2022 Comprehensive Flood and Stormwater Master Plan

VOLUME II - Technical Plan | July 2022

In association with:
Tetra Tech
Water Resource Associates
Wright Water Engineers

PURPOSE STATEMENT:

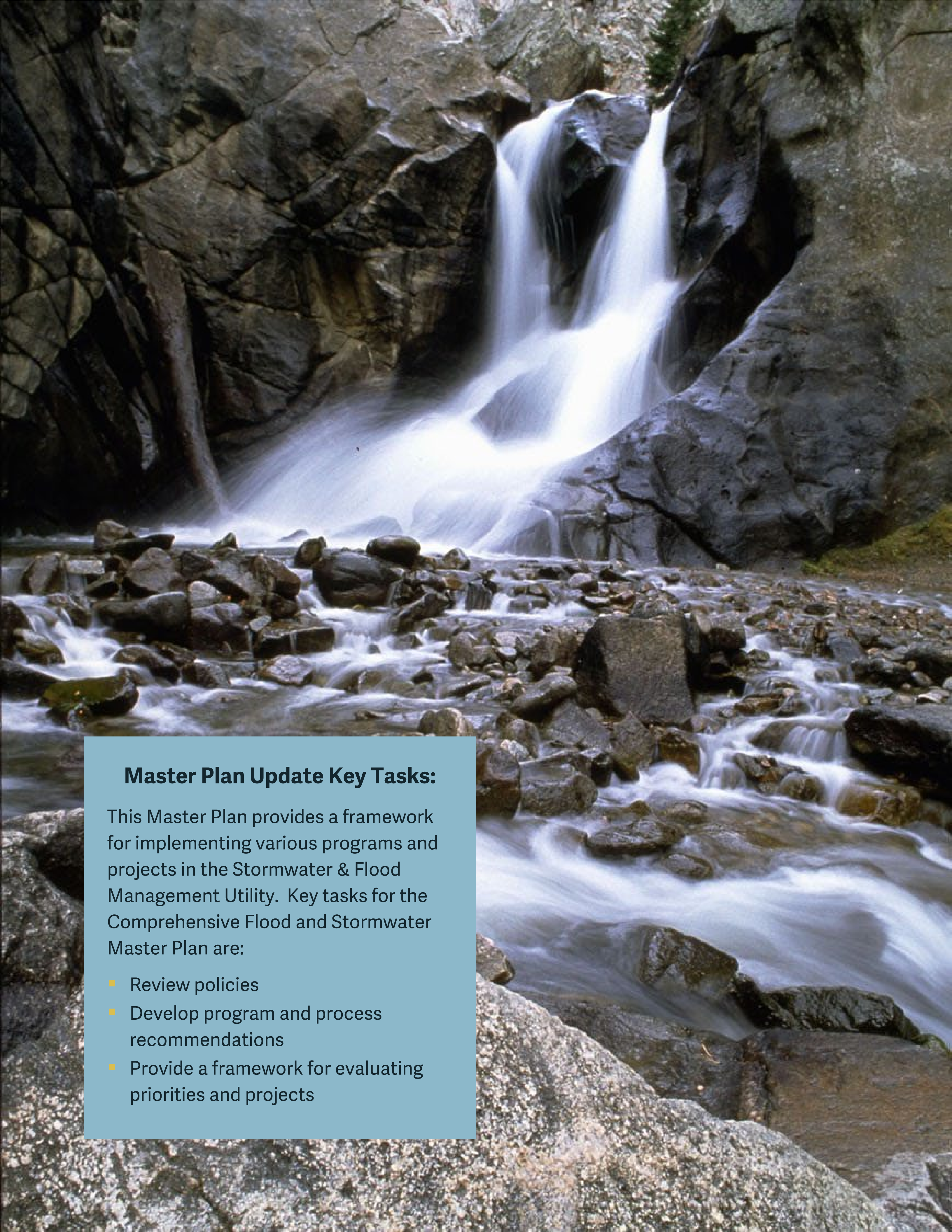
The purpose of this Master Plan is to improve the management of stormwater to help protect people, places, property, and ecosystems in the City of Boulder in a way that builds resilience and is consistent with community values.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES



Master Plan Update Key Tasks:

This Master Plan provides a framework for implementing various programs and projects in the Stormwater & Flood Management Utility. Key tasks for the Comprehensive Flood and Stormwater Master Plan are:

- Review policies
- Develop program and process recommendations
- Provide a framework for evaluating priorities and projects

1 Introduction

The Comprehensive Flood and Stormwater Master Plan (CFS Master Plan or "Master Plan") is an update to the previous document (October 2004) and provides a framework for implementing various programs and projects in the Stormwater and Flood Management Utility (Utility). It is intended to be a policy document focused on improving the management of stormwater to help protect people, places, property, and ecosystems in the City of Boulder (city) in a way that builds resilience and is consistent with community values. This Master Plan was informed by community input, lessons learned from the 2013 flood, Boulder's Racial Equity Plan, and the increasing evidence of climate change, among other considerations.

The Master Plan outlines both a long-term vision for how to complete major projects and recommends guidelines and standards needed to carry out day-to-day operations of the Utility. Key tasks for this CFS Master Plan include a) review existing policies, b) develop program and process recommendations, and c) provide a framework for evaluating priorities and projects.

