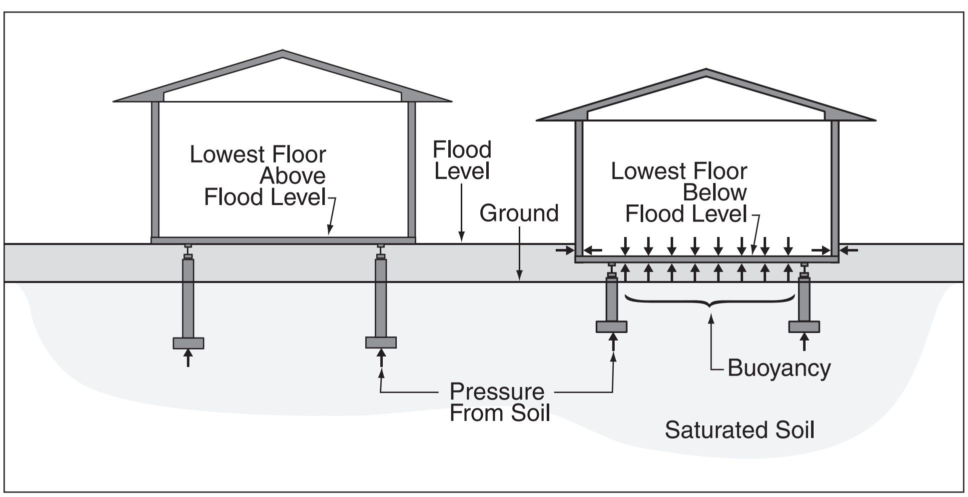


Figure 5-5. Buoyancy forces acting on a structure.

5.2.4 Hydrodynamic Forces

Forces due to moving floodwaters are called hydrodynamic forces. The magnitude of these forces depends on the floodwater depth, floodwater velocity, and the drag coefficient. Higher depths and velocities produce greater hydrodynamic forces. The drag coefficient is a function of the shape of the body subjected to the hydrodynamic forces.

Moving floodwaters can cause foundation failure by pushing (sliding failure) (Figure 5-6) or by overturning. Either can topple foundation elements and destroy a home. In addition, moving floodwaters can cause erosion and scour that can undermine foundation elements (Figure 5-7).

Figure 5-6. Failure due to sliding.

Figure 5-7. A manufactured home destroyed by the hydrodynamic forces of flooding.

Flood velocity depends on the slope and roughness of the terrain. For example, water moves faster along streams in steep mountains than streams in flatter areas, and water moves faster over a parking lot with a paved surface as opposed to an area with dense vegetation or other obstacles. Flood velocities are not shown on the FIRMs, but can be found in the FIS for floodways where floodways have been studied. Mean floodway velocities can be obtained from the FIS by matching the cross-section on the FIRM with the cross-section in the floodway data table. The floodway's mean velocity usually overestimates the flood velocity within the flood fringe; floodwaters generally move slower as they extend outward from the floodway. However, the floodway velocities can be used as a general measure to determine cross-section locations within the floodplain where floodwaters will move relatively faster or slower, and provide an upper limit for velocities in the flood fringe. One of the best sources for flood velocities is records of past flood events. In addition to the FIS, a list of potential sources for documentation of past flooding is included in Table 5-1.

Coastal areas are particularly hazardous because of flooding accompanied by wave impacts that are associated with storm surges from coastal storms. Flow velocity can be further increased by manmade or natural obstructions that restrict floodwaters and channel the flow.

The hydrodynamic force exerted by a fluid in the direction of the flow stream is defined as the drag force F_d. Hydrodynamic forces are calculated as follows:

$$F_d = \frac{C_d \text{ x } A \text{ x } \gamma \text{ x } V^2}{2g}$$

Where: F_d = hydrostatic force (pounds)

C_d = dynamic coefficient (1.25 for round piers; 2.0 for square or rectangular piers; 1.4 for continuous foundations)

γ = specific weight of water

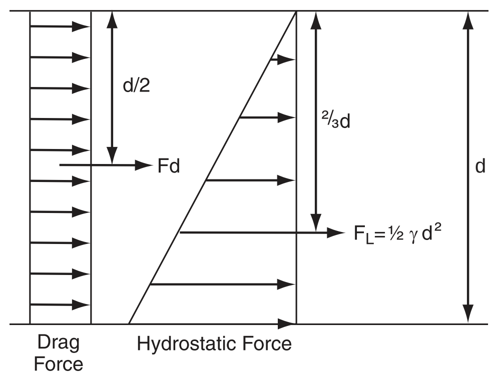
g = acceleration due to gravity (32.2 ft/s^2)

V = floodwater velocity (fps)

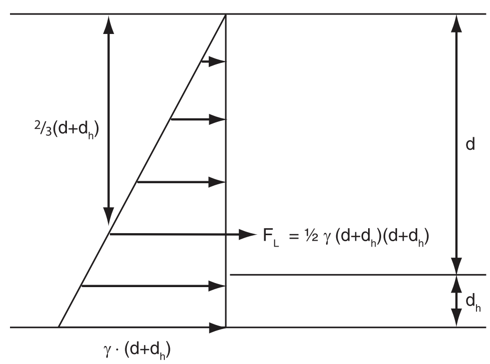
A = projected vertical area submerged (sq. ft.)

A = d x w

w = width of the submerged object



Hydrostatic and Hydrodynamic Force Distribution



Equivalent Hydrostatic Load Approach to Consider Hydrodynamic Force

An alternative approach to consider the dynamic effects of moving water is to use an equivalent hydrostatic load approach. When water velocities are less than 10 fps, ASCE 7 permits adding an equivalent surcharge water depth to the design flood elevation to simulate the hydrodynamic load.

The equivalent surcharge water depth (d_h) is determined by:

$$d_h = \frac{C_d \times V^2}{2g}$$

Where: C_d = dynamic coefficient (1.25 for round piers; 2.0 for square or rectangular piers; 1.4 for continuous foundations)

V = average velocity of water (fps)

g = acceleration due to gravity (32.2 ft/s^2)

Hydrodynamic forces apply to any portion of the home or its foundation exposed to moving floodwaters. Elevating the home so that its lowest floor is at the BFE reduces the effects of hydrodynamic forces on the building envelope. However the floor framing, chassis frame, and the foundation elements remain exposed to the hydrodynamic forces. For open foundations, elevating the home so the lowest chassis frame member is at the BFE reduces the effects of hydrodynamic forces by reducing the number of components exposed to those forces during a base flood event.

5.2.5 Erosion and Scour

Erosion is the result of moving waters removing soil from the ground surface. Scour is the result of those moving waters removing soil beneath and around objects located in the path of flow. Scour under and around building foundations and erosion of fill embankments can result in foundation failure. For example, when Hurricane Ike struck Galveston, Texas, in 2008, several homes were destroyed due to a loss of lateral support of pile foundations caused by scouring. Moving floodwaters will erode soil around any obstruction placed in the flow until a maximum scour depth is reached. The maximum scour is a function of flow velocity, soil particle size, and obstruction geometry. Determining maximum potential scour is critical in designing a foundation system that prevents failure during and after flooding. In coastal areas, scour depth can be significant due to both storm-induced erosion and localized scour resulting from storm surge. Because storm-induced erosion is difficult to predict, local regulatory officials should be contacted for further information and historical perspectives.

Scour susceptibility is a function of foundation geometry, flow depth, flow velocity, and the soil particle size. Fine grain soils (i.e., silts and clays) scour at a lower flow velocity than coarse grain soils. Coarse grain, non-cohesive soils can erode and/or scour quickly, possibly reaching the ultimate scour depth in a single flood event. Fine grain, cohesive soils can scour just as deep but take longer to reach the ultimate depth. It is important to note that foundations frequently are well above the ultimate scour depth and that foundation undermining can occur in a relatively short time period. Undermining of foundations can result in the collapse of the home.

Because flood velocities are not shown on FIRMs, the FIS must be consulted to determine flood velocities, which are only provided for floodways. In some SFHAs, floodways and mean floodway velocities have not been determined as part of the FIS.

The preferred scour mitigation technique is to place the manufactured home's foundation below the predicted ultimate scour depth. In areas where placing foundations below maximum scour depth is not economically feasible, alternative scour protection methods include reinforcing foundation soils with large diameter materials such as coarse aggregate or riprap.

5.2.6 Debris Impact Forces

Floodwaters can transport objects of all types (e.g., trees, portions of flood-damaged buildings, automobiles, boats, storage tanks, manufactured homes, etc.). In cold climates, winter floods can also carry large pieces of ice. Substances such as dirt, oil, gasoline, sewage, and various types of debris add to the dangers of flooding. Even when flow velocity is relatively low, large objects carried by floodwaters can easily damage windows, doors, walls, and, more importantly, critical structural components. As the flood velocity increases, the danger of damage from floodborne debris also increases.

Waterborne debris impacts caused significant damage to buildings and enclosures, slabs, decks, utilities, and other ancillary features when Hurricane Ivan struck the Florida panhandle and coastal Baldwin County, Alabama in 2004. Manufactured homes typically are not designed to withstand loads to walls or floor systems that may be exerted by attached carports, decks, porches, or awnings, although some manufacturers have designed homes that are "awning ready" to provide a load path through the structure to handle the increased stresses. The alternative is to build the attachments with adequately anchored foundations to resist these debris impact forces.

Damages caused by floodborne debris impacting a manufactured home depend not only on the weight and velocity of the debris, but also on the size and material. Historically, the forces developed when floating debris hits a home have been estimated using the principles of conservation of momentum with impact duration of 1 second. Recent research, however, indicates that the impact from floodborne debris occurs over intervals of only 0.01 to 0.05 second. Since impact force is inversely proportional to duration (i.e., the shorter the duration, the larger the impact force), historical methods may underestimate impact forces. Typical impact duration ranges from 0.1 second for stiff foundations (such as concrete) to 1 second for flexible foundations (such as wood).

$$F_i = (W/g) \times (V_b/t)$$

Where: F_i = impact force (pounds)

W = weight of floodborne object (pounds)

V_b = velocity of object (fps)

t = time for object to decelerate from V_b to zero (seconds)

g = acceleration due to gravity (32.2 ft/s^2)

ASCE 7-05 updates the methods of calculating impact debris forces. Recent research indicates that the impact durations are much shorter and impact loads are significantly higher than previously recommended. Foundations for manufactured homes located in SFHAs should be designed to resist floodborne debris impact forces calculated based on the most recent edition of ASCE 7 protocols.

The relatively light and frequently unreinforced foundation systems used to support and anchor manufactured homes are susceptible to impact damage from floating debris. The cost to strengthen foundations, ground anchors, and anchor straps to resist debris impact may be economically impractical. An alternative method is to install additional foundation elements to provide redundancy in the system. For example, reducing the frame span length by reducing pier spacing allows the frame to span across a damaged pier without excessive deflections or failure. This method requires post-flood inspection and maintenance to repair or replace damaged foundation elements to allow the home's foundation to survive any subsequent events. Also, if more foundation elements than what have been assumed are damaged, a finite risk of system failure remains.

5.3 Wind

Design and installation of foundations of manufactured homes is a controlling factor on the homes' ability to withstand forces from wind events. Connections used to secure the manufactured homes to the foundations have historically lacked the attention given to the manufacturing of the homes themselves. Lack of proper connections has caused numerous homes to fail during high-wind events. Figures 5-8 and 5-9 are examples of wind damage to modular and manufactured homes.

Several factors influence the direction and magnitude of wind forces on a structure, which should be considered in manufactured home foundation design.

When a structure is exposed to these wind forces in combination with flood forces, the damage potential is greatly increased.

Figure 5-8. Failure of a modular home due to high winds. The home lifted off of its foundation (concrete slab) when the connections failed.

Figure 5-9. A manufactured home that failed during a high-wind event.

5.3.1 Wind Forces on Structures

The texture and roughness of the terrain, as well as its surface contours and topography, have a profound effect on the wind loads. A structure in an open flat area with few trees and obstructions is likely to see a substantially higher wind load than one situated in a developed area with numerous buildings or other obstructions. Similarly, a structure situated on a hilltop may be subjected to significantly greater loads than one on flat terrain. All structures should be built to withstand the forces caused by the strongest wind speeds likely to happen at the site.

The basic design wind speeds for the United States can be obtained from the map given in Figure 6-1 of ASCE 7. The wind speeds correspond to 3-second gust speeds in mph at 33 feet (10 meters) above the ground for open terrain with scattered obstructions having heights generally less than 30 feet (9.1 meters), Exposure C category. This includes flat open country and grasslands.

When a building is exposed to wind, the wind flows over and around the building. This imposes positive pressure on the windward side of the building and negative pressure (suction) on the leeward side and roof of the building.

5.3.2 Wind Forces in Combination with Flood Forces

Damage potential is increased when wind forces are exerted on a structure in combination with flood forces, as is often the case in coastal and mountainous areas. For example, tensile forces can develop at the windward piers and the home can be lifted. If the windward piers are exposed to moving floodwaters, they can topple when no longer in contact with the home's steel frame.

Elevating a manufactured home to minimize the effects of flood forces does not significantly increase the wind loads on the home.

The HUD *Model Manufactured Home Installation Standards* require foundations to consider flood and wind load combinations. Sections 2.3.3 and 2.4.2 in Chapter 2 of ASCE 7, *Minimum Design Loads for Buildings and Other Structures* contain load combinations that should be used.

5.4 Earthquakes

Designing resistance of structures and foundations for earthquakes requires a different approach than that used for flooding and wind. Because earthquakes can affect internal building elements without requiring penetration of the building like flooding or wind, there are design considerations specific to earthquakes.

Often designing for wind load standards will allow a manufactured home installation to be adequate for protecting the home from earthquake forces. However, there are instances when forces resulting from earthquakes can result in greater loads than those for wind.

5.4.1 Design Philosophy

Earthquake-caused ground accelerations cause forces on building elements attached to or into the ground. Foundation movements are transmitted to structural and non-structural components. Consequently, exterior and interior building components should be designed for seismic loads to be transferred to the remaining elements.

In the event of an earthquake, a structure will be simultaneously subjected to vertical and horizontal accelerations. The weight of a manufactured home on its foundation is not sufficient to resist a moderate or severe earthquake. Therefore, the manufactured home and its foundation should be properly connected to avoid damage during an earthquake event. Soil liquefaction resulting from an earthquake is also an important consideration for earthquake design because soil liquefaction is a major cause of damage in a seismic event. Refer to Chapter 6 for a discussion on liquefaction.

5.4.2 Design Standard

Regulations governing the construction and design of manufactured homes currently do not specifically address seismic loads but rather specify loading requirements primarily to provide basic wind resistance. However, seismic requirements exist in most model codes and standards. Seismic requirements have been included in the *Model Manufactured Home Installation Guide* (NFPA 225).

Historically, communities with low seismicity have considered wind load provisions as sufficient for resisting seismic events. Although this may be true in the case of transverse loading (i.e., wind pressures acting on the long walls) where wind loads are high, it is often not the case with longitudinal loading where wind loads are low. Also, the nature of seismic loading is greatly different than wind loading. These differences make comparisons between wind resistance and seismic resistance tenuous at best.

Studies list the following typical damages to manufactured homes during design earthquakes:

- Homes falling off support systems
- Damage to floors from piers puncturing them
- Disruption of gas, water, and electrical lines from seismic motions of the home
- Fire resulting from damaged water heaters, and gas and electric lines. (A simple and cost-effective seismic mitigation measure for manufactured homes is to strap the water heater to a wall to prevent it from falling over.)

For a manufactured home installed on a foundation system, providing adequate resistance to lateral movement, uplift, and rotation is very important. It is also necessary to provide tensile connections between the main frame and the piers supporting the home to resist all seismic forces. Earthquake-resistant bracing systems (ERBSs) can be installed to minimize damage to the home, but they do not provide the protection of a seismic-resistant foundation system. ERBSs are secondary supports that do not resist seismic forces, but rather allow the home to fall from its primary supports and "catch" it before it hits the ground.

The State of California has had an ERBS certification program since 1987. To be certified, the ERBS must be able to limit seismic movement and limit vertical drop of the manufactured home to 2 inches. A list of certified ERBSs is available from the State of California, Department of Housing and Community Development, Division of Codes and Standards. The price range of ERBSs is from approximately $2,000 up to $5,000; the average cost of an ERBS is about $2,500. The State of California also permits the use of other systems that do not require the home to fall off supports, as is the case with ERBSs.

5.5 Evaluation of Multi-Hazards

Manufactured homes, like all buildings, can be simultaneously subjected to many natural hazards, and the combined effects of the forces generated from these hazards must be considered. The different loads that must be considered in the design of a manufactured home foundation are shown in Table 5-2.

Table 5-2. Load Combination Nomenclature (ASCE 7)

Nomenclature	Load Description
D	Dead load
L	Live load
F	Load due to fluid with well-defined pressures and maximum heights
F_a	Flood loads
H	Load due to lateral earth pressure, groundwater pressure, or pressure of bulk materials
T	Self-straining force

Table 5-2. Load Combination Nomenclature (ASCE 7) (continued)

Nomenclature	Load Description
L_r	Roof live load
S	Snow load
R	Rain load
W	Wind load
E	Earthquake load

Load combinations are used in the design process to take into account the simultaneous occurrence of different hazards. Manufactured homes and their foundations should be designed to the load combinations indicated by the applicable building code for the area. In the absence of a building code, the manufactured home should be designed in accordance with the load combinations given in ASCE 7.

5.5.1 Load Combinations (ASCE 7)

5.5.1.1 Strength Design (Load and Resistance Factor Design)

Strength design is defined as a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not exceed the member design strength.

According to ASCE 7, the basic load combinations for strength design (using the nomenclature in Table 5-2) are as follows:

1. $1.4(D+F)$
2. $1.2(D+F+T) + 1.6(L+H) + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.8W)$
4. $1.2D + 1.6W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.6W + 1.6H$
7. $0.9D + 1.0E + 1.6H$

When a structure is located in a flood zone, the following load combinations must also be considered:

1. In V zones or Coastal A zones, 1.6W in combinations (4) and (6) shall be replaced with $1.6W + 2.0F_a$.

2. In non-Coastal A zones, 1.6W in combinations (4) and (6) shall be replaced by 0.8W + $1.0F_a$.

5.5.1.2 Allowable Stress Design (also known as Working Stress Design)

Allowable stress design (ASD) is defined as a method of proportioning structural members such that computed stresses produced in the members by nominal loads do not exceed specified allowable stresses.

According to ASCE 7, the basic load combinations for ASD are as follows:

1. D + F
2. D + H + F + L + T
3. D + H + F + (L_r or S or R)
4. D + H + F + 0.75(L + T) + 0.75(L_r or S or R)
5. D + H + F + (W or 0.75E)
6. D + H + F + 0.75(W or 0.7E) + 0.75L + 0.75(L_r or S or R)
7. 0.6D + W + H
8. 0.6D + 0.7E + H

When a structure is located in a flood zone, the following load combinations must be considered:

1. In V zones or Coastal A zones, 1.5 F_a shall be added to other loads in combinations 5, 6, and 7 and E shall be set equal to zero in 5 and 6.
2. In non-Coastal A zones, $0.75F_a$ shall be added to combinations 5, 6, and 7 and E shall be set equal to zero in 5 and 6.

Either ASD or strength-based design can be used for manufactured housing. In both design methods, wind and seismic loads need to be evaluated. In addition, increases in allowable stress shall be used with these load combinations where allowed by the locally adopted building code.

6 Soils

Soil properties can significantly impact manufactured homes exposed to flooding. Properly determining soil type and allowable bearing capacity is important for the selection and performance of the foundation. It is recommended that a geotechnical engineer make these determinations. For example, highly erodible soils are not desirable as fill for elevating a structure in a high velocity area because it can be washed away by moving floodwaters. Other soils lose strength as moisture content increases, reducing a foundation's load capacity. This chapter discusses the effect of flooding on soil properties.

6.1 Bearing Capacity

Bearing capacity is a soil's capability to support load without catastrophic failure. Bearing capacity is derived from the soil shear strength, which is expressed as:

$$s = c + \rho\ (\tan \phi)$$

Where s = soil shear strength

c = soil cohesive strength

ρ = lateral confining pressure

ϕ = soil angle of internal friction

The general bearing capacity equation is:

$$q = (\gamma b/2)N_\gamma + cN_c + \rho N_\rho$$

Where q = soil bearing capacity

γ = unit weight of soil

b = footing width

N_γ = bearing capacity factor for soil density and footing size

N_c = bearing capacity factor for cohesion

N_ρ = bearing capacity factor for surcharge

As previously discussed, soil strength frequently changes as a function of moisture content. In granular soils, as moisture content approaches saturation (i.e., intergranular voids are 100 percent filled with water), the effective unit weight is reduced, thus reducing the confining pressure (ρ).

For preliminary design purposes, allowable bearing capacities can be established based on national model codes, local building codes, and soil surveys. Local officials may also have information on soil types and soil bearing capacities.

Soil classifications of a general nature and a typical range of their maximum allowable bearing capacities can be found in publications such as the IBC (2009 Edition), NFPA 5000 (2009 Edition), and NFPA 225 (2009 Edition). These documents can provide the allowable bearing pressures considered sufficient to support foundations at well drained sites. Excessive foundation movement or settlement may occur where unusual soil or moisture conditions are encountered. A geotechnical engineer should be consulted when unusual soil or moisture conditions are present.

6.2 Effects of Flood Duration and Frequency on Soil

For granular soils located below the water surface, the effective confining pressure (ρ') is used to determine the effective shear strength'. The effective confining pressure is calculated using the effective unit weight of the soil where:

$\gamma' = \gamma_s - \gamma_w$

γ' = effective unit weight of soil

γ_s = total unit weight of soil and

γ_w = unit weight of water

The submerged weight can be estimated as about half of the total weight of many granular soils. The angle of internal friction (ϕ) is not appreciably changed by submergence. Therefore, if the water table rises from a depth greater than the width of the footing to the ground surface, as can be the case of flooding, the bearing capacity of the soil is reduced by approximately 50 percent.

Cohesive soils (silt and clay) are bound together by electrochemical bonds between individual particles. Increasing the moisture content can change the distance between particles, decreasing the strength of the inter-particle bonds. The decrease in bond strength results in a decrease in cohesion and a loss of shear strength.

6.3 Soil Liquefaction

Seismic soil liquefaction is an important consideration for earthquake design because soil liquefaction can be a major cause of damage in a seismic event. Liquefaction is defined as the significant loss of strength resulting from an increase in soil pore pressure. Seismic vibrations act to realign soil particles into a denser configuration. The realignment decreases the inter-particle void space, thus increasing the water pressure in the voids. The increase in water pressure has the effect of decreasing the effective strength of the soil. A sufficient increase in pore pressure can reduce the effective strength to zero, at which time the soil mass behaves as a liquid. The loss of shear strength in soils supporting buildings can be catastrophic. Building foundations can slide or unevenly settle, bridges can collapse, and empty fuel tanks buried under ground can rise to the surface.

Liquefaction-induced soil movements can push foundations out of place to the point where the manufactured home will lose support.

Loose clean sands with relatively few fines, and silty soils with little or no clay, are vulnerable to seismic induced liquefaction. It is necessary to identify the presence of liquefaction susceptible soils expected to support building foundations, and design the manufactured home foundation accordingly.

To reduce liquefaction hazards, the best approach is to avoid construction on soils susceptible to liquefaction. Other options such as making the structure liquefaction resistant or improving the strength, density, and/or drainage characteristics of the soil are probably not economical for most manufactured home sites.

6.4 Recommended Soil Testing and Criteria for Manufactured Home Installations

Shallow subsurface investigations should be conducted to evaluate the soil bearing conditions at the proposed manufactured home site. An experienced geotechnical engineer can conduct an appropriate investigation using hand augers, field strength tests, and visual classification methods. Field strength testing includes dynamic cone penetration tests, pocket penetrometer tests for cohesive soils, and torvane tests for granular soils. The investigation should evaluate soils to a depth of twice the width of the bearing surface or 5 feet, whichever is greater. The investigation will provide information on soil type and bearing capacity.

When footings are eccentrically loaded, the effective bearing area is reduced so footing sizes must be increased accordingly. Eccentric loading occurs when piers are not centered over footings and when a manufactured home frame is not centered on its pier. Eccentrically loaded foundation conditions should be avoided.

Ground anchors consist of a specific anchoring device designed to transfer home anchoring loads to the ground (24 CFR 3285.5). Axially loaded ground anchors support loads by mobilizing soil shear strength along a subsurface shear plane. Ground anchors loaded non-axially resist loads through both the axial shear strength and passive soil resistance against the horizontal component of the non-axial load. Development of passive soil resistance requires some soil movement. The required movement will generally result in larger total movement in non-axially loaded anchors than axially loaded anchors in the same soil conditions.

7 Ground Anchors

Both the NFIP regulations (44 CFR 60.3) and the HUD *Model Manufactured Home Installation Standards* (24 CFR 3285.305) require that manufactured homes installed in flood-prone or SFHAs be anchored to resist flotation, collapse, or lateral movement.[1]

Ground anchors consist of a specific anchoring assembly designed to transfer home anchoring loads to the ground (24 CFR 3285.5). They are used extensively in manufactured home installations. Ground anchors are economical, readily available, and can be installed with relatively lightweight tools and equipment.

Ground anchors have potential limitations. One significant limitation arises from multiple soil-anchor response mechanisms as a function of soil type, anchor depth, and load configuration. Ground anchors have historically been allowed to move up to 3 inches horizontally or 2 inches vertically as the basis for determining acceptable performance. (Appendix E of the IRC established a ground anchor moving 2 inches in the direction of pull of the load as being acceptable.) When a manufactured home is secured with ground anchors, it too can move up to 3 inches when exposed to flood, wind, or seismic events.

Three inches of horizontal movement can produce eccentrically applied loads on piers under a home, which can cause the piers to topple and the home to collapse. Two inches of vertical movement can allow the home to lift and lose contact with the supporting piers. Unless the home is securely fastened to the piers and the piers constructed as monolithic units, the loss of contact can make the piers vulnerable to being displaced by moving floodwaters.

Ground anchor movements of several inches can have significant negative impacts on long-term performance. In cohesive soils, such anchor movements in a vertical direction can approach or exceed the soil's shear strength. In such cases, the ground anchor is supported by the soil's residual shear strength, resulting in a decrease in anchor capacity. In granular soils, large lateral movements may produce failure planes that can reduce the strength on the vertical direction.

Anchor assemblies, including ground anchors, should be inspected periodically, especially after hazard events. Loose anchor straps need to be retightened, and loose or failed anchors need to be reset or replaced. If movement has made the manufactured home structurally unstable, it should be reset to center it on its supporting piers. If this maintenance is not performed, the anchor assembly may fail during subsequent hazard events, resulting in significant damage to or destruction of the home. Tightening ground anchor straps typically costs a few hundred dollars or less. Replacing anchors or resetting a home is estimated to cost at least $1,000.

1 44 CFR 60.3(a), 44 CFR 60.3(b), and 24 CFR 3285.305 use the phrase "flotation, collapse or lateral movement." 44C FR 60.3(c) uses the phrase "flotation, collapse and lateral movement." To account for both usages, this publication uses "or."

7.1 Types of Anchors and Installed Configurations

7.1.1 Types of Anchors

Several styles of anchor assemblies are available that can adequately secure a manufactured home to resist flood, wind, and seismic forces. Helical earth anchors, cast-in-place concrete footings, drilled concrete anchors, and cross drive anchors are just a few of the types available.

7.1.1.1 Helical Earth Anchors

Helical earth anchors are designed to be augured (screwed) into the ground and are often referred to as ground anchors. Helical earth anchors typically consist of a shaft, head, and one or more helixes. The head is used for installing and fastening the anchor to the home, and tensioning the anchor. Toward the bottom of the shaft, there is one (single) or more helical disks for the anchor to be screwed into the soil. The helix provides much of the anchor's load capacity. The typical lengths of helical ground anchors are 30, 36, 48, and 60 inches.

Helical anchors also may be installed with stabilizer plates to increase the lateral capacity of the anchor by enlarging the surface area used to develop passive soil resistance.

7.1.1.2 Concrete Anchors

Concrete anchors use dead weight of a concrete footing or a combination of concrete weight and soil uplift resistance. Uplift resistance can be increased by the use of drilled concrete piers. In both cases, the home must be securely attached to the concrete elements using anchor bolts, tie-rods, or other structural connection. Anchor attachments placed in concrete must be installed with adequate depth to develop the required strength. The load capacity of the anchors must be sufficient to resist applicable design loads.

7.1.1.3 Cross Drive Anchors

Like helical ground anchors, cross drive anchors are constructed with a head secured to a metal shaft. Cross drive anchors are shafts driven into competent soils to develop their resistance. As their name implies, cross drive anchors are driven in pairs that form an "X" or cross (Figure 7-1). The heads of the anchors are secured to the home with metal straps.

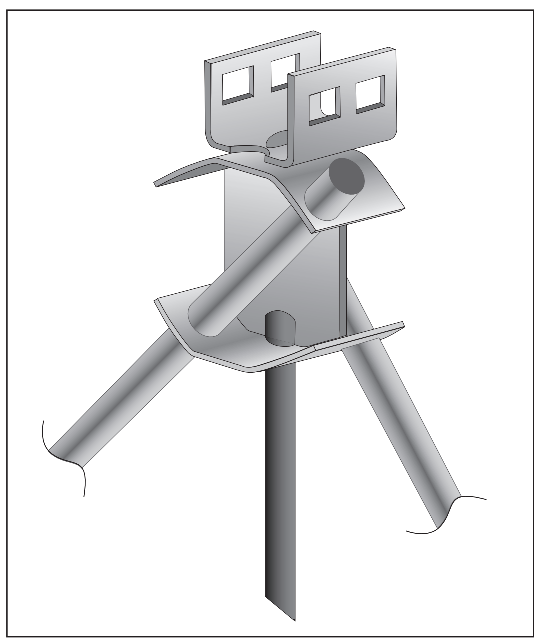


Figure 7-1. Cross drive anchor. (Courtesy of Tie Down Engineering)

7.1.2 Anchor Construction and Capacity

Steel ground anchors are the most common anchor assembly application for manufactured home installations. Ground anchors are typically constructed with a circular shaft of one or more helixes; a head connects at the opposite end of the anchor, which then connects to the home's frame and/or sidewalls with steel straps or cables. Anchor shafts are typically 5/8 inch to 3/4 inch in diameter, and helixes range from 3 inches to 8 inches in diameter. Most anchors used for manufactured home applications have one helix, although anchors with two to four helixes are available (Figure 7-2).

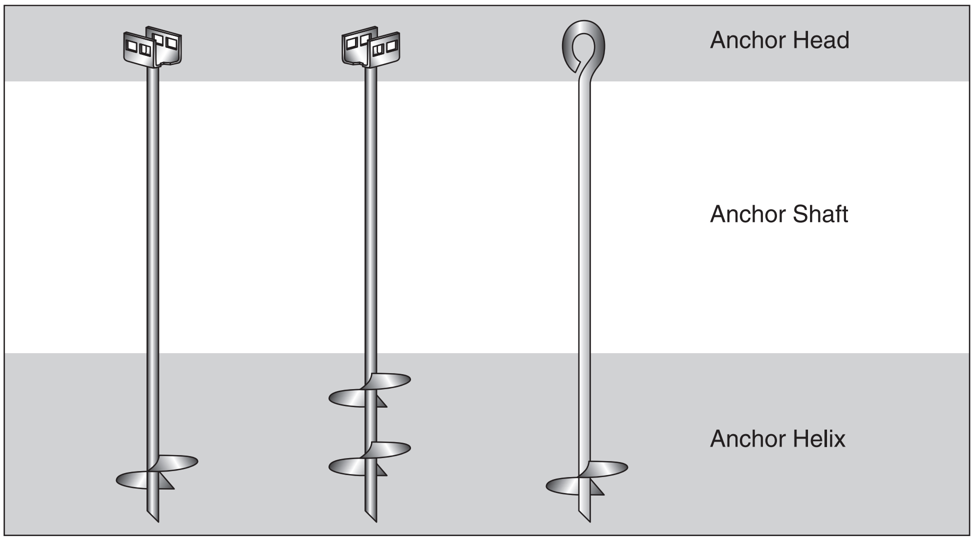


Figure 7-2. Single and double helix ground anchors with strap connection and single helix anchor with a closed-eye connection.

Most anchor heads are "U" shaped and contain predrilled bolt holes. The bolts connect the anchor to the home's frame or sidewalls with 1¼-inch anchor straps. Some anchors have heads with closed eyes for cable connections. The bolts in "U" shaped anchor heads can be used to pre-tension the anchor. Pre-tensioning an anchor with closed-eye heads requires using other devices like turnbuckles.

HUD requires anchoring equipment and anchoring assemblies to be capable of resisting allowable minimum working loads of 3,150 pounds and ultimate loads of 4,725 pounds without failure of either the anchoring equipment or the attachment point on the manufactured home.

7.1.3 Anchor Selection

Ground anchors should be selected based on the specific soils conditions at the manufactured home site. Short anchors with smaller helixes may be used in firm, well compacted soils. Longer anchors or anchors with larger or multiple helixes are required in weaker soils.

Most anchors are selected based on standard torque probe tests conducted at the site. During those tests, a 5-foot long auger probe is screwed into the ground to the approximate depth of the anchor helix. A torque wrench measures the torque required to advance the probe. The resulting torque value is used to classify the soils and select an appropriate anchor based on recommendations of the anchor manufacturers. Table 7-1 depicts how one anchor manufacturer classifies soils for anchor selection.

Table 7-1. Soil Classifications Using a Standard Torque Probe (STP)

Soil Class	Test Value (in. lbs.)	Soil Description
1	N/A	Sound hard rock.
2	550+	Very dense and/or cemented sands, coarse gravel, cobbles, preloaded silts, clays, and coral.
3	350 to 550	Medium dense coarse sands, sandy gravels, very stiff silts and clays.
4a	275 to 350	Loose to medium dense sands, firm to stiff clays and silts, alluvial fill.
4b	175* to 275	Loose sands, firm clays and silts, alluvial fill.

*Below 175 in. lbs. a professional engineer should be consulted

7.1.4 Anchor Installation

Anchors can be machine-installed or hand-installed. Machine installation involves using portable torque equipment to rotate and advance the anchors into the supporting soils. Figure 7-3 shows an electric installation device, also known as a portable anchor drive machine.

Figure 7-3. Electric anchor drive machine. (Courtesy of Tie Down Engineering)

Hand installation involves excavating holes for the anchors, placing the anchors into the holes, and then backfilling and compacting the removed soil. Hand installation disturbs significantly more soil than machine installation and reduces anchor load capacity. Manufacturers typically limit the depth of pre-drilling to two-thirds the anchor length. They also recommend against hand installations in areas with poor soils.

Anchors are typically installed vertically or inclined slightly from vertical to facilitate installation. Typical inclinations range from approximately 5 to 15 degrees from vertical. Where required, stabilizer plates are installed adjacent to the anchor shaft (Figure 7-4). This allows anchors to be installed after the manufactured home is positioned and locates the exposed anchor heads behind the manufactured home's skirting. Anchor straps are then installed to the manufactured home frames and, in HUD Wind Zones II and III, to the wall ties installed when the home is fabricated. When used in this configuration, stabilizer plates are installed to provide additional lateral resistance for the anchor assembly.

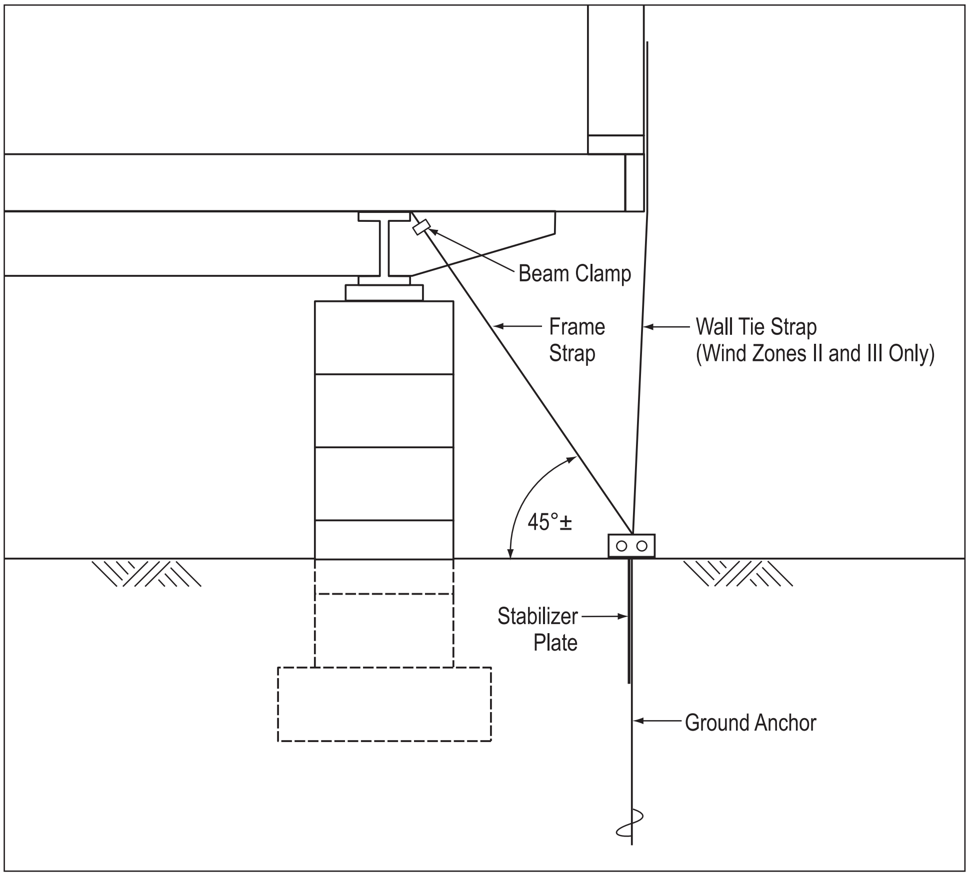


Figure 7-4. Typical ground anchor installation.

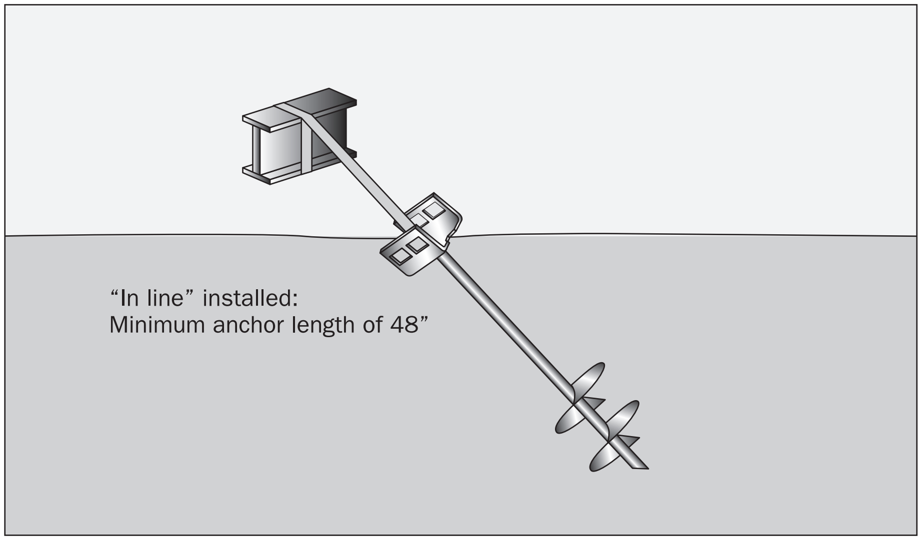
When fastened as vertical wall ties and loaded axially, ground anchors may be used without stabilizer plates. When ground anchors are used with some proprietary foundation systems, anchors can be installed 45 degrees to the horizontal and loaded axially (Figure 7-5).

7.1.5 Anchor Performance

The capacity of anchoring systems is a function of the soil response to loads applied to the anchor assembly. For ground anchors, important geotechnical considerations include soil type or classification, soil shear strength, load-deformation characteristics (i.e., modulus of subgrade reaction, or stiffness), and moisture condition. Research has identified additional considerations impacting the capacity and performance of ground anchors, including anchor geometry, anchor depth, anchor orientation, and direction of load relative to that orientation.

Soil response mechanisms are different for axially and non-axially loaded ground anchors. Soil response for axially loaded ground anchors is the result of shear stresses along the failure plane.

Figure 7-5. In line ground anchor installation.



Failure occurs when the stresses exceed the soil shear strength. The geometry of the failure surface varies based on the critical depth of the anchor. Ground anchors with an embedment depth less than the critical depth to anchor base width ratio ($(D/B)_{cr}$) respond as a shallow foundation. Ground anchors with a depth greater than $(D/B)_{cr}$ respond as a deep foundation.

Non-axially loaded ground anchors resist lateral movement by mobilizing the passive resistance of the surrounding soil. As small diameter rods develop little passive soil pressure resistance, stabilizer plates are used in the contact area to increase the passive resistance and reduce movement.

Figure 7-6 plots anchor load (in pounds) as a function of anchor head displacement (in inches), and shows the typical response for an anchor installed vertically and loaded axially. A test load of 6,000 pounds resulted in a movement of less than 2 inches. The graph also indicates that little or no movement occurred at loads less than about 225 pounds.

Vertical, axially loaded anchors are relatively efficient. The soil shear failure is a symmetrical, roughly truncated cone extended from the anchor bearing plate to the ground surface. Non-vertical, axially loaded ground anchors are somewhat less efficient due to the asymmetrical shape of the shear failure surface. The asymmetry is the result of the shallow depth at the top side of the anchor relative to the bottom side.

Movements of axially loaded anchors are proportional to the applied loads. The load-movement is approximately linear in granular or non-cohesive soils. Cohesive soils tend to be less linear, particularly as the amount of clay in the soil increases. Soil related anchor failure in granular soils may occur rapidly and may cause ground surface movements around the anchor. Anchors in cohesive soil typically fail more slowly.

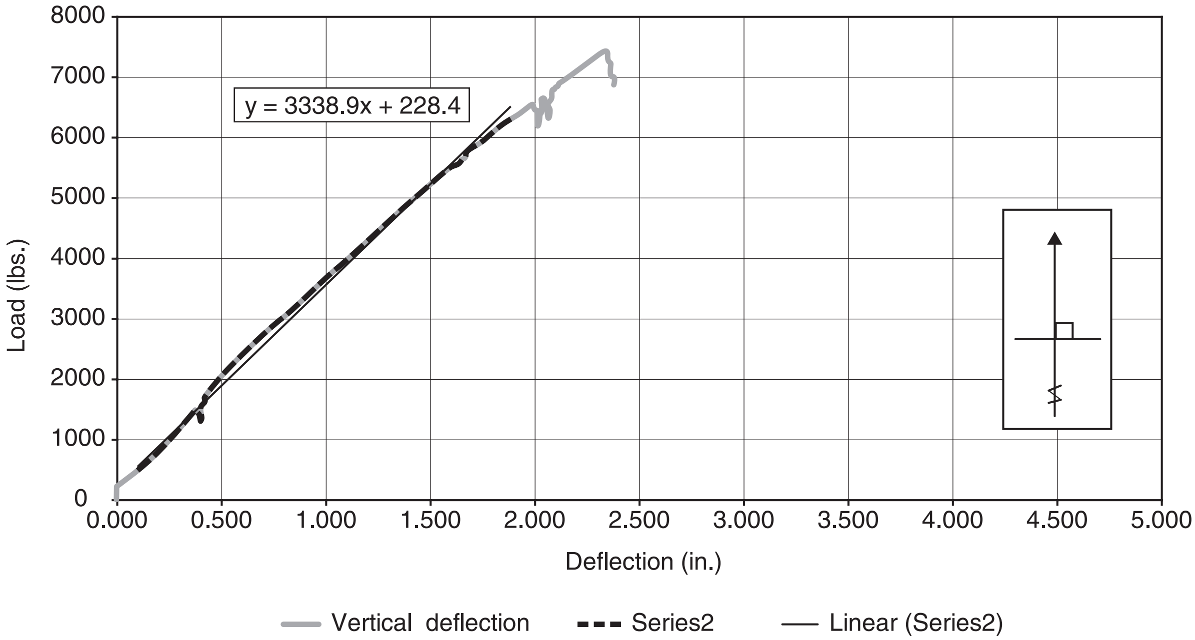


Figure 7-6. Typical response for an axially loaded anchor.

Anchor failure may also result from weld failure between the anchor shaft and the anchor head, weld failure between the shaft and the helix, collapsing of the anchor helix, or metal tearing around the anchor head strap bolts.

Anchors used with stabilizer plates respond differently than axially loaded anchors. Figure 7-7 shows the typical response for non-axially loaded anchors used with stabilizer plates. The small diameter shaft does not create much passive resistance in the soil; therefore, small loads produce relatively large movements. After the anchor shaft contacts the stabilizer plate, lateral movement as a function of load decreases significantly as a result of a larger area of passive resistance mobilized by the stabilizer plate. After the shaft contacts the stabilizer plate, stiffness, as indicated by the slope of the load vs. movement curve, increases significantly. However, the apparent stiffness, as indicated by the slope of the curve, remains less than axially loaded anchors.

For both axially and non-axially loaded anchors, the design stiffness should be selected to account for the variability of individual anchor performance during anchor tests, including an assessment of the upper limit of the applicability of the stiffness factor.

Shear strength in saturated soil is typically less than in non-saturated soils. Thus, anchors in saturated soils have a lower load capacity than non-saturated soils, and may exhibit decreased stiffness, especially in clays.

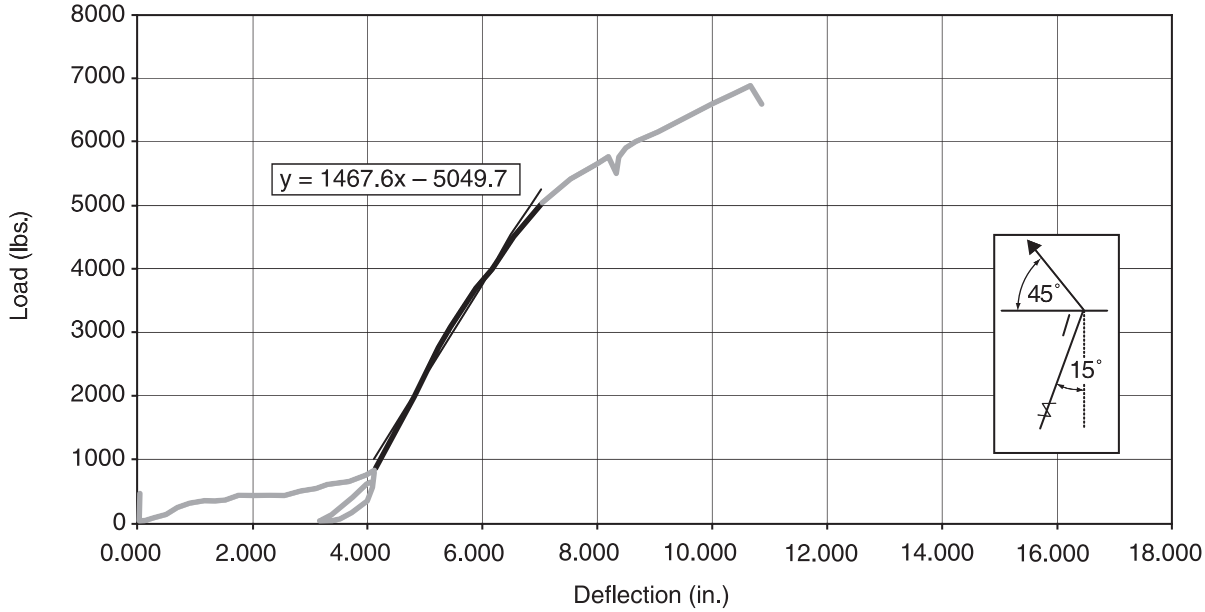


Figure 7-7. Typical response for a non-axially loaded anchor used with a stabilizer plate.

7.1.6 Anchors and Other Foundation Elements

Ground anchors are used with masonry piers, wood posts, or steel jack stands. For satisfactory performance, the piers, posts, and stands must function with relatively large displacements that the anchors may experience when subjected to flood, high-wind, or seismic loads. Large displacements are especially likely for non-axially loaded ground anchors. If subjected to relatively large movements, many foundation components cannot maintain their integrity. Piers, for example, can experience failure due to sliding of unmortared blocks or overturning of reinforced piers supported on ground surface pads (Figure 7-8).

7.2 FEMA Anchor Test Program

7.2.1 Anchors in Saturated Soils

Flooding can decrease soil shear strength and change the subsurface hydrostatic pressures as a result of an increase in the pressure gradient. The two mechanisms affect ground anchor performance differently. The effects are a function of soil characteristics, anchor end plate diameter, installation depth, and change in hydrostatic pressure. Research has indicated that, for a fixed depth, the ultimate capacity of screw anchors in dry sand is higher than screw anchors in submerged conditions. The impact of the reduction in capacity is significantly greater for shallow anchors than for deep anchors.

In 2002, FEMA participated in a field test program of 120 anchors to provide performance data for developing pre-engineered foundation designs using ground anchors. Sixty anchors were tested in a saturated site, and 60 anchors were tested in an adjacent dry site as a control group.

Figure 7-8. Failed foundation system that used masonry piers.

The results generally support the findings of previous research and have been used to develop the foundation designs included in this guide.

The tests were conducted by representatives from FEMA and its engineering consultants, HUD, the Manufactured Housing Institute (MHI), Florida Manufactured Housing Association (FMHA) and several ground anchor manufacturers (Tie Down Engineering, Oliver Technologies, Minute-Man, and Style Crest).

7.2.2 Anchor Test Results

Tables 7-2 and 7-3 contain the test results for dry site anchors and wet site anchors, respectively. Figure 7-9 shows three anchor configurations described in Tables 7-2 and 7-3. The data shown are for anchor stiffness or the amount of load the anchors develop per inch of anchor head movement. The data are raw data and are not indicative of design or working load values.

The data also include the standard deviations for the data groups. The data show that the performance of individual ground anchors varies significantly from the average performance of the group of anchors. This variance, or "spread" in ground anchor performance has a significant effect on appropriate design values. The greater the relative spread in individual anchor performance, the lower the appropriate design value.

Table 7-2. Dry Site Anchor Data

Anchor Style and Installation	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	1,505	3,283	2,426	543
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	1,774	6,639	3,801	1,394
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,006	2,001	1,475	294
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch acrylonitrile butadiene styrene (ABS) stabilizer plate (Figure 7-9b)	1,019	2,612	1,721	497
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	817	1,614	1,197	257

Table 7-3. Wet Site Anchor Data

Anchor Style and Installation*	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	2,874	9,019	5,506	1,829
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	2,166	6,581	4,112	1,391
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	833	1,412	1,094	193
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch ABS stabilizer plate (Figure 7-9b)	655	2,006	1,538	370
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,024	1,894	1,319	300

* See Figure 7-9.

Note that anchor stiffness values are based on the linear portion of the load deflection data. In most cases, the non-axially loaded anchors' significant movements occurred prior to reaching the linear response range. It should also be noted that the upper and lower limits of applicability of the stiffness values have not been fully evaluated. For axially loaded anchors in dry sand, the linear zone appears to exceed 6,000 pounds, about the limit of the test. Vertically loaded vertical anchors in wet sand had similar results; however, axially loaded anchors installed at 45 degrees in wet sand had an upper limit of about 4,500 to 5,000 pounds. Similar differences were observed for inclined anchors.

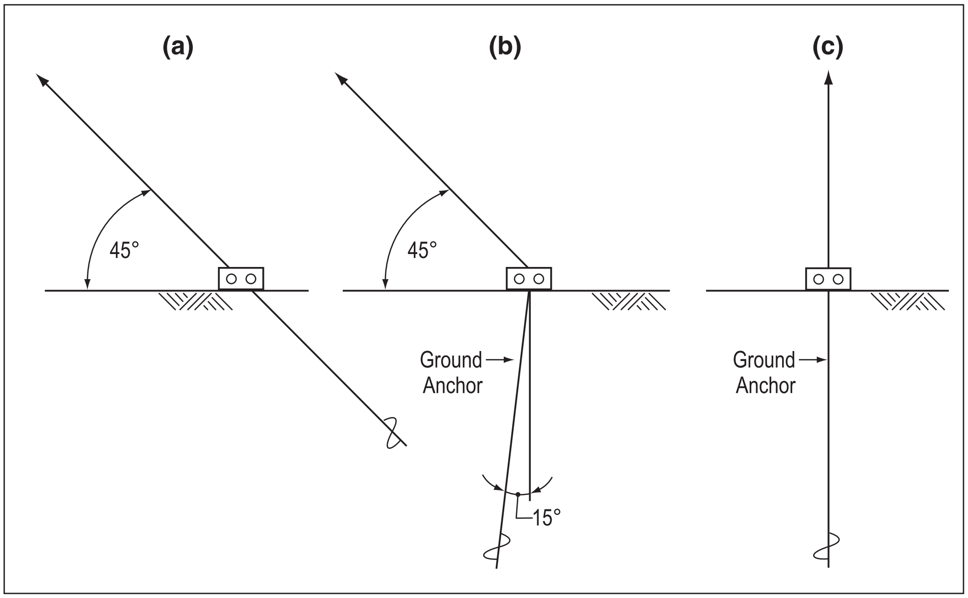


Figure 7-9. Three graphics showing the anchor configurations described in Tables 7-2 and 7-3. From left to right, they are (a) ground anchor installed at 45 degrees and loaded axially, (b) ground anchor installed at 15 degrees from vertical and loaded 45 degrees from horizontal, and (c) ground anchor installed vertically and loaded axially.

7.3 Recommended Ground Anchor Certification, Performance, and Design Values

7.3.1 Recommended Ground Anchor Certification Performance

Currently, there is no consensus based standard protocol for certifying ground anchors used to anchor manufactured homes. Some States have developed certification procedures and a task group under HUD's Manufactured Housing Consensus Committee (MHCC) has been working on a Ground Anchor Test Protocol (GATP) for certifying ground anchors. Although no standard protocol had been completed at the time this guide was published, the ground anchor design strengths included in this guide assume that the ground anchors will achieve a level of performance that can be relied upon to anchor the home and resist applied loads from a design event.

7.3.2 Recommended Ground Anchor Design Values

The following data present recommended ground anchor design values for use when ground anchors have not been load tested or otherwise certified for a specific capacity. The information, while limited, is based on the best available data from the FEMA ground anchor testing program. FEMA's testing program gathered data on ground anchor performance and soil saturation effects, and was conducted on sandy Class 4b soils.

The recommended design loads contained in Table 7-4 were developed by applying the statistical factors required to produce a design load that provides a 10 percent lower exclusion limit with a 90 percent confidence level. The factors were applied to the FEMA test data.

Table 7-4. Recommended Design Loads – from FEMA Ground Anchor Testing Program

Anchor Style and Installation – FEMA Tests	Recommended Design Load (pounds)
5-foot anchor installed at 45°and loaded axially	3,150
5-foot anchor installed vertically and loaded axially	3,000
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	2,000
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000

Recommended design stiffness values were selected that provide a 90 percent confidence level; this means that no more than 10 percent of individual anchors would provide resistances less than design values. This level of statistical performance is less conservative, but similar to statistical performance levels applied to other structural materials like steel or concrete.

The lowest stiffness values from the dry and wet sites were selected for design. Generally, the dry site values controlled for axial pull anchors while the saturated site anchor values controlled for anchors using stabilizer plates. Table 7-5 lists the recommended design stiffness for the anchors tested.

Table 7-5. Recommended Design Stiffness for Tested Anchors

Anchor Style and Installation	Anchor Design Stiffness (pound/inch)	Controlling Soils
5-foot anchor installed at 45° and loaded axially	1,200	dry
5-foot anchor installed vertically and loaded axially	1,010	dry
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	675	wet
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	708	wet
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	659	wet

With a 3-inch displacement, the axially loaded anchors provide working loads greater than the 3,150-pound loads required by HUD (e.g., 1,200 pounds/inch x 3 inches = 3,600 pounds). However, the anchors with stabilizer plates provide only about two-thirds of the HUD required capacity. The anchor stiffness values in Table 7-5 are based on the linear portion of the load-deflection curve. Designers need to evaluate potential deflections at loads below the linear range, particularly for inclined anchors loaded non-axially.

7.4 Ground Anchors in Seismically Active Areas

While data exist on the performance of ground anchors in static saturated soils, no definitive testing has been completed that predicts how ground anchors will perform in saturated soils during a seismic event. Seismic events can result in soil liquefaction, particularly in fine sands like those in the test program. Liquefaction may result in a significant and potentially total loss of anchor capacity during a seismic event. A registered engineer should be consulted to evaluate the liquefaction potential at the proposed manufactured home installation site.

8 Foundation Systems

8.1 Introduction

Properly designed and constructed manufactured home foundations can significantly reduce the potential for damages from flooding, high winds, and seismic events. Many styles of foundations are available for supporting manufactured homes. Continuous perimeter walls, constructed of concrete, masonry, or treated wood; concrete or masonry piers; wood posts and piles; and systems consisting of piers and ground anchors are some of the options available to a manufactured homeowner and installer.

To be effective, manufactured home foundations must perform the following:

- Support the weight of the home, its contents, and its occupants
- Resist design loads from wind, snow, seismic events, and moving floodwaters
- Elevate the home sufficiently to prevent losses from a design flood event

Elevated foundations are classified as enclosed or open. As the name implies, enclosed foundations enclose the space below the elevated home. Perimeter masonry, concrete, or sheathed wood walls are enclosed styles. Open foundations consist of a system of individual members that support the home only at discrete locations. Pier, post, and pile foundation systems are open systems. Many open foundations have a non-structural skirting to enclose the space below the home. The skirting is primarily for aesthetics and does not add to the strength of the foundation. Skirting can help to protect piping installed below the home from freezing and reduce both heat loss from the home and the potential for animal or insect entry into the home.

Selecting an appropriate foundation system depends on a number of variables, including the building site conditions (elevation, slope, access restrictions, drainage); the flood zone; the design loads (wind, flood, snow, and, if appropriate, seismic) at the site; the availability of materials; on-site soil characteristics; local construction practices; and cost. Whatever foundation system is chosen, both the HUD Code and NFIP require a foundation to resist flotation, collapse, or lateral movement during a design event to prevent damages to the home and surrounding structures. Tables 8-1 through 8-3 at the conclusion of this chapter provide guidance to the selection of appropriate manufactured home foundation systems as a function of flood depth and flow velocity.

Proprietary systems are also an option for the manufactured homeowner. Proprietary systems are discussed in Section 2.2.2 and the system must meet the design and performance criteria described in Chapter 9.

More information on proprietary foundations is contained in the SBRA's *Guide to Foundation and Support Systems for Manufactured Homes* available at http://www.research-alliance.org/pages/foundations_guide.htm.

8.2 Enclosed Foundations

Enclosed foundations consist of perimeter foundation walls placed on continuous footings. The walls enclose the area below the living space of the home (Figure 8-1). Perimeter walls are commonly constructed of concrete, masonry, or wood. Enclosed foundations are occasionally used to raise manufactured homes, often creating the appearance of a site-built home (Figure 8-1).

Figure 8-1. A manufactured home elevated on a perimeter foundation wall. Although it appears the openings are too high, the bottoms of the openings are less than 1 foot above the top of the interior slab.

NFIP regulations permit enclosed foundations for manufactured homes in SFHA A zones with a requirement that the foundation walls include flood vents. 44 CFR 60.3(c)(5) requires that:

> "all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other covering or devices provided that they permit the automatic entry and exit of floodwaters."

This elevation technique should not be used in high-velocity or highly erosive flood conditions, and is not permitted in V zones. Additional information on wall vents for floodwater flow is provided in FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).

Perimeter walls of enclosed foundations should include adequate reinforcement to resist unbalanced hydrostatic and/or hydrodynamic loads that may occur in fast rising flood events. Such floods may result in water levels higher on the exterior side of the wall than the inside until flow through the flood vents can equalize them.

8.3 Open Foundations and Breakaway Walls

NFIP regulations require manufactured homes in SFHAs designated V1-30, VE, or V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls (44 CFR 60.3(e)(5)). Elevating a manufactured home on an open foundation involves raising it onto piers, posts, or piles. If the home is located in an area of coastal flooding, an open foundation is the only way to safely elevate the home. If the home is subjected to high-velocity riverine floodwaters, significant water depth, or potential erosions, the home should also be elevated on an open foundation. Open foundations are intrinsically more resistant to moving floodwaters and breaking waves than enclosed foundations since the home has a smaller surface area exposed to flood forces. Selection of the proper open foundation for various flooding and site characteristics is critical to the success of the foundation.

Breakaway walls, including non-structural skirting around a manufactured home, are walls that are not part of the structural support of the home. They are designed and constructed to fail under the loads imposed by floodwaters without jeopardizing the elevated portion of the home or the structural support of the home. Because such enclosures are designed to fail at a lateral load of no greater than 20 pounds per square foot, they will transfer minimal additional loads to the foundation. Insect screening and latticework both allow floodwaters to pass through. Detailed discussions on design and construction for breakaway walls can be found in FEMA Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls* (2008).

8.3.1 Pier Systems

Most manufactured homes are placed on pier foundations. Although there are many variations, pier foundations fall into two general styles. One style contains pier foundations combined with other components (such as anchors and frame straps) for lateral stability; the second style relies on the piers and their footings to resist all imposed loads. The foundation styles that use supplemental lateral-supporting devices often do not require reinforced piers. The determination of the need for and the amount of reinforcing required is part of the design analyses. The final design requirements for pier reinforcing is a function of the combination of flood, wind, and seismic loads acting on the manufactured home, and the resulting pier capacity required to resist flotation, collapse, or lateral movement.

When flood velocities are less than 1 fps, piers can be constructed using unbonded (dry-stacked) concrete blocks or steel piers. When pier foundation systems are used without separate components to resist lateral loads, the piers and footings must be much stronger. They not only have to transfer all imposed loads to the bearing soils, but also must do so in a manner that does not damage the piers and footings or overload the supporting soils.

Piers designed to resist lateral and/or uplift loads without the use of ground anchors or straps typically consist of reinforced brick masonry, reinforced concrete masonry units, or reinforced cast-in-place concrete with steel reinforcing bars for both the piers and the below-grade footings. Because the ground around pier footings in SFHAs can be susceptible to erosion and scour, the footings must be embedded below the anticipated scour depth.

In areas exposed to moving floodwaters, special consideration must also be given to controlling scour around the pier foundation elements. Moving floodwaters can remove soil around and beneath foundations, potentially reducing their load capacity to the point of foundation failure.

Floodwaters with high flow rates and floodwaters that carry a large sediment load create more scour than low velocity or clear water flood flow. Because of this, scour is particularly damaging where floodwaters converge or abruptly change direction. Scour is generally greatest around discrete interior piers and the corners of perimeter wall foundations.

Scour removes soil particles from beside and, in severe cases, from beneath foundations. The loss of soil around and/or beneath a foundation affects its capacity to support the design loads. The loss of vertical foundation capacity can result in large settlements and potential collapse. The loss of lateral capacity not only reduces the capacity of the foundation to resist lateral wind and flood loads, but also can reduce the vertical capacity. The loss of lateral support for long thin vertical elements (e.g., single block masonry stack piers) can result in buckling under the design vertical loads.

Piers designed to resist lateral and/or uplift loads must be constructed using mortared horizontal joints between courses and reinforced grout used to fill the vertical cell. The piers must be firmly attached to the supporting footings.

8.3.1.1 Reinforced Pier Systems

Reinforced piers typically have steel reinforcements placed inside of the piers. Reinforced pier systems are commonly constructed of concrete masonry units (CMUs) or cast-in-place concrete (Figure 8-2).

In high-wind areas and in areas exposed to seismic or hydrodynamic loads, piers may require much larger footings to ensure applied loads do not exceed the soil's bearing capacity or allow tensile forces to develop in foundation elements in the upstream and windward side of the home. Laterally bracing the piers can allow the structure to distribute imposed loads to the entire foundation system. Lateral bracing also provides protection against buckling failure of vertical elements due to loss of confining soil from erosion or scour.

Concrete Masonry Unit (CMU) Reinforced Piers

The *International Residential Code* limits the height of solid masonry piers, including hollow concrete masonry units filled solidly with concrete or Type M or S mortar to ten times their least dimension. The height limitation for unfilled hollow concrete masonry unit piers is four times their least dimension (IRC§606.6).

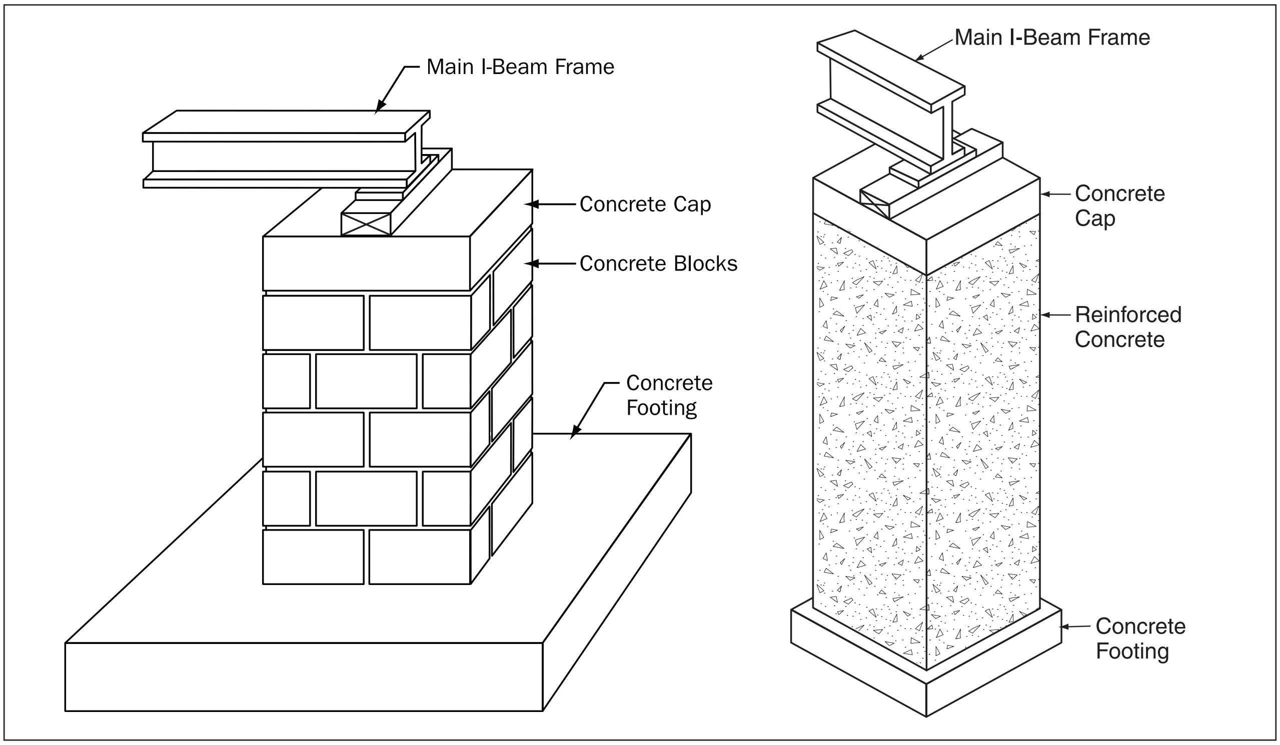


Figure 8-2. Reinforced masonry and concrete piers.

Adequate connections between the piers and the manufactured home are necessary for the manufactured home and its foundation to resist lateral and uplift loads from floods, winds, and earthquakes. Generally, multiple fastener bolted connections are needed to connect the top of the piers to the manufactured home frames when the piers must transfer moments. If the piers must resist only uplift loads, fastening requirements may be simplified. Regardless of the complexity of the connection, consult the manufactured home manufacturer to ensure the factory built components are not overloaded. Figure 8-3 shows a method used to fasten a home's steel frames to reinforced masonry piers using nuts, steel plates, and bolts grouted into the piers.

8.3.1.2 Unreinforced Pier Systems

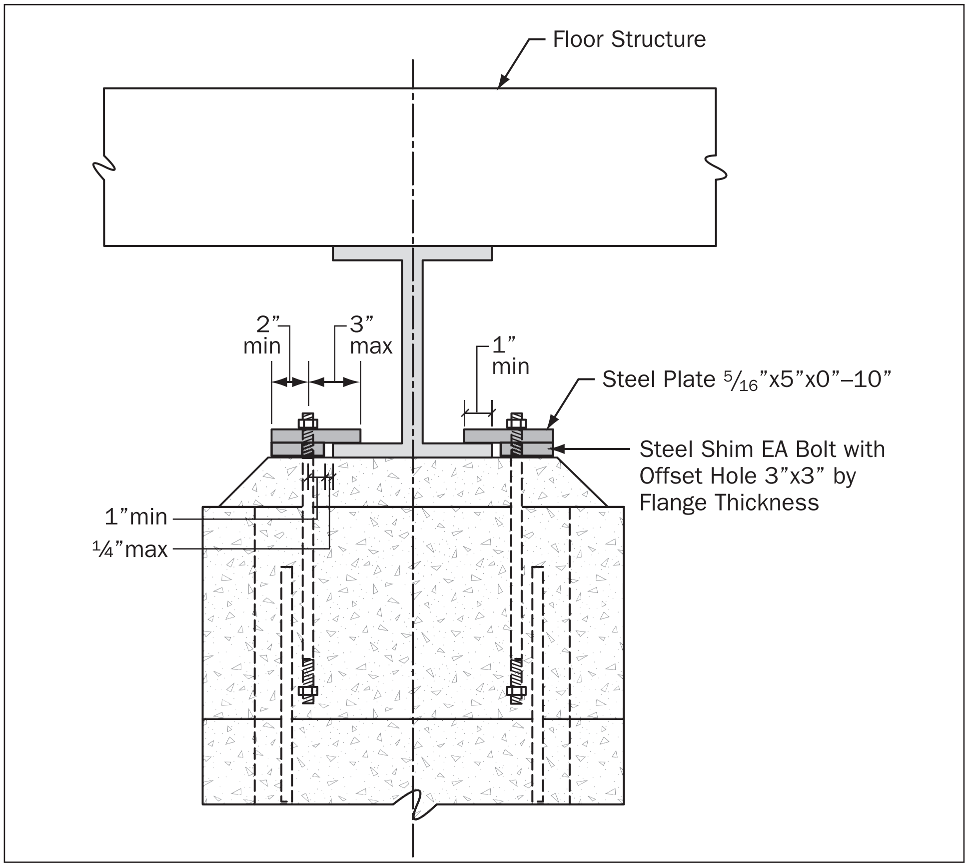
Unreinforced brick or CMU pier systems have no reinforcing steel and, therefore, have very little resistance to overturning, sliding, and uplift. Because of this, unreinforced piers should always be provided with other stabilizing devices like ground anchors.

When used with stabilizing devices, many styles of unreinforced piers are available to support manufactured homes; the styles provide varying degrees of strength to resist loads on the home. These systems can be constructed without mortar (called dry-stacked masonry); with dry-stacked block lightly secured with a surface bonding material; with mortared block; or with fully mortared, grouted block.

Dry-Stacked Piers

Dry-stacked block piers can fail when a home is exposed to combined wind and fooding (ASCE 7, Load Combination #6). Failure results when wind forces lift the manufactured home's frame off its windward piers. Without the weight of the home to stabilize the piers, the piers can easily fail by sliding or overturning.

Figure 8-3. Bolted connection between frame and reinforced pier.



When placed directly on concrete footings or pads, 3-foot tall piers constructed with single, dry-stacked blocks to create an 8-inch by 16-inch pier can only resist flood velocities of approximately 1.0 fps. Three-foot tall (16-inch by 16-inch) double-stacked piers can resist flood velocities of approximately 1.75 fps. Dry-stacked piers or posts supported on ABS pads fail at lower velocities than piers supported on concrete. The failure at lower velocities is due to a reduced frictional resistance between the pier blocks or posts and the ABS pad. The design flood velocity for double-stacked piers on ABS pads is 1.25 fps.

If dry-stacked piers are not fully submerged, they can resist higher flood velocities. This is because the portion of the pier above the water line adds to the pier's stability but does not add to the flood load that the pier must resist. Engineers can calculate the ability of partially submerged piers to resist moving floodwaters or their resistance can be determined by testing.

Applying surface-bonding materials strengthens the piers by increasing their shear resistance. However, surface bonding has limited impact on their resistance to bending moments from lateral loads; therefore, surface bonded piers still need to be used with other foundation components. The increased shear resistance allows 3-foot tall (16-inch by 16-inch) piers to resist hydrodynamic loads from floodwaters moving at approximately 2.0 fps for single-stacked piers and 3.0 fps for double-stacked piers. This resistance to moving floodwaters can only be achieved when the surface bonding materials not only bond the individual pier blocks to each other, but also the pier to the concrete footing below. A FEMA sponsored testing program conducted at the Haynes Coastal Engineering Laboratory, Texas A&M University verified the design values.

The Texas A&M testing program included piers constructed using a polyurethane based masonry adhesive as joint bonding material. The Illinois Tool Works (ITW) TACC Division's Mason Bond was certified by ICC Evaluation Service as meeting the IBC and IRC for Types M, N, O, and S Portland cement/lime mortar. Test results showed the single stack adhesive bonded piers to be the strongest configuration tested.

Mortared block and fully grouted mortared block are much stronger than dry-stacked and surface-bonded piers, but their strengths do not match piers with #3 reinforcing steel bars grouted into the vertical cells. Mortared and fully grouted piers usually require other foundation components (like shear walls) to resist lateral loads.

Reinforced piers (constructed by introducing reinforcing steel to fully grouted piers) can be made to resist lateral and vertical loads when used with other foundation components like large concrete footings.

Unreinforced piers cannot be used in V zones. In Coastal A zones, fully grouted piers may be adequate for low flood velocities, but reinforcing with steel is recommended.

8.3.2 Pile Foundations

Pile foundations provide protection for the broadest range of flooding conditions. This foundation system consists of the pile supports, horizontal beams, longitudinal support under the manufactured home, and foundation bracing for additional resistance to lateral wind, floodwaters, and seismic events. A properly designed pile foundation can withstand high-wind and water velocities, and can resist erosion and scour around its base if embedded to an adequate depth (Figure 8-4). Because of this, pile foundations meet the NFIP requirements for installation in V zones. Pile foundations are also appropriate for Coastal A zones and for areas exposed to high-velocity riverine flooding.

Figure 8-4. Manufactured home on a pile foundation.