1 Introduction

1.1 Background

The Federal Emergency Management Agency (FEMA) first published the *Coastal Construction Manual* (FEMA 55) in 1981. The Manual was updated in 1986 and provided guidance to public officials, designers, architects, engineers, and contractors for over a decade. In that time, however, construction practices and materials changed, and more information on hazards and building performance was developed and used to update the Manual again in 2000.

Over the past several decades, the coastal population in the United States has increased significantly. The increased coastal population led to increased coastal development, which led in turn to greater numbers of structures at risk from coastal hazards. Additionally, many of the residential buildings constructed today are larger and more valuable than those of the past, resulting in the potential for larger economic losses when disasters strike. A FEMA study estimates that the combination of population growth and sea level rise may increase the portion of the U.S. population residing in a coastal floodplain from 3 percent in 2010 to as much as 4 percent in 2100 (FEMA 2010a [draft]).

In response to increased hazards and lessons learned from past storms, regulatory requirements for construction in coastal areas have increased over the past decade. In 2000, the International Code Council (ICC) created the International Code Series (I-Codes) based on the three regional model building codes: the Building Officials Code Administrators

CROSS REFERENCE

Regulatory requirements, including the I-Codes, CZMA, and the NFIP, are addressed in Chapter 5.

The ***Coastal High Hazard Area*** (or Zone V) is explained in Section 3.6.2 of this Manual.

International (BOCA) National Building Code (NBC), the Southern Building Code Congress International (SBCCI) Southern Building Code (SBC), and the International Conference of Building Officials (ICBO) Uniform Building Code (UBC). Based on data included in the Insurance Services Office (ISO) Building Code Effectiveness Grading Schedule (BCEGS) database, 86.5 percent of jurisdictions in the hurricane-prone region have adopted wind-resistant building codes, and 47.25 percent of flood-prone jurisdictions have adopted flood-resistant building codes (ISO 2011). As of the publication of this Manual, 33 of the 35 coastal States and U.S. territories, in implementing the Coastal Zone Management Act (CZMA) of 1972, have instituted construction setbacks and coastal resource protection programs. Many jurisdictions now require geotechnical studies and certifications from design professionals for construction along the coastline. Finally, as of May 2011, over 21,450 communities participate in the National Flood Insurance Program (NFIP), which requires, among other things, that plans for new buildings constructed in Coastal High Hazard Areas be certified by a design professional.

Investigations conducted by FEMA and other organizations after major coastal disasters have consistently shown that properly sited, well-designed, and well-constructed coastal residential buildings generally perform well (refer to Chapter 2 for a discussion of the FEMA investigations). This updated *Coastal Construction Manual*—prepared by FEMA with assistance from other agencies, organizations, and professionals involved in coastal construction and regulation—is intended to help designers and contractors identify and evaluate practices that will improve the quality of construction in coastal areas and reduce the economic losses associated with coastal disasters.

The design and construction techniques included in this Manual are based on a comprehensive evaluation of:

- Coastal residential buildings, both existing and under construction
- Siting, design, and construction practices employed along the U.S. coastlines
- Building codes, floodplain management ordinances, and standards applicable to coastal construction
- Performance of coastal buildings based on post-disaster field investigations

1.2 Purpose

This Manual provides guidance for designing and constructing residential buildings in coastal areas that will be more resistant to the damaging effects of natural hazards. The focus is on new residential construction and substantial improvement or repairs of substantial damage to existing residential buildings—principally detached single-family homes, attached single-family homes (townhouses), and low-rise (three-story or less) multi-family buildings. Some of the recommendations of the Manual may also apply to non-substantial improvements or repairs. Discussions, examples, and example problems are provided for buildings in or near coastal flood hazard areas in a variety of coastal environments subject to high winds, flooding, seismic activity, erosion, and other hazards.

This Manual is intended to be used by contractors, designers, architects, and engineers who are familiar with the design and construction of one- to three-story residential buildings in coastal areas of the United States and its territories. Readers less familiar with design and construction practices, as well as State and community officials, should also refer to FEMA P-762, *Local Officials Guide for Coastal Construction* (FEMA 2009),

for guidance on planning and design considerations for improving the performance of coastal residential buildings before using this Manual.

1.3 Objectives

The goal of this Manual is to provide professionals guidance to assist them in pre-design, planning tasks and decisions as well as design and construction practices that will lead to building successful, disaster-resistant homes. For any project, it is critical that the project be well planned in order to minimize potential issues later on during the design and construction process and when the building is impacted by an event. These items are summarized in the following sections and elaborated on in detail throughout this Manual.

1.3.1 Planning for Construction

One objective of this Manual is to highlight the many tasks and decisions that must be made ***before actual construction begins***. These tasks include, but may not be limited to:

- Evaluating the suitability of coastal lands for residential construction
- Planning for development of raw land and for infill or redevelopment of previously developed land
- Identifying regulatory, environmental, and other constraints on construction or development
- Evaluating site-specific hazards and loads at a building site
- Evaluating techniques to mitigate hazards and reduce loads
- Identifying risk, insurance, and financial implications of siting, design, and construction decisions

1.3.2 Successful Buildings

A second objective of this Manual is to identify the best design and construction practices for ***building successful disaster-resistant structures***.

In coastal areas, a building can be considered successful only if it is capable of resisting damage from coastal hazards and processes over a period of decades. This does not mean that a coastal residential building will remain undamaged over its intended lifetime, but that undermining from erosion and the effects of a design-level flood or wind event (or series of lesser events with combined impacts equivalent to a design event) will be limited.

NOTE

The designer should be familiar with the recommendations in this Manual, along with the building codes and engineering standards cited, as these may establish an expected level of professional care.

A ***successful building*** is considered a building for which the following are true after a design-level event:

- The building foundation is intact and functional
- The envelope (lowest floor, walls, openings, and roof) is structurally sound and capable of minimizing penetration of wind, rain, and debris

TERMINOLOGY: DESIGN EVENT

For the purposes of this Manual, a design event is the minimum code-required event (for natural hazards, such as flood, wind, and earthquake) and associated loads that the structure must be designed to resist.

NOTE

Design of a ***successful coastal building*** must consider the effects of coastal hazards and coastal processes over a period of decades.

CROSS REFERENCE

For more information about enclosures and the use of space below elevated buildings, see Section 2.3.5 of Chapter 2.

- The lowest floor elevation is high enough to prevent floodwaters from entering the building envelope
- The utility connections (e.g., electricity, water, sewer, natural gas) remain intact or can be easily restored
- The building is accessible and habitable
- Any damage to enclosures below the lowest floor does not result in damage to the foundation, utility connections, or elevated portions of the building or nearby structures
- For buildings affected by a design level seismic event, the building protects life and provides safety, even if the structure itself sustains significant damage

1.3.2.1 Premise and Framework for Achieving Successful Designs

The underlying goal of a successful design is expressed through its basic premise: ***Anticipated loads must be transferred through the building in a continuous path to the supporting soils.*** Any weakness in that continuous path is a potential point of failure. To fulfill this design premise, designers must address a variety of issues and constraints. These are illustrated in Figure 1-1 and summarized as follows:

Funding. Any project is constrained by available funding, and designers must balance building size and expense against the

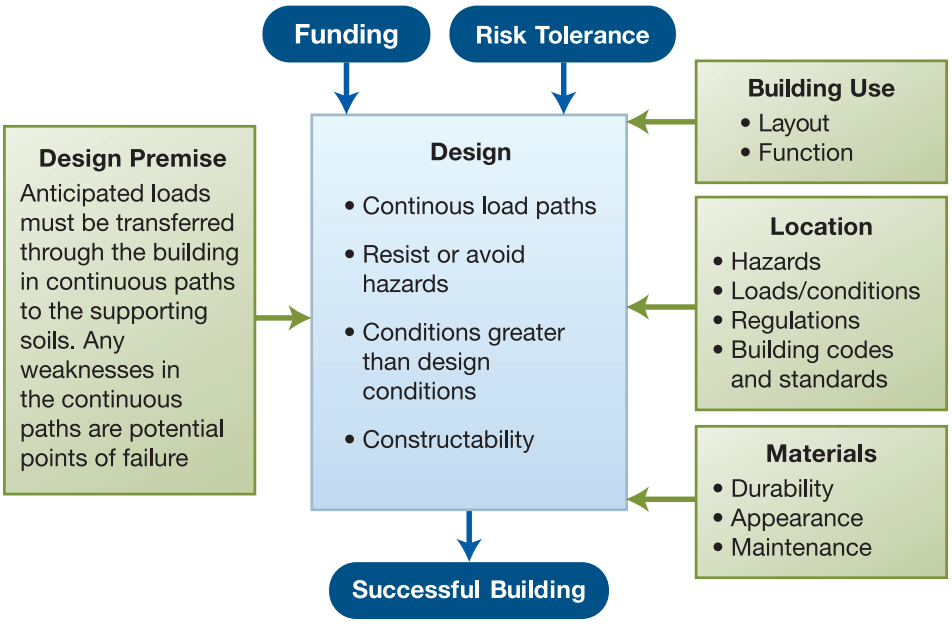

Figure 1-1.
Design framework to achieve successful buildings

desire for building success. Initial and long-term costs should be factored into the design. Higher initial construction costs may result in increased closing costs or higher mortgage rates, but may minimize potential building damage, reduce insurance rates, and reduce future maintenance costs.

Risk tolerance. Some owners are willing and able to assume a high degree of financial and other risks, while other owners are more conservative and seek to minimize potential building damage and future costs.

Building use. The intended use of the building will affect its layout, form, and function.

Location. The location of the building will determine the nature and intensity of hazards to which the building will be exposed; loads and conditions that the building must withstand; and building codes, standards, and regulations that must be satisfied.

Materials. A variety of building materials are available, and some are better suited to coastal environments than others. Owners and designers must select appropriate materials that address both aesthetic and durability issues. If an owner is prepared for frequent maintenance and replacement, the range of available materials will be wider; however, most owners are not prepared to do so, and the most durable materials should be used.

Continuous load paths. Continuous load paths must be constructed and maintained over the intended life of the building.

Resist or avoid hazards. The magnitudes of design forces acting on structures, coupled with project funding, building location, and other factors, will determine which forces can be resisted and which must be avoided. Structures are typically designed to resist wind loads and avoid flood loads (through elevation on strong foundations).

Conditions greater than design conditions. Design loads and conditions are based on some probability of exceedance, and it is always possible that design loads and conditions can be exceeded. Designers can anticipate this and modify their initial design to better accommodate higher forces and more extreme conditions. The benefits of doing so often exceed the costs of building higher and stronger.

Constructability. Ultimately, designs will only be successful if they can be implemented by contractors. Complex designs with many custom details may be difficult to construct and could lead to a variety of problems, both during construction and once the building is occupied.

1.3.2.2 Best Practices Approach

To promote best practices, portions of the Manual recommend and advocate techniques that exceed the minimum requirements of model building codes; design and construction standards; or Federal, State, and local regulations. The authors of the Manual are aware of the implications of such recommendations on the design, construction, and cost of coastal buildings, and make them only after careful review of building practices and subsequent building performance during design level events.

Some of the recommended best practices and technical solutions presented in the previous version of FEMA 55 (2000, third edition) have been incorporated into the model building codes. For example:

- The 2009 and 2012 editions of the International Residential Code (IRC)—see sections R322.2.1(2) and R322.3.2(1)—require 1 foot of ***freeboard*** in the Coastal A Zone and in certain Zone V situations. Past minimum code provisions did not require any freeboard. Note that more than 1 foot of freeboard may

be indicated once the design framework steps outlined in Figure 1-1 are accomplished.

- The 2006, 2009, and 2012 editions of the International Building Code (IBC) require conformance with American Society of Civil Engineers (ASCE) Standard 24-05, *Flood Resistant Design and Construction*. ASCE 24-05 requires new buildings situated in the Coastal A Zone to be designed and constructed to Zone V requirements. Thus, the 2000 version of the *Coastal Construction Manual* recommendation to treat Coastal A Zone buildings like Zone V buildings is now being implemented for IBC-governed buildings through the building code.

TERMINOLOGY: FREEBOARD

Freeboard is an additional height that buildings are elevated above the base flood elevation (BFE). Freeboard acts as a factor of safety to compensate for uncertainties in the determination of flood elevations, and provides an increased level of flood protection. Freeboard will result in reduced flood insurance premiums.

Sustainable building design concepts are increasingly being incorporated into residential building design and construction through green building rating systems. While the environmental benefits associated with adopting green building practices can be significant, these practices must be implemented in a manner that does not compromise the building's resistance to natural hazards. FEMA P-798, *Natural Hazards and Sustainability for Residential Buildings* (FEMA 2010b), examines current green building rating systems in a broader context. It identifies green building practices—the tools of today's green building rating systems—that are different from historical residential building practices and that, unless implemented with an understanding of their interactions with the rest of the structure, have the potential to compromise a building's resistance to natural hazards. FEMA P-798 discusses how to retain or improve natural hazard resistance while incorporating green building practices.

1.4 Organization and Use of This Manual

This Manual first provides a history of coastal disasters in the United States, an overview of the U.S. coastal environment, and fundamental considerations for constructing a building in a coastal region. The Manual covers every step in the process of constructing a home in a coastal area: evaluating potential sites; selecting a site; locating, designing, and constructing the building; and insuring and maintaining the building. Flowcharts, checklists, maps, equations, and details are provided throughout the Manual to help the reader understand the entire process. In addition, example problems are presented to demonstrate decisions and calculations designers must make to reduce the potential for damage to the building from natural hazard events.

The Manual also includes numerous examples of siting, design, and construction practices—both good and bad—to illustrate the results and ramifications of those practices. The intent is twofold: (1) to highlight the benefits of practices that have been employed successfully by communities, designers, and contractors, and (2) to warn against practices that have resulted in otherwise avoidable damage or loss of coastal residential buildings.

1.4.1 Organization

Because of its size, the Manual is divided into two volumes, with a total of 15 chapters. Additional supporting materials and resources are available at the FEMA Residential Coastal Construction Web site.

Volume I

Chapter 1 – Introduction. This chapter describes the purpose of the Manual, outlines the content and organization, and explains how icons are used throughout the Manual to guide and advise the reader.

Chapter 2 – Historical Perspective. This chapter summarizes selected past coastal flood and wind events and post-event evaluations, and other major milestones. It documents the causes and types of damage associated with storms and tsunamis ranging from the 1900 hurricane that struck Galveston, TX, to the Samoan tsunami that struck American Samoa following an earthquake in September 2009.

Chapter 3 – Identifying Hazards. This chapter describes coastal processes, coastal geomorphology, and coastal hazards. Regional variations for the Great Lakes, North Atlantic, Middle Atlantic, South Atlantic, Gulf of Mexico, Pacific, Alaska, Hawaii, and U.S. territories are discussed. This chapter also discusses hazards that influence the design and construction of a coastal building (coastal storms, erosion, tsunamis, and earthquakes) and their effects.

Chapter 4 – Siting. This chapter describes the factors that should be considered when selecting building sites, including small parcels in areas already developed, large parcels of undeveloped land, and redevelopment sites. Guidance is also provided to help designers and contractors determine how a building should be placed on a site. Detailed discussions of the coastal construction process begin in this chapter.

Chapter 5 – Investigating Regulatory Requirements. This chapter presents an overview of building codes and Federal, State, and local regulations that may affect construction on a coastal building site. Additionally, the NFIP, Coastal Barrier Resources Act (CBRA), and Coastal Zone Management (CZM) programs are described.

Chapter 6 – Fundamentals of Risk Analysis and Risk Reduction. This chapter summarizes acceptable levels of risk; tradeoffs in decisions concerning siting, design, construction, and maintenance; and cost and insurance implications that should be considered in coastal construction.

Volume II

Chapter 7 – Pre-Design Considerations. This chapter introduces the design process, minimum design requirements, inspections, and sustainable design considerations. It discusses the cost and insurance implications of decisions made during design and construction. It also outlines the contents of Volume II.

Chapter 8 – Determining Site-Specific Loads. This chapter explains how to calculate site-specific loads, including loads from high winds, flooding, seismic events, and tsunamis, as well as combinations of more than one load. Example problems are provided to illustrate the application of design load provisions of ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures* (ASCE 2010).

Chapter 9 – Designing the Building. This chapter contains information on designing each part of a building to withstand expected loads. Topics covered include structural failure modes, load paths, building

systems, application of loads, structural connections, building material considerations, requirements for breakaway walls, and considerations for designing appurtenances.

Chapter 10 – Designing the Foundation. This chapter presents recommendations for the selection and design of foundations. Design of foundation elements including pile capacity in soil, installation methods, and material durability considerations are discussed.

Chapter 11 – Designing the Building Envelope. This chapter describes how to design roof coverings, exterior wall coverings, exterior doors and windows, shutters, and soffits to resist natural hazards.

Chapter 12 – Mechanical Equipment and Utilities. This chapter provides guidance on design considerations of mechanical equipment and utilities, as well as techniques that can improve the capability of equipment to survive a natural disaster.

Chapter 13 – Constructing the Building. This chapter describes how to properly construct a building in a coastal area and how to avoid common construction mistakes that may lessen the ability of a building to withstand a natural disaster. It includes guidance on material choices and durability, and construction techniques for improved resistance to decay and corrosion.

Chapter 14 – Maintaining the Building. This chapter explains special maintenance concerns for new and existing buildings in coastal areas. Methods to reduce damage from corrosion, moisture, weathering, and termites are discussed, along with building elements that require frequent maintenance.

Chapter 15 – Retrofitting Existing Buildings. This chapter includes broad guidance for evaluating existing residential structures to assess the need and feasibility for wildfire, seismic, flood, and wind retrofitting. It also includes a discussion of wind retrofit packages that encourage homeowners to take advantage of opportunities to strengthen their homes while performing routine maintenance (e.g., roof shingle replacement).

Resources and Supporting Material

The FEMA Residential Coastal Construction Web site (http://www.FEMA.gov/rebuild/mat/fema55.shtm) provides guidance and other information to augment the content of this Manual. The material provided on the Web site includes a glossary for this Manual as well as:

- **Resource documents.** Examples include *Dune Walkover Guidance, Material Durability in Coastal Environments,* and *Swimming Pool Design Guidance.*
- **Links and contact information.** Government agencies, professional and trade organizations, code and standard organizations, and natural hazard and coastal science organizations.
- **Links to additional Web sites and coastal construction resources published by FEMA.** Examples include the *Wind Retrofit Guide for Residential Buildings* (FEMA P-804), *Home Builder's Guide to Coastal Construction* (FEMA P-499), and the FEMA Safe Room and Building Science Web sites.

NOTE

In previous editions of the Coastal Construction Manual, Volume III contained appendices and information that expanded on content provided in Volumes I and II. The FEMA Residential Coastal Construction Web site now serves as the location for additional content.

1.4.2 Using the Manual

This Manual uses icons as visual guides to help readers quickly find information. These icons call out notes, warnings, definitions, cross references, cost considerations, equations, example problems, and specific hazards.

Notes. Notes contain supplemental information that readers may find helpful, including things to consider when undertaking a coastal construction project, suggestions that can expedite the project, and the titles and sources of other publications related to coastal construction. Full references for publications are presented at the end of each chapter of the Manual.

Warnings. Warnings present critical information that will help readers avoid mistakes that could result in dangerous conditions, violations of ordinances or laws, and possibly delays and higher costs in a coastal construction project. Any questions about the meanings of warnings in this Manual should be directed to the appropriate State or local officials.

Terminology. The meanings of selected technical and other special terms are presented where appropriate.

Cross references. Cross references point the reader to information that supplements or further explains issues of interest in this Manual, such as technical discussions, regulatory information, equations, tables, and figures.

Cost Considerations. Cost consideration notes discuss issues that can affect short-term and lifecycle and insurance costs associated with a coastal residential construction project.

Equations. Volume II includes equations for calculating loads imposed by forces associated with natural hazard events. It also presents equations used in the design of building components intended to withstand the loads imposed by design events. Equations are numbered for ease of reference.

Examples. In Volume II, example problems demonstrate the calculation of flood, wind, and seismic loads on a coastal residential building. Example problems are numbered for ease of reference.

1.4.3 Hazard Icons

Hazard icons will help readers find information specific to their needs (see below). To use the icons effectively, readers must determine in which flood zone the property or building site in question is located. Chapter 3 of this Manual explains how to make such a determination and includes detailed definitions of the flood hazard zones.

Zone V. Portion of the ***Special Flood Hazard Area*** (SFHA) that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or tsunamis.

Coastal A Zone. A subset of Zone A. Specifically, that portion of the SFHA landward of Zone V (or landward of a coastline without a mapped Zone V) in which the principal source of flooding is coastal storms, and where the potential base flood wave height is between 1.5 and 3.0 feet.

Zone A. Portion of the SFHA in which the principal source of flooding is runoff from rainfall, snowmelt, or coastal storms where the potential base flood wave height is between 0.0 and 3.0 feet.

TERMINOLOGY: SPECIAL FLOOD HAZARD AREA

The SFHA is the land area covered by the floodwaters of the base flood on NFIP maps. It is the area where the NFIP's floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. The SFHA includes Zones A, AO, AH, A1-30, AE, A99, AR, AR/A1-30, AR/AE, AR/AO, AR/AH, AR/A, VO, V1-30, VE, and V.

Zone X. Includes shaded and unshaded Zone X. The flood hazard is less severe here than in the SFHA.

1.4.4. Contact Information

Every effort has been made to make this Manual as comprehensive as possible. However, no single manual can anticipate every situation or need that may arise in a coastal construction project. Readers who have questions not addressed herein should consult local officials. Information is also available from the FEMA Building Science Helpline (Web: http://www.fema.gov/rebuild/buildingscience/, e-mail: FEMA-Buildingsciencehelp@dhs.gov, telephone: 866-927-2104), and the Mitigation Division of the appropriate FEMA Regional Office. Contact information for FEMA personnel, the State NFIP Coordinating Agencies, and the State Coastal Zone Management Agencies are provided on the FEMA Residential Coastal Construction Web page.

1.5 References

ASCE (American Society of Civil Engineers). 2005. *Flood Resistant Design and Construction*. ASCE Standard ASCE 24-05.

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FEMA (Federal Emergency Management Agency). 2000. FEMA 55 (3rd Edition). *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas.* May.

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