The second volume of this Master Plan covers the technical detail on background, policy and regulations, issues, system management, and recommendations. Volume II provides the framework necessary for future execution of programs and projects. It is prepared more for an audience having or desiring detailed institutional knowledge of the flood and stormwater system.

Volume II Outline

Chapter 2 summarizes background information concerning the city's Stormwater and Flood Management Utility and related programs and policies. Review includes documents related to the city's floodplain regulations, the Community Rating System, floodplain mapping, mitigation planning, property acquisition, the Capital Improvement Program (CIP), stormwater quality, stormwater drainage system, flood recovery, and flood warning and response. Documents reviewed as part of this process are shown to the right.

Chapters 3 through 9 discuss the improvement actions and programmatic requirements of the Utility as they relate to policy and operations. Topics also include areas where the Utility may not be directly responsible for implementation, but often plays a supporting role. This includes modifications to city regulations and emergency warning, response, and recovery efforts.

Chapter 10 details the development of a Project Prioritization Framework and decision-making tool that will support the city in methodically prioritizing pending flood mitigation projects in alignment with community values. The framework specifically incorporates racial and social equity as a consideration, which will function to repair systemic and institutional racial inequities.

Chapter 11 includes a discussion of financial considerations for the Utility including a funding and policy analysis. Funding scenarios are described to determine the resources needed to accelerate flood mitigation projects, including associated funding, staffing needs, and the community and political will to proceed with project implementation.

Policies, Regulations and Plans

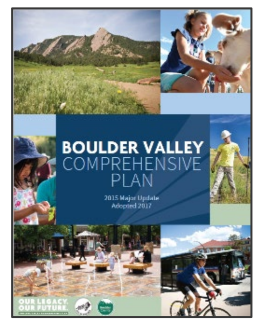
- Boulder Valley Comprehensive Plan
- Boulder Charter and Revised Code
- Urban Storm Drainage Criteria Manual (MHFD)
- MS4 Permit (State of Colorado)
- National Flood Insurance Program (FEMA)
- Design and Construction Standards
- Stormwater Master Plan
- Greenways Master Plan
- Multi-Hazard Mitigation Plan
- Resilience Strategy
- Transportation Master Plan
- *E. coli* TMDL Implementation Plan
- Green Infrastructure Strategic Plan
- Keep It Clean Partnership Annual Water Quality Reports
- Water Quality Strategic Plan
- Bear Canyon Creek Mitigation Study
- Boulder Creek Restoration Master Plan
- Fourmile/Wonderland Mitigation Plan
- Gregory Canyon Creek Mitigation Plan
- South Boulder Creek Mitigation Plan
- Climate, Ecosystems and Community
- Racial Equity Plan

2 Background

The city's overarching approach to flood and stormwater management is established in the Boulder Valley Comprehensive Plan (BVCP). The plan is adopted by City Council, Planning Board, the Boulder County Commissioners, and the Boulder County Planning Commission. The BVCP is used by the City of Boulder and Boulder County to guide long-range planning, and to review development proposals and other activities that shape the built and natural environments in the Boulder Valley.

The BVCP informs updates to the Boulder Revised Code (1981) and to master plans such as this Comprehensive Flood and Stormwater Master Plan. City ordinances and master plans in turn inform implementation of regulations, projects, and programs.

Boulder Valley Comprehensive Plan (2015)



Policies included in the BVCP guide decisions about growth, development, preservation, and environmental protection, and inform decisions about the manner in which urban services are provided, including stormwater utilities and flood control, as presented in the 2021 update. Policy 1.28 of the BVCP states that the city will consider the importance of the other objectives of the Boulder Valley Comprehensive Plan in the planning and operation of the water, wastewater, stormwater, and flood management utilities. These other objectives include resilience, in-stream flow maintenance, floodplain preservation and flood management, enhancement of recreational opportunities, water quality management, preservation of natural ecosystems, open space and irrigated agricultural land, and implementation of desired timing and location of growth patterns.

Guiding Principles

The BVCP references the following guiding principles for managing the Utility:

Floodplain Management

The BVCP states that the city will manage the potential for floods by implementing the guiding principles:

1) Preserve floodplains
2) Preparation for floods
3) Help people protect themselves from flood hazards
4) Prevent unwise uses and adverse impacts in the floodplain
5) Seek to accommodate floods, not control them

In addition, the city will prepare for, respond to, and manage flood recovery by implementing multi-hazard mitigation programs and projects, preparing flood response and recovery plans, and regulating the siting and protection of critical facilities in floodplains. The city seeks to manage flood recovery by protecting critical facilities in the 500-year floodplain and implementing multi-hazard mitigation and flood response and recovery plans.

Stormwater Quality

1) Preserve our streams
2) Prevent adverse impacts from stormwater
3) Protect and enhance stream corridors

Stormwater Drainage

1) Maintain and preserve existing and natural drainage systems
2) Reduce and manage developed runoff
3) Eliminate drainage problems and nuisances

The following policies from the BVCP are applicable to the Stormwater and Flood Management Utility:

Policy	Summary
Policy 2.23 Boulder Creek, Tributaries & Ditches as Important Urban Design Features	Boulder Creek, its tributaries and irrigation ditches will serve as unifying urban design features for the community with multiple co-benefits for a resilient community. The city and county will support the preservation or reclamation of the creek corridors to provide flood management and improve water quality. The city and county will support agriculture by recognizing and accommodating irrigation ditch maintenance practices and operations.
Policy 3.01 Incorporating Ecological Systems into Planning	The city and county will approach planning and policy decisions in the Boulder Valley through an ecosystem framework in which natural regions like bioregions, airsheds and watersheds are considered into planning.
Policy 3.05 Maintain & Restore Natural Ecological Processes & Natural Disturbances	Recognizing that natural ecological processes, such as wildfire and flooding, are integral to the productivity and health of natural ecosystems, the city will work to maintain or replicate natural processes ensuring that appropriate precautions have been taken for human safety and welfare.
Policy 3.06 Wetland & Riparian Protection	Because wetlands and riparian areas are so scarce in the Front Range and are continually degrading, the city and county will develop programs to protect, enhance, and educate the public about the value of these features. The city will strive for no net loss and management of these areas.
Policy 3.10 Climate Change Mitigation & Adaption & Resilience	The city and county are working to help mitigate climate change and recognize that climate change adaptation is an important area for consideration. This includes specific management guidance and direction regarding climate change mitigation, adaptation, and resilience when city and county agencies prepare master plans.
Policy 3.21 Preservation of Floodplains	Undeveloped floodplains will be preserved or restored where possible through public land acquisition of high hazard properties, private land dedication and multiple program coordination. Comprehensive planning and management of floodplain lands will promote the preservation of natural and beneficial functions of floodplains whenever possible.

Policy	Summary
Policy 3.22 Floodplain Management	The city and county will protect the public and property from the impacts of flooding in a timely and cost-effective manner while balancing community interests with public safety needs. The city and county will continue to monitor the effects of climate change on floodplain delineation and management and amend regulation and management practices as needed. The city and county will prepare for, respond to and manage flood recovery by implementing multi-hazard mitigation programs and projects, prepare flood response and recovery plans, and regulate the siting and protection of critical facilities within the 500-year floodplain.
Policy 3.23 Non-Structural Approach to Flood Management	Non-structural approaches should be applied to drainageway improvements whenever possible to preserve the natural values of local waterways while balancing private property interests and associated costs to the city.
Policy 3.24 Protection of High Hazard Areas	High hazard areas within the floodplain contain the greatest risk to loss of life due to floodwater velocity. The city will prevent redevelopment of significantly flood-damaged properties in high hazard areas. The city will prepare a plan for property acquisition and other forms of mitigation for flood-damaged and undeveloped land in high hazard areas.
Policy 3.25 Larger Flooding Events	The city and county will seek to better understand the impact of larger flood events beyond the 100-year event and evaluate context-appropriate, cost-effective policies and floodplain management strategies to address these risks.
Policy 3.26 Protection of Water Quality	The city and county will continue to reduce point and nonpoint sources of pollutants, protect and restore natural water systems and conserve water resources. Special emphasis will be placed on regional efforts, such as watershed planning, and priority will be placed on pollution prevention over treatment.
Policy 3.29 In-Stream Flow Program	The city will pursue expansion of the existing in-stream flow program consistent with applicable law and manage stream flows to protect riparian and aquatic ecosystems within the Boulder Creek watershed.
Policy 3.30 Surface & Groundwater	Surface and groundwater are part of an integrated environmental system that will be protected as a resource and managed to prevent their degradation and to protect and enhance aquatic, wetland and riparian ecosystems. Land use, development, and public land management practices will consider potential impacts to these resources from pollutant sources, changes in hydrology, drilling, mining, and dewatering activities. The city will consider additional regulation of activities impacting groundwater that may create nuisances to other properties.

Additional policies that are indirectly related to the operations of the Stormwater and Flood Management Utility include:

- Policy 1.01 Regional & Statewide Cooperation
- Policy 1.07 City's Role in Managing Growth & Development
- Policy 1.10 Growth Requirements

- Policy 1.20 Definition of Adequate Urban Facilities & Services
- Policy 2.04 Open Space Preservation
- Policy 2.06 Preservation of Rural Areas & Amenities
- Policy 2.22 Urban Open Lands
- Policy 2.37 Environmentally Sensitive Urban Design
- Policy 3.02 Adaptive Management Approach
- Policy 3.03 Native Ecosystems
- Policy 3.04 Ecosystem Connections & Buffers
- Policy 3.07 Invasive Species Management
- Policy 3.11 Urban Environmental Quality
- Policy 3.18 Hazardous Areas
- Policy 3.19 Erosive Slopes & Hillside Protection
- Policy 3.20 Wildfire Protection & Management
- Policy 3.27 Water Resource Planning & Acquisition
- Policy 8.07 Safety
- Policy 9.01 Support for Agriculture
- Policy 10.02 Community Engagement

In addition to policies, Chapter 7 Urban Service Criteria & Standards discusses minimum requirements and thresholds as a part of development projects. Stormwater and flood management standards are included to address responsiveness, funding, operational effectiveness, personnel, and equipment.

The BVCP Mid-Term Update, a routine process to ensure the BVCP incorporates recent area plans and current maps, was approved on March 2, 2021. There were no substantive stormwater or flood management policy items contained in the update.

Boulder Revised Code (1981)

The Boulder Revised Code (BRC, 1981) contains ordinances adopted by City Council, including the city's floodplain and wetland regulations (Title 9 – Chapter 3) and the Stormwater and Flood Management Utility (Title 11 – Chapter 5). These chapters outline the zoning, land use programs, construction of improved drainageways, stormwater conveyance, and stormwater quality. Regulations are informed by both the BVCP and the CFS and apply to both private development and city projects.

The following policy statements are provisions included in the BRC specific to the Utility:

- Promote public health, safety and welfare by permitting the movement of emergency vehicles during flooding periods and minimizing flood losses and the inconvenience and damage resulting from uncontrolled and unplanned stormwater runoff in the city.
- Establish a master plan for stormwater and flood management and its implementation, including, without limitation, a coordinated program of creating upstream ponding or temporary detention of stormwater.

- Establish a Stormwater and Flood Management Utility to coordinate, design, construct, manage, operate and maintain the stormwater and flood management system.
- Establish reasonable stormwater and flood management fees based on the use of stormwater and flood drainage facilities.
- Encourage and facilitate urban water resources management techniques, including, without limitation, detention of stormwater and floods, reduction of the need to construct storm sewers, reduction of pollution and enhancement of the environment.
- Prevent the introduction of pollutants to the municipal storm sewer system that may adversely affect the environment or may cause a violation of the city's Municipal Separate Storm Sewer (MS4) permit or may contribute to the need for modification of that permit.
- Establish standards for permanent stormwater runoff controls.
- Establish requirements for the long-term responsibility for maintenance of structural stormwater control improvements and nonstructural stormwater management practices to ensure that they continue to function as designed, are maintained, and do not threaten public safety.

Additionally, the BRC includes the following legislative intent statements related to floodplain management:

- Restricting or prohibiting certain uses that are hazardous to life or property in time of flood
- Restricting the location of structures intended for human occupancy and regulating the manner in which such structures may be built in order to minimize danger to human life within and around such structures
- Requiring that those structures allowed in the floodplain be expanded or enlarged, and equipment and fixtures be installed or replaced, in a manner designed to prevent their being washed away and to assure their protection from severe damage
- Regulating the method of construction and replacement of water supply and sanitation systems in order to prevent disease, contamination, and unsanitary conditions
- Maintaining for public inspection available maps delineating areas subject to such provisions in order to protect individuals from purchasing or using lands for purposes that are not suitable
- Protecting and preserving the water-carrying and water-retention characteristics and capacities of watercourses used for conveying and retaining floodwaters
- Obtaining and maintaining the benefits to the community of participating in the National Flood Insurance Program

Title 9 – Chapter 3: Floodplain Regulations as Overlay Districts

The floodplain regulations are adopted within the city's land use regulations in the Boulder Revised Code as an "overlay district" in Sections 9-3-2 to 9-3-9 and function in a manner similar to zoning ordinances. They contain the city's floodplain regulations that restrict or prohibit certain uses within the 500-year floodplain (applies to critical facilities and lodging only), the 100-year floodplain, the conveyance zone, and the high hazard zone. Additionally, this chapter includes provisions for the protection of streams, wetlands, and waterbodies, but does not apply to irrigation ditches. The regulations related to streams, wetlands, and waterbodies detail the activities that are prohibited within these areas, as well as encourage avoidance and minimization of other regulated activities.

Title 11 – Chapter 5: Stormwater and Flood Management Utility

This chapter establishes requirements related to the management of stormwater within the city. It establishes the development of a master drainage plan to include all completed or proposed drainage facilities required to carry surface waters without overflow or discharge, as well as drainageways and basins that directly or indirectly affect drainage within the city. It requires that all land development activities within the city must ensure adequate drainage and management of stormwater and floods falling on or flowing onto the property. Construction and post-construction water quality design, inspection and maintenance, and other MS4 permit requirements are included as well.

Design and Construction Standards (2019)

The City of Boulder Design and Construction Standards (DCS) provide minimum standards required for the design and construction of public infrastructure, improvements, and landscaping on city-owned property including rights-of-way and public easements, and the design of private transportation and utility improvements that are connected to or impact public infrastructure. Any privately owned property that discharges stormwater to the city's drainage facilities is considered to be connected to public infrastructure.

Chapter 7 of the Design and Construction Standards covers stormwater and provides design requirements for a stormwater utility system to mitigate safety hazards and minimize property losses and disruption during heavy stormwater runoff or flooding events. The intent is to maintain travel on public streets during storm events, enhance water quality of stormwater runoff, manage increased runoff due to development, establish long-term management of natural drainageways, and provide for ongoing and emergency maintenance of the public stormwater system.

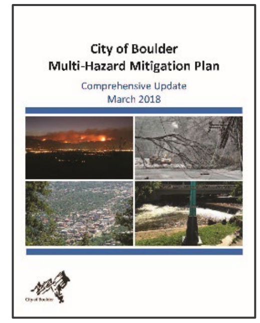
Topics Covered in DCS Chapter 7:

- Drainage Reports and Stormwater Plans
- Hydrology
- Design of open drainageways
- Storm sewer design
- Street drainage and inlet design
- Culvert design
- Detention system design
- Construction stormwater management
- Post-construction stormwater quality requirements, design, inspection, and maintenance

Additionally, the Design and Construction Standards identify which sites must comply with the above requirements and which sites are exempt. For example, stormwater detention requirements apply to development sites with the exception of single-family lots, single-family split lots (not part of a larger development), and projects that can convey runoff from the entire tributary basin directly to a major drainage system without adverse impacts to surrounding properties and facilities (including upstream and downstream). Post-construction water quality requirements only apply to new development or redevelopment sites that result in a land disturbance of greater than or equal to one acre. Further, four different sets of Stormwater Quality Design Standards and associated treatment approaches are detailed for use based on the presence of infiltration constraints. Large lot single family residential projects greater than or equal to 2.5 acres in size with less than 10% impervious area, and certain paving projects are exempt from the post-construction stormwater quality requirements. All projects must demonstrate the consideration of low impact development (LID) principles in their design.

Flood Management

Multi-Hazard Mitigation Plan (2018)



The purpose of this plan is to reduce or eliminate long-term risk to people and property from natural hazards and their effects in the city. It identifies several mitigation goals and objectives based on the results of a risk assessment and includes a review of the city's current capabilities to reduce hazard impacts and specific actions that the city can implement over time to reduce future losses from hazards. The plan was prepared to meet the Disaster Mitigation Act of 2000 requirements in order to maintain the city's eligibility for FEMA Pre-Disaster Mitigation and Hazard Mitigation Grant Programs.

Flood Mitigation and Stream Restoration Plans

Flood mitigation or restoration plans have been created for 9 of the 16 major drainageways within the Boulder Creek watershed. The purpose of these plans is to analyze existing conditions, develop drainageway planning concepts to mitigate anticipated flood damages, and to prepare and prioritize recommended flood mitigation improvements. Additionally, the restoration plan for Boulder Creek provides guidance to improve resilience and guide stream and ecological restoration along the creek. These plans are typically used to incorporate immediate changes into the city's Capital Improvement Program (CIP), to qualify for funds from the Mile High Flood District (MHFD), and Federal and State funding.

Mile High Flood District

The City of Boulder is part of the Mile High Flood District (formerly known as the Urban Drainage and Flood Control District), which was established in 1969 by the Colorado Legislature to assist local governments in the Denver metropolitan area with multi-jurisdictional drainage and flood management challenges. The MHFD receives funding for its programs through a mill levy on property taxes within participating communities. The mill levy for Boulder County is 0.608 mills. For example, a house with an assessed value of $500,000 would pay $304 per year based on the current mill. The MHFD coordinates the following four programs:

Program	Summary
Master Planning	Assists local agencies with flood mitigation planning efforts. Projects identified through master plans are eligible for design, construction, and maintenance funding through the MHFD.
Design, Construction and Maintenance	Projects identified through master plans are eligible for design, construction, and maintenance funding through the MHFD. The MHFD provides routine maintenance of designated drainageways, 100 percent of the funding for identified maintenance projects, and up to 50 percent of the funding for identified capital improvement projects or flood mitigation planning efforts.
Floodplain Management	Assists local governments with delineating flood risks through floodplain mapping efforts, including limited funding availability.

Program	Summary
Information Services and Flood Warning	This program is responsible for contracting private meteorological services to provide daily forecasts of flood potential and notify local agencies when threatening conditions develop. The MHFD also installs and maintains a system of rainfall and stream flow gauges to help monitor the potential for flooding.

As part of their work, the MHFD actively maintains policy and engineering standards through the Urban Storm Drainage Criteria Manual (USDCM). The policies, standards, and technical design criteria within the USDCM form the basis for many policies and design standards adopted by the City of Boulder for flood risk management, stormwater management, stormwater quality, and erosion control.

The Master Planning program assists local agencies with flood mitigation planning efforts. Projects identified through the master plans are then eligible for design, construction, and maintenance funding through the MHFD. The Floodplain Management program focuses on assisting local governments with delineating flood risks through floodplain mapping efforts. The Information Services and Flood Warning program is responsible for contracting with a private meteorological service to provide daily forecasts of flood potential and notify local agencies when threatening conditions develop. The MHFD also installs and maintains a system of rainfall and stream flow gauges to help monitor the potential for flooding.

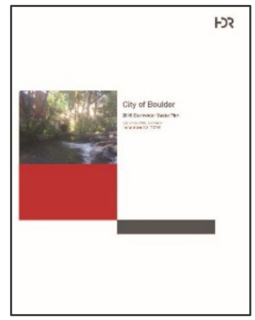
Each year, the City of Boulder requests funding assistance from the MHFD for maintenance and capital improvement projects. The MHFD also provides routine maintenance of designated drainageways, which includes debris removal and mowing. The MHFD provides 100 percent of the funding for maintenance projects and up to 50 percent for capital improvements. Maintenance projects are managed and coordinated by the MHFD, whereas the city is responsible for the management and oversight of capital projects. The MHFD also provides up to 50 percent of the funding for flood mitigation planning efforts, which are coordinated by the city. Limited funding is available for floodplain mapping updates, which are also the responsibility of the city. The MHFD is currently providing financial assistance for capital improvement projects for South Boulder Creek, Gregory Canyon Creek, and Fourmile Canyon Creek; the flood mitigation planning studies for Upper Goose Creek, Twomile Canyon Creek, Skunk Creek, Bluebell Canyon Creek, and King's Gulch; and the floodplain mapping study for Sunshine Canyon Creek.

Stormwater Management

The Utility is tasked with protecting public health, safety and welfare from damage caused by stormwater runoff and with protecting and enhancing the water quality of the local receiving waters in a manner consistent with the federal Water Pollution Control Act and the state Water Quality Control Act through the regulation of non-stormwater discharges to the municipal storm sewer system.

A description of the master plans, permits and requirements is included below.

Stormwater Master Plan (2016)



This master plan provides the city with a guide to proactively address existing and future stormwater drainage and stormwater quality through a series of recommended improvements to the city's stormwater collection system. It develops a master plan for the collector and local drainage systems to alleviate current capacity and flooding problems, as well as evaluates the existing stormwater infrastructure with respect to system analysis criteria created as part of the master plan. Finally, it ranks problem areas for conveyance and water quality in terms of severity and provides a recommended plan with preferred alternatives, detailed cost estimates, and significant implementation. The following policy recommendations are included as part of this master plan:

Policy	Summary
Policy 1 Stormwater Drainage System Infrastructure	The city will provide an adequate stormwater collection and conveyance system for existing and future development within the city.
Policy 2 Maximize Existing Infrastructure	The city will maximize the use of existing storm drainage infrastructure and optimize the size of required drainage system improvements.
Policy 3 Open Channel Drainage Systems	The city will strive to minimize flooding, stream bank and channel erosion within the open channel stormwater drainage system by controlling the rate and volume of stormwater runoff from development and redevelopment projects.
Policy 4 Stormwater Quality CIP Projects	The city will strive to protect the quality of water in the stormwater drainage system and receiving waters, including Boulder Creek, to maintain and enhance the environment, quality of life, and economic well-being of the City of Boulder by identifying and implementing stormwater quality CIP projects.
Policy 5 Stormwater Planning and Coordination	The city will continue to integrate the quantity and quality aspects of stormwater in the planning, design, and construction of development and redevelopment projects, and will look for opportunities to address stormwater issues when planning and designing other capital projects in the city, including projects involving water, wastewater, transportation, and parks.

Policy	Summary
Policy 6 Separation of Stormwater Outfalls from Irrigation Ditches	Storm sewer outfalls (point discharges) are to be separated from irrigation ditches within the city limits.
Policy 7 Groundwater Impacts Resulting from Development	The city will continue to address groundwater issues related to development proposals and the associated discharge locations of pump groundwater flows including water quality impacts due to potential groundwater quality issues at registered locations.

Recommendations from this plan include improvements to the local and collector stormwater drainage system and water-quality problem locations using three tier prioritization systems. As a National Pollutant Discharge Elimination System (NPDES) Phase 2 community, discharges from the city's storm sewer system are regulated under an MS4 permit issued by the State of Colorado. Implementation and stormwater quality recommendations are presented as follows:

- Develop a Program Description Document (PDD) and make it available to the public on the city's website
- Develop an enforcement escalation process for violations of city Code
- Increase recordkeeping of illicit discharge detections to comply with the MS4 permit requirements
- Set up a program to target hot spots and business types that are known to pollute
- Improve the city's construction procedures, including design review, methods for increased construction stormwater compliance, streamlining of requirements, and enforcement and inspection for erosion control permits and dewatering permits
- Create a centralized database to track construction projects and instances of compliance/non-compliance
- Implement oversight of sites that are less than one acre and require stormwater controls to prevent pollution
- Implement standardized processes for permanent BMPs, including design, construction, maintenance, and inspection requirements
- Streamline maintenance and inspection activities including implementing clear schedules, budget for and assign maintenance to specific city groups, provide and track training, improve or create computerized maintenance and inspection management systems, and develop standardized methodology for infrastructure rehabilitation and replacement program
- Address possible future Regulation 85 requirements (Colorado regulation to reduce point sources of nutrient pollution) by updating GIS information on storm drains, outfalls, and land use data; and updating and maintaining the XPSWMM model for water quality
- Set up additional flow monitoring and sampling in various locations throughout the city to evaluate *E. coli* and nutrient concentrations to develop storm-event based loadings from the MS4 to better understand the event mean concentration nutrient loadings associated with Regulation 85

- Coordinate on protecting surface water in stormwater detention and infiltration facilities from water rights by documenting and reporting the facilities to the extent required by CRS 37-92-602
- Look for additional ways to incorporate green infrastructure into both city and private projects

Stormwater Quality

MS4 Permit [COR090000] (2016)

The city's discharge from its Municipal Separate Storm Sewer System (MS4) is authorized under General Permit COR090000 under the Colorado Discharge Permit System, originally issued in 2016 and since modified and expiring in 2021. The MS4 permit provides detailed administrative, programmatic, and recordkeeping requirements with the primary programmatic areas of focus including:

- Public involvement and participation
- Public education and outreach
- Illicit discharge detection and elimination
- Construction site stormwater management (e.g., erosion and sediment control)
- Post-construction stormwater management in new development and redevelopment
- Pollution prevention/good housekeeping for municipal operations

Additionally, the city has specific requirements related to implementation of the Boulder Creek *E. coli* Total Maximum Daily Load (TMDL). These requirements include:

- Monitoring to identify progress toward meeting the TMDL
- Annual reporting requirements addressing:
    - Control measures implemented to reduce *E. coli* discharges
    - Identification of illicit discharges contributing *E. coli*
    - Actions taken or planned to control illicit discharges
    - Monitoring activities

Under the MS4 permit, the city has substantial programmatic and technical requirements to protect water quality. The portion of the permit that is most directly related to future policy includes the city's responsibility to address the selection, installation, implementation, and maintenance of permanent stormwater control measures (SCMs, also known as BMPs) at applicable development sites, which include new development or redevelopment that disturbs one acre or more of land. The city is also responsible for ensuring long-term operation and maintenance of permanent stormwater control measures.

E. Coli TMDL Implementation Plan (2019)

Section 303(d) of the Clean Water Act authorizes the U.S. Environmental Protection Agency to assist states in listing impaired waters and developing TMDLs for the affected waterbody. TMDLs are created for surface waters that are impaired due to prior exceedances of water quality standards and serve as a starting point or planning tool for restoring water quality. These TMDLs establish the maximum amount of a pollutant a waterbody can receive without exceeding water quality standards. The segment of Boulder Creek from North Boulder Creek to South Boulder Creek was placed on the State's impaired waters list for bacteria in 2011 due to elevated *E. coli* levels.

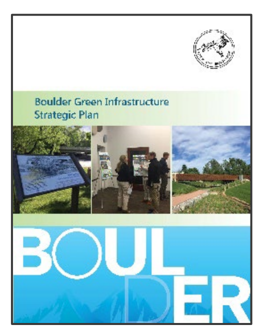
In 2019, the city updated its Total Maximum Daily Load Implementation Plan. The primary focus of the updated TMDL Implementation Plan was elevated *E. coli* in dry weather flows from the storm drain system. Although the implementation plan is limited to the TMDL segment, concepts in the plan are also applicable to other stream segments that are currently identified as impaired on the 2020 Colorado 303(d) List for *E. coli*.

Because *E. coli* originates from both natural and human sources and can persist in biofilms and sediment, it can be particularly challenging to understand and control in urban environments. The city's Stormwater Quality Program includes a multi-pronged adaptive management approach to address *E. coli*, including systematically investigating sources of *E. coli* by sewershed, ensuring compliance with city codes, standards and policies, implementing of MS4 permit requirements, and on-going monitoring. Further, because the greatest health risk to recreators is exposure to *E. coli* from human sources, *E. coli* controls are prioritized to focus on human sources in dry weather discharges, controllability of *E. coli* sources, and recreation risk. The primary actions recommended in the 2019 TMDL Implementation Plan that may help to address controllable sources of *E. coli* loading to the stream include:

- Infrastructure assessment to identify cross connections, sanitary sewer leakage, and septic systems
- Non-structural control measures:
  - Pet waste disposal
  - Illicit discharge detection and elimination
  - Good housekeeping/trash management
  - MS4 facility inspection and storm drain/catch basin cleaning
  - Street sweeping
- Assessment of water quality impacts from homeless encampments

Once solutions are identified that are appropriate for a sewershed, a sewershed management plan can be developed, implemented, and assessed for effectiveness.

Green Infrastructure Strategic Plan (2019)



The Green Infrastructure Strategic Plan identifies and describes how the city can meet the post-construction requirements of the Phase II MS4 permit, proactively identifies future city projects that can be addressed by green infrastructure and promotes the use of green infrastructure throughout the city. Through the planning process with an internal stakeholder group, policy changes were proposed to meet MS4 permit requirements for post-construction through a tiered design approach that emphasizes the consideration of infiltration/green infrastructure first. In addition to focusing on process and policy, the plan also developed a prioritization tool to be used for the identification of green infrastructure pilot projects within the city that could be adopted as part of current and future Capital Improvement Program (CIP) projects.

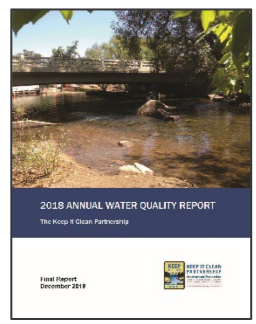
To address process and policy objectives, the plan developed strategies for the integration of Low Impact Development principles and Green Infrastructure Stormwater Control Measures (GI SCMs) for both private and public land development projects including design, construction, and maintenance. Key recommendations include:

- Update the Boulder Design and Construction Standards to address the post-construction requirements of the Phase II MS4 permit.
- Development of interdepartmental Standard Operating Policy and Procedures for use on city land development projects

The strategic plan recommended development of future work plans to support implementation of high priority strategies including:

- Work Plan 1: Establish Water Quality and Environmental Services as the city authority for MS4 permit-required SCMs
- Work Plan 2: Develop post-construction stormwater education and training
- Work Plan 3: Upgrade long-term operation and maintenance program for city-owned SCMs
- Work Plan 4: Further develop and implement a water quality CIP project

Keep It Clean Partnership Annual Water Quality Report (2018)

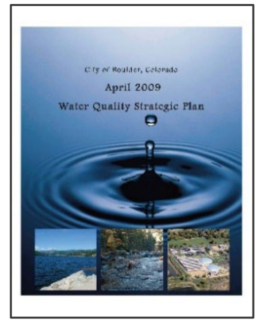


The Keep it Clean Partnership (KICP) is an organization made up of seven partner communities within Boulder County: the cities of Boulder, Longmont, Louisville, and Lafayette; the towns of Erie and Superior; and Boulder County. While these communities originally came together to collaborate on stormwater management, the organization's focus has shifted to also include broader watershed level efforts. For example, the KICP coordinated monitoring program was initiated in 2014 in conjunction with a 319 non-point source management plan for the Boulder-St. Vrain Basin. The original objectives for the collaborative monitoring plan were to leverage data to target impaired stream reaches for improvement, identify changes in water quality, and evaluate the return on investment for capital improvements. Since 2015, the KICP has continued to pursue these objectives along with enhanced communication and integration of data with the public and other organizations. The KICP provides water quality data to the partnership on an annual basis to be included in the watershed level report.

Recommendations pertinent to the city from the 2018 Water Quality Report include:

- Continue to study, monitor, and analyze long-term water quality trends
- Consider an active role in state water quality rulemaking hearings for new nutrient standards
- Focus bacteria reduction efforts on source determination and mitigation
- Further evaluate arsenic, silver, and selenium standards for appropriateness (given naturally occurring conditions)

Water Quality Strategic Plan (2009)



This plan was first prepared in 2009 to develop source water quality goals, outline strategies and performance measures to achieve these goals, and provide a process to address current and future water quality challenges. Water quality goals were developed using an inventory of existing water quality goal statements found in the city's master plans, policies, and regulations, starting with the Boulder Valley Comprehensive Plan.

The following five goal statements were developed:

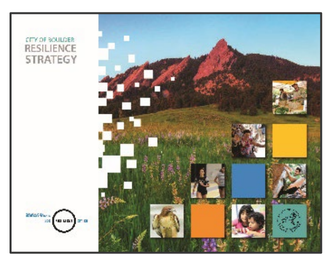
1) Provide safe and high-quality drinking water
2) Manage pollutants from wastewater and other point sources
3) Manage pollutants from stormwater and other non-point sources
4) Protect, preserve, and restore natural water systems
5) Conserve water resources

Other Plans

Greenways Master Plan (2011)

The Greenways Master Plan applies to the riparian areas along Boulder Creek and the major tributaries of Boulder Creek. The plan provides a framework for implementation through coordination of planning, construction, maintenance, and funding sources of city departments and outside agencies. Objectives of the Greenways Program are to protect and restore riparian, floodplain, and wetland habitat; enhance water quality; mitigate storm drainage and floods; provide alternative modes of transportation routes or trails for pedestrians and bicyclists; provide recreation opportunities; and protect cultural resources.

Resilience Strategy (2016)

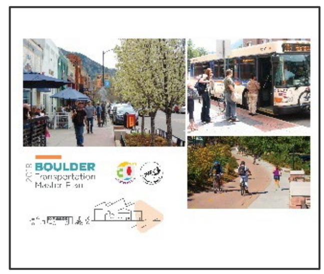


This document defines strategies to help the city adapt to and thrive in a changing climate, economy, and society by outlining a path forward to address major shocks and long-term stresses. Resilience strategies are identified to represent main action areas, along with actions and frontiers required to address the identified issues. Actions are defined as immediate priority activities to be implemented over the next two to three years, and frontiers are defined as transformative investments in community resilience that currently have no models to emulate.

The following actions and frontiers apply to the city's stormwater and flood control infrastructure:

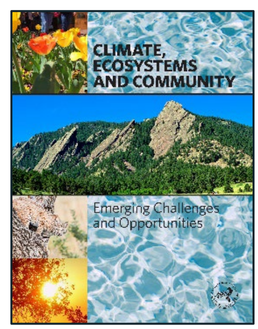
Action/Frontier	Description
Action 1.2 Activate Volunteerism	Develop a volunteer community preparedness training program
Frontier 1 Invest in the Future	Prioritize city investments to promote community resilience and proactively address future risks
Action 3.2 Foster Climate Readiness	Build climate preparedness capacity across the city organization
Action 3.5 Manage Thriving Ecosystems	Develop an integrated approach to managing ecosystems and green infrastructure

Transportation Master Plan (2019)



The Transportation Master Plan pursues two goals – to provide mobility and access within the city in a way that is safe and convenient and to preserve Boulder's quality of life by minimizing the impacts from auto traffic such as air pollution, congestion, and noise. The document provides a policy framework to create and maintain a safe and efficient transportation system that meets the city's sustainability goals; however, stormwater is not addressed as part of this plan. The word 'flood' is only mentioned in reference to the Boulder Municipal Airport being able to provide disaster-related support for floods.

Climate, Ecosystems and Community (2018)

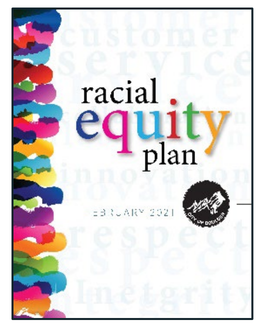


In 2018, the city formed a cross-departmental team to address connections between climate change, climate action, community, and ecosystems. As part of this work, they assessed existing and emerging ecological issues affecting Boulder and identified three categories of ecological change issues as outlined in the table below. The document describes initiatives that have been launched to address these issues and identifies areas for further action, particularly at the community level. Four major areas were targeted as part of a framework of action for future efforts and include: urban forest protection, species protection, soil regeneration and sequestration, and ecosystems monitoring and assessment.

Issue	Factors
Land Cover Changes	▪ Urban Cover: Loss of tree canopy primarily due to Emerald Ash Borer. Ash makes up 20-25% of Boulder's urban tree canopy. ▪ Wildland Cover: Climate change is resulting in increases in wildfires, both in frequency and in size.

Issue	Factors
Species Loss	▪ Pollinators: Annual losses in pollinator colonies have increased dramatically over the last decade. ▪ Aquatic Invertebrates: Climate change and anthropogenic factors are causing decreases in species. ▪ Neonicotinoids: The use of neonicotinoid pesticides have major impacts on the decline of pollinators and aquatic invertebrates.
Soils	▪ Soil Loss and Desertification: Over 1,000 acres in Boulder's 14,000 acres of open space agricultural lