Final Report

Reducing Losses through Higher Regulatory Standards

Best Practices and Cost-Effective Strategies Report

FEMA-DR-4145-CO

March 30, 2015

Federal Emergency Management Agency
Department of Homeland Security
500 C Street SW
Washington, DC 20742

This document was prepared by:
Dewberry Consultants LLC
8401 Arlington Boulevard
Fairfax, VA 22031

Contract No.: HSFEHQ-09-D-1129
Task Order: HSFE60-14-J-0007

Acknowledgements

Federal Emergency Management Agency:
Doug Bausch (FEMA Region VIII), Project Monitor
Brooke Buchanan, PE (FEMA Region VIII), Technical Monitor
Michael Gease (FEMA Region VIII)
Jesse Rozelle (FEMA Region VIII)
Casey Zuzak (FEMA Region VIII)

Dewberry:
Catherine Bohn, GISP
John Squerciati, PE, CFM
Kelly Clark, EIT
Deborah Mills, CFM

ACRONYMS AND ABBREVIATIONS i

ACRONYMS AND ABBREVIATIONS I

EXECUTIVE SUMMARY 1

SECTION ONE INTRODUCTION 1-1
- 1.1 Purpose of the Document 1-1
- 1.2 Intended Audience 1-1
- 1.3 Background 1-2
  - 1.3.1 Description of Study Area 1-2
  - 1.3.2 Methodology 1-2
- 1.4 Layout of Report 1-3

SECTION TWO OVERVIEW OF THE SEPTEMBER 2013 COLORADO FLOODS 2-1
- 2.1 Flood Characteristics 2-1
  - 2.1.1 Types of Flooding 2-1
  - 2.1.2 Flood Hazard Forces 2-11
- 2.2 Building Construction and Site Features 2-17
  - 2.2.1 Age 2-17
  - 2.2.2 Foundations 2-18
  - 2.2.3 Basements 2-20
  - 2.2.4 Proximity to Stream 2-20
- 2.3 Event Losses 2-21
- 2.4 Data Collection 2-23
  - 2.4.1 Meetings 2-23
  - 2.4.2 Types of Data 2-25
- 2.5 Overview of Sites Visited 2-26

SECTION THREE BEST PRACTICES AND STRATEGIES 3-1
- 3.1 Freeboard 3-2
  - 3.1.1 Description 3-2
  - 3.1.2 Benefits and Impacts 3-4
  - 3.1.3 Community Successes and Challenges 3-8
- 3.2 Floodplain Development Restrictions 3-8
  - 3.2.1 Critical Facility Siting Restrictions 3-9
  - 3.2.2 Property Acquisition 3-12
- 3.3 Floodway Development Restrictions 3-16
  - 3.3.1 Description 3-16
  - 3.3.2 Benefits and Impacts 3-21
  - 3.3.3 Community Successes and Challenges 3-23
- 3.4 Basement Restrictions 3-23
  - 3.4.1 Description 3-23
  - 3.4.2 Benefits and Impacts 3-24
  - 3.4.3 Community Successes and Challenges 3-28
- 3.5 Outreach Projects 3-28
  - 3.5.1 Description 3-28
  - 3.5.2 Benefits and Impacts 3-29

3.5.3 Community Successes and Challenges 3-31
3.6 Local Drainage Improvements 3-34
3.6.1 Description 3-34
3.6.2 Benefits and Impacts 3-34
3.6.3 Community Successes and Challenges 3-36
3.7 Structural Flood Protection Measures 3-36
3.7.1 Description 3-36
3.7.2 Benefits and Impacts 3-38
3.7.3 Community Successes and Challenges 3-39
3.8 Miscellaneous Measures 3-39
3.8.1 Description 3-39
3.8.2 Benefits and Impacts 3-41
3.8.3 Community Successes and Challenges 3-42

SECTION FOUR CONCLUSION – COST EFFECTIVENESS OF BEST PRACTICES AND STRATEGIES 4-1
4.1 Summary – Comparison of Scenarios to Test Cost-Effectiveness of Strategies 4-1
4.2 Other Best Practices and Strategies 4-4

SECTION FIVE REFERENCES 5-1

APPENDIX A FACTORS THAT INFLUENCE COST EFFECTIVENESS A-1

Figures

Figure 2-1: Aerial Photograph of Colorado Stream Channel Migration (Right) when the Original Channel (Left) Flooded its Banks during the September 2013 Flood. (Source: FEMA Region VIII) 2-3

Figure 2-2: Aerial Photograph of Colorado Community Showing Roadway Damage (Circled in Red) from Stream Bank Erosion and Channel Migration. (Source: FEMA Region VIII) 2-3

Figure 2-3: Garage Undermined by Erosion and Stream Channel Migration in Lyons, Boulder County, CO. (Source: FEMA Contractor, June 18, 2014) 2-4

Figure 2-4: Aerial Photograph of County Line Road Showing Stream Channel Migration through Gravel Pits, Longmont, CO. (Source: City of Longmont) 2-4

Figure 2-5: Flash and Alluvial Fan Flood Damage to Roadways and Concrete Paths at 2-Mile Canyon Creek along Broadway, City of Boulder, CO. (Source: City of Boulder) 2-5

Figure 2-6: Alluvial Fan Flood-Borne Debris in Residential Garage on Willowbrook Court, City of Boulder, CO. (Source: City of Boulder) 2-6

Figure 2-7: Aerial Photograph of One of Over 200 miles of Colorado Highways Undermined by Stream Bank Erosion and Damaged by the Flood. (Source: FEMA Region VIII) 2-7

Figure 2-8: Mobile Home Park Damages, Lyons, Boulder County, CO. According to FEMA Individual Assistance Program Data, the 2013 Flood Damaged 8 Percent of Mobile Homes Located in the SFHA. (Source: FEMA Contractor, June 18, 2014) 2-8

Figure 2-9: Aerial Photograph of Longmont Wastewater Treatment Plant Flood Damage, Longmont, CO. Flood Mitigation Strategies for WWTPs Include Perimeter Flood Barriers or Elevation of Key Equipment and Components. (Source: City of Longmont) 2-8

Figure 2-10: Photos Showing Similarities Between the September 2013 Flood (left) and the 1894 Flood (right) from Left Hand Creek at Main Street, Longmont, CO. Both Events were Locally Estimated as 100-year Floods. (Source: City of Longmont) 2-9

Figure 2-11: Poudre River Flooding from a 50-year Event on Downstream Side of Shields Street Bridge in Fort Collins, CO. (Source: City of Fort Collins Utilities, September 13, 2013) 2-9

Figure 2-12: High Water Mark on Wall of Ground Level Condominium Unit in SFHA from Trash Rack Backup Flooding along nearby Wonderland Creek, City of Boulder, CO. (Source: City of Boulder) 2-10

Figure 2-13: Diagram of Hydrostatic Forces. (Source: FEMA P-259) 2-11

Figure 2-14: Diagram of Hydrodynamic Forces. (Source: FEMA P-259) 2-12

Figure 2-15: Diagram of Flood-Borne Debris Impact. (Source: FEMA P-259, modified) 2-13

Figure 2-16: Washout of County Line Road Bridge during the September 2013 Flood, Longmont, CO. Flooding along County Line Road caused by Floodwaters Flowing into Gravel Pits (Source: City of Longmont) 2-14

Figure 2-17: Scour Action around a Ground-Level Building. (Source: FEMA P-259). 2-14

Figure 2-18: Bank Erosion Damage along Big Thompson Creek in Estes Park, CO. (Source: FEMA Contractor, August 19, 2014) 2-15

Figure 2-19: Greenway Undermined by Erosion and Stream Migration along Fish Creek, Estes Park, CO. (Source: FEMA Contractors, August 19, 2014) 2-16

Figure 2-20: Erosion Damage at No Name Creek Subdivision in Frederick, CO. (Source: FEMA Contractor, August 19, 2014) 2-16

Figure 2-21: Foundation Types. (Source: FEMA P-784) 2-19

Figure 2-22: Summary of 2013 Flood Losses for Study Communities. 2-22

Figure 2-23: Detail Map of Six Study Communities within Boulder, Larimer and Weld Counties. (Source: Regulatory Losses Avoided Study) 2-28

Figure 3-1: Concept of Freeboard. (Source: FEMA P-259, Figure 4-5 [adjusted]) 3-3

Figure 3-2: *Left* - An Estes Park business owner next to his building that was not damaged in the 2013 flooding due to elevating the structure. *Right* - View behind the elevated structure looking at the Big Thompson River during the 2013 flooding. (Source: Town of Estes Park) 3-4

Figure 3-3: Overall Impact on Losses Avoided in Boulder, Larimer, and Weld Counties Associated with Varying Freeboard for the 100-year Flood..... 3-6

Figure 3-4: Study Community Losses and Losses Avoided Associated with +2 feet Freeboard in the 100-year Flood Event..... 3-7

Figure 3-5: Distribution of Study Community Losses Avoided Associated with +2 feet Freeboard in the 100-year Flood Event..... 3-7

Figure 3-6: Study Community Losses and Losses Avoided Associated with Removal of Critical Facilities from the SFHA in the 100-year Flood Event..... 3-10

Figure 3-7: Distribution of Study Community Losses Avoided Associated with Removal of Critical Facilities from the SFHA in the 100-year Flood Event 3-10

Figure 3-8: Royal Mobile Home Park Flood Damage – Property Purchased and Converted to Perpetual Green Space by the City Following the 2013 Flood, Longmont, CO. (Source: City of Longmont, CO)..... 3-13

Figure 3-9: Study Community Losses and Losses Avoided to SFHA Structures in Boulder, Larimer, and Weld Counties in the 100-year Flood Event 3-14

Figure 3-10: Distribution of Study Community Losses Avoided to SFHA Structures in Boulder, Larimer and Weld Counties in the 100-year Flood Event 3-15

Figure 3-11: Typical Riverine Floodplain Cross Section Showing the Floodway and Surcharge Height (Source: FEMA P-259, Figure 2-3) 3-16

Figure 3-12: Floodway Location Shown as Cross-Hatched Area on FIRM. (Source: FEMA Map Service Center, FIRM for Lyons in Boulder County, CO) .. 3-17

Figure 3-13: Open space preserved in McMurry Natural Area and Legacy Park along the Poudre River in Fort Collins. Floodwaters in the September 2013 event were able to spread out and slow down and not cause any damages. (Source: City of Fort Collins) 3-18

Figure 3-14: Elmer's Two Mile Creek Greenways Project, Which Suffered Minimal Flood Damage, City of Boulder, CO. (Source: FEMA Contractor, August 2014) 3-19

Figure 3-15: Left Hand Creek Channel Improvement Projects Protected Nearby Residence from September 2013 Flood Damage. (Source: FEMA Contractor, June 2014)..... 3-20

Figure 3-16: Total Losses and Losses Avoided to Floodway Structures in Study Communities in the 100-year Flood Event 3-22

Figure 3-17: Distribution of Total Losses to Floodway Structures in Study Communities in the 100-year Flood Event 3-22

Figure 3-18: Total Losses to Basement Structures in the SFHA for Study Communities in the 100-year Flood Event 3-25

Figure 3-19: Distribution of Total Losses to Basement Structures in the SFHA for Study Communities in the 100-year Flood Event 3-26

Figure 3-20: Total FEMA IA Losses to Basement Structures in the September 2013 Flood Event 3-27

Figure 3-21: Distribution of Total FEMA IA Losses to Basement Structures in the September 2013 Flood Event 3-28

Figure 3-22: NFIP Policies Inside Versus Outside the SFHA for Select CRS Study Communities 3-30

Figure 3-23: NFIP Pre-FIRM Versus Post-FIRM Policies for Select CRS Study Communities 3-30

Figure 3-24: NFIP Claims Inside Versus Outside the SFHA and Distribution of Total Claims for Select CRS Study Communities 3-31

Figure 3-25: Gilbert White Flood Elevation Memorial along Boulder Creek, Boulder CO 3-32

Figure 3-26: City of Fort Collins *Floodplain Management Public Information Committee: A Program for Public Information*, August, 2014. (Source: Marsha Hilmes-Robinson). 3-33

Figure 3-27: Regional Flood Detention Pond, Frederick, CO. (Source: FEMA Contractor, August 2014) 3-35

Figure 3-28: Stormwater Management Pond on Colorado State University Campus, City of Boulder, CO (Source: FEMA Contractor, October 2014) 3-35

Figure 3-29: Post-Flood Residential Elevation in Progress, Lyons, Boulder County, CO. (Source: FEMA Contractor, June 2014) 3-37

Figure 3-30: Aerial Photograph of Seven Lakes Business Park Elevated Buildings Protected from Flood Damage, Fort Collins, CO. (Source: City of Fort Collins Utilities, September 2013) 3-37

Figure 3-31: Non-Residential Dry Floodproofing Project on 15th Street, City of Boulder, CO. (Source: FEMA Contractor, August 2014) 3-38

Figure 3-32: Residences along Fish Creek in Estes Park were Protected by Erosion Setbacks. (Source: FEMA Contractor, August 2014) 3-40

Figure 3-33: The Toby Lane Development in Boulder was protected from September 2013 flood damage because homes were elevated two feet above the 100-year flood elevation. (Source: City of Boulder) 3-41

Figure 4-1: Comparison of 100-year Flood Event Losses Avoided in Lyons for Best Practices and Strategies 4-1

Figure 4-2: Comparison of 100-year Flood Event Losses Avoided in Longmont for Best Practices and Strategies 4-2

Figure 4-3: Comparison of 100-year Flood Event Losses Avoided in City of Boulder for Best Practices and Strategies 4-2

Figure 4-4: Comparison of 100-year Flood Event Losses Avoided in Fort Collins for Best Practices and Strategies 4-3

Figure 4-5: Comparison of 100-year Flood Event Losses Avoided in Study Communities for Best Practices and Strategies 4-3

Tables

Table 2-1: Communities Visited for the Best Practices and Strategies Report 2-1

Table 2-2: Summary of Structure Age Information for Communities Visited 2-17

Table 2-3: Summary of Basement Information for Communities Visited 2-20

Table 2-4: Summary of Structure Flood Zone Information for Communities Visited .. 2-21

Table 2-5: NFIP Claims Paid from the 2013 Flood 2-22

Table 2-6: IA Program Loss Claims as a Result of the 2013 Flood Event 2-23

Table 2-7: SBA Verified Losses as a Result of the 2013 Flood Event 2-23

Table 2-8: Interviews 2-23

Table 2-9: Summary of Information Obtained in Community Interviews 2-24

Table 2-10: Data Collected from Community Officials 2-25

Table 2-11: Summary of Population and Total Losses Verified by FEMA IA, NFIP Claims Data, and SBA in Study Communities 2-26

Table 3-1: Summary of Best Practices and Strategies by Study Communities Where Applied 3-1

Table 3-2: Freeboard Impacts to Counties for Predicted 100-year Flood Event 3-5

Table 3-3: Open Space Preserved in the Poudre River 100-year Floodplain in Fort Collins. 3-18

Table 3-4: Losses Avoided Results for the Left Hand Creek Channel Improvement in Longmont, CO. 3-20

Table 3-5: Residential Basement Types in Study Area 3-24

Table 3-6: Total Buildings with Basements in Study Communities 3-25

Table 3-7: FEMA IA Basement Only Loss Data for the 2013 Flood in Study Communities 3-26

Table 3-8: CRS Communities in Boulder, Larimer, and Weld Counties 3-29

Table 3-9: 2013 Colorado Floods Erosion Setback Assessment 3-42

Table 4-1: Summary of Overall Cost-Effectiveness of Best Practices and Strategies for the Study Communities Based on the 100-year Flood Event.....4-4

ACRONYMS AND ABBREVIATIONS

BCA	Benefit Cost Analysis
BFE	Base Flood Elevation
BRV	Building Replacement Value
CFM	Certified Floodplain Manager
CRS	Community Rating System
CRV	Contents Replacement Value
DDF	Depth Damage Function
DFE	Design Flood Elevation
FEMA	Federal Emergency Management Agency
FFE	First Floor Elevation
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
HMGP	Hazard Mitigation Grant Program
HWM	High Water Mark
JFO	Joint Field Office
IA	Individual Assistance
LA	Losses Avoided
LAS	Loss Avoidance Studies
LP	Loss of Productivity
MP_A	Mitigation Project Absent
MP_C	Mitigation Project Complete
NFIP	National Flood Insurance Program
PDM	Pre-Disaster Mitigation
PVC	Present Value Coefficient
PW	Project Worksheets
RI	Recurrence Interval
SD	Substantial Damage
SDE	Substantial Damage Estimator
SFHA	Special Flood Hazard Area
UDFCD	Urban Drainage and Flood Control District

EXECUTIVE SUMMARY

In September 2013, an unprecedented rainfall event occurred along Colorado's Front Range of the Rocky Mountains resulted in catastrophic flooding that impacted 18 Colorado counties and 132 jurisdictions. After an event of this magnitude, the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) would typically conduct a loss avoidance study (LAS) to assess the cost-effectiveness of mitigation measures such as acquisition of properties in the floodplain and implementing flood control measures. However, the September 2013 floods provided a unique opportunity to evaluate the losses avoided through a non-traditional approach. The primary focus of this study is to evaluate the impacts of floodplain management through higher regulatory standards and policy actions. Additionally, the LAS examined a more traditional mitigation project in Longmont, Colorado.

While 18 counties experienced significant damages from the September 2013 floods, the most substantial and severe damages were in Boulder, Larimer, and Weld Counties. Moreover, these counties have some of the highest-rated National Flood Insurance Program (NFIP) Community Rating System (CRS) jurisdictions in Colorado. Conversely, several jurisdictions in these counties do not participate in the NFIP, providing an opportunity to compare community-level approaches to floodplain management. This report was developed based on a review of existing 2013 flood event damage data supplemented with site visits to six impacted communities (Lyons, Longmont, City of Boulder, Fort Collins, Estes Park, and Frederick) in the study area of Boulder, Larimer, and Weld Counties. This effort identified and evaluated best practices and potentially cost-effective strategies based on the regulatory LAS described in *Reducing Losses through Higher Regulatory Standards 2013 Colorado Floods Case Study (FEMA-DR-4145-CO)*. This report uses specific scenarios developed from the regulatory LAS for the 100-year flood event to assess and compare the benefits of implementing higher regulations, and includes a summary of results.

This report discussed a wide range of observed and anecdotal best practices and potentially cost-effective strategies that were successful in reducing losses from the September 2013 floods. Further analysis of these best practices and strategies led to the following key findings and conclusions:

- Based on a comparison of 100-year flood event losses avoided achieved from various best practices and strategies related to higher regulatory standards in the six impacted communities highlighted in this study, regulatory best practices and strategies determined to have the most impact were:
    - Requiring increased freeboard as part of design standards
    - Restricting floodplain development
    - Restricting construction of basements in new or expanded Special Flood Hazard Areas (SFHAs)
- Restricting floodway development and eliminating critical facilities from the SFHA were considered to have significant positive impacts on losses avoided.

- In addition to best practices and strategies related to implementing higher regulatory standards, best practices and strategies observed in the field to have the potential to be cost-effective were:
  - Outreach projects in communities that participate in the NFIP's Community Rating System (CRS) to make residents and business owners more aware of flood risks were shown to increase the number of flood insurance policies purchased in and outside the SFHA. For example, the City of Boulder, a CRS Class 5 community, had 4,012 NFIP policies in force as of December 31, 2012, far exceeding the 1,932 NFIP policies in the remaining communities and unincorporated areas of Boulder County.
  - Local drainage improvements such as channel modifications, stormwater management regulations and practices, and construction of detention ponds can also reduce the impacts of flood events and reduce nuisance flooding from local drainage issues. Minimal losses in Fort Collins point to the value of extensive investments in drainage improvement, stormwater management, and river and stream stability projects in the city. This extends to the campus of Colorado State University, where an aggressive landscape architecture approach to floodproofing has yielded numerous best practices and has resulted in greatly reduced flood damages since installation.
  - Basement losses to buildings outside of the SFHA accounted for 22 percent of the loss documented through building inspections performed for the FEMA Individuals and Households Assistance Program. As Flood Insurance Rate Maps (FIRMs) are updated and the SFHA changes, basements will not be allowed in new construction. Communities may also wish to restrict basements in an expanded geographic footprint such as the 500-year floodplain or in mapped alluvial fan areas.
  - Structural flood protection measures that include more traditional structural mitigation projects such as elevation, dry floodproofing, and flood barriers were successful in preventing or minimizing flood damage. These projects were observed to be successful in mitigating flood damages, but represent a small percentage of building stock in the studied communities.
  - Miscellaneous measures such as erosion setbacks, systems or protocols to expedite post-flood recovery, and higher standards for Approximate A-Zones were successful in reducing flood damages and losses.
- While acquisition of flood-prone properties is considered the gold standard of mitigation, it often presents challenges. With nearly 6,000 buildings in the regulated floodplain in the three study counties, it is unlikely that funding would be available to acquire all properties and convert them to open space, or that all property owners would be willing to participate. Additionally, some community officials may resist large-scale property acquisitions out of concerns related to reducing the local tax base or discouraging growth.

SECTION ONE INTRODUCTION

In March 2014, FEMA Region VIII initiated an evaluation of the impacts of floodplain management regulation and policy on losses avoided in flood events because of the 2013 Colorado floods. The desired outcome of the analysis was to determine and highlight the best practices and cost-effective strategies that proved effective in minimizing flood damages. The tasks undertaken in this study include the evaluation of best practices, higher standards floodplain management ordinance requirements, and strategies used. Lessons learned and observations by community officials were interpreted and incorporated into the analysis of best practice strategy performance and losses avoided for a predicted 100-year flood event.

This section describes the purpose of this report, its intended audience, the study area and methodology, and the report layout.

1.1 PURPOSE OF THE DOCUMENT

The report identifies and evaluates best practices and cost-effective strategies designed to reduce flood damage losses in the future. Best practices are mitigation measures that are proven to be effective in reducing flood damages and economic losses; this study focuses on implementation of higher floodplain management regulatory standards as a best practice. A LAS entitled *Reducing Losses through Higher Regulatory Standards - 2013 Colorado Floods Case Study* ("Regulatory LAS"), summarizes the 2013 Colorado flood event losses and evaluates the effectiveness of various regulatory measures. This companion report focuses on the floodplain management ordinance requirements evaluated in that study. In addition, this volume summarizes mitigation measures not included in the Regulatory LAS that were observed from event accounts or field observations that were effective in preventing or reducing the severity of flood damage.

Higher standards that can be included in community floodplain management ordinances were reviewed for success as well as cost effectiveness. Cost effectiveness is related to the value of buildings exposed to flood hazards, along with their risk and vulnerability. Cost effectiveness is determined through analysis of the cost of implementing the regulatory measure, the expected useful life of the building, and the overall effectiveness of the measure to reduce future flood damages and losses. These factors were evaluated and incorporated into this study.

1.2 INTENDED AUDIENCE

This report is intended for floodplain administrators, emergency managers, building inspectors, code enforcers, planning districts, and community officials. The details of this study will assist community officials in making informed decisions about considering adopting higher standards in their floodplain management ordinances, joining the CRS, or employing other best practices or mitigation measures. The findings and recommendations are also relevant for representatives from FEMA's hazard mitigation program and state agencies.

1.3 BACKGROUND

The background section provides a description of the study area and of the study methodology. The study focuses on six communities in the study area of Boulder, Larimer, and Weld Counties. These communities are Lyons, Longmont, City of Boulder, Fort Collins, Estes Park, and Frederick. The study methodology involves site visits, data collection, analysis, and review of the potential best practices and cost-effective strategies. The methodology is described in Section 1.3.2.

1.3.1 Description of Study Area

The September 2013 Colorado floods caused extensive damage and losses in Boulder, Larimer, and Weld Counties. The impacted communities in these three counties include some of the highest-rated NFIP CRS jurisdictions in Colorado, as well as jurisdictions that do not participate in the NFIP. Significant losses occurred both in and outside regulatory floodplains as a direct result of riverine flooding, as well as due to soil erosion and overland flooding.

Community-specific information was collected for Fort Collins, Longmont, Estes Park, Frederick, Lyons, and City of Boulder between June and August of 2014 through field visits and meetings with local officials. These communities are all in the 2013 flood-impacted area, have Geographic Information Systems (GIS) data available, and participate in the NFIP. In addition, three communities (City of Boulder, Longmont, and Fort Collins) participate in the CRS, and the City of Boulder is located in the Urban Drainage and Flood Control District (UDFCD), which assists local governments in floodplain management.

1.3.2 Methodology

The best practices and cost-effective strategies study methodology involves data collection, analysis and field observation of 2013 flood event losses, review of the Regulatory LAS analysis, and a 100-year flood event analysis of the proposed best practices and cost-effective strategies. The approach is as follows:

1) Collect 2013 Colorado flood event data including event photographs and data from FEMA and local officials.
2) Conduct site visits to impacted areas with local officials and FEMA Region VIII and meet with community floodplain managers and other officials to discuss lessons learned including local successes and failures observed from the 2013 Colorado flood event.
3) Review flood characteristics of the 2013 Colorado flood event and the building construction and siting features of the study area.
4) Review the Regulatory LAS results to identify the best practices included in the study.
5) Identify mitigation measures as potential best practices and strategies.
6) Perform a baseline (100-year flood event) analysis of losses avoided for the measures identified to quantify the effectiveness of best practices and strategies in reducing losses, then summarize the factors that impact the success of the measure.

1.4 LAYOUT OF REPORT

The study methodology is described in Section Three and Appendix A. In total, this report is composed of five sections and one appendix.

Executive Summary – summarizes the main points of the report, reviews best practices and cost-effective strategies studied, and lists general conclusions.

Section 1 – Introduction describes the purpose of the report, the intended audience, the study background information, and the report layout.

Section 2 – Overview of the September 2013 Colorado Flood describes the specific issues related to the September 2013 Colorado flood event throughout the studied impact area.

Section 3 –Best Practices and Strategies summarizes and describes the best practices and strategies included in the study and includes best practice examples from throughout the study region.

Section 4 – Conclusions - Cost Effectiveness of Best Practices and Strategies summarizes the relative cost-effectiveness of best practices and strategies evaluated in this study. In this section, the 100-year base flood event is used as the baseline for comparing the effectiveness of the strategies.

Section 5 – References used in this study as well as other publications that can be useful to local officials, property owners, policy makers, contractors, and designers are listed. Many are archived on the FEMA website at www.fema.gov.

Appendix A – Cost-Effectiveness Study Methodology contains a technical summary of the key factors that influence cost effectiveness and details on the cost effectiveness methodology.

SECTION TWO OVERVIEW OF THE SEPTEMBER 2013 COLORADO FLOODS

Section Two provides an overview of the September 2013 Colorado floods (FEMA-DR-4145-CO). Sections 2.1, 2.2 and 2.3 address the unique flood characteristics, building construction and siting features, and regulatory frameworks in the communities in Boulder, Larimer, and Weld Counties that were impacted by the declared flood event. Section 2.4 describes the data collected for this study. Section 2.5 provides an overview of six communities visited in Boulder, Larimer, and Weld Counties shown in Table 2-1.

Table 2-1: Communities Visited for the Best Practices and Strategies Report

Community	County	Visit Date(s)
Lyons	Boulder	June 18, 2014
Longmont	Boulder	June 18, 2014 and August 20, 2014
City of Boulder	Boulder	August 20, 2014
Fort Collins	Larimer	June 18, 2014
Estes Park	Larimer	August 19, 2014
Frederick	Weld	August 19, 2014

2.1 FLOOD CHARACTERISTICS

This section addresses the types of flooding and the associated flood hazards that were encountered in the six visited communities in Boulder, Larimer, and Weld Counties during the September 2013 Colorado flood.

2.1.1 Types of Flooding

As indicated in the Regulatory LAS report, the September 2013 Colorado flood first formed on September 9, 2013, when a slow-moving cold front stalled over Colorado and combined with warm, humid air from the south to generate heavy rainfall for several days in Boulder County and surrounding counties. Statistics from the Colorado Climate Center recorded over 17 inches of rainfall between September 11, 2013 and September 15, 2013, which shattered previous records and approached Boulder County's average annual precipitation of 20.7 inches. According to the National Oceanic and Atmospheric Administration's Hydrological Design Studies Center, this amounted to a maximum 1,000-year rainfall event (0.1% annual probability) in some locations.

This unprecedented rainfall resulted in a wide range of flood characteristics in the various watersheds of the 18 declared jurisdictions. The following is a brief description of the types of flooding that occurred in the six communities visited in Boulder, Larimer, and Weld Counties.

<u>Flash Flooding (Channel Migration)</u>

Flash flooding is a type of flooding that occurs in or near areas with steep topography such as mountain canyons or in small drainage areas, where floodwaters can rise quickly without

warning. Flash floods are typically accompanied by deep, rapidly moving floodwaters with significant potential for flood-borne debris impacts, and erosion and scour. In some cases, the magnitude and speed of a flash flood can lead to channel migration, which occurs when a rapidly moving flash flood overwhelms the existing stream channel and creates a new channel. Flash flooding and channel migration occurred in several communities during the September 2013 flood including Lyons, Longmont, and City of Boulder.

Colorado is a semi-arid dry gulch state and has experienced flash flooding throughout its recorded history. The Big Thompson River begins around Estes Park in northern Colorado and flows east through the state into Big Thompson Canyon. On July 31, 1976, meteorological conditions similar to what happened in September 2013 caused what is now called the Big Thompson Flood of 1976. During the first hour, eight inches of rainfall was recorded; a total of 12 inches fell during the first three hours. One hundred-forty four people lost their lives and roughly $140 million in damages (adjusted to 2013 values) occurred.

Comparatively to the Big Thompson Flood of 1976, the September 2013 flood was caused by approximately 15 inches of rainfall over the span of a week, which killed eight people and caused $2 billion in damage. The rainfall in 2013 was clearly more than that in 1976; however, the flooding was more intensive in 1976 because the rain fell in a much shorter time frame and caught many people by surprise. In 2013, The Big Thompson River experienced peak flow rates near Loveland, Colorado of 4,500 cubic feet per second (cfs) before the measuring gauge was destroyed by floodwaters. In 1976, the same area of the river saw peak flow rates of 31,200 cfs. As a result, this is not the worst flooding Colorado has seen, but it is the heaviest rainfall Colorado has seen.

The photographs at Figures 2-1 through 2-5 show examples of flash flood impacts, channel migration, and building damages.

Figure 2-1: Aerial Photograph of Colorado Stream Channel Migration (Right) when the Original Channel (Left) Flooded its Banks during the September 2013 Flood. (Source: FEMA Region VIII)

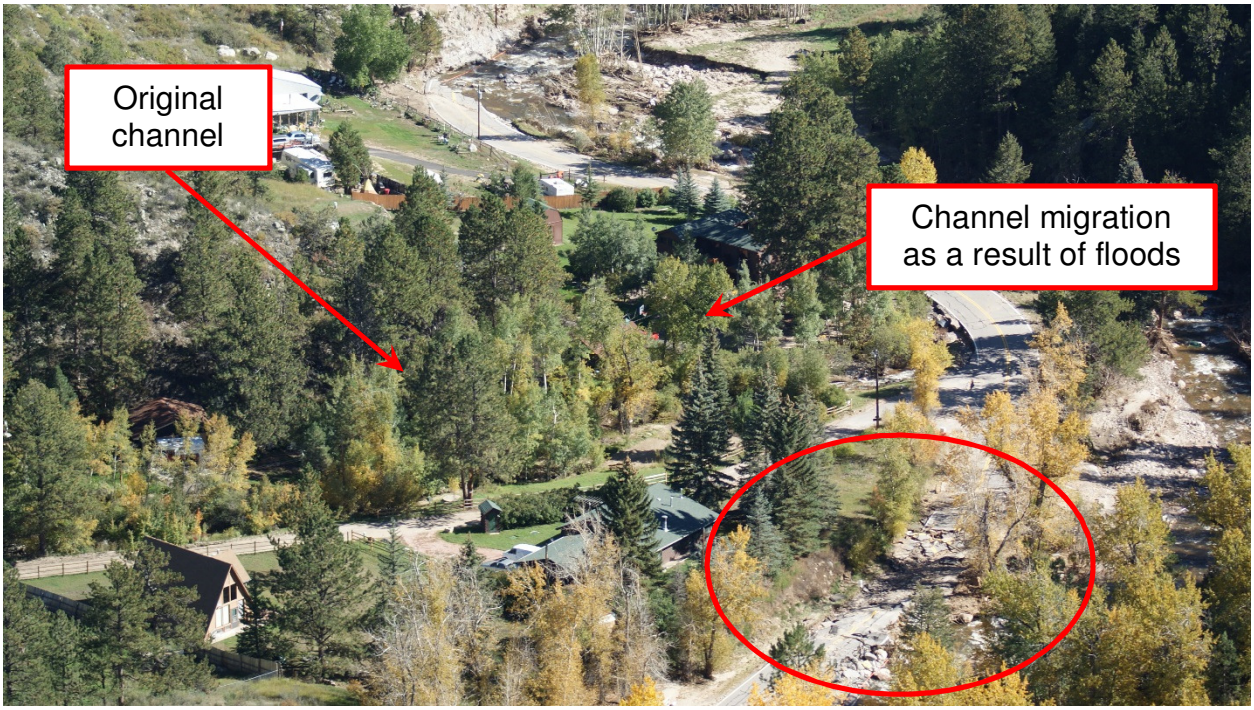

Figure 2-2: Aerial Photograph of Colorado Community Showing Roadway Damage (Circled in Red) from Stream Bank Erosion and Channel Migration. (Source: FEMA Region VIII)

Figure 2-3: Garage Undermined by Erosion and Stream Channel Migration in Lyons, Boulder County, CO. (Source: FEMA Contractor, June 18, 2014)

Figure 2-4: Aerial Photograph of County Line Road Showing Stream Channel Migration through Gravel Pits, Longmont, CO. (Source: City of Longmont)

Figure 2-5: Flash and Alluvial Fan Flood Damage to Roadways and Concrete Paths at 2-Mile Canyon Creek along Broadway, City of Boulder, CO. (Source: City of Boulder)

2.1.1.1 Alluvial Fan Flooding

Alluvial fan flooding is a type of flooding that occurs in mountainous regions such as Colorado. Alluvial fans are formed in mountainous regions by floodwater that spreads out in a fan shape as it flows from the mouth of a watershed to the valley below. Alluvial fan floods are characterized by heavy flows of rapidly moving floodwater, mud, and debris, accompanied by erosion and scour that spread out over the surface of the alluvial fan. Over time, the floodwaters repeatedly erode the steep slopes of the watershed and deposit layers of sediment in a cone or fan shape over the flatter land creating an alluvial fan. Although some media reports indicated widespread alluvial fan flooding in areas of Colorado during the September 2013 flood, a review of data from Boulder, Larimer, and Weld Counties provided only a handful of alluvial fan flooding accounts (Figures 2-5 and 2-6). Additionally, of the six communities discussed in Section Three, only the City of Boulder indicated a limited occurrence of alluvial fan flooding during the September 2013 event. Refer to Appendix D of FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, Third Edition (January 2012) for additional details on alluvial fan flooding hazards. Additional information on alluvial fans is found in FEMA 165, *Alluvial Fans: Hazards and Management*, available for scan download at http://www.fema.gov/media-library-data/20130726-1504-20490-3060/fema165.pdf.

Figure 2-6: Alluvial Fan Flood-Borne Debris in Residential Garage on Willowbrook Court, City of Boulder, CO. (Source: City of Boulder)

2.1.1.2 Riverine Flooding

Riverine flooding is a common type of flooding that occurs when a stream channel overflows its banks and spreads into the surrounding floodplain. Riverine flooding is typically triggered by rain storms or snowmelt that flows downstream under the force of gravity, and is accompanied by moving floodwaters as well as the potential for flood-borne debris, erosion, and scour. The depth, duration, and velocity of a riverine flood can vary based on a broad range of factors, including storm characteristics, topography, watershed size and slope, and the degree of upstream development. Other factors that can impact the severity of a riverine flood include channel obstructions caused by accumulated debris, bridge or culvert openings that are insufficient to convey floodwaters, stream bank erosion, level of sediment deposition, and density of floodway and floodplain development.

Riverine flooding occurred in many communities during the September 2013 flood, including Longmont, Frederick, and Fort Collins. Figures 2-7 through 2-11 are photographs showing examples of riverine flooding from the September 2013 flood.

Figure 2-7: Aerial Photograph of One of Over 200 miles of Colorado Highways Undermined by Stream Bank Erosion and Damaged by the Flood. (Source: FEMA Region VIII)

Figure 2-8: Mobile Home Park Damages, Lyons, Boulder County, CO. According to FEMA Individual Assistance Program Data, the 2013 Flood Damaged 8 Percent of Mobile Homes Located in the SFHA. (Source: FEMA Contractor, June 18, 2014)

Figure 2-9: Aerial Photograph of Longmont Wastewater Treatment Plant Flood Damage, Longmont, CO. Flood Mitigation Strategies for WWTPs Include Perimeter Flood Barriers or Elevation of Key Equipment and Components. (Source: City of Longmont)

Figure 2-10: Photos Showing Similarities Between the September 2013 Flood (left) and the 1894 Flood (right) from Left Hand Creek at Main Street, Longmont, CO. Both Events were Locally Estimated as 100-year Floods. (Source: City of Longmont)

Figure 2-11: Poudre River Flooding from a 50-year Event on Downstream Side of Shields Street Bridge in Fort Collins, CO. (Source: City of Fort Collins Utilities, September 13, 2013)

2.1.1.3 Local Drainage Flooding

Local drainage flooding is another common type of flooding that occurs as a consequence of riverine flooding. Local drainage flooding typically occurs when the level of overland water flow from rainfall or snowmelt exceeds the capacity of a community's stormwater drainage system, leading to flooding of buildings and infrastructure. The characteristics and severity of local drainage flooding can vary based on the same factors as riverine flooding, as well as the design capacity of the local stormwater drainage system. Local drainage flooding occurred in many communities during the September 2013 flood, including Longmont, City of Boulder, Estes Park, and Frederick. Figure 2-12 shows damages from local drainage flooding. Note that local drainage flood hazards are not always mapped on FIRMs.

Figure 2-12: High Water Mark on Wall of Ground Level Condominium Unit in SFHA from Trash Rack Backup Flooding along nearby Wonderland Creek, City of Boulder, CO.
(Source: City of Boulder)

2.1.2 Flood Hazard Forces

This section briefly describes the flood hazard forces observed in the September 2013 flood event and the types of flooding associated with these forces.

2.1.2.1 Hydrostatic Forces (Inundation)

Hydrostatic forces are generated by standing water and are primarily a function of flood depth. As illustrated in Figure 2-13, hydrostatic forces include lateral hydrostatic forces on walls and vertical hydrostatic (buoyancy) forces on slabs and floors. Lateral hydrostatic forces can become large enough to force water through walls, fail connections between walls and floors, and collapse wood or masonry walls at flood depths as low as three feet. Vertical hydrostatic forces can become large enough to crack or collapse floor slabs. Refer to Chapter 4 of FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, Third Edition (January 2012) for additional details on calculating hydrostatic forces. The structural damage associated with lateral and vertical hydrostatic forces can be reduced to zero if structures are elevated above the design flood elevation (DFE) and hydrostatic openings are added below the flood elevation in accordance with NFIP regulations; however, once floodwaters flow into unfinished basements or enter the interior finished areas of a structure, the non-structural elements and contents of these areas are subject to inundation damage and other losses caused by the deterioration of interior finishes, damage and losses of building systems, and loss of contents.

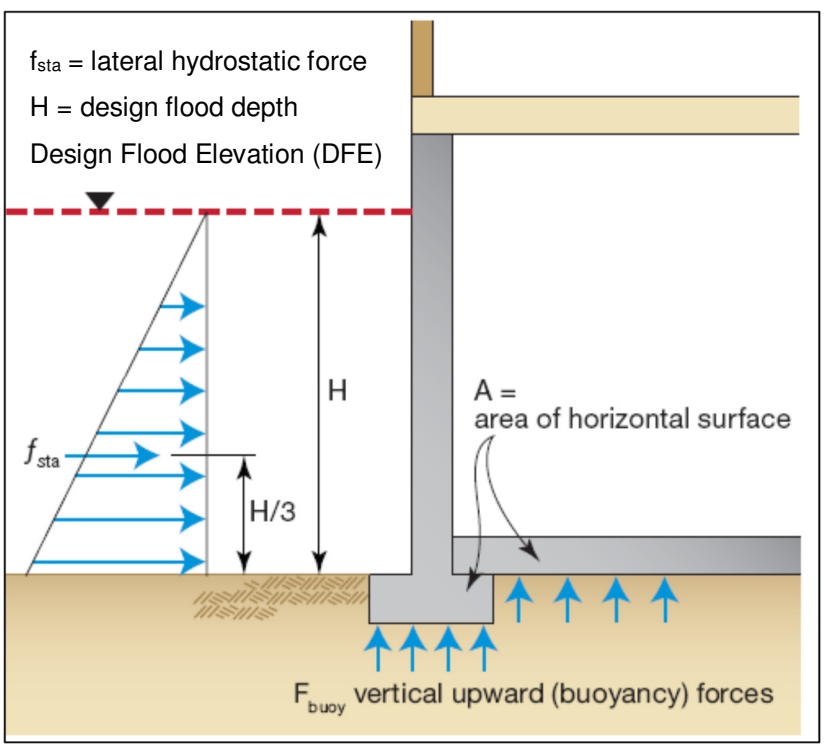

Figure 2-13: Diagram of Hydrostatic Forces. (Source: FEMA P-259)

Hydrostatic forces and flood water inundation can occur in all of the types of flooding listed in Section 2.1.1 (i.e., flash, alluvial fan, riverine, and local drainage) and were observed in all six communities visited in Boulder, Larimer, and Weld Counties. Figure 2-12 illustrates damages from hydrostatic forces and flood inundation that resulted from localized drainage flooding.

2.1.2.2 Hydrodynamic Forces

Hydrodynamic forces are generated by moving water and are primarily a function of flood velocity. As illustrated in Figure 2-14, hydrodynamic forces that can act on a structure include frontal impact on the upstream side, drag effects on the sides as the water moves around the structure, and negative pressure or suction on the downstream side. As flood velocities increase beyond 5 to 10 feet per second, hydrostatic forces from severe flooding can become large enough to move a building off its foundation; additionally, larger hydrodynamic forces from high-velocity flooding are associated with flood-borne debris impact, erosion, and scour. Refer to Chapter 4 of FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures,* Third Edition (January 2012) for additional details on calculating hydrodynamic forces.

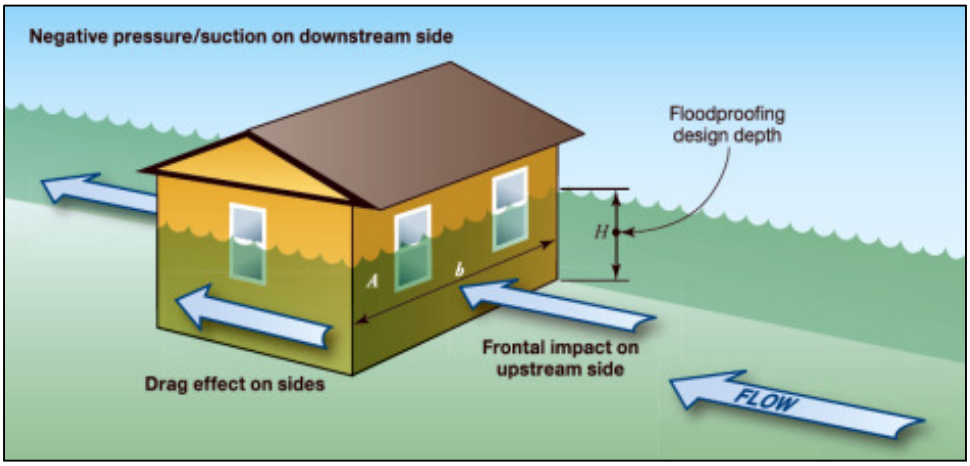

Figure 2-14: Diagram of Hydrodynamic Forces. (Source: FEMA P-259)

Hydrodynamic forces can occur in all of the types of flooding listed in Section 2.1.1 (i.e., flash, alluvial fan, riverine, and local drainage), but tend to be the most severe in high-velocity riverine, flash, or alluvial fan floods. Hydrodynamic forces were observed in most of the communities visited in this study including Lyons, Longmont, City of Boulder, and Estes Park. Damages from this type of flooding occurred throughout the Front Range communities during the September 2013 flood as well as the 1976 Big Thompson Flood. Figures 2-5 and 2-11 from Section 2.1.1 provide examples of damage from hydrodynamic forces due to flash/alluvial fan and riverine flooding, respectively.

2.1.2.3 Flood-borne Debris Impact

Moving floodwaters usually carry some debris that has been picked up upstream, as shown in Figure 2-15. The debris carried by floodwaters commonly includes tree limbs, dislodged tanks, and remnants of structures. In some cases, debris strikes cause damage to buildings and retaining

wall structures. In other cases, the debris can accumulate around culverts or bridge openings, constricting their ability to convey floodwaters and imposing additional loads, leading culverts or bridges to 'blow out', or diverting floodwaters into other structures. In more extreme cases, the debris carried by floodwaters may include less common objects such as boats, large logs, or ice floes. This massive debris can destroy structures and cause widespread flood damage. Flood-borne debris impact forces on structures are a function of the weight of the object, the velocity of the moving water, and the type of structure that is struck. Refer to Chapter 4 of FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, Third Edition (January 2012) for additional details on calculating flood-borne debris impact forces.

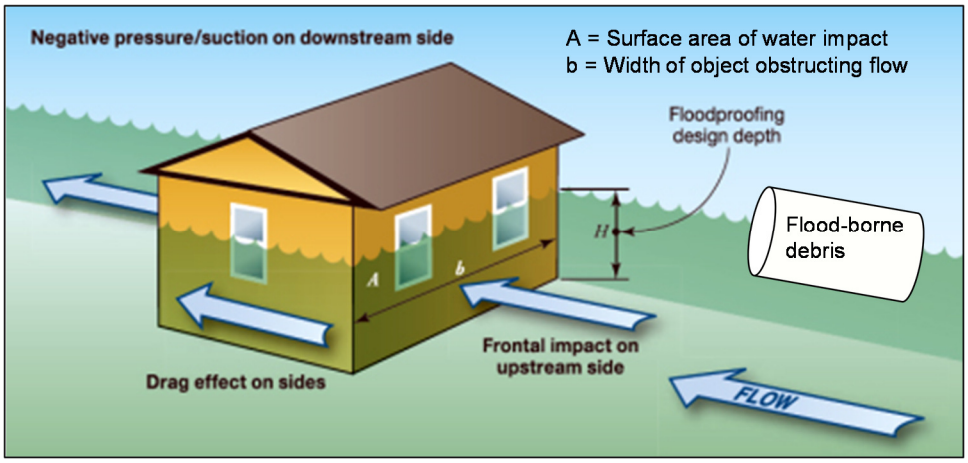

Figure 2-15: Diagram of Flood-Borne Debris Impact. (Source: FEMA P-259, modified)

Flood-borne debris impact forces can occur in all of the types of flooding listed in Section 2.1.1 (i.e., flash, alluvial fan, riverine, and local drainage), but tend to be more severe in high-velocity riverine, flash, or alluvial fan floods. Common flood-borne debris impact damages were observed in several of the communities visited in this report including Lyons, Longmont, City of Boulder, and Estes Park. Figure 2-6 from Section 2.1.1 provides an example of flood-borne debris impact damage from potential alluvial fan flooding, and Figure 2-16 provides an example of flood-borne debris contributing to a bridge washout from riverine flooding.

2.1.2.4 Erosion and Scour (Mudslides)

For the purposes of this report, erosion can be defined as the loss of soil at the ground surface due to moving water. Erosion is typically accompanied by scour, which is the localized loss of soil around an obstruction, structure, or foundation element at or below grade, as shown in Figure 2-17. Erosion and scour typically occur along stream embankments, coastlines, and along steep slopes. When accelerated by high rainfall or flood events, erosion and scour along stream embankments can undermine and lead to the loss of soil supporting bridge foundations, culverts, and waterside structures. Along a steep slope, storm-induced erosion and scour can trigger mudslides or debris slides similar to an alluvial fan flood event. Erosion and scour are a function of soil type, ground slope, flood velocity, and the configuration of the obstruction to flow. Refer

to Chapter 4 of FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, Third Edition (January 2012) for additional details on erosion and scour.

Figure 2-16: Washout of County Line Road Bridge during the September 2013 Flood, Longmont, CO. Flooding along County Line Road caused by Floodwaters Flowing into Gravel Pits
(Source: City of Longmont)

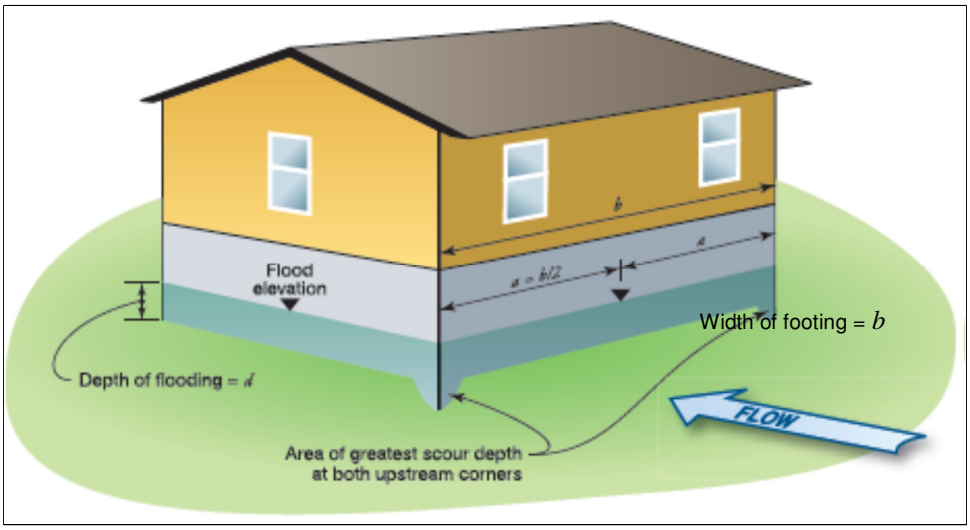

Figure 2-17: Scour Action around a Ground-Level Building. (Source: FEMA P-259)

Erosion and scour can occur in all of the types of flooding listed in Section 2.1.1 (i.e., flash, alluvial fan, riverine and local drainage), but tend to be more severe in high-velocity riverine, flash, or alluvial fan floods. Erosion and scour damages were observed in all of the communities

visited for this report including Lyons, Longmont, City of Boulder, Fort Collins, Estes Park, and Frederick. Figures 2-2 and 2-3 from Section 2.1.1 provide examples of damage from erosion and scour due to flash flooding; Figure 2-7 from Section 2.1.1 shows damages from erosion and scour due to riverine flooding; and Figures 2-18 through 2-20 show examples of erosion and scour damage.

Figure 2-18: Bank Erosion Damage along Big Thompson Creek in Estes Park, CO.
(Source: FEMA Contractor, August 19, 2014)

Figure 2-19: Greenway Undermined by Erosion and Stream Migration along Fish Creek, Estes Park, CO. (Source: FEMA Contractor, August 19, 2014)

Figure 2-20: Erosion Damage at No Name Creek Subdivision in Frederick, CO. (Source: FEMA Contractor, August 19, 2014)

2.2 BUILDING CONSTRUCTION AND SITE FEATURES

The vulnerability of structures to flood damage depends on many building construction factors as well as the building site relative to the flood source. This section briefly describes some of the key building construction and siting features encountered in the six communities in Boulder, Larimer, and Weld Counties visited following the September 2013 flood event.

2.2.1 Age

The age of a structure can help provide an indication of several key building construction factors that relate to the vulnerability of structures to flooding. Age-related building factors include building condition, applicable building codes, design standards, and floodplain management regulations in place at the time of construction. Table 2-2 provides a summary of structure age information for the six communities visited in Boulder, Larimer, and Weld Counties.

Table 2-2: Summary of Structure Age Information for Communities Visited

Community	Number of structures	Community NFIP entry year	Number of pre-FIRM structures	Number (%) of pre-FIRM structures in SFHA	Number of post-FIRM structures	Number (%) post-FIRM structures in SFHA
Lyons	513	1980	316	89 (28%)	197	61 (31%)
Longmont	28,592	1977	12,447	364 (3%)	16,145	297 (2%)
City of Boulder	26,608	1978	17,971	1,423 (8%)	8,637	597 (7%)
Fort Collins	57,178	1979	21,055	69 (<1%)	36.123	176 (<1%)
Estes Park	5,103	1979	2,235	65 (3%)	2,868	33 (1%)
Frederick	6,332	1979	2,121	3 (<1%)	4,211	31 (<1%)
Totals/Averages	*124,326*		*56,145*	*2,013 (4%)*	*68,181*	*1,195 (2%)*

A review of the information in Table 2-2 indicates that:

- In two communities in Boulder County – Lyons and the City of Boulder – the majority of buildings are pre-FIRM structures. This indicates that development in these two communities is well established and the structures may be older. A detailed analysis of structure data for Lyons and the City of Boulder indicates the current average age of structures in the two communities is between 50 and 55 years old. Additionally, Lyons and the City of Boulder have higher-than-average proportions of pre-FIRM and post-FIRM structures located in the SFHA. This suggests that structures in these two established communities were originally constructed closer to the floodplains, which may make it more difficult to limit floodplain development even after joining the NFIP. This could also be an indication of limited available areas for development, pushing some new construction into the SFHA even after adoption of FEMA FIRMs, FIS, and a floodplain management ordinance.
- In the other four communities – Longmont in Boulder County, Fort Collins and Estes Park in Larimer County, and Frederick in Weld County – the majority of the buildings are post-FIRM structures. This suggests that development in these communities may be more recent

and the structures may be newer. A detailed analysis of structure data for Longmont, Fort Collins, Estes Park, and Frederick indicates the current average age of structures in the these communities is between 24 and 37 years old. Additionally, Longmont, Fort Collins, Estes Park, and Frederick have lower-than-average proportions of pre-FIRM and post-FIRM structures located in the SFHA. This suggests that the structures in these more recently-developed communities were originally constructed further away from the floodplain, which may have made it easier to limit floodplain development after joining the NFIP. Finally, the City of Boulder, Fort Collins, and Longmont have aggressive programs to preserve areas adjacent to rivers, streams, and floodplains as open space, often using it for linear parks and recreational areas rather than development allowing residential and commercial structures.

Overall, a review of the data in Table 2-2 indicates that the average building stock in the six communities visited in Boulder, Larimer, and Weld Counties is close to evenly split between pre- and post-FIRM structures, with slightly more post-FIRM structures (55 percent) than pre-FIRM structures (45 percent). Additional detailed analysis of structural data indicates the current overall average age of structures is between 24 and 55 years old. This suggests a mixed vulnerability to flooding (higher for pre-FIRM and lower for post-FIRM) and fair-to-average building condition (given the difficulty of maintaining buildings over 25 years old in good-to-excellent condition). Finally, the proportion of structures constructed in the floodplain is relatively low, with only 4 percent of pre-FIRM structures and 2 percent of post-FIRM structures built in the SFHA.

2.2.2 Foundations

The type of foundation is a second key building construction factor related to the vulnerability of structures to flooding. As shown in Figure 2-21 taken from the *Substantial Damage Estimator (SDE) User's Manual and Workbook* (FEMA P-784, July 2010), there are a number of foundation types that can be used for residential and commercial construction:

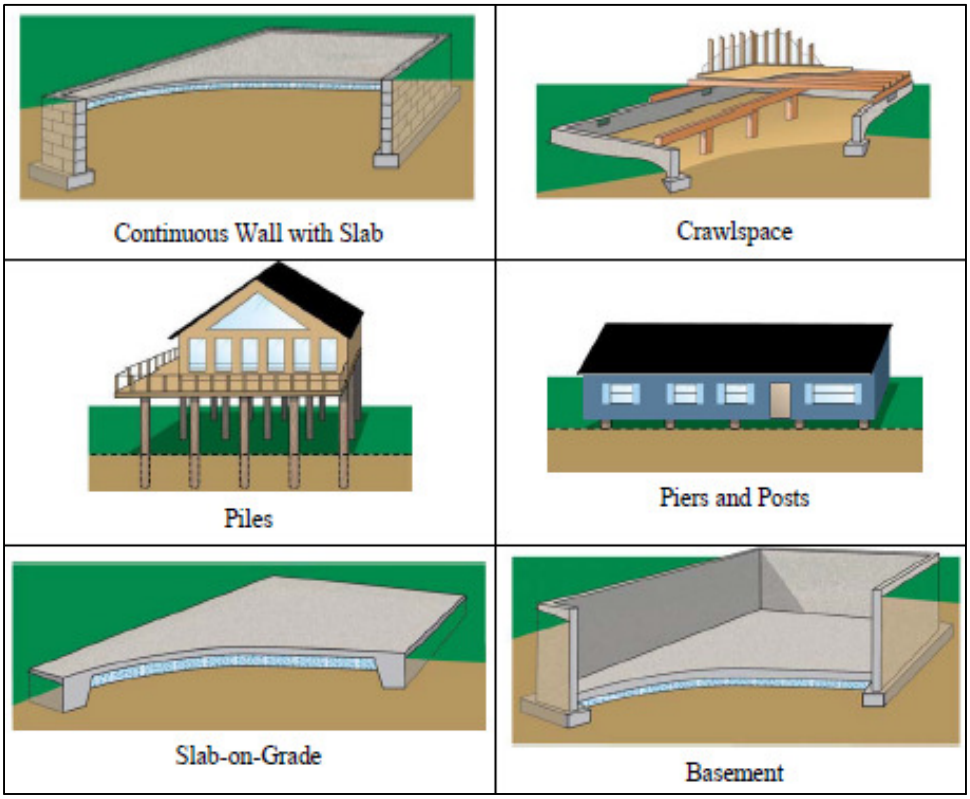

Figure 2-21: Foundation Types. (Source: FEMA P-784)

- *Continuous Wall with Slab (Stem Wall)* – This system consists of low concrete or masonry perimeter stem walls supported on footings and connected to a raised slab, which may be at or above grade.
- *Crawlspace* – A shallow, unfinished space beneath the floor of the building, a crawlspace can provide access to ductwork, plumbing, and other utilities, but can also lead to dampness and mold problems. Crawlspace foundation elements generally include spread footings and either piers or posts.
- *Piers and Posts* – This system is often seen on manufactured housing, and consists of placing the structure on multiple small piers or posts that are shallowly embedded into the ground. These foundations vary widely in quality, from code-compliant systems with proper embedment and connections, to systems that are blocks with little-to-no embedment with gravity loads providing connections.
- *Piles* – This type of foundation supports an elevated structure and consists of multiple columns driven into the ground and embedded several feet below grade, including both timber and precast concrete piles.
- *Slab-on-Grade* – For this type of foundation, the lowest floor of the building is formed by a concrete slab that sits directly on the ground.

- *Basement* – A basement is a below-grade enclosure. All sides of the foundation are enclosed with at least one side below grade. The basement can be either finished or unfinished.

A review of the data from the various site visits and field observations indicates that the four most common foundation types encountered in Boulder, Larimer, and Weld Counties are stem wall, crawlspace, slab-on-grade, and basement. Piers and posts were rarely encountered except in mobile home parks, and few, if any, pile foundations were observed in the field. In general, stem wall foundations appear to have been less vulnerable to flood damages than other foundation types, while basement foundations tended to be the most vulnerable to flood damage.

2.2.3 Basements

The presence of a basement in a structure is another key building construction factor related to a structure's vulnerability to flooding. Experience has shown that structures with basements, either finished or unfinished, are generally more vulnerable to flood damage than structures without basements. Post-FIRM structures in the floodplain are less likely to have basements than pre-FIRM structures due to NFIP elevation requirements that limit the ability to construct compliant basements. Table 2-3 summarizes unfinished and finished basement structure information for the six study communities. A review of this data indicates that 29 percent of the current building stock has unfinished basements and 19 percent has finished basements. Based on discussions with various floodplain managers, the trend is that buildings with basements, both in and outside the floodplain, sustain far more frequent flood damage than structures with no basements. Since about half of the analyzed building stock has basements, this represents a significant flood hazard vulnerability to the studied communities.

Table 2-3: Summary of Basement Information for Communities Visited

Community	County	Number of structures	Community NFIP entry year	Number (%) of structures with unfinished basements	Number (%) of structures with finished basements
Lyons	Boulder	513	1980	90 (18%)	24 (5%)
Longmont	Boulder	28,592	1977	12,745 (45%)	3,317 (12%)
City of Boulder	Boulder	26,208	1978	7,397 (28%)	4,437 (17%)
Fort Collins	Larimer	57,178	1979	13,291 (23%)	15,164 (27%)
Estes Park	Larimer	5,103	1979	255 (5%)	1,082 (21%)
Frederick	Weld	6,332	1979	2,669 (42%)	0 (0%)
Totals		*124,326*		*36,447 (29%)*	*24,024 (19%)*

2.2.4 Proximity to Stream

The proximity of a structure to the stream channel and floodway is the final building construction factor influencing the vulnerability of structures to flooding. Table 2-4 provides a summary of structures by flood zone for the six communities visited in Boulder, Larimer, and Weld Counties. A review of the information in Table 2-4 indicates that only 0.3 percent of the

current building stock is located in the floodway closest to the stream channel; 2.2 percent is located in the SFHA outside the floodway (also known as the flood fringe); and 1.4 percent is located in the 500-year floodplain. The vast majority (96.1 percent) of the current building stock is located outside the 500-year floodplain, which suggests the overall proximity of structures to the stream channel is relatively low. The data in Table 2-4 also show that while Lyons has the highest proportion (5.1 percent) of its building stock in the floodway (26 structures), the City of Boulder actually has the highest number of structures in the floodway (282 structures or 1.1 percent).

Table 2-4: Summary of Structure Flood Zone Information for Communities Visited

Community	County	Number (%) structures in floodway	Number (%) structures in flood fringe (AE, AO, AH)	Number (%) structures in 500-yr floodplain	Number (%) structures outside 500-yr floodplain
Lyons	Boulder	26 (5.1%)	124 (24.2%)	43 (8.4%)	320 (62.4%)
Longmont	Boulder	40 (0.1%)	621 (2.2%)	523 (1.8%)	24,708 (95.9%)
City of Boulder	Boulder	282 (1.1%)	1,738 (6.5%)	1,081 (4.1%)	23,507 (88.3%)
Fort Collins	Larimer	39 (0.1%)	206 (0.4%)	32 (0.1%)	56,901 (99.5%)
Estes Park	Larimer	43 (0.8%)	55 (1.1%)	18 (0.4%)	4,987 (97.7%)
Frederick	Weld	0 (0.0%)	34 (0.5%)	0 (0.0%)	6,298 (99.5%)
Totals		*430 (0.3%)*	*2,778 (2.2%)*	*1,697 (1.4%)*	*119,421 (96.1%)*

2.3 EVENT LOSSES

This section provides a brief summary of the losses experienced in the six study communities in the September 2013 flood event. The information presented is verified loss information gathered from FEMA NFIP policy flood claims data and building inspection damage estimates made for the FEMA Individual and Households Program and the Small Business Administration (SBA) disaster recovery loan program. These are summarized in Figure 2-22. The total combined FEMA-validated losses (FVL) to residential property from the 2013 flood event were $81 million, with approximately two-thirds of the losses coming from the City of Boulder. It should be noted that the $81 million in validated losses does not include losses to second homes, uninsured properties, and other properties where the property owner did not report damage or register for assistance.

Figure 2-22: Summary of 2013 Flood Losses for Study Communities.

Tables 2-5 through 2-7 break down the NFIP claims paid, FEMA IA Program losses, and SBA verified losses used to prepare Figure 2-22. For Table 2-5, note that Longmont had the highest average claim per impacted structure, presumably due to higher-than-average real estate values.

Table 2-5: NFIP Claims Paid from the 2013 Flood

Community	Total Building and Contents Claims Paid	Total Number of Claims	Percentage of Claims Inside the SFHA	Percentage of Claims Outside the SFHA	Average Claim per Impacted Structure
Lyons	$3,557,950	65	86%	14%	$54,738
Longmont	$5,066,698	50	80%	20%	$101,134
City of Boulder	$17,555,373	903	37%	63%	$19,441
Fort Collins	$26,581	5	60%	40%	$5,316

Community	Total Building and Contents Claims Paid	Total Number of Claims	Percentage of Claims Inside the SFHA	Percentage of Claims Outside the SFHA	Average Claim per Impacted Structure
Estes Park	$1,317,514	55	49%	51%	$23,955
Frederick	$19,345	4	50%	50%	$4,836

Table 2-6: IA Program Loss Claims as a Result of the 2013 Flood Event

Community	Total FEMA IA Building and Contents Paid	Total Number of Claims	Average Claim per Impacted Structure
Lyons	$2,835,479	265	$10,670
Longmont	$3,652,445	711	$5,137
City of Boulder	$11,913,157	6086	$1,957
Fort Collins	$22,138	20	$1,107
Estes Park	$540,408	317	$1,705
Frederick	$255,279	142	$1,798

Table 2-7: SBA Verified Losses as a Result of the 2013 Flood Event

Community	SBA Verified Loss	Total Count	Average SBA Loss
Lyons	$27,119	1	$27,119
Longmont	$4,772,506	118	$40,445
City of Boulder	$24,261,141	783	$30,985
Fort Collins	$2,663,817	37	$71,995
Estes Park	$1,913,494	22	$86,977
Frederick	$534,663	23	$23,246

2.4 DATA COLLECTION

Information was collected for the best practices and cost-effective strategies study through interviews and site visits with local floodplain administrators and community officials. This section provides an overview of the information gathered in meetings and the technical information collected for study and review.

2.4.1 Meetings

Interviews were conducted with city officials in June and August of 2014. The meetings were held on-site on the dates shown in Table 2-8. No meeting was held with Lyons, but a site visit was conducted to gather data

Table 2-8: Interviews

Date	Community or District	Participants
June 18, 2014	Fort Collins	FEMA Region VIII, FEMA Contractor , City Floodplain Administrators

Date	Community or District	Participants
June 19, 2014	Urban Drainage and Flood Control District	FEMA Region VIII, FEMA Contractor, UDFCD representatives
August 19, 2014	Estes Park	FEMA Region VIII, FEMA Contractor Town Floodplain Administrators and Town Administrator
August 19, 2014	Frederick	FEMA Region VIII,FEMA Contractor, City engineer and Engineering and Utilities Director
August 20, 2014	Longmont	FEMA Region VIII, FEMA Contractor, City Floodplain Administrator
August 20, 2014	City of Boulder	FEMA Region VIII, FEMA Contractor, former City Floodplain Administrator and assistant

The interviews were used to obtain historical information from community officials as well as to obtain an overview of the community's floodplain regulations. The interviews also discussed the 2013 flood events in the community and lessons learned. Table 2-9 summarizes the information gathered in the interviews.

Table 2-9: Summary of Information Obtained in Community Interviews

Community or District	Interview summary and notable regulations
Fort Collins	• Adopted higher regulatory standards for the Poudre River floodplain • Expanded critical facilities definition in the Poudre River floodplain • Prohibited critical facilities from the 100- and 500-year floodplains • Established erosion buffer regulations • Mapped the floodway using half-foot channel rise
Urban Drainage and Flood Control District	• Assists communities in creating regulations that aim for the restoration of natural floodplain function • Began a master planning program after evaluating channels in the district and discovering channel maintenance and other needs • Maps undeveloped floodplains • Provides mailings and outreach to floodplain occupants • Published a floodplain design manual, now known as the UDFCD Criteria Manual • Published floodplain preservation guidelines
Frederick	• Modeled its stormwater management standards after UDFCD • Designed stormwater system to handle a 100-year event • Requires flood studies to be performed on unnumbered A-zones for new subdivisions • Community is expanding; utility infrastructure needs to be planned and updated where below standard.
Estes Park	• Three major rivers flow within the town and the confluence of rivers is a source of flooding • Adopted setback requirements in subdivisions • Is considering participation in the CRS • Requested FEMA adoption of advisory maps of migrated watercourses and regulates to current, preliminary new floodplain boundaries

Community or District	Interview summary and notable regulations
Longmont	• Regulates the 100-year floodplain by a floodway district and a floodway fringe district • Completed channel improvement mitigation project on Left Hand Creek prior to the 2013 flood event • Planning a future channelization mitigation project on the St. Vrain Creek • Community has a history of flood events
City of Boulder	• Adopted high hazard zone designation - high hazard areas are "portions of the floodplain where an unacceptably high hazard to human safety exists" • Adopted 2 feet of freeboard for development in floodplain • Continue revision of FIRM and FIS resources in high hazard areas • Revised website immediately after flood to reflect flood recovery services and progress. Website has returned to pre-flood format but retains 2013 flood recovery progress focus.

2.4.2 Types of Data

Information was collected during and after the meetings described above. Site visits were conducted in conjunction with the interviews and were focused on the 2013 flood event. A site visit was conducted in Lyons with FEMA Region VIII to view damages. Section Three reviews best practices and strategies based on observations, insights, and success stories presented by local officials during meetings and site visits.

The information types collected are shown in Table 2-10. Local officials shared historical flood and floodplain management information and historical floodplain management ordinances for reference. Current (June and August 2014) photographs of damages that occurred in September 2013 were obtained during the site visits. The visits provided the opportunity to evaluate best practices and cost-effective strategies following various lengths of recovery and rehabilitation.

Table 2-10: Data Collected from Community Officials

Data	Lyons	Longmont	City of Boulder	Fort Collins	Estes Park	Frederick
Interviews with local officials		x	x	x	x	x
Photos from 2013 flood event		x	x	x	x	
Current floodplain regulations	x	x	x	x	x	x
Historical floodplain regulations	x	x	x	x	x	x
GIS data	x	x	x	x	x	x
Historical flood events (photos, maps and damage accounts)		x				
2013 flood-event-related memos or presentations		x	x	x	x	
Site visits (See Section Three)	x	x	x	x	x	x

Additional information was obtained:

- Longmont supplied its Pre-disaster Mitigation (PDM) application and supporting documentation for the Left Hand Creek mitigation project.
- The City of Boulder provided resident flood survey data dated August 29, 2014. A GIS shapefile of the survey results was also provided.
- Fort Collins's 2011 Poudre River Flood Damage Impact Assessment covers a flood loss estimation analysis performed with Hazus. Fort Collins regulates the Poudre River floodplain to higher regulatory standards than the other floodplains in the community. For a review of community regulations, the City's Quick Guide Floodplain Regulations were provided for both floodplain areas.
- Estes Park submitted a hydrology report dated August 21, 2014 for Fish Creek. Estes Park created emergency provisions for regulating development adjacent to drainages because channels had migrated and widened during the 2013 flood event. The October 1, 2013 Emergency Provisions Policy and a follow-up November 12, 2013 memo were provided. The Floodplain Administrator, the Chief Building Official, and the Community Development Director summarized Estes Park 2013 flood event impacts for the Town Administrator and documented this in an official report copied to the FEMA contractor.

2.5 OVERVIEW OF SITES VISITED

Table 2-11 provides a summary of demographic and loss information in the six best practice communities; their locations are noted on Figure 2-23 at the end of this section. These six communities provide a representative cross-section of flood impacted communities while exploring varying populations, building stock, critical infrastructure, watersheds, and societal diversity.

Table 2-11: Summary of Population and Total Losses Verified by FEMA IA, NFIP Claims Data, and SBA in Study Communities

Community	County	CRS Class	Population (2010 US Census)	Sept 2013 Event Total FEMA Verified Loss (IA, NFIP, SBA)
Lyons	Boulder	-	2,033	$8,306,923
Longmont	Boulder	8	86,270	$11,372,960
City of Boulder	Boulder	5	97,386	$53,729,671
Fort Collins	Larimer	4	143,986	$75,838
Estes Park	Larimer	-	5,858	$6,630,428
Frederick	Weld	-	8,679	$809,287

Lyons: Lyons, the "Double Gateway to the Rocky Mountains" is a small town and a former resort community where many residents are now employed by a large industrial cement plant. Lyons is noted for its award-winning Lyons Whitewater Park in Meadow Park, which is a noted regional whitewater kayaking destination. Numerous music and arts festivals are held annually in

Meadow Park, helping to sustain a recreation and visitor-based economy. Lyons was devastated by the September 2013 flood. In response, a unique community-based recovery plan has been developed with support from FEMA, the State of Colorado Governor's Recovery Office and the American Planning Association.

Longmont: This family-friendly city features ample outdoor recreation around Left Hand Creek, St. Vrain Creek, and several reservoirs; many Longmont residents are employed in the computer technology industry. Many of these areas – especially along Left Hand Creek – have been acquired by the City and dedicated to open space, featuring trails for hiking, running, and cycling. While many of these areas were severely impacted by the 2013 floods, those that had been stabilized in mitigation and stream restoration projects prior to the flood fared much better, serving as best practice examples.

City of Boulder: This vibrant community is home to the iconic University of Colorado campus that features sandstone masonry buildings with bright red tile roofs. Its population is a mix of generations with a young spirit who spend much of their free time outdoors. Floodways and floodplains converted into community green space feature trails enjoyed by walkers, joggers, and cyclists. Boulder Creek is one of the city's major flood sources, along with multiple drainage concerns.

Fort Collins: Like the City of Boulder, Fort Collins is an energetic university city with a vibrant citizenry and a restored downtown dating to the late nineteenth century. The area was originally a military fort and outpost. The city faces flood threats from several water bodies as well as inadequate stormwater drainage, with large areas of the Colorado State campus and the downtown mall at risk.

Estes Park: Northwest of Lyons, Estes Park is a small town whose population grows and shrinks with the seasons since it is the eastern gateway to Rocky Mountain National Park. During the September 2013 flood, Estes Park's population was waning after the busy summer; floodwaters backed up at the confluence of Big Thompson Creek, Fall River, and Black Canyon Creek and under various bridges that had minimal conveyance, leading to sheet flow impacting downtown businesses and some limited bank erosion that damaged some residential deck/patio foundations. Outside of Estes Park, high velocity flood discharges along Fish Creek caused widespread embankment erosion and scour that undermined riverside recreational facilities as well as some utilities and residential buildings.

Frederick: Frederick is a small town with a mining history that prides itself on its young families with children. In the plains east of the Front Range, the town features historic buildings and ample park and recreational facilities including the unique Bulrush Wetland Park developed in cooperation with the U.S. Army Corps of Engineers.

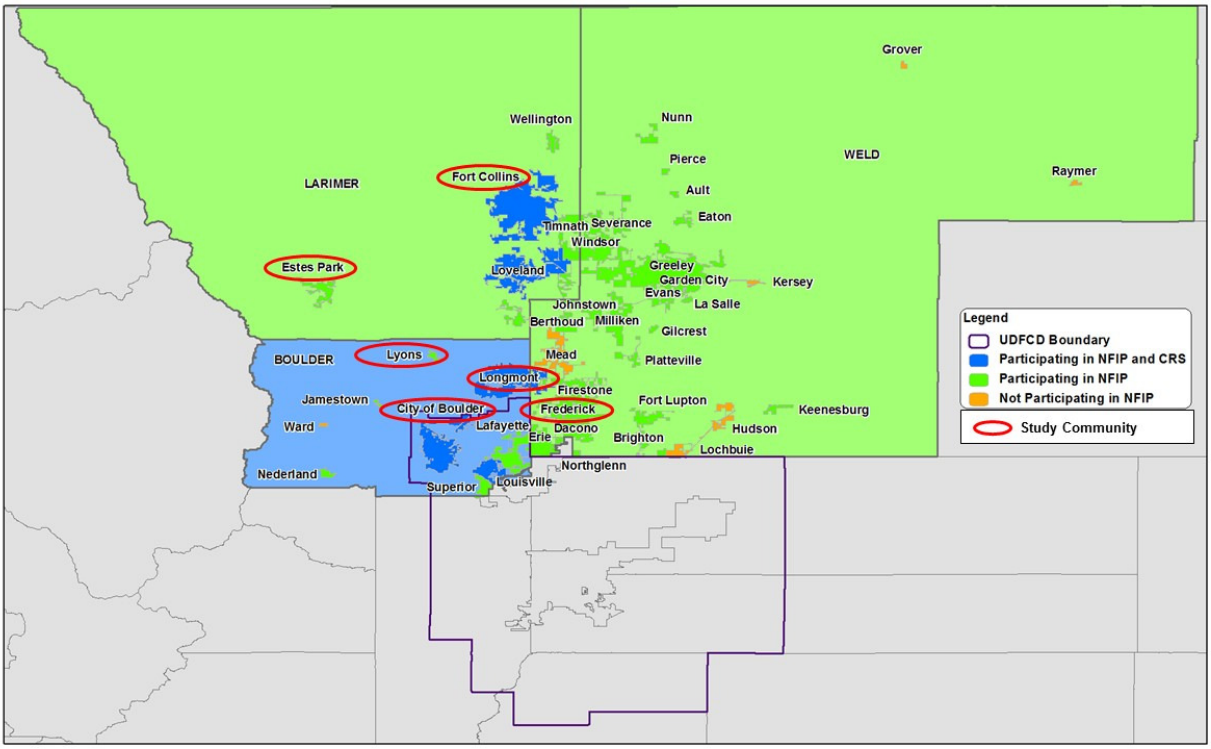

Figure 2-23: Detail Map of Six Study Communities within Boulder, Larimer and Weld Counties.
(Source: Regulatory Losses Avoided Study)

SECTION THREE BEST PRACTICES AND STRATEGIES

Section Three presents the best practices and strategies derived from the Regulatory LAS report and findings of site visits to the six communities in Boulder, Larimer, and Weld Counties. Table 3-1 provides an overview of the best practices and strategies discussed in each subsection and the communities where the practices and strategies were observed. Each subsection is organized to include:

- A description of each best practice or strategy, including photos and/or sample case studies from one of the six study communities;
- Potential benefits and impacts of each best practice or study, including available loss avoidance values for the six study communities; and
- Community factors that contributed to success and factors that can present challenges to implementing a best practice or strategy.

Table 3-1: Summary of Best Practices and Strategies by Study Communities Where Applied

Best Practice or Strategy	Report Sub-Section	Lyons	Longmont	City of Boulder	Fort Collins	Estes Park	Frederick
Freeboard	3.1	x	x	x	x	x	x
Floodplain Development Restrictions – Critical Facility Siting Restrictions	3.2.1	x	x	x	x	x	
Floodplain Development Restrictions – Property Acquisition	3.2.2	x	x	x	x	x	
Floodway Development Restrictions	3.3	x	x	x	x	x	
Basement Restrictions in SFHA	3.4		x	x	x		
Outreach	3.5		x	x	x		
Local Drainage Improvements	3.6	x	x	x	x	x	x
Structural Flood Protection Measures	3.7	x		x		x	
Miscellaneous Measures (Erosion Setbacks, etc.)	3.8		x		x	x	

Subsections 3.1 through 3.4 address the regulatory best practices and strategies from the Regulatory LAS report that were analyzed for economic benefits:

- Freeboard
- Floodplain development restrictions – including critical facility siting restrictions
- Floodway development restrictions
- Basement restrictions

Subsections 3.1 through 3.4 also include the loss estimation analyses for each best practice. Losses avoided, or the calculations of economic losses prevented by a given mitigation action, were estimated for a 100-year flood scenario in Boulder, Larimer, and Weld Counties and five of the six study communities discussed in Section Two. Data were not available to perform these calculations for Frederick.

Subsections 3.5 through 3.8 address additional categories of best practices and strategies observed to include:

- Outreach projects
- Local drainage improvements
- Structural flood protection
- Miscellaneous measures

References and resources for additional information on other flood mitigation measures that can be applied in Colorado and elsewhere can be found in Section Five

3.1 FREEBOARD

3.1.1 Description

FEMA defines freeboard as a safety factor usually expressed in feet above a defined flood level such as the Base Flood Elevation (BFE) for purposes of floodplain management. The concept of freeboard is illustrated in Figure 3-1. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a modeled flood event and floodway conditions, such as wave action, size and orientation of bridge openings, and the hydrological effect of urbanization of the watershed. Freeboard is not required by minimum NFIP standards, but communities are encouraged to adopt at least one foot of freeboard. Freeboard results in significantly lower flood insurance rates due to lower flood risk. Perhaps of more importance, freeboard adds an extra measure of protection through elevation of residential and non-residential first floors, utility connections to buildings, and critical infrastructure that can prevent injury to people and reduce damage to property.

Freeboard is implemented through structural elevation. When adopted by communities, freeboard regulations require that the first floor of a building or the lowest level of a utility is designed and built to an additional height above the BFE. These requirements may be specified at the state or community level; typically, if freeboard is specified at the state level, it serves as an effective standard of one foot of freeboard for new and substantially changed structures, as shown in the attached insert. This includes buildings, utilities, and infrastructure such as pipelines or water treatment plants. A jurisdiction can adopt a higher freeboard requirement, and property owners and infrastructure managers can add freeboard without an ordinance requirement to ensure a greater level of protection or to reduce insurance costs.

The freeboard requirement allows a community to enforce a higher standard of protection than the predicted regulatory BFE on NFIP FIRMs and FIS. While the use of freeboard generally reduces the damages during a flood, flooding can impact properties outside of the regulatory floodplain where freeboard is not required by regulation or commonly used; this was the case in the September 2013 flooding in Colorado. Freeboard also improves the effectiveness of structural elevation projects, as was observed in Estes Park in Larimer County. Refer to the insert and Figure 3-2 for details on the Estes Park stream setbacks and elevation measures that used freeboard.

Current State of Colorado Freeboard Requirements

In November 2010, Colorado adopted updated rules concerning freeboard that became effective in January 2011. The updated rules require a state freeboard of BFE +1 foot for all SFHA structures, and for critical facilities a BFE +2 feet. The updated rules require adoption by local communities, as a result of local land use authorities, and they are required for a community to remain in good standing in the NFIP. Communities that do not adopt the freeboard requirements are ineligible for state flood grants, ineligible for HMGP and other disaster mitigation grants, and risk suspension from the NFIP. There were no additional modifications to the updated rules following the September 2013 floods.

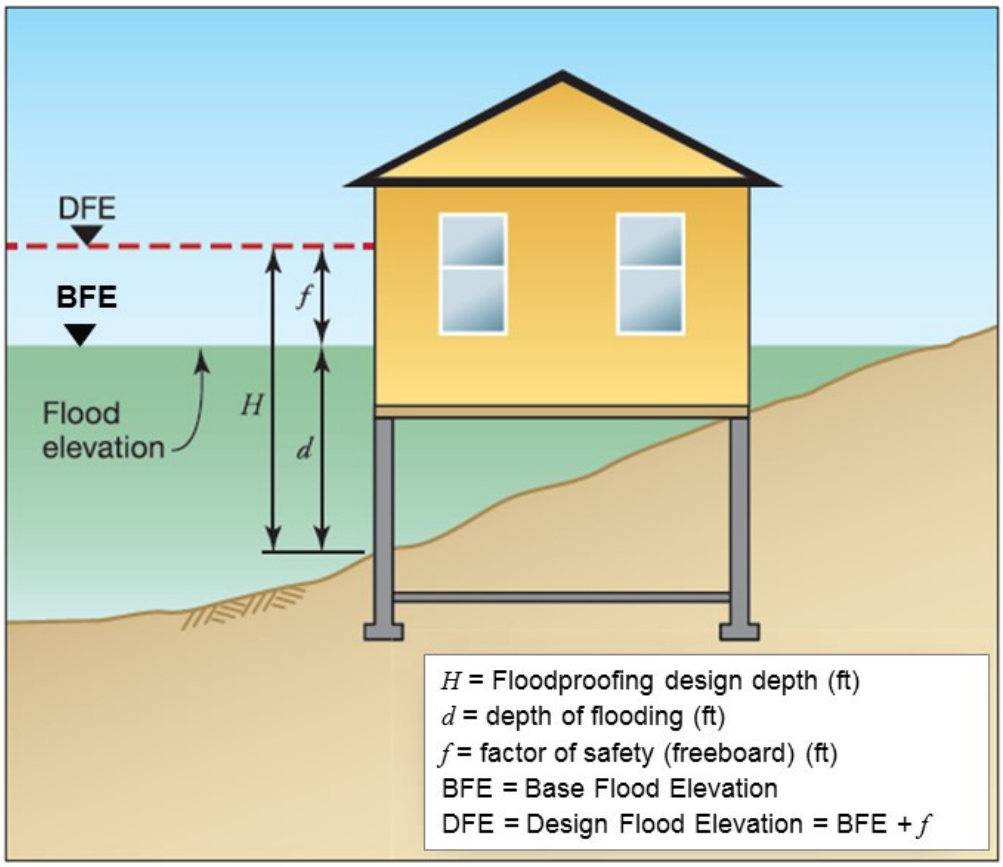

Figure 3-1: Concept of Freeboard. (Source: FEMA P-259, Figure 4-5 [adjusted])

Stream Setbacks and Elevation with Freeboard Show Their Value – Town of Estes Park, CO

Submitted by: Will Birchfield, Chief Building Official, CFM

CRS Activities: 420 – Natural Shoreline Protection, 430 – Higher Regulatory Standards (Freeboard = 1 foot).

Description: Estes Park has not joined the CRS yet, but has considered joining for a number of years. The town has proactive standards in place that helped provide protection during the 2013 flooding. In the town's Land Use Code, there are stream setbacks that in most cases result in new construction being located outside the Special Flood Hazard Area. In the past 15 years, there have only been four permits issued for new structures in the 100-year floodplain. All of these buildings were permitted prior to the town having adopted freeboard standards. However, building permit staff strongly encouraged those property owners to elevate the new structures. That recommendation paid off, because each structure was elevated two to three feet above the 100-year flood level and none were damaged in the September floods (Figure 3-2). In fact, every building that sustained structural damage, including one that was completely destroyed, was outside the mapped floodplain. Estes Park now has a required freeboard standard of one foot.

Figure 3-2: *Left* - An Estes Park business owner next to his building that was not damaged in the 2013 flooding due to elevating the structure. *Right* - View behind the elevated structure looking at the Big Thompson River during the 2013 flooding. (Source: Town of Estes Park)

3.1.2 Benefits and Impacts

The economic benefits of freeboard have been documented by previous studies such as the American Institutes for Research report, *Evaluation of the National Flood Insurance Program's Building Standards*, October 2006. As noted in the insert on page 3-3, the State of Colorado applied this knowledge through adoption of statewide freeboard requirements in late 2010. In Section Six of the Regulatory LAS report, freeboard is analyzed by comparing the estimated

damages to buildings built to existing freeboard regulations to estimated damages to buildings built to lower or higher freeboard standards (plus or minus two feet) to answer the question:

> *If today's freeboard was regulated when the community first joined the NFIP, what losses would this regulation have avoided?*

Table 3-2 shows the benefits of freeboard in avoiding losses in the three studied counties from the 100-year flood base event in terms of losses avoided. As shown in Table 3-2, the three study counties have nearly 6,000 buildings in the SFHA. Section Six of the Regulatory LAS report illustrates the benefits of higher freeboard on post-regulatory structures in Boulder, Larimer, and Weld counties in terms of reduced losses. Overall, there would have been a 33 percent reduction in total losses in the study area in the 2013 event if the additional two-foot freeboard regulation had been implemented earlier.

Table 3-2: Freeboard Impacts to Counties for Predicted 100-year Flood Event

County	Freeboard Increase	Total SFHA Buildings	SFHA Buildings Impacted	Percent Decrease in Buildings Impacted	Value of Losses Avoided
Boulder	+2 feet	4072	3,542	87%	$342M
Larimer	+2 feet	1,177	988	84%	$87M
Weld	+2 feet	703	675	96%	$38M

For Boulder, Larimer, and Weld Counties, Figure 3-3 shows the overall impact on losses avoided in the 100-year flood event as the freeboard is varied from -2 feet to +2 feet. The negative losses avoided shown for the -2 feet freeboard scenario depicted in Figure 3-6 illustrate that predicted losses where freeboard was in place are less than losses sustained by structures in communities without a freeboard requirement. This was confirmed by field visits to the impacted communities.

Additionally, Section Six of the Regulatory LAS report assesses the estimated increase in 100-year flood losses to SFHA buildings in Boulder, Larimer, and Weld counties if freeboard had never been adopted. The results of this analysis indicate that:

- The increase in losses in Boulder County is greater than 300 percent if freeboard regulations had never been adopted. In other words, the current freeboard regulations in Boulder County (including the two-foot freeboard adopted by the City of Boulder) have reduced damages by $1.5 billion.
- The increase in losses in Larimer County is 68 percent if freeboard regulations had never been adopted. The current freeboard regulations in Larimer County have reduced damages by $71 million.
- The increase in losses in Weld County is 148 percent if freeboard regulations had never been adopted. The current freeboard regulations in Weld County have reduced damages by $73 million.

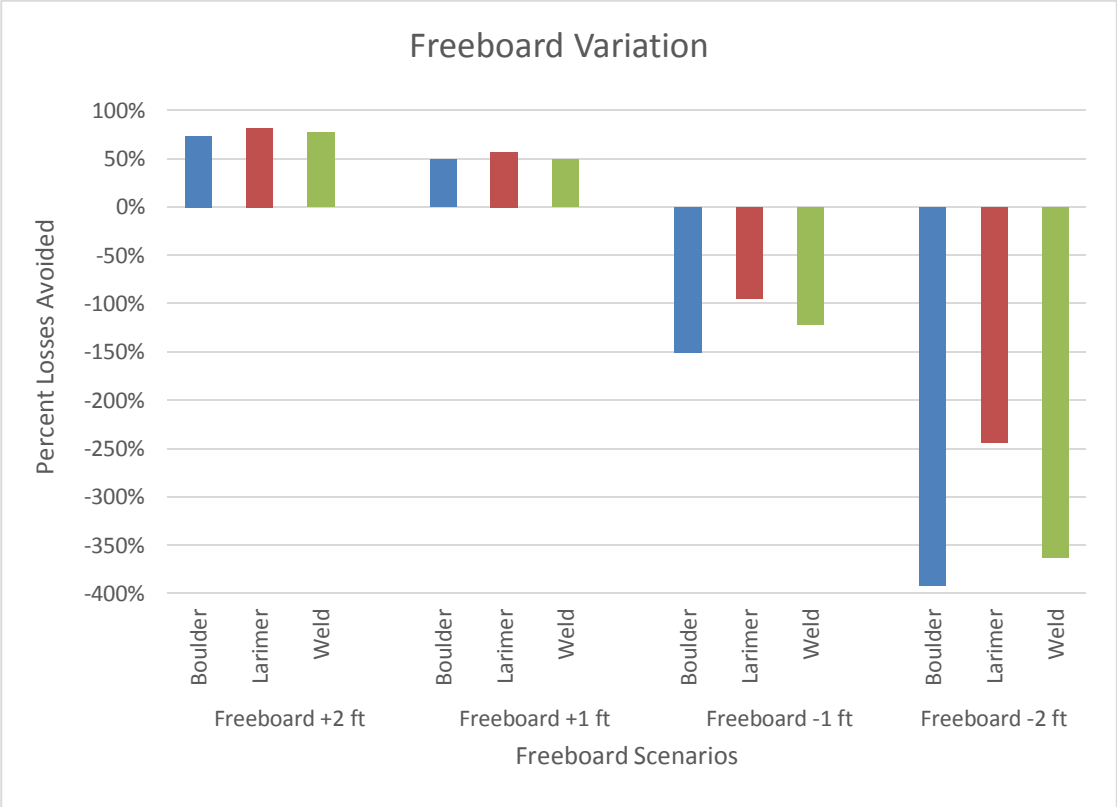

Figure 3-3: Overall Impact on Losses Avoided in Boulder, Larimer, and Weld Counties Associated with Varying Freeboard for the 100-year Flood

For the six communities studied in this report, the analysis data from Section Six of the Regulatory LAS report shows significant benefits from the use of freeboard. Figure 3-4 shows the total losses and the losses avoided associated with a two-foot increase in freeboard in a 100-year flood event, and Figure 3-5 shows the distribution of 100-year avoided losses. Data were not available to perform the analysis for Frederick.

In addition to the benefits of freeboard quantified in Table 3-2 and Figures 3-3 through 3-5, positive impacts associated with adding freeboard include reduced insurance premiums for buildings and infrastructure elevated above the BFE and the potential for further, community-wide flood insurance premium discounts for jurisdictions that participate in the NFIP CRS. Perhaps more importantly, there is a significant added measure of safety through prevented harm to people, reduced damage to property, and lessened community disruption from infrastructure and critical facility impacts.

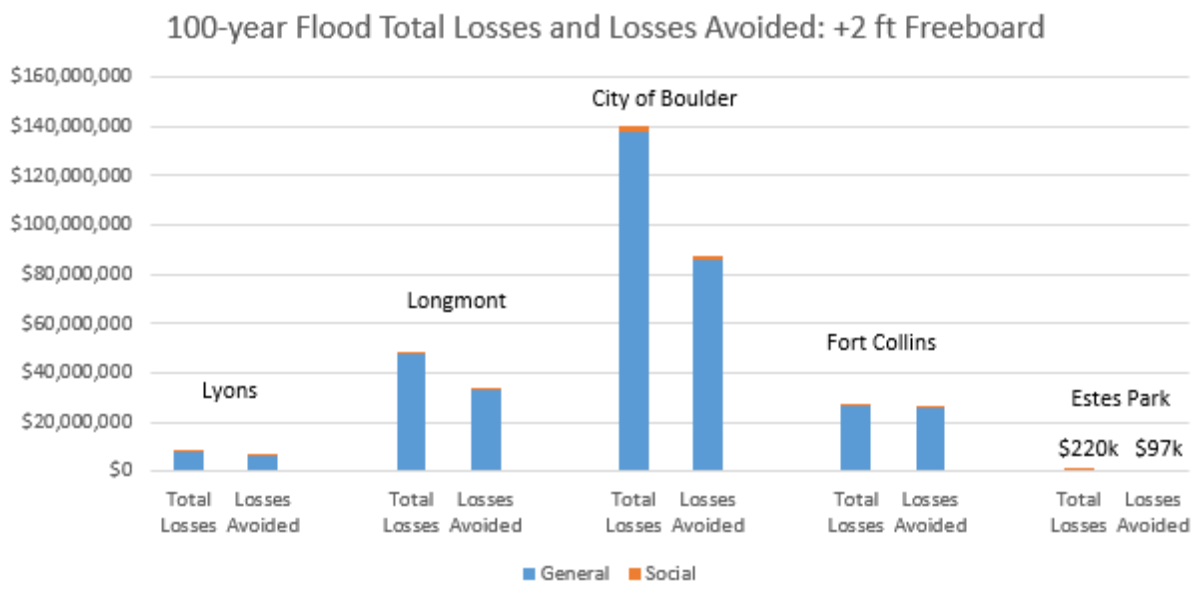

Figure 3-4: Study Community Losses and Losses Avoided Associated with +2 feet Freeboard in the 100-year Flood Event

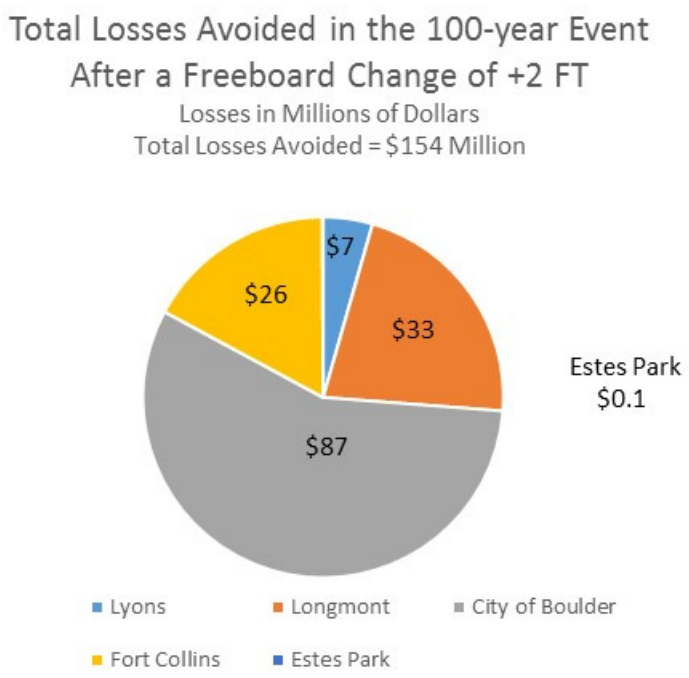

Figure 3-5: Distribution of Study Community Losses Avoided Associated with +2 feet Freeboard in the 100-year Flood Event

3.1.3 Community Successes and Challenges

Adding freeboard to new development requirements through modification of the community floodplain management ordinance adds protection to homes, non-residential structures, and critical facilities. Communities that had freeboard in place generally suffered less flood damage and experienced shorter disruption of services in the 2013 floods. They also had less damage or loss to buildings and contents and shorter duration of utility service disruption. Communities with additional freeboard receive points in the NFIP CRS. For each CRS class that a CRS community achieves, each flood insurance policy premium in the jurisdiction's SFHA is reduced by 5 percent. As flood insurance policies cost near actuarial rates, this can be extremely beneficial for high-risk buildings in the SFHA, especially those built prior to adoption of the community floodplain management ordinance and use of freeboard.

Adoption of freeboard is not always easy; some community officials and stakeholders such as realtors, builders, and developers argue that incorporation of freeboard increases building costs by adding to the height of the foundation. However, studies such as the *Evaluation of the National Flood Insurance Program's Building Standards*, October 2006 and this report have conclusively demonstrated the economic benefits of freeboard. Other community policymakers are reluctant to revise ordinances because of lengthy processes that compete with limited time available to elected officials to oversee the community's business.

Freeboard can sometimes be achieved through elevation of priority residential, non-residential, and critical facilities when funded through federal programs that require elevation with freeboard. This is currently happening throughout Region VIII through the FEMA Hazard Mitigation Grant Program (HMGP) and US Department of Housing and Urban Development Community Development and Block Grant (CDBG) Programs matched by the State of Colorado, local communities, and property owners as part of the September 2013 flood recovery effort.

3.2 FLOODPLAIN DEVELOPMENT RESTRICTIONS

Floodplain development restrictions can reduce risk to people, property, utilities, and infrastructure in the SFHA.

Two scenarios were analyzed using the 100-year base flood event to evaluate the effect of SFHA floodplain development restriction regulations on damages. First, the lack of floodplain development restrictions for critical facilities located in the SFHA was compared to application of mitigation measures to apply floodplain development restrictions to critical facilities. The second scenario compares the lack of any floodplain development restrictions to impacts of floodplain development restrictions for any development in the 100-year floodplain. The current condition, where SFHA development is permitted, was compared to conditions where the mitigation measure was completed. Section Six of the Regulatory LAS depicts predicted total losses and losses avoided in the SFHA for Boulder, Larimer, and Weld Counties with and without floodplain protection measures in the 100-year flood event.

3.2.1 Critical Facility Siting Restrictions

3.2.1.1 Description

Critical facilities are structures whose operation or function are essential to public safety and society. Examples of critical facilities include police stations, emergency operations centers, hospitals, fire stations, wastewater treatment facilities, evacuation shelters, and electrical power substations. The location of a critical facility in the floodplain increases the risk of losses to the facility and disruption of basic societal functions and public safety.

Floodplain management or zoning ordinances to protect critical facilities from flood risks may include increasing the freeboard requirements for critical facilities, locating critical facilities outside of the regulated floodplain, or locating critical facilities outside of the 500-year floodplain. Mitigation measures can include requiring emergency generators or redundant power, elevation or hardening of utilities, floodproofing and hardening buildings, and continuity of operations and emergency response planning. In this study, the floodplain development restriction of critical facilities from the 100-year floodplain was analyzed.

3.2.1.2 Benefits and Impacts

Critical facilities and utilities located in the SFHA are at greater risk from flood damage because of their proximity to the stream, river, lake, or wetland that is the source of flooding. Restricting development in the regulated floodplain reduces exposure to flood damages. For critical facilities, reduced or eliminated flood risk not only prevents property damage, but reduces disruption to the community from lack of public service functions and utilities and shortens recovery. Of particular note, protection of or location of public safety facilities like fire stations, police departments, and emergency services first responders is critical to maintaining public safety and swift response during and immediately after a flood emergency. In particular, police or sheriff precinct, facility, and vehicle protection facilitates full response and protective capacity, which can discourage and reduce post-disaster public safety issues such as looting. In Section Six of the Regulatory LAS report, site restrictions on critical facilities were analyzed by assuming no critical facility development in the SFHA for the 100-year flood event to answer the question:

> *What would the losses and losses avoided be if development of critical facilities in the SFHA had never been permitted?*

The charts in Section Six of the Regulatory LAS report illustrate the benefits of removing critical facilities from the SFHA in Boulder, Larimer, and Weld counties in terms of reduced losses. Overall, there would be a $22.8 million reduction in damages in the 100-year event if this regulation was implemented in the three counties.

For the six communities studied in this report, the analysis data from Section Six of the Regulatory LAS report shows the benefits of removal of critical facilities from the SFHA. Figure 3-6 shows the total losses and the losses avoided associated with removal of critical facilities from the SFHA in a 100-year flood event, and Figure 3-7 shows the distribution of 100-year avoided losses.

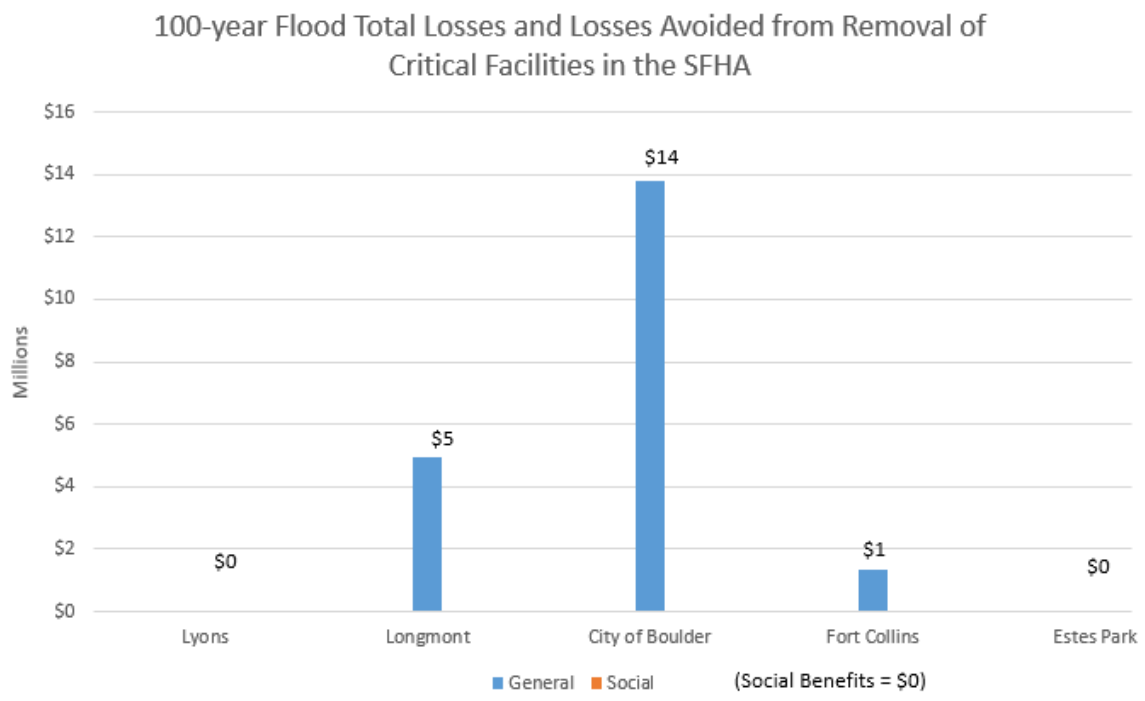

Figure 3-6: Study Community Losses and Losses Avoided Associated with Removal of Critical Facilities from the SFHA in the 100-year Flood Event

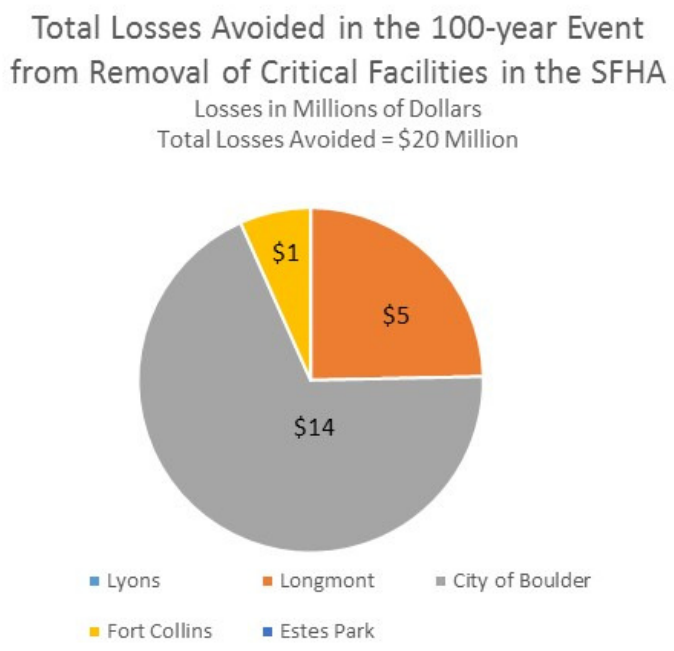

Figure 3-7: Distribution of Study Community Losses Avoided Associated with Removal of Critical Facilities from the SFHA in the 100-year Flood Event

In total, there is a projected $20 million reduction in damages in the 100-year event if this regulation was implemented in the six study communities. Note that data were not available to perform this analysis for Lyons, Estes Park, or Frederick; however, given that Lyons experienced damage to its water treatment plant in the September 2013 flood event, the data for Lyons may be incomplete or the plant may not have been considered a critical facility. The lack of data for Estes Park and Frederick may also indicate that there are no critical facilities in their SFHAs and thus no losses to be avoided.

In addition to the benefits quantified in Figures 3-6 and 3-7, positive impacts associated with removing critical facilities from the SFHA include reduced insurance premiums for buildings and critical facilities elevated above the BFE, and the potential for further, community-wide flood insurance premium discounts for jurisdictions that participate in the NFIP CRS. Perhaps more importantly, there is a significant added measure of safety, reduced damage to critical facilities, and lessened community disruption from critical facility impacts.

3.2.1.3 Community Successes and Challenges

Colorado communities such as Estes Park have been successful in implementing critical facility siting restrictions. Restriction of critical facilities in the 100-year floodplain results in reduced losses and elimination of disruptions to essential services. Moving existing critical facilities out of the floodplain, especially those that are historic or pre-FIRM, can be challenging because of their historical presence and service to the community. A review of the data collected on the six study communities confirms that key factors for successful siting of critical facilities outside the SFHA are linked to age of construction and level of development, as shown below.

- Age of Construction: Communities such as Frederick, with a relatively large proportion of newer, post-FIRM construction, are more likely to have fewer critical facilities in the floodplain than communities that have a relatively large proportion of older, pre-FIRM construction. This may be because the pre-FIRM neighborhoods in the SFHA would need nearby critical facilities, thus increasing critical facility vulnerability and making it more difficult to restrict critical facility development in the SFHA.
- Proximity of Development to Stream: Communities such as Fort Collins, with a relatively small proportion of overall development in the floodplain, are more likely to have fewer critical facilities in the floodplain than communities that have a relatively large proportion of overall development in the floodplain. This may again be because increased development in the SFHA would require additional nearby critical facilities, making it more difficult to impose restrictions on critical facility development in the SFHA.

Other facilities such as wastewater treatment plants are, by their function, dependent on proximity to the water body to function properly. Although the above factors indicate that successful implementation of critical facilities restrictions may be limited by historic development that cannot be removed, the factors also suggest that future community planning and floodplain management can help limit placement of future critical facilities in the SFHA.

FEMA regulations now require repair and replacement of critical facilities to 500-year flood standards. The federally-funded repairs following the 2013 floods will fund repair and replacement of critical facilities such as the Lyons water treatment plant to the higher 500-year standard. Projects like this will serve as excellent examples of critical facility resiliency. Total relocation or replacement of critical facilities in the study area would require significant economic resources and will likely be delayed until facilities reach the end of their design life and require replacement.

3.2.2 Property Acquisition

3.2.2.1 Description

Property acquisition is a best practice commonly applied to repetitive loss properties or substantially damaged structures. Physically removing a structure from a property in the SFHA eliminates the hazard to that structure completely. Acquired properties are converted to perpetual green space easement owned by the sponsoring community if the project is federally funded; the onsite structures can be moved to a new location outside of the regulatory floodplain or demolished. Acquisition projects are considered strong best practices because the flood losses avoided are high and permanent for these projects.

Following property acquisition, the parcel of land may be restored to a natural state, which has additional benefits. The restoration of a parcel in the floodplain increases the open space in the floodplain and can create “roughness” as the land re-vegetates, which can slow down flood waters and creates additional area for floodwater storage and conveyance. Depending on the location of the parcel, there may be riparian benefits that can lessen the impact of flooding in other parts of the floodplain. Refer to Figure 3-8 for an example of property acquisition in the City of Longmont.

Figure 3-8: Royal Mobile Home Park Flood Damage – Property Purchased and Converted to Perpetual Green Space by the City Following the 2013 Flood, Longmont, CO.
(Source: City of Longmont, CO)

3.2.2.2 Benefits and Impacts

Homes and buildings located in the SFHA are at greater risk to flood damages because of their proximity to the stream, river, lake, or wetland that is the source of flooding. Restricting development in the regulated floodplain reduces exposure to flood damages. In Section Six of the Regulatory LAS report, floodplain development restrictions related to acquisition are analyzed by assuming removal of all development in the SFHA for the 100-year flood event to answer the question:

> *If no development in the SFHA was allowed when the community first entered the NFIP, what losses would this regulation have avoided in the 100-year event?*

The beginning of Subsection 3.2.1.2 notes the benefits of removing facilities from the SFHA in reducing or preventing losses in the three studied counties from the 100-year flood base event, in terms of total losses and losses avoided (LA), as well as the distribution of the 100-year event losses by county. The beginning of Sub-section 3.2 further illustrates the benefits of removing buildings from the SFHA in Boulder County in terms of reduced losses. Overall, there would be a $486 million reduction in damages in the 100-year event in the three counties if this restriction was implemented.

For the six communities studied in this report, the analysis data from Section Six of the Regulatory LAS report shows the benefits of removing and/or acquiring all properties in the SFHA. Figure 3-9 shows the total losses and the losses avoided associated with removal of all

structures from the SFHA in a 100-year flood event, and Figure 3-10 shows the distribution of 100-year losses avoided. Overall, there would be a $157 million reduction in damages from the 100-year event in five of six communities if this restriction was implemented. Note that data were not available to perform this analysis for Frederick. Additionally, there are no losses avoided associated with Estes Park, presumably due to floodplain development restrictions already imposed on post-FIRM construction.

Reducing development in the floodplain through acquisition of floodplain tracts and removal of any structures can enhance the carrying capacity of the floodway to accommodate rising flood waters. Floodplain acquisition and conversion to natural areas creates green space that can enhance habitats for numerous plant, animal, avian, and aquatic species. When vegetation is returned, increased roughness in the floodplain can mitigate the force of flood waters and reduce downstream impacts. Recreation can be enhanced if floodplain corridors are interconnected into regional byway systems for bicycling, walking, and jogging.

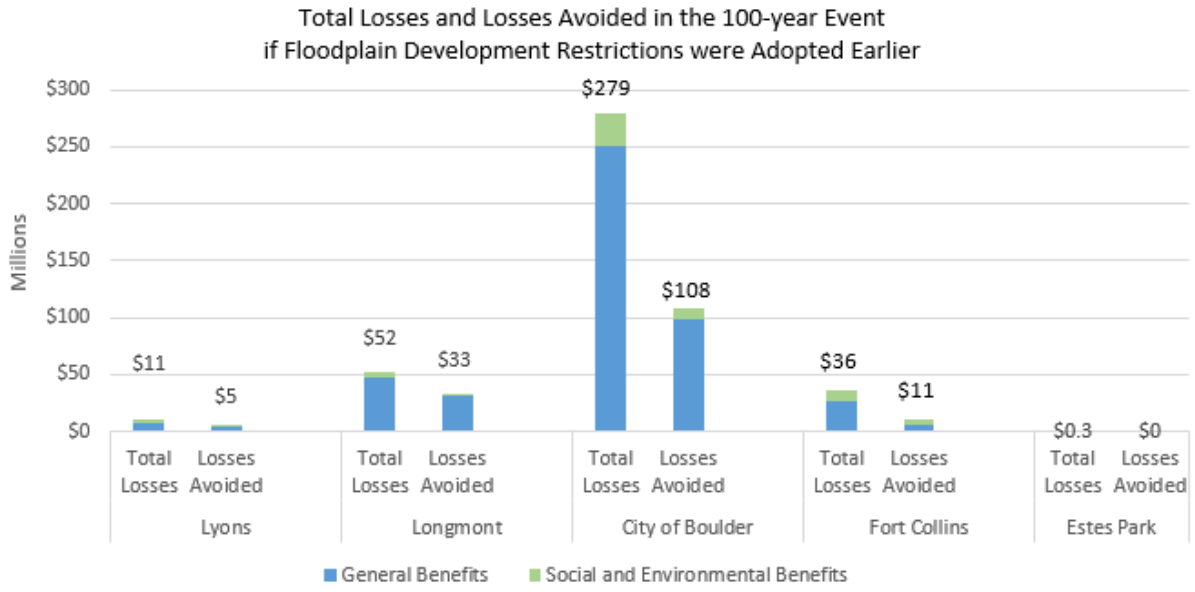

Figure 3-9: Study Community Losses and Losses Avoided to SFHA Structures in Boulder, Larimer, and Weld Counties in the 100-year Flood Event

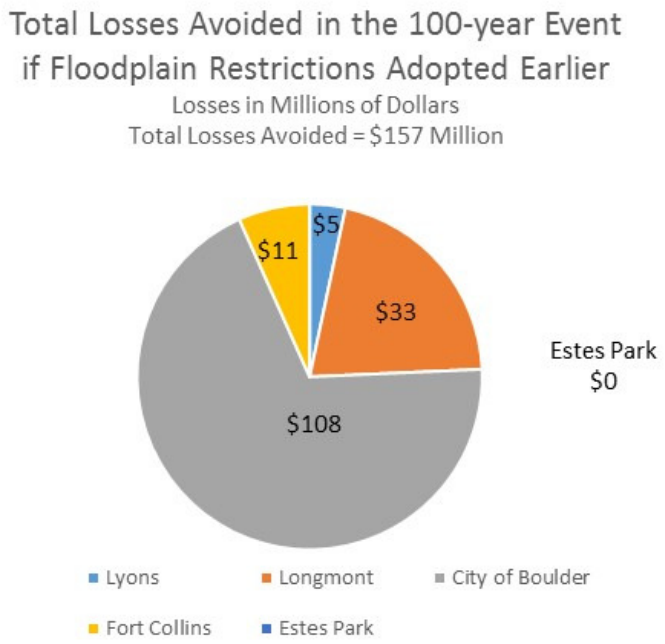

Figure 3-10: Distribution of Study Community Losses Avoided to SFHA Structures in Boulder, Larimer and Weld Counties in the 100-year Flood Event

3.2.2.3 Community Successes and Challenges

Some Colorado communities such as Fort Collins have been successful in acquiring SFHA tracts through negotiations with developers, cooperative agreements, donations, and other means. With limited local funds, acquisition of these areas is often a low priority, and maintenance is a concern. In addition, some have the view that restriction of development in the floodplain impedes economic growth by reducing the area available for development or redevelopment.

Since there is usually a higher identified flood hazard risk in the SFHA, floodplain development restrictions have the potential to provide significant economic benefits. However, in some communities, the lack of well-defined floodplains due to aging or non-existent flood mapping can underestimate the flood risk in any area, especially in mountain regions with steep topography and "flashy" streams where flood levels can rapidly rise. The floodplain development restrictions described in this section focus on critical facility siting restrictions and property acquisitions.

Restriction of floodplain development through restricted critical facility siting and acquisition has positive impacts on a jurisdiction's CRS rating, as they receive points for having these restrictions in their floodplain management ordinance and implementing these practices.

3.3 FLOODWAY DEVELOPMENT RESTRICTIONS

3.3.1 Description

FEMA defines the "regulatory floodway" in 44 CFR 59.1 as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated surcharge height. Figure 3-11 represents a typical floodplain section showing the floodway with the designated minimum one-foot surcharge height. This surcharge can be lowered if specified in local floodplain management regulations. As noted in Section Two, damages in the floodway throughout the Front Range region and in the three counties and six communities were extensive.

Current State of Colorado Floodway Study Requirements

In November 2010, Colorado adopted updated rules concerning floodways that became effective in January 2011. The updated rules require that floodway studies after the effective date of the FIRM be based on a designated surcharge height of 0.5 foot. However, Letters of Map Revision (LOMRs) are exempt from the updated rule in order to avoid criteria conflicts with FEMA. As with freeboard restrictions, the updated rules require adoption by communities because of local land use authorities, but are essentially required for a community to remain in good standing with the NFIP. There were no additional modifications to the updated rules following the September 2013 flood.

Colorado understands the importance of floodway development and adopted statewide floodway study surcharge requirements in late 2010 (see insert above).

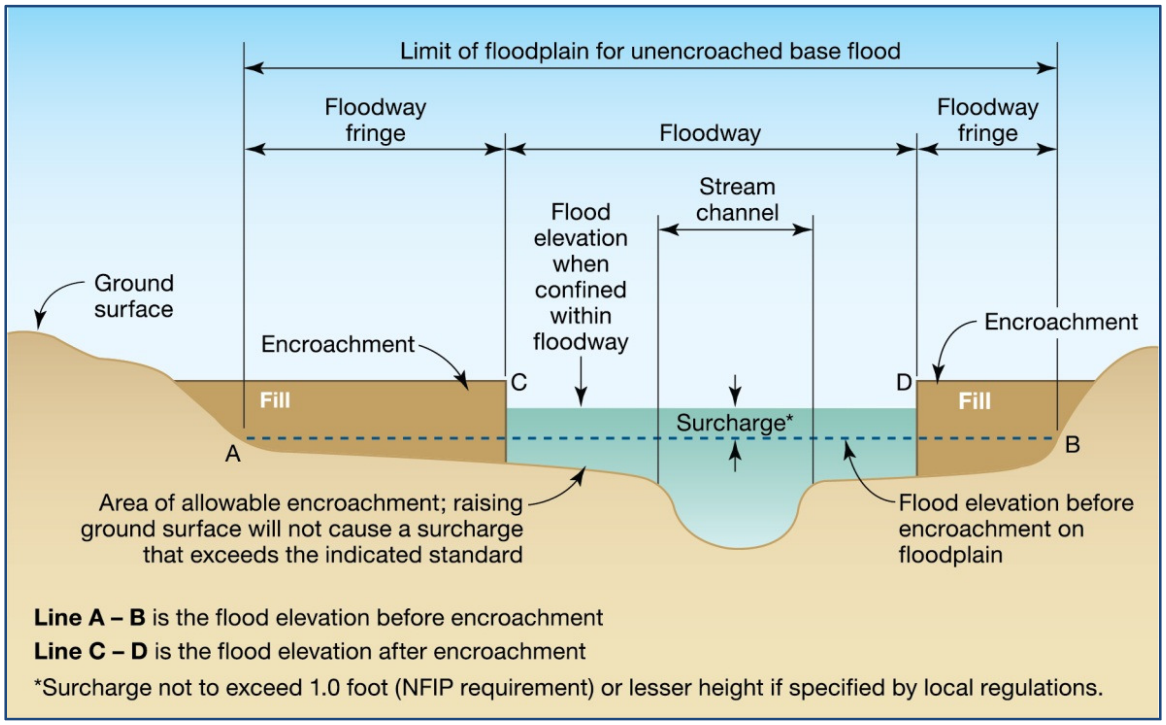

Figure 3-11: Typical Riverine Floodplain Cross Section Showing the Floodway and Surcharge Height (Source: FEMA P-259, Figure 2-3)

Figure 3-12 shows the floodway on a typical FIRM. Communities that participate in the NFIP must adopt regulations to restrict or prohibit development in the floodway to ensure there are no increases in upstream flood elevations. The regulatory floodway is designated on the FIRM and is based on a hydraulic analysis of a waterway to determine the area needed to discharge the base flood without impact to the base flood elevation. Restrictions on floodway development may prohibit floodway encroachment or prohibit all development in the floodway. A community may reduce losses across the entire floodplain by regulating development in the floodway.

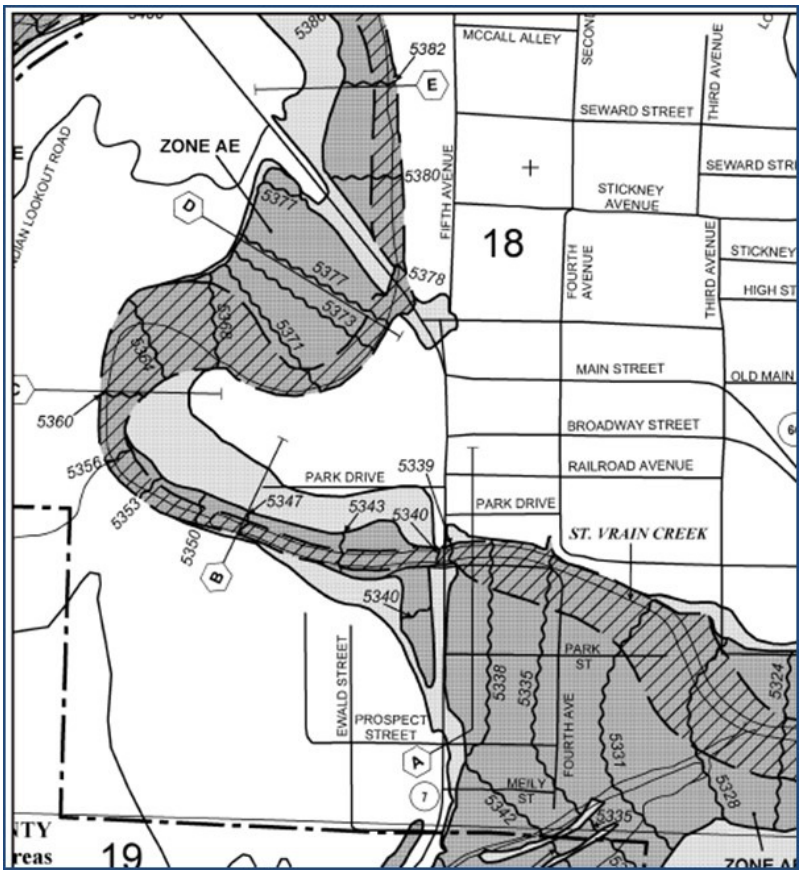

Figure 3-12: Floodway Location Shown as Cross-Hatched Area on FIRM.
(Source: FEMA Map Service Center, FIRM for Lyons in Boulder County, CO)

Floodway development restrictions also provide environmental benefits to communities through increased green space and increased flood channel capacity during flood events.

- **Acquisition and Open Space Preservation:** Acquisition of floodway properties and community purchases of open space for preservation have been used by several communities resulting in reduced damages during the September 2013 flood event. One example was Fort Collins's acquisition of properties and open space preservation along the Poudre River, which contributed to the reduction of flood damages in that watershed as shown in the example containing Table 3-3 and Figure 3-13.

Poudre River Acquisition Projects and Open Space Preservation – City of Fort Collins, CO

Submitted by: Marsha Hilmes- Robinson, Floodplain Administrator, CFM

CRS Activities: 420 – Open Space Preservation, 520 – Acquisition

Description: The September 2013 flooding on the Poudre River was a 50-year event with a flow of approximately 10,400 cfs at the mouth of the canyon. There was very minor damage in the city limits, in large part due to the preservation of open space and acquisition of high risk structures. For several decades, the Fort Collins Natural Areas Program has proactively purchased property along the Poudre River Corridor, most of which is in the floodplain. In addition, the City's Parks Department owns and maintains several parks in the floodplain. Table 3-3 compares the floodplain acreage in the city limits to the amount of open space preserved by Fort Collins. Preserving this land as open space not only minimizes damages during a flood, it also enhances the natural and beneficial functions of the floodplain including allowing floodwaters to spread out and slow down and providing beneficial habitat (Figure 3-24).

Table 3-3: Open Space Preserved in the Poudre River 100-year Floodplain in Fort Collins.

Parks in 100-year Floodplain (acres)	Natural Areas in 100-year Floodplain (acres)	Total Open Space Preserved (acres)	100-year Floodplain Inside City Limits (acres)	
54.8	923.9	978.7	1484.6	**66% of the 100-year floodplain is** preserved as **open space**.

Figure 3-13: Open space preserved in McMurry Natural Area and Legacy Park along the Poudre River in Fort Collins. Floodwaters in the September 2013 event were able to spread out and slow down and not cause any damages. (Source: City of Fort Collins)

In addition to preserving large tracts of open space, the city's Stormwater Department, in coordination with the Natural Areas Department, purchased several properties in the College Avenue and Vine Drive area as part of a Willing Seller-Willing Buyer program. Two commercial structures and one residential structure have been removed. At the time of the flood, a second residential structure had been purchased, but the building had not yet been demolished. That structure had 8 to10 inches of water in the basement from the flood and is expected to be removed in the near future.

- **Stream Channel Improvements:** Several study communities including Longmont, City of Boulder, and Estes Park have implemented stream channel improvements that restrict floodway development. Greenway preservation used as bike paths and walkways enhanced the areas while reducing flood damages. While some areas suffered damage during the September 2013 flood, local floodplain managers have acknowledged that the green space achieved floodplain development limitation goals while reducing damage to residential and commercial properties, critical facilities, and utilities. Examples include the Elmer's Two Mile Creek Greenways Project in the City of Boulder shown in Figure 3-14, and the Left Hand Creek Channel Improvement in Longmont, as described in the insert with Table 3-4 and Figure 3-15. These channel improvement projects reduced damage during the September 2013 flood.

Figure 3-14: Elmer's Two Mile Creek Greenways Project, Which Suffered Minimal Flood Damage, City of Boulder, CO. (Source: FEMA Contractor, August 2014)

Left Hand Creek Channel Improvement – City of Longmont, CO

Point of Contact: David Hollingsworth, Floodplain Administrator, CFM

CRS Activities: 420 – Open Space Preservation, 520 – Acquisition

Description: In 2010, the City of Longmont Left Hand Creek Flood Project was proposed as a Pre-Disaster Mitigation (PDM) Program project at a cost of $5.7 million. It was awarded and completed in 2012. The mitigation project was designed to increase the flow capacity of the Left Hand Creek channel through a mixed use area. The Left Hand Creek Flood Project improved the Left Hand Creek channel design and updated and resized two bridge culverts (see Figure 3-26). The proposal identified 110 structures to be removed from the SFHA as depicted on the FIRM.

Subsequent to the completion of the PDM project, two LOMRs were issued, one on August 21, 2014 and another on October 22, 2014, to reflect the construction of the project and revise the FIRM in the project area. The September 2013 flood closely aligned to the SFHA as depicted on the LOMR. According to the Longmont Floodplain Administrator, the 2013 flood in Left Hand Creek channel was approximately a 100-year flood event.

As part of this report, a traditional loss avoidance study was conducted for the Left Hand Creek Channel Improvement. The study included 204 structures – the 110 designated project structures plus an additional 94 structures surrounding the project area. As indicated in Table 3-4, the project avoided $22.4 million in damages and losses during a 100-year flood event for a return on investment of $3.91 for every dollar spent from just this one event. Refer to Appendix G of the Regulatory LAS report for additional details on the loss avoidance study for this project.

Table 3-4: Losses Avoided Results for the Left Hand Creek Channel Improvement in Longmont, CO.

100-year Flood Event Pre-Project Losses	100-year Flood Event Post-Project Losses	100-Year Event Project Losses Avoided	Project Cost (Including Annual Maintenance)	**Project Return on Investment (ROI)** = [(22,453,091)/(5,744,858)] = $**3.91 for every dollar spent**
$23,449,720	$996,629	$22,453,091	$5,744,858	

Figure 3-15: Left Hand Creek Channel Improvement Projects Protected Nearby Residence from September 2013 Flood Damage. (Source: FEMA Contractor, June 2014)

3.3.2 Benefits and Impacts

Homes and buildings located in the floodway are at greatest risk to flood damages not only because of their proximity to the source of flooding but also because of the severity of flood conditions, particularly flood velocity. Restricting development in the regulated floodway reduces exposure to flood damages. In Section Six of the Regulatory LAS report, floodway development restrictions related to acquisition were analyzed by assuming no development in the floodway for the 100-year flood event to answer the question:

> *If no development in the floodway was allowed when the community first entered the NFIP, what losses would this regulation have avoided in the 100-year event?*

Section Six of the LAS report shows the benefits of removing all buildings from the floodway in reducing or preventing losses in the three studied counties from the 100-year flood base event in terms of total losses and losses avoided as well as the distribution of the 100-year event losses by county. The report further illustrates the benefits of removing buildings from the floodway in Boulder, Larimer, and Weld Counties in terms of reduced losses. Overall, there would be a $109 million reduction in damages from the 100-year event in the three counties if this restriction was implemented. Note that Larimer County accounts for the largest proportion of the losses avoided. This is because 1) the highest percentage of impacted floodway structures are in Larimer County, and 2) there are twice as many acres of Larimer floodway parcels as there are in Boulder or Weld Counties, thereby increasing the environmental benefits, which greatly increases the value of the losses avoided.

For the six communities studied in this report, the analysis data from Section Six of the Regulatory LAS report shows the benefits of removing and/or acquiring all properties in the floodway. Figure 3-16 shows the total losses and the losses avoided associated with removal of all structures from the floodway in a 100-year flood event, and Figure 3-17 shows the distribution of 100-year avoided losses. Overall, there would be a $24 million reduction in damages in the 100-year event in the three counties if this restriction was implemented. Note that data were not available to perform this analysis for the Town of Frederick. Additionally, there are no losses avoided associated with Estes Park, mainly due to floodway development restrictions already imposed on post-FIRM construction, or lack of detailed floodway data.

Restricting development in the floodway is usually implemented through a clause in the community floodplain management ordinance. Benefits are similar to those described in the Floodplain Acquisition section with amplified benefits to riparian habitats and stream restoration. Floodway parcel acquisitions that include building demolition will be amplified during the next few years as HMGP and CDGB funds expand into the study communities and the entire Front Range region as part of the federal, state, and local recovery efforts from the 2013 floods. Those projects include conversion of those parcels to publicly held green space.

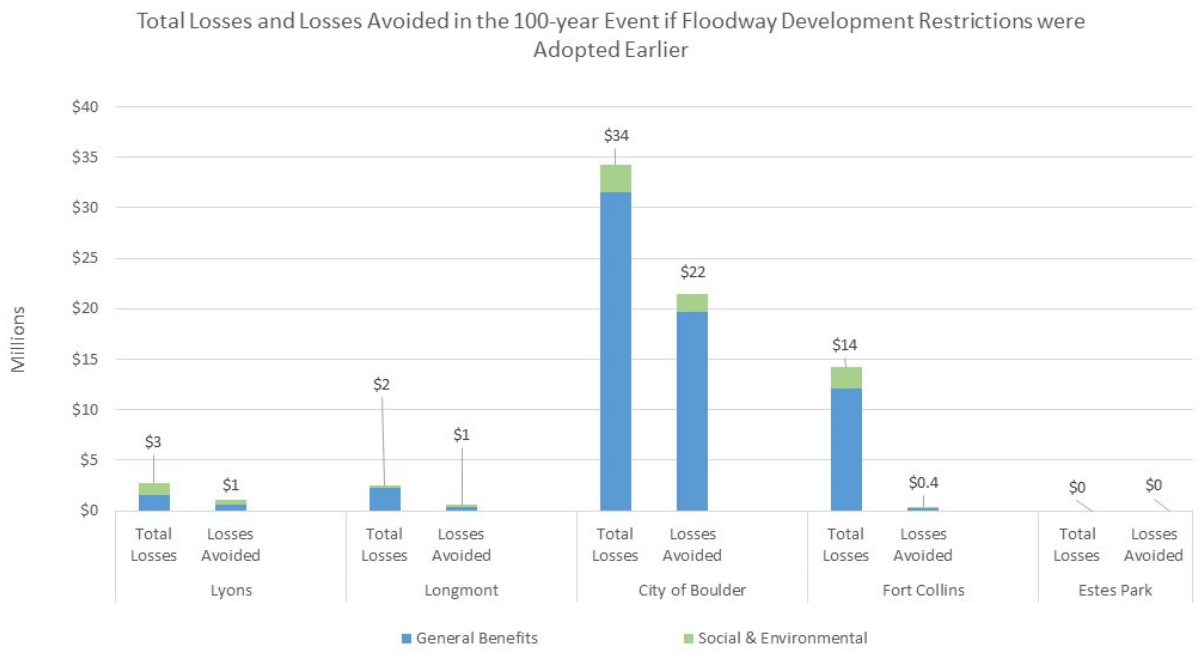

Figure 3-16: Total Losses and Losses Avoided to Floodway Structures in Study Communities in the 100-year Flood Event

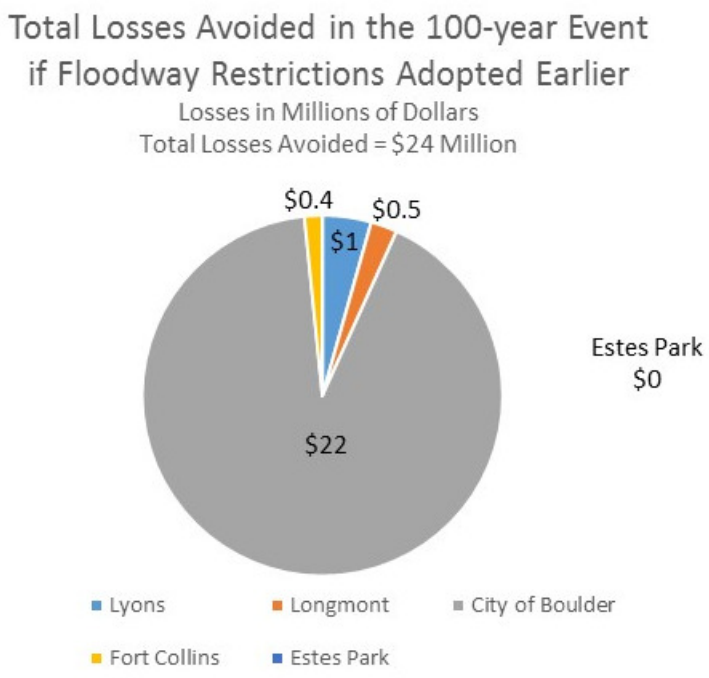

Figure 3-17: Distribution of Total Losses to Floodway Structures in Study Communities in the 100-year Flood Event

3.3.3 Community Successes and Challenges

Replacement of eligible buildings and critical facilities located in the floodway that were severely damaged or destroyed during the 2013 flood is ongoing through federal, state, and local support. These will be sited outside of the floodway in accordance with current federal requirements designed to increase critical facility resiliency. Removing the facilities from the floodway reduces flood insurance premiums due to reduced risk from flood event damages. CRS points may also be awarded for critical facility mitigation projects. Other critical facility replacement will likely be delayed until end-of-life replacement is necessary because of limited available funding in many communities.

One of the most successful floodway acquisitions is the Boulder Creek corridor in the City of Boulder, which sustained minimal damage during the 2013 flood despite significant increases in flood levels and hydraulic forces. The Gilbert White Memorial, which is sited in the floodway, did not sustain any damage in part due to corridor preservation and stream channel improvements. The floodway and floodplain adjacent to Boulder Creek, now in dedicated open space and used for recreation featuring a trail, allowed reduced force and height of floodwaters, which reduced damages.

In some study areas that are rich in open space and land, there may be a perception that more open space or recreational areas are not needed, and that acquisition of more open space is an impediment to economic development and increased community economic vitality. As discussed previously, some communities rarely revise ordinances because of the time consuming process that takes time away from other leadership functions of elected officials; however, the findings of the Regulatory LAS and the data in this report indicate the significant benefits of floodway restrictions that can be achieved through open space preservation.

3.4 BASEMENT RESTRICTIONS

3.4.1 Description

The presence of a basement in a building may increase its flood hazard risk by providing a lower point of entry for floodwaters. Even though the water depth is not deep enough to impact the first floor of a structure, there may be building and contents damages to a building's basement that can damage the foundation, causing building failure, damaging contents and utilities, and creating a health risk from the presence of polluted flood waters and increased mold problems in the structure. Buildings with basements may be more vulnerable because:

- Basements may have windows and doors that are not flood-proofed, allowing water entry;
- Basements may contain finishes, contents, and utilities, some of which are uninsured;
- Basements usually are not waterproofed; and
- Hydrostatic forces can cause foundation or basement wall failure resulting in building collapse.

Whether the basement is finished or unfinished, enclosed or walkout, losses may occur. Four basement types were analyzed in the study as described in Table 3-5.

Table 3-5: Residential Basement Types in Study Area

Basement type	Description
Finished walk-out basement	A garden basement or a walk-out basement that has a finished floor level below the first floor elevation (FFE). (In this scenario, the FFE is considered to be the basement floor elevation.)
Finished enclosed basement	A subterranean or enclosed basement that has a finished floor level that is the FFE
Unfinished walk-out basement	A garden basement or a walk-out basement that is unfinished but has a basement floor level below the FFE
Unfinished enclosed basement	A subterranean or enclosed basement that is unfinished; the first finished floor of the house is at the FFE

Basement development restrictions in the SFHA, and more conservatively in the 500-year floodplain, are best practices because they protect the buildings' structural integrity and reduce losses. Current Colorado basement development restrictions are summarized in the adjacent insert. As observed in the September 2013 flood event, many losses were due to local drainage that flooded basements. Basement damages throughout the study communities and the region occurred in the SFHA, as well as in areas beyond the regulated floodplain.

Current State of Colorado Basement Restrictions

In November 2010, the State of Colorado adopted updated rules concerning higher floodplain management standards that became effective in January 2011. The updated rules include a restriction on basements in areas removed from the floodplain due to a Letter of Map Revision based on Fill (LOMR-F). As with freeboard and floodway restrictions, the updated rules require adoption by local communities because of local land use authorities, but are essentially required for a community to remain in good standing with the NFIP. There were no additional modifications to the updated rules following the September 2013 flood.

3.4.2 Benefits and Impacts

The number of structures with basements in five of the six study communities is shown in Table 3-6; no information was available for Frederick. Detailed information was not available for the 739 structures with basements in Estes Park, but none of the structures were impacted by the 100-year flood event.

The 100-year flood scenario was used to conduct an assessment of damages and losses to structures with basements. In Section Six of the Regulatory LAS report, basement restrictions were analyzed by estimating that structures without basements were not allowed in the SFHA to answer the question:

> *If no construction of basements was allowed in the SFHA, what losses would this restriction have avoided in the 100-year event?*

Table 3-6: Total Buildings with Basements in Study Communities

Number of structures with basements	Lyons	Longmont	City of Boulder	Fort Collins	Estes Park
Finished	34	5,187	6,275	5,822	Unknown
Unfinished	107	11,171	7,529	5,086	Unknown
Total	**141**	**16,358**	**13,804**	**10,908**	**739**
Total Impacted by predicted 100-year flood	82	163	620	166	0

For the six communities studied in this report, Figure 3-18 shows the total losses and the losses avoided associated with not allowing basements in the SFHA for a 100-year flood event, and Figure 3-19 shows the distribution of 100-year losses avoided. Overall, there would be a $50.5 million reduction in damages at the 100-year event in the three counties if this restriction was implemented. Note that data were not available to perform this analysis for Frederick. Additionally, there are no losses avoided associated with Estes Park, presumably due to a lack of structures with basements in the SFHA.

The scenario results in Figure 3-18 and 3-19 are limited in scope because only structures located in the SFHA with basements were included in the analysis. According to the Regulatory LAS report, basement-only losses for the September 2013 event were mostly outside the SFHA and accounted for 22 percent of the total FEMA Individual Assistance (IA) program losses to residential buildings.

Figure 3-18: Total Losses to Basement Structures in the SFHA for Study Communities in the 100-year Flood Event

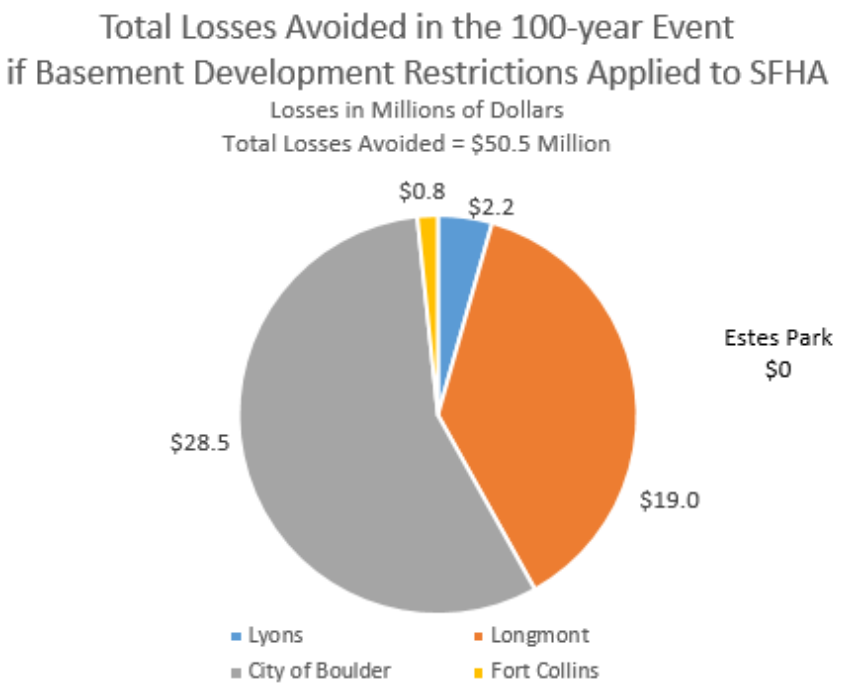

Figure 3-19: Distribution of Total Losses to Basement Structures in the SFHA for Study Communities in the 100-year Flood Event

To address the limitations of the first basement restriction scenario, a second analysis was conducted based on FEMA IA claims data from the September 2013 flood event, expanding basement restrictions outside the SFHA in order answer the question:

> *If no construction of basements was allowed inside the SFHA, and mitigation strategies were implemented for basements in flood prone areas outside the SFHA, what losses would this restriction have avoided in the 2013 flood event?*

A summary of the FEMA IA basement-only loss data for the six study communities is provided in Table 3-7.

Table 3-7: FEMA IA Basement Only Loss Data for the 2013 Flood in Study Communities

Study Community	Basement-Only Loss Structures	% Inside SFHA	% Outside SFHA	Total Basement Only IA Losses	Total IA Losses	% of Total IA Losses
Lyons	71	14%	86%	$129,064	$2,835,479	5%
Longmont	261	1%	99%	$1,011,434	$3,652,445	28%
City of Boulder	3,857	7%	93%	$5,970,366	$11,913,157	50%
Fort Collins	4	0%	100%	$2,278	$22,138	10%
Estes Park	317	100%	0%	$162,234	$540,408	30%
Frederick	115	0%	100%	$201,738	$255,279	79%

For the six communities studied in this report, Figure 3-20 shows the total IA losses associated with basements in the six study communities and Figure 3-21 shows the distribution of losses between structures inside and outside the SFHA. Overall, there would have been be a $7.5 million reduction in the September 2013 damages if this restriction was implemented, with 94 percent of the $7.5 million reduction in basement losses attributable to structures with basements outside the SFHA. Therefore, the importance of basement flood mitigation applies to structures outside the floodplain as much–if not more–than it does to structures in the floodplain.

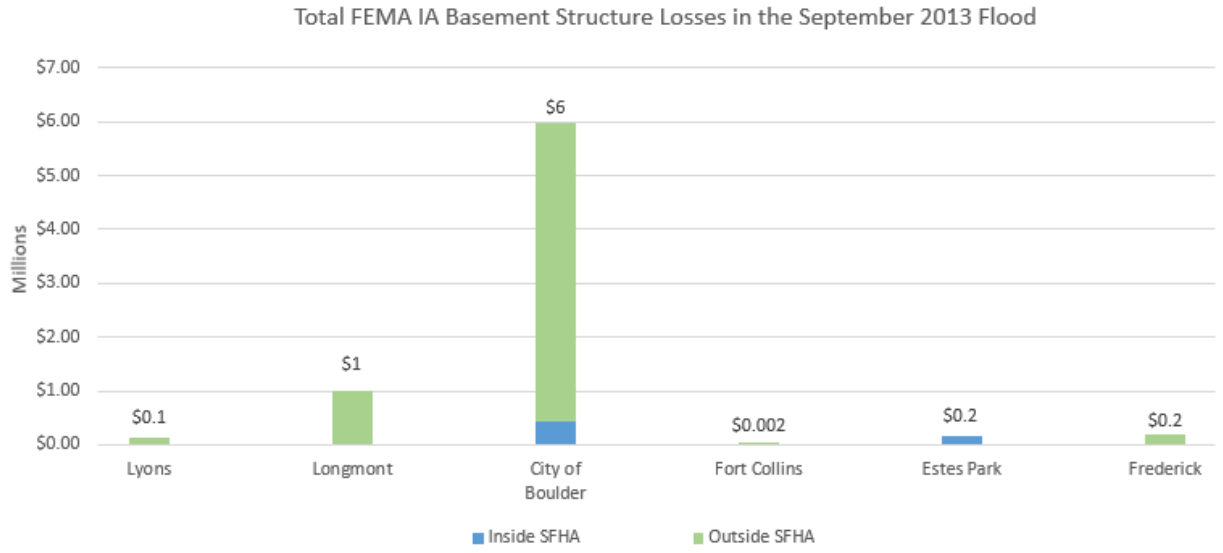

Figure 3-20: Total FEMA IA Losses to Basement Structures in the September 2013 Flood Event

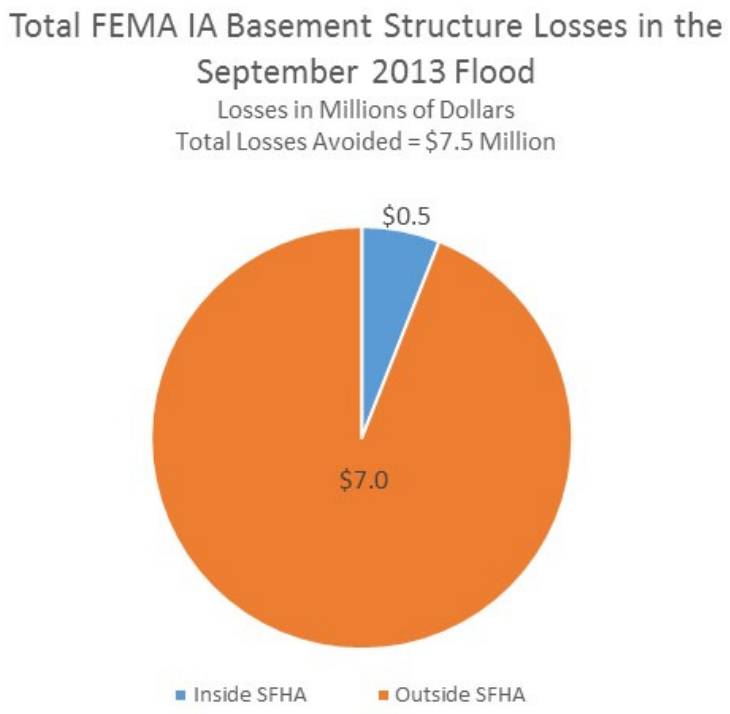

Figure 3-21: Distribution of Total FEMA IA Losses to Basement Structures in the September 2013 Flood Event

3.4.3 Community Successes and Challenges

Other than the current statewide restrictions, most Colorado communities have had limited success in implementing basement restrictions in their existing floodplain management approach. Some of this can be attributed to the size and age of structures in the community and their relative proximity to flooding sources indicated on the FIRM. Basements may be flooded by localized drainage or runoff, as well as sewer backflow. The significant amount of basement-only losses and the fact that the International Building Code includes provisions for restricting basements in flood prone areas, should embolden floodplain managers to take the following actions:

1) Identify flood-prone areas outside the SFHA in which to regulate basement development.
2) Assess basement mitigation strategies such as flood proofing and backflow prevention to reduce basement losses.

3.5 OUTREACH PROJECTS

3.5.1 Description

The strategy of performing outreach projects is a non-structural best practice. Several communities in the study area have active floodplain and emergency managers who have

become community activists, using a variety of methods to inform stakeholders about floodplain management issues, including ways property owners and citizens can protect themselves and the community. Many floodplain management outreach activities are awarded points in the NFIP CRS.

The NFIP CRS is a voluntary incentive program implemented by the NFIP in 1990 that recognizes and encourages community floodplain management activities and programs that exceed the minimum federal NFIP requirements. It uses a class rating system to determine flood insurance premium reductions for residents based on a point system tied to community activities that exceed minimum NFIP requirements, including enhanced floodplain management regulations, local mitigation projects, and outreach activities. CRS classes range from 9 to 1 with 1 being the highest and therefore receiving the highest discounts on flood insurance. Each CRS class improvement produces an additional 5 percent discount on flood insurance premiums for properties in the SFHA, and can also produce discounts from 5 to 10 percent on policies for properties located outside SFHAs. The points are organized by a series of activities designed to reduce property damages, strengthen and support the NFIP, and encourage a comprehensive community floodplain management program. One activity series is outreach.

Nearly 1,300 communities currently participate in the CRS nationwide. In Boulder, Larimer, and Weld Counties, there are six jurisdictions that participate in the CRS. These jurisdictions, their CRS class, and flood insurance premium discounts are shown in Table 3-8, which indicates that three of the six study communities—Longmont, City of Boulder, and Fort Collins—participate in the CRS (shown in bold text).

The potential benefits of outreach that are recognized by CRS are discussed in Subsection 3.5.2.

Table 3-8: CRS Communities in Boulder, Larimer, and Weld Counties

Community	County	CRS Class	Premium Reduction In SFHA	Premium Reduction Outside SFHA
Boulder County (Unincorporated)	Boulder	7	15%	5%
City of Boulder	**Boulder**	**5**	**25%**	**10%**
Longmont	**Boulder**	**8**	**10%**	**5%**
Louisville	Boulder	8	10%	5%
Fort Collins	**Larimer**	**4**	**30%**	**10%**
Loveland	Larimer	7	15%	5%

3.5.2 Benefits and Impacts

For the CRS communities, the score for outreach projects (the c330 score) was reviewed against NFIP policy statistics to answer the question:

Is there a correlation between NFIP policies, claims, and the CRS outreach score?

The City of Boulder and Fort Collins earned c330 points for outreach activities, while Longmont did not apply for points under c330 activities. As illustrated in Figures 3-22 and 3-23, the two communities that undertook outreach activities had more structures insured by the NFIP, both in and outside the SFHA as well as for pre-FIRM and post-FIRM structures, than Longmont, which did not receive CRS points for outreach.

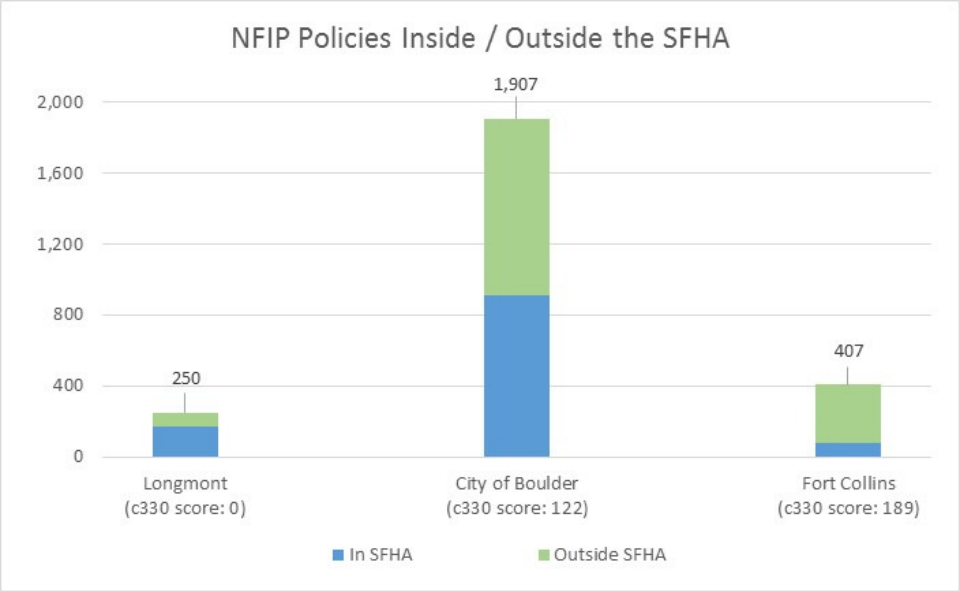

Figure 3-22: NFIP Policies Inside Versus Outside the SFHA for Select CRS Study Communities

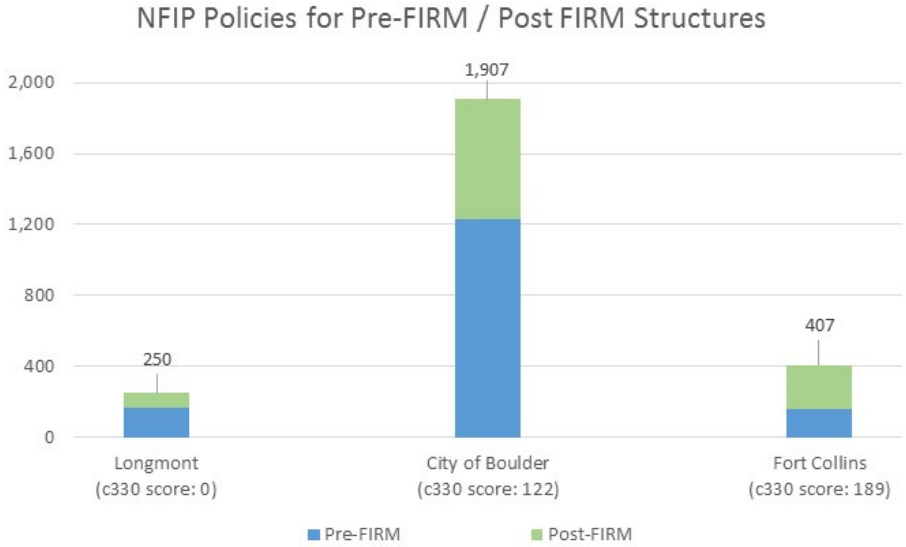

Figure 3-23: NFIP Pre-FIRM Versus Post-FIRM Policies for Select CRS Study Communities

Figure 3-24 provides the 2013 NFIP claims data for the three CRS communities in the study area. Although the City of Boulder had the most overall claims, the average NFIP claim value was higher in Longmont, which received no CRS points for outreach. Communities with higher

outreach scores may have citizens that better understand their individual risk, making them more likely to purchase insurance or implement mitigation measures as a result of outreach, leading to a reduction in the average size of insurance claim.

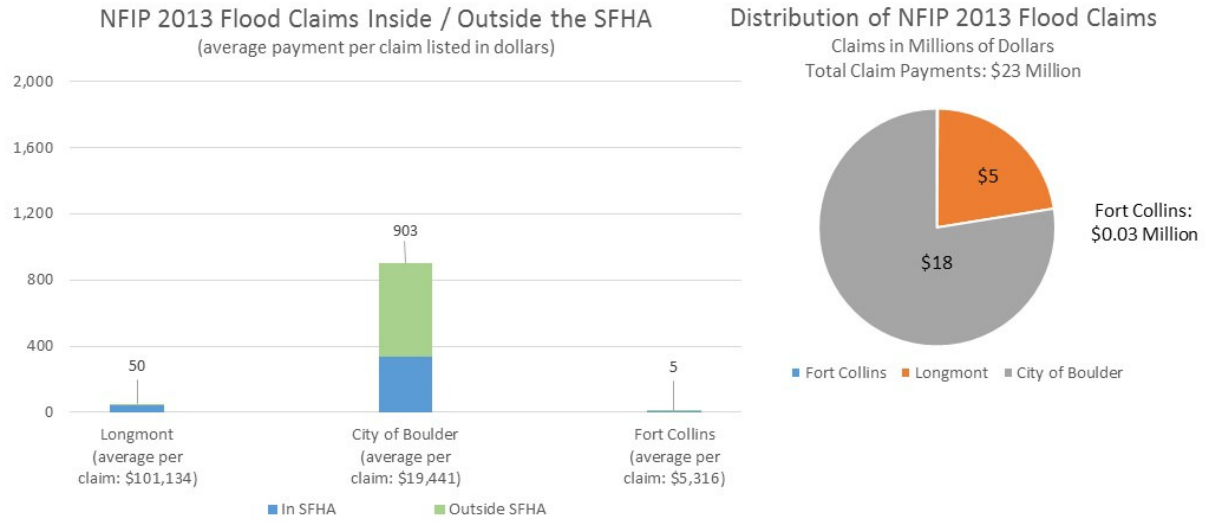

Figure 3-24: NFIP Claims Inside Versus Outside the SFHA and Distribution of Total Claims for Select CRS Study Communities

3.5.3 Community Successes and Challenges

The City of Boulder and Fort Collins have been successful in implementing outreach as part of their existing floodplain management approach. Outreach success can depend on a variety of community factors, including the size of the community, age of structures, level of floodplain development, and population demographics. As a result of outreach, community awareness of flood risk has increased, resulting in increased NFIP participation and a commitment to support additional floodplain management regulations for increased resilience.

Longmont: While Longmont has not included outreach in their CRS Program, the city does have a robust outreach program. One vibrant example is an annual citizen open house at which the building department (which includes floodplain management) sets up stations staffed by city program managers. Residents visit stations focused on various programs and ongoing or proposed projects. The March 4, 2015 Open House focused in part on the South Main Street and Sunset Street bridge flood recovery projects along with comprehensive St. Vrain River restoration and park reconstruction projects. While the open house has been an annual event, based on resident feedback, the city will likely begin conducting the meetings biannually. The next meeting will be conducted in fall of 2015.

Longmont residents extensively use a city-wide riparian trail system for walking, running, and biking. One of the most successful outreach components of the city's program is a stream and river camera system that residents can monitor live:

http://longmontcolorado.gov/departments/departments-n-z/public-information/flood-information/flood-preparedness/status-and-monitoring.

City of Boulder: The City of Boulder has a robust floodplain management outreach program that has evolved over the past several decades. The centerpiece of the outreach program is their city floodplain management comprehensive website, https://bouldercolorado.gov/flood. Created more than a decade ago, the website has grown to provide comprehensive flood hazard information including floodplain hazard maps, flood recovery and resilience, flood preparation, progress on flood-related city projects, property protection methods, and city technical support resources.

The website had undergone a major reorganization in 2013 before the September flood. Immediately after the flood its focus changed to a flood response and then flood recovery resource. It has since returned to "the new normal" reflecting the 2013 pre-flood organization that emphasizes flood recovery resources, projects, and long-term resiliency. This not only keeps residents informed but capitalizes on heightened interest in flood hazards.

While the website is one centerpiece of the Boulder Floodplain Management Outreach Program, full technical support services are available through phone or in-person contact for those who do not have internet access. In addition, enhanced signage is located on city greenways and trails. One example of this is the Gilbert White Memorial flood elevation sculpture along Boulder Creek (Figure 3-25).

Figure 3-25: Gilbert White Flood Elevation Memorial along Boulder Creek, Boulder CO

Fort Collins: Fort Collins has a robust public outreach program that was recently re-organized, planned and prompted in part to better align to new CRS scoring criteria. Release of the new CRS Outreach criteria provided a good opportunity to evaluate the city's floodplain management outreach program. The city assembled a team of floodplain managers, emergency managers, Colorado State University, the city Public Information Officer, environmental groups, social sustainability experts, and the American Red Cross to determine floodplain management outreach priorities, messages, and how to get messages out.

The effort resulted in Colorado's first Program for Public Information (PPI) for a CRS community. This plan outlines target audiences, messages and projects.

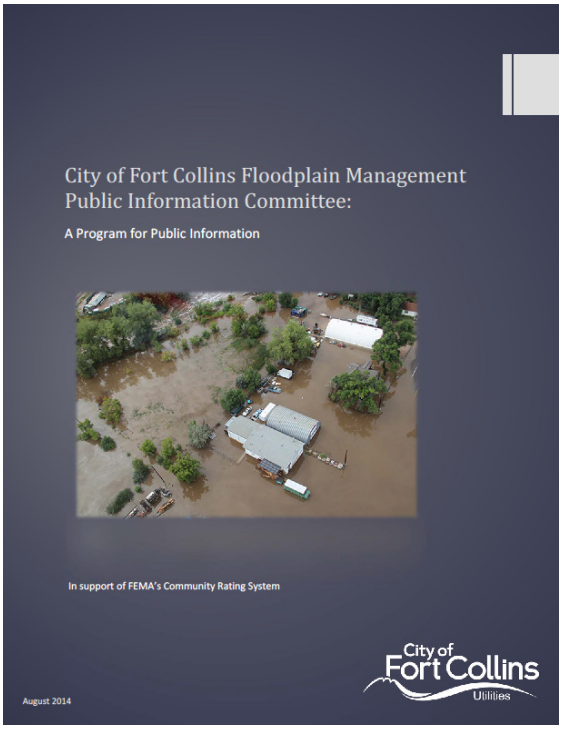

Figure 3-26: City of Fort Collins *Floodplain Management Public Information Committee: A Program for Public Information*, August, 2014. (Source: Marsha Hilmes-Robinson).

The process to develop the PPI strengthened relationships between participants. In particular, Colorado State University invited city officials to participate in the 2014 and 2015 Colorado State University Safety Fair, enabling city representatives to discuss renters' flood insurance with students, reverse 911 sign up, and other relevant projects.

The city's website, fcgov.com/flooding, allows users to locate their property on FIRMs by address or tax parcel number, track project progress, and learn about floodplain management and drainage activities. The city's flood warning system can be accessed online in real time where rainfall and stream flow gages are constantly updated. Residents use this information for flood risk awareness as well as water conservation. fcgov.com/floodwarningsystem.

3.6 LOCAL DRAINAGE IMPROVEMENTS

3.6.1 Description

Local drainage flooding is a persistent problem in many Colorado communities impacted by the September 2013 flood event. Best practices and strategies observed to be cost-effective during the post-flood site visits included:

- **Drainage Improvements:** Drainage improvements such as installation of larger bridges and culverts that improve water conveyance can protect against local drainage flooding as well as reduce damages associated with riverine flooding. Fort Collins has implemented several drainage improvement projects funded with FEMA's Pre-disaster Mitigation Program (PDM) which have improved stream drainage and surface water drainage in the city. In addition, numerous drainage improvement projects have been implemented on the Colorado State Campus in Fort Collins that are incorporated into campus hard-scaping like walkways and in drainage swales and green areas.
- **Stormwater Management Improvements:** Urban Drainage and Flood Control District (UDFCD) communities with strong, long-standing stormwater management improvements tended to experience fewer local drainage-related flooding issues than communities that did not. One stormwater management improvement observed in several Colorado communities was the establishment of a stormwater management district, with stormwater utility fees that could be applied to jurisdictions for maintaining current systems and funding future projects.
- **Detention Ponds:** The construction of detention ponds, as shown in Figures 3-27 and 3-28 in Frederick and City of Boulder, help store excess local drainage accumulated during large storms and reduce the potential for local drainage flooding.

3.6.2 Benefits and Impacts

Due to the complexity of local drainage flooding issues, this report did not prepare a formal losses avoided analysis for local drainage improvements related to the 100-year event or the 2013 flood event. However, as indicated in Subsection 3.4.2, many basements outside the SFHA were damaged during the September 2013 event due to existing local drainage issues and vulnerabilities that were exposed by the event.

The benefits of local drainage improvements are similar to many of the floodplain management best practices and strategies discussed in Subsections 3.1 through 3.4, including reduced damages to buildings and contents, reduced displacement cost for residents and business owners, reduced service losses for critical facilities, and avoided losses in productivity and flood-related stress and anxiety. Unlike the floodplain management best practices and strategies, however, the benefits of local drainage improvements can extend to buildings that are located well outside the SFHA.

Figure 3-27: Regional Flood Detention Pond, Frederick, CO. (Source: FEMA Contractor, August 2014)

Figure 3-28: Stormwater Management Pond on Colorado State University Campus, City of Boulder, CO (Source: FEMA Contractor, October 2014)

The UDFCD was established in 1969 to assist local governments in the Denver metropolitan area with multi-jurisdictional drainage and flood control problems. The regulations, Flood Hazard Area Delineations, and other tools developed by the UDFCD over the past four decades have helped multiple jurisdictions in and around Denver to reduce the impacts of flooding and local drainage issues. Refer to Subsection 2.4 of this report and Subsection 2.2 of the Regulatory LAS report for additional information on the UDFCD.

3.6.3 Community Successes and Challenges

Many Colorado communities such as the City of Boulder and Lyons have been successful in preparing local drainage improvements to reduce drainage issues. The success of implementing local drainage improvements depends on a variety of community factors, notably the size of the community, age and extent of stormwater drainage infrastructure, and level of floodplain development. However, discussions with local floodplain management officials in various jurisdictions demonstrate that implementing local drainage improvements is ultimately dependent on the establishment of a stormwater management district that adheres to UDFCD standards and charges fees that can be used to construct and maintain stormwater infrastructure.

3.7 STRUCTURAL FLOOD PROTECTION MEASURES

3.7.1 Description

The following structural flood protection measures applied to individual residential and commercial buildings were observed to be effective in reducing damages from the September 2013 flood during post-event site visits:

- **Structural Elevation:** Raising an existing structure above the BFE is a well-established method of protecting new buildings and retrofitting existing residential buildings from flood damage in accordance with NFIP regulations, with the added benefit of potentially reducing flood insurance premiums. See Figure 3-29 for an example of an ongoing elevation project in Lyons and Figure 3-30 for an example elevation project in Fort Collins. The effectiveness of structural elevation may be further improved by adding freeboard (see Subsection 3.1).
- **Non-Residential Dry Floodproofing:** Dry floodproofing masonry or concrete buildings by making them essentially watertight using wall sealants and shields can be an effective, NFIP-compliant approach to reducing damages to non-residential buildings; however, the effectiveness of the measure is limited to low depths of flooding, and there must be adequate warning time to implement the dry floodproofing measures. See Figure 3-31 for an example of a non-residential dry floodproofing project in the City of Boulder.

Figure 3-29: Post-Flood Residential Elevation in Progress, Lyons, Boulder County, CO. (Source: FEMA Contractor, June 2014)

Figure 3-30: Aerial Photograph of Seven Lakes Business Park Elevated Buildings Protected from Flood Damage, Fort Collins, CO. (Source: City of Fort Collins Utilities, September 2013)

Figure 3-31: Non-Residential Dry Floodproofing Project on 15th Street, City of Boulder, CO. (Source: FEMA Contractor, August 2014)

- **Passive Flood Barrier/Floodwall:** Construction of an automatic, or passive flood barrier or floodwall around a structure can be effective at reducing flood damages to residential or non-residential buildings. However, construction of a flood barrier for an individual structure will not bring a substantially damaged pre-FIRM building into compliance with the NFIP and may be subject to local floodplain management restrictions in some communities.
- **Improvised Flood Protection:** Improvised flood protection measures such as sandbags or using interior barriers or moving equipment to higher floors can be effective at reducing non-structural and contents damage; however, such measures may not be feasible without adequate warning time and will not reduce NFIP flood insurance premiums.

3.7.2 Benefits and Impacts

Due to the number, extent, and variability of individual projects, this report did not prepare a formal losses avoided analysis for structural flood protection measures related to the 100-year event or the 2013 flood event; however, the June and August 2014 site visits to the various study communities indicated that a range of structural flood protection measures were successful in reducing damages and losses to residential and non-residential buildings during the September 2013 flood event similar to the structural elevation and non-residential dry floodproofing projects highlighted in Figures 3-29 through 3-31.

The benefits of structural flood protection measures include reduced damages to buildings and contents, reduced displacement cost for residents and business owners, reduced service losses for critical facilities, and avoided losses in productivity and flood-related stress and anxiety.

While the benefits of individual structural flood protection measures cannot be determined without a LAS or Benefit Cost Analysis (BCA), recent FEMA guidance can be used to estimate the potential benefits associated with residential structural elevation projects. On August 15, 2013, FEMA Mitigation released the policy memorandum, "Cost Effectiveness Determinations for Acquisitions and Elevations in Special Flood Hazard Areas Using Pre-calculated Benefits." Based on a FEMA Risk Reduction Division analysis of 11,000 elevation and acquisition projects, the policy memorandum provides a pre-calculated benefit of $175,000 for structural elevation projects (for acquisition projects, the pre-calculated benefit is $276,000) that can be used to determine cost-effectiveness. Structural elevation projects that are documented as being in the SFHA with a project cost less than $175,000 may be considered cost-effective without the need for a separate BCA. Structural elevation projects can provide additional benefits to building owners through reduced NFIP flood insurance premiums.

3.7.3 Community Successes and Challenges

Many Colorado communities such as Lyons and the City of Boulder have been successful in implementing structural flood protection measures. The success of implementing structural flood protection measures issues depends on a wide range of factors:

- Flood characteristics – flood depth, velocity, frequency, and duration
- Building characteristics – Structure type, age, condition, and foundation
- Site characteristics – topography and soil conditions
- Owner preferences – cost, accessibility, aesthetics
- Community characteristics – CRS Class rating, floodplain management ordinance, local planning and zoning regulations

In general, communities that have been successful in implementing flood protection measures are ones where local officials and residents are committed to resilience and encourage flood hazard mitigation projects. Successful communities also tend to provide the local match for federal hazard mitigation grant programs such as FEMA's Unified Hazard Mitigation Assistance (HMA) program guidance.

3.8 MISCELLANEOUS MEASURES

3.8.1 Description

The following miscellaneous measures applied to individual residential and commercial buildings were observed during the post-event site visits to be effective in reducing damages and protecting residents from the September 2013 flood:

- **Erosion Setbacks:** Some study communities have erosion setback requirements to protect structures adjacent to streams from erosion and scour damage. Figure 3-32 shows an example of an erosion setback in Estes Park.

Figure 3-32: Residences along Fish Creek in Estes Park were Protected by Erosion Setbacks.
(Source: FEMA Contractor, August 2014)

- **Expedited Post-Flood Recovery:** Some study communities prepared systems or protocols to speed up post-flood recovery and reduce the impact of the event on businesses and residences. For example, Longmont established systems for conducting expedited permitting and residential and commercial debris removal. Another example was the Estes Park floodplain administrator, who worked proactively with town officials to establish protocols for conducting expedited post-flood inspections by a large cadre of experienced staff; this allowed commercial properties in the central business district to reopen within two weeks. These systems and protocols helped reduce business losses and allowed the communities to recover more quickly.
- **Higher Standards for Approximate A-Zones:** Some communities imposed higher regulatory standards for Approximate A-Zones that are mapped on FIRMs but do not have an established BFE. One example of higher regulatory standards was observed at the Toby Lane Development in the City of Boulder, as described in the text box shown with Figure 3-33. Another example was Estes Park's approach that allowed Approximate A-Zones to be regulated based on a BFE established at the high water mark.
- **Flood Warning System:** Flood warning systems in communities such as Fort Collins allowed residents to evacuate to safer locations, and allowed owners valuable time to take some measures to protect their residences and businesses from the impending flood.

Toby Lane Development - City of Boulder, CO

Submitted by: Katie Knapp, Engineering Project Manager, P.E., Certified Floodplain Manager

CRS Activities: 430 – Higher Regulatory Standards (Freeboard = 2 feet), 410- Additional Flood Data (New Study)

Description: The Toby Lane Development was in the newly re-mapped floodplain of South Boulder Creek (Figure 3-33). The City of Boulder started regulating development in the re-mapped floodplain prior to approval by FEMA. Houses were required to meet the city's higher freeboard standard of two feet above the 100-year flood elevation. Because the homes were elevated, they were not damaged in the 2013 flood.

Figure 3-33: The Toby Lane Development in Boulder was protected from September 2013 flood damage because homes were elevated two feet above the 100-year flood elevation.
(Source: City of Boulder)

3.8.2 Benefits and Impacts

This report did not prepare a formal losses avoided analysis for these miscellaneous measures related to the 100-year event or the 2013 flood event. This is because some of the measures, such as expedited post-flood recovery and flood warning systems, are active measures that rely on human intervention for the measures to be effective. Such measures are generally too difficult to quantify using traditional LAS or BCA techniques; however, the Regulatory LAS did conduct an erosion setback assessment in Boulder County based on a preliminary erosion zone established by the St. Vrain Creek Coalition in November 2014. The intent of the erosion setback assessment was to analyze the scenario:

> *What would the losses and losses avoided from the 2013 Colorado floods have been if development in the St. Vrain Creek erosion zone had been prohibited?*

These losses avoided results for the erosion setback of structures in the St. Vrain Creek erosion hazard area are summarized in Table 3-8. Refer to Section 6.4 of the Regulatory LAS for details.

Table 3-9: 2013 Colorado Floods Erosion Setback Assessment

St. Vrain Erosion Hazard Area Structures	2013 Flood Event Impacted Structures	Losses Avoided
698	153	$1,431,876

The benefits of erosion setbacks used in this analysis are similar to many of the floodplain management best practices and strategies discussed in Subsections 3.1 through 3.4, including reduced damages to buildings and contents, reduced displacement cost for residents and business owners, and reduced service losses for critical facilities; however, losses avoided in productivity, flood-related stress and anxiety, and environmental benefits were not considered.

3.8.3 Community Successes and Challenges

Many Colorado communities such as Longmont, City of Boulder, and Estes Park have been successful in implementing miscellaneous measures to reduce drainage issues. The success of implementing these measures depends on a variety of factors, including the size of the community and the level of floodplain development, as well as the type of measure to be considered, and its applicability to and effectiveness in addressing flooding and drainage problems. Discussions with local floodplain management officials in various jurisdictions demonstrate that implementing miscellaneous measures ultimately depends on the commitment of local floodplain management officials to work with other community stakeholders such as the building department to plan, design, construct, and maintain the measures.

SECTION FOUR CONCLUSION – COST EFFECTIVENESS OF BEST PRACTICES AND STRATEGIES

Section Four summarizes the various best practices and strategies discussed in Section Three and draws conclusions about the anticipated cost-effectiveness of these best practices and strategies.

4.1 SUMMARY – COMPARISON OF SCENARIOS TO TEST COST-EFFECTIVENESS OF STRATEGIES

This study analyzed the potential cost-effectiveness of implementing several strategies and best practices related to higher regulatory standards by analyzing the 100-year base flood scenario. The 100-year base flood scenario was used because it is the most common regulatory standard and it allows a comparison of the benefits between the scenarios discussed in Subsections 3.1 through 3.4. Figures 4-1 through 4-4 provide a comparison of the regulatory losses avoided for various categories of best practices and strategies for four of the six communities studied in Boulder, Larimer, and Weld Counties. Due to insufficient flood hazard data for Estes Park and Frederick, these communities were not fully analyzed for this part of the study. Therefore, results are not displayed for 100-year losses avoided for Estes Park and Frederick. For Estes Park, the 100-year flood event losses avoided for freeboard (+2 feet) was $101,474.

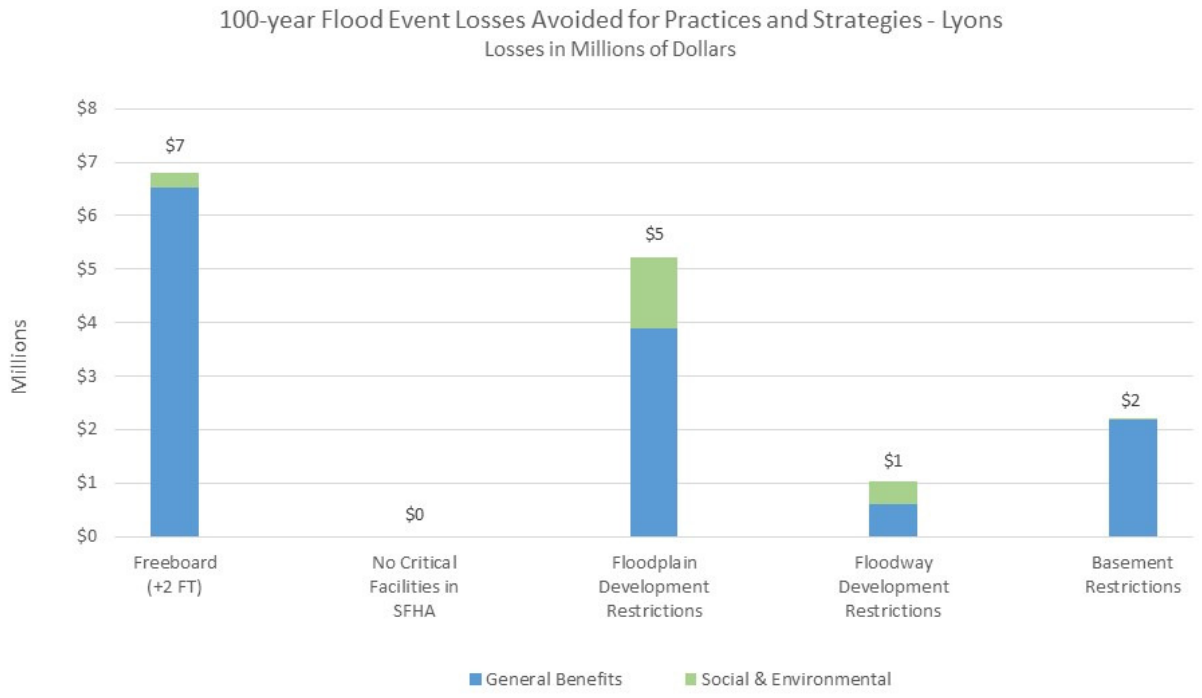

Figure 4-1: Comparison of 100-year Flood Event Losses Avoided in Lyons for Best Practices and Strategies

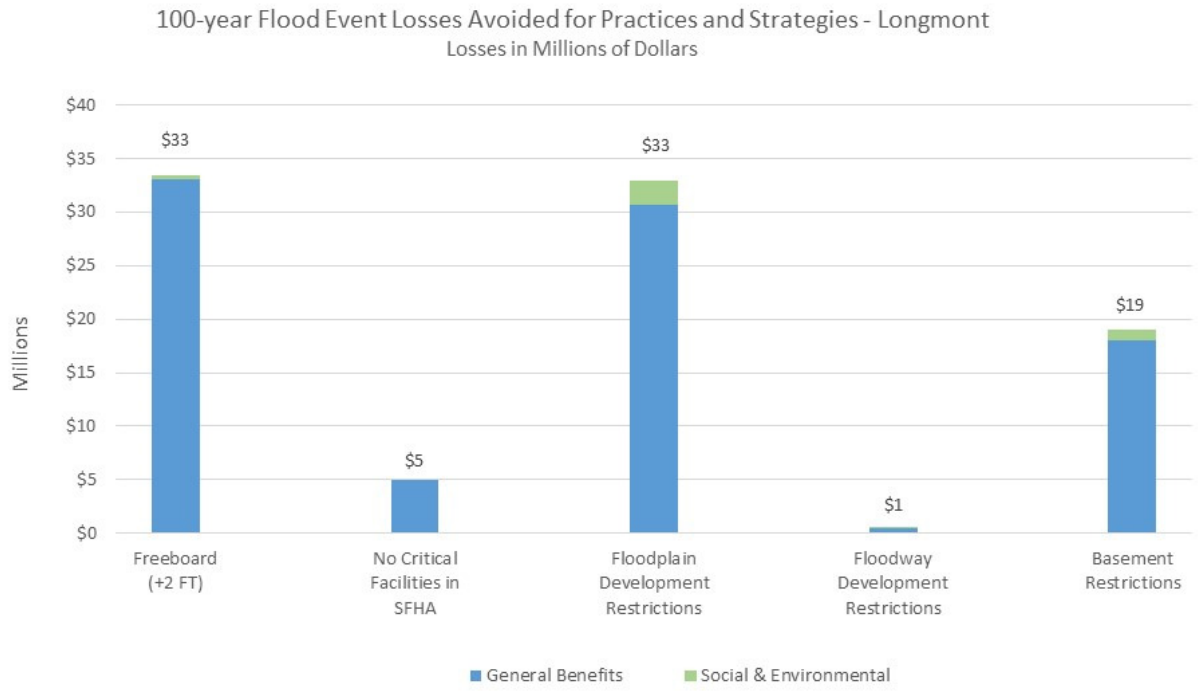

Figure 4-2: Comparison of 100-year Flood Event Losses Avoided in Longmont for Best Practices and Strategies

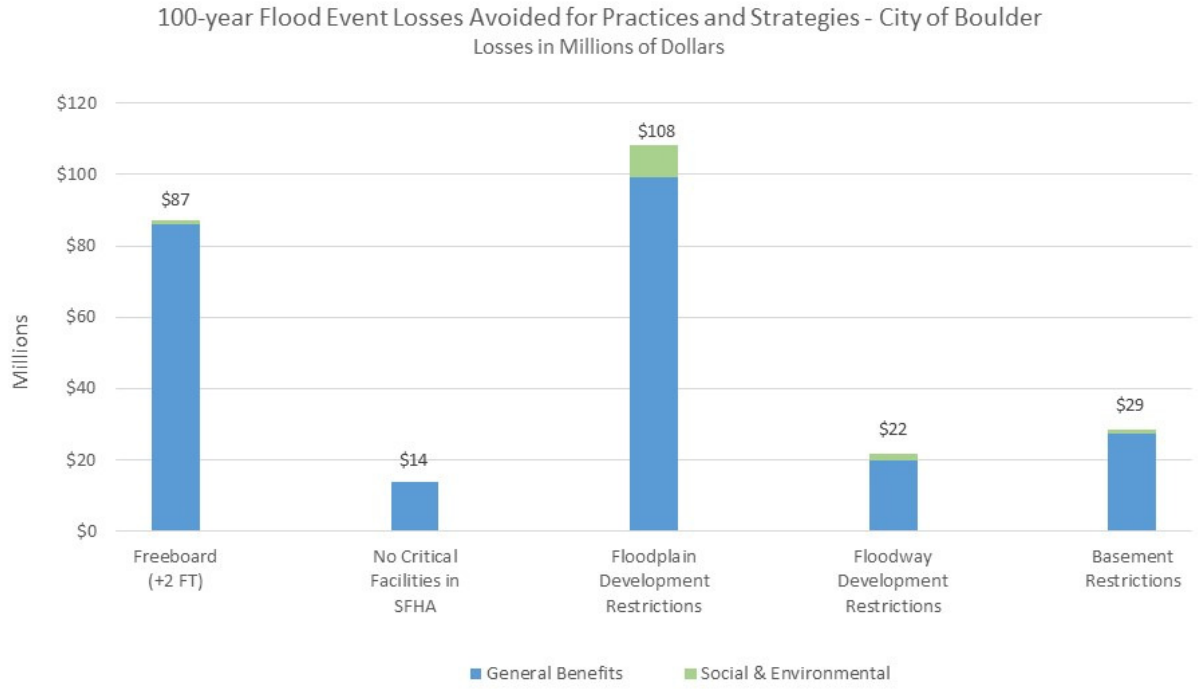

Figure 4-3: Comparison of 100-year Flood Event Losses Avoided in City of Boulder for Best Practices and Strategies

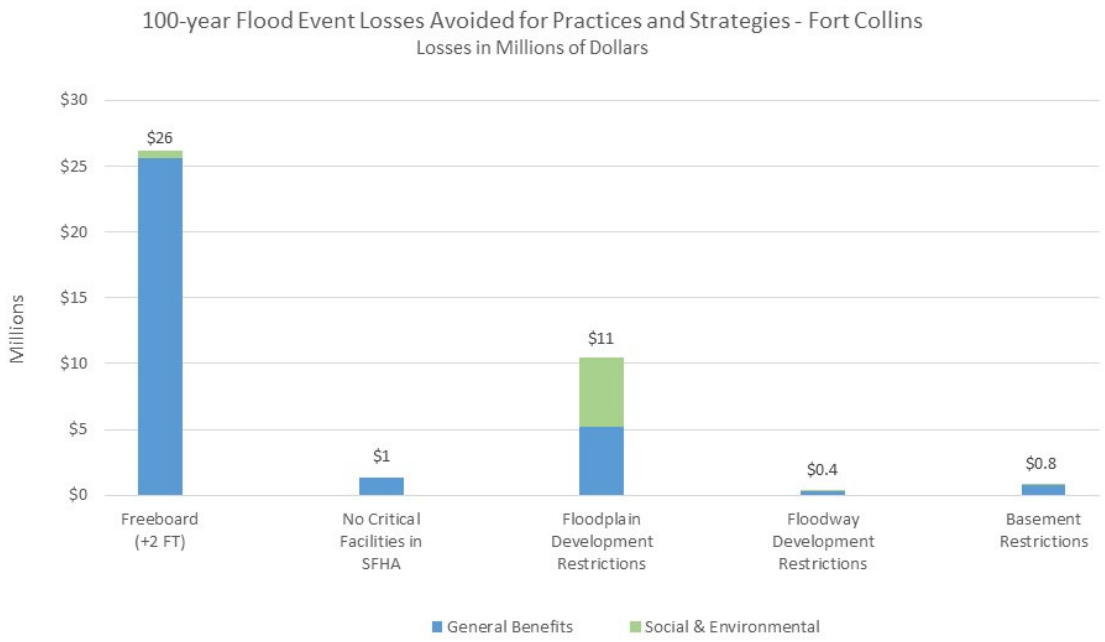

Figure 4-4: Comparison of 100-year Flood Event Losses Avoided in Fort Collins for Best Practices and Strategies

Figure 4-5 shows the combined total losses for the study communities shown in Figures 4-1 through 4-4 in order to evaluate the total benefits associated with each best practice and strategy.

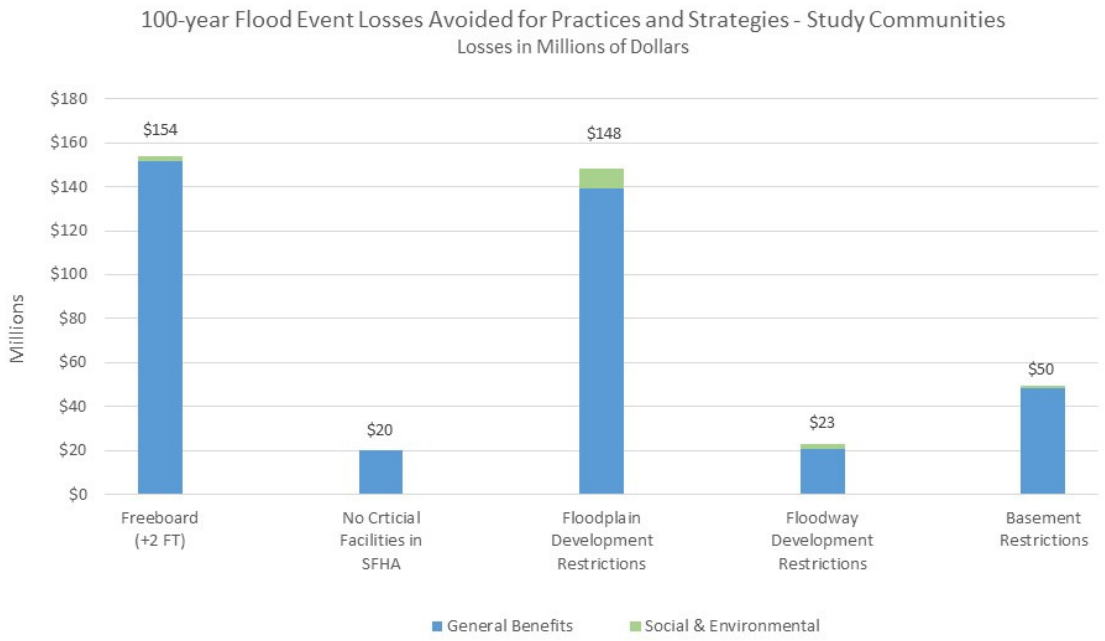

Figure 4-5: Comparison of 100-year Flood Event Losses Avoided in Study Communities for Best Practices and Strategies

Based on the information in Figures 4-1 through 4-5, adding two feet of freeboard and restricting development in the floodplain results in the greatest losses avoided. In addition, it can be observed that:

- Overall, **adding two feet of freeboard** is the best practice that yields the **highest total benefits** (and the highest general benefits), reducing potential damages by $154 million in the study communities.
- For most of the communities studied, **adding two feet of freeboard is the best practice that yields the largest general benefits**. (The only exception was the City of Boulder in Boulder County, which may be due to the large quantity and value of properties in the community's SFHA as well as large numbers of basements present in the SFHA.)
- Overall, **floodplain development restriction** is the best practice that yields the second highest total benefits, reducing potential damages by $148 million in the study communities and **yielding the largest social and environmental benefits.**
- For all of the communities studied, **floodplain development restriction is the best practice that yields the largest social and environmental benefits**.
- Basement restriction is the best practice that yields the **third** highest total benefits, reducing potential damages by $50 million in the study communities.
- Floodway development restriction is the best practice that yields the **fourth** highest total benefits, reducing potential damages by $23 million in the study communities.
- Removing critical facilities from the SFHA is the best practice that yields the **fifth** highest total benefits, reducing potential damages by $20 million in the study communities.

4.2 OTHER BEST PRACTICES AND STRATEGIES

This study reviewed other best practices and strategies discussed in Subsections 3.5 through 3.8, but did not conduct formal losses avoided analyses for the 100-year base flood or the 2013 flood scenarios. Table 4-1 summarizes the highlights of the overall assessment of best practices and strategies for the study communities based on a review of the data in Subsections 3.5-3.8.

Table 4-1: Summary of Overall Cost-Effectiveness of Best Practices and Strategies for the Study Communities Based on the 100-year Flood Event

Best Practice / Strategy	Highlight(s)
Outreach Projects	• CRS communities with positive outreach scores have greater participation in the NFIP with more subsequent benefits than communities with no outreach.
Local Drainage Improvements	• Local drainage improvements can reduce damages and losses both in and outside the SFHA.
Structural Flood Protection	• Structural elevation project benefits may be assumed to average $175,000 **per structure.** This equates to an average annualized losses avoided of $14,100 per year over the 30-year project useful life.

Best Practice / Strategy	Highlight(s)
Miscellaneous Measures - Erosion Setbacks	• If development of new structures was regulated in the St. Vrain Creek erosion zone, there would have been an estimated losses avoided of $1.4 million from the 2013 event.

SECTION FIVE REFERENCES

References used in this study as well as other publications that can be useful to a community, property owners, policy makers, contractors, and designers are listed below. Many are archived on the FEMA website, www.fema.gov.

- State of Colorado. 2013. *Colorado Action Plan for Disaster Recovery*. Available at http://dola.colorado.gov/cdbg-dr/sites/dola.colorado.gov.cdbg-dr/files/cdbg-dr_docs/revised-action-plan.pdf.
- FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Buildings*, Third Edition, January 2012: Guidance for design professionals and building officials on the five basic methods of retrofitting existing residential buildings to resist flood damage (i.e., elevation, relocation, wet floodproofing, dry floodproofing, floodwalls, and levees.)
- FEMA P-312, *Homeowner's Guide to Retrofitting*, 3rd Edition, June 2014: Guidance for homeowners on the basic methods of retrofitting existing residential buildings to resist flood damage discussed in FEMA P-259.
- FEMA 511, *Reducing Damage from Localized Flooding*, June 2005: Guidance for communities on a wide-range of strategies and techniques that can reduce flood damages and losses.
- FEMA P-936, *Floodproofing Non-Residential Buildings*, July 2013: Information for designers on dry floodproofing and other flood protection methods for commercial buildings and core areas of critical facilities.
- FEMA P-798, *Natural Hazards and Sustainability for Residential Buildings*, September 2010: Provides information on sustainable or green building design concepts and addresses sustainability for floods and other natural hazards
- FEMA P-348, *Protecting Building Utilities from Flood Damage*, November 1999: Guidance for designers on designing and constructing flood-resistant building utility systems.
- FEMA 499, *Home Builder's Guide to Coastal Construction,* FEMA P-499, December 2010: Although written for coastal flooding areas, this publication provides a series of useful fact sheets for home builders on measures that can protect buildings from higher-velocity flood damage.
- *National Flood Insurance Program (NFIP) Community Rating System (CRS): A Local Official's Guide to Saving Lives, Preventing Property Damage, Reducing the Cost of Flood Insurance.* This brochure introduces the NFIP CRS as a way of promoting the awareness of flood insurance.

- *Reducing Flood Losses through the International Code Series*©, 4th Edition, 2014: Guidance for local officials on integration of the 2009 and 2012 I-Codes into their current floodplain regulatory processes to meet or exceed NFIP requirements.
- FEMA. June 2005. FEMA 511, *Reducing Damage from Localized Flooding*.
- FEMA. July 2010. FEMA P-784. *Substantial Damage Estimator (SDE) User's Manual and Workbook.*
- FEMA. 1989. FEMA 165 *Alluvial Fans: Hazards and Management*

APPENDIX A: FACTORS THAT INFLUENCE COST-EFFECTIVENESS

The best practices and strategies discussed in Section Three and summarized in Section Four of this report resulted in reduced damages and losses during the 100-year flood event; however, just because a practice or strategy reduces damages and losses does not automatically mean the measures and strategies are cost-effective. This appendix reviews five factors that have the most influence on cost effectiveness of a hazard mitigation best practice or strategy. Note that although the discussion in this report is focused on flood hazards, these same cost-effectiveness factors can be applied to any natural hazard.

For details on the loss avoidance study methodology and case study scenarios used to test the cost effectiveness of many of the identified best practices, please refer to the regulatory LAS, *Reducing Losses through Higher Regulatory Standards 2013 Colorado Floods Case Study (FEMA-DR-4145-CO).*

A.1 FREQUENCY (RECURRENCE INTERVAL)

The frequency or recurrence interval (RI) of flooding is a major factor that influences cost effectiveness. The RI is used to express the probability of a specific flood event being equaled or exceeded over a one year period. This concept is best illustrated by the 100-year flood frequency used by the NFIP to indicate the base flood risk on FIRMs. Floodplain managers understand that the "100-year" flood frequency is a flood that has a recurrence interval of 100-years or 1-percent (1/100 = 0.01) probability of being equaled or exceeded in any given year; however, property owners sometimes misinterpret the 100-year flood to mean a flood that occurs once every 100 years. For this reason, FEMA and NFIP guidance has moved away from the terms "100-year" and "500-year" flood, and replaced them with "1-percent annual chance" and "0.2-percent annual chance" flood, respectively.

As the length of time increases, so does the probability that a flood of a specific magnitude or greater will occur. For example, as indicated in Table A-1, during a 30-year time period (the traditional lending period for a home mortgage), the probability that a 100-year or greater RI flood will occur is 26 percent; during a 75-year time period (the potential useful life of many buildings), the probability increases to 39 percent.

Table A-1: Annual Percent Chance of Flood RIs by Time Period (Source: FEMA P-259)

Length of time period (years)	Annual chance of 10-year RI flood (%)	Annual chance of 25-year RI flood (%)	Annual chance of 50-yr RI flood (%)	Annual chance of 100-yr RI flood (%)	Annual change of 500-yr RI flood (%)
1	10%	4%	2%	1%	0.2%
10	65%	34%	18%	10%	2%
20	88%	56%	33%	18%	2%
25	93%	64%	40%	22%	5%
30	99%	71%	45%	26%	6%
50	99+%	87%	64%	39%	10%

Length of time period (years)	Annual chance of 10-year RI flood (%)	Annual chance of 25-year RI flood (%)	Annual chance of 50-yr RI flood (%)	Annual chance of 100-yr RI flood (%)	Annual change of 500-yr RI flood (%)
100	99.99+%	98%	87%	63%	18%

When assessing best practices and strategies, Table A-1 indicates that smaller RI flood events play a more important role in determining cost-effectiveness than larger RI events because they tend to occur more frequently and cause more damage over time.

A.2 VULNERABILITY OF BUILDINGS

The vulnerability of buildings is another key factor that influences cost-effectiveness. The overall vulnerability of a building is measured based on determination of building value and hazard exposure, as described below.

- **Building Value:** The building value reflects the importance of a building to the community. Building value is determined on a combination of factors including the building replacement value, contents replacement value, potential displacement costs, and the value of services associated with the building.
- **Hazard Exposure:** Hazard exposure reflects the relative potential for building damage or loss. In terms of flood risk, the vulnerability of a building is related to its first floor elevation relative to the flood elevation.

When assessing best practices and strategies, protecting higher value buildings that are vulnerable to flooding will be more cost effective than protecting lower value buildings that are not vulnerable to flooding, because they will be more likely to experience significant damage over time.

The key factors of flood probability and building vulnerability taken together reflect the flood hazard risk. Experience has shown that the most cost-effective flood mitigation best practices and strategies are the ones that eliminate the highest risk at the lowest cost, while the least cost-effective best practices and strategies are the ones that eliminate the lowest risk at the highest cost.

A.3 ANTICIPATED COSTS

A third factor that influences cost-effectiveness is the anticipated cost of best practices or strategies. The anticipated costs include the initial or up-front cost of construction or implementation, plus any additional annual operation and maintenance costs. For structural projects such as elevation or dry floodproofing, estimating the anticipated costs of up-front design and construction plus annual operation and maintenance is relatively straightforward; however, for regulatory measures such as floodplain development restrictions, estimating the anticipated costs can be more complex. Since the anticipated costs of regulatory best practices

and strategies are difficult to quantify, the focus of this report is on best practices and strategies that provide the maximum annual benefits.

A.4 EXPECTED USEFUL LIFE

Another factor that influences cost-effectiveness is the expected useful life of best practices or strategies. The expected useful life is the period of time over which a best practice or strategy will remain effective at reducing damages and losses. In FEMA BCA, the expected useful life is referred to as the project useful life, and is the key element of the present value coefficient (PVC), which is the economic term used to reflect the present value of annualized benefits that occur over the expected useful life. The PVC is calculated as follows:

$$PVC = [1 - (1 + r)^{-T}]/r$$

Where:

PVC = Present Value Coefficient

T = Project useful life (expected useful life)

r = the discount rate that accounts for the time value of money, set by the Office of Management and Budget at 7.0 percent for all federally-funded mitigation projects

Table A-2 provides the expected useful life of various best practices and strategies and the associated PVCs based on current FEMA BCA guidance. As shown in Table A-2, the best practices and strategies with the longest expected useful life are the ones with the highest PVCs and generate the largest benefits.

Table A-2: Project Useful Life and PVCs Associated with Selected Best Practices and Strategies

Best practice or strategy	Expected useful life (years)	PVC at 7% discount rate
Regulatory measures (floodplain management restrictions, floodway restrictions, basement restrictions)	100	14.27
Acquisition/open space	100	14.27
Public works projects (channelization, bridge reconstruction)	50	13.80
Structure elevation (residential or commercial), culverts with end treatments, dry floodproofing	30	12.41
Culverts without end treatments	10	7.02

A.5 OVERALL EFFECTIVENESS AT REDUCING DAMAGES AND LOSSES

The final factor that influences cost-effectiveness is the overall effectiveness of best practices or strategies. With the exception of acquisition, most of the best practices and strategies will not be 100 percent effective at eliminating all future flood damages and losses. As with structural flood mitigation projects, best practices and strategies have a design level of effectiveness based on a flood elevation or a flood RI. Once this design level of effectiveness is reached, the best practice or strategies may be of little or no effectiveness. For structural elevation measures designed to a

two-foot freeboard, the measure will be fully effective until flood elevations reach the BFE plus two feet, and will be of reduced effectiveness for higher flood elevations. For flood barriers or dry floodproofing measures designed to meet the same two-foot freeboard, the measure will be fully effective until flood elevations reaches the BFE plus two feet, and will not be effective for higher flood elevations. All other factors being equal, best practices and strategies with a higher level of design effectiveness will be more cost effective than those with a lower level of design effectiveness because they will reduce higher levels of damage over time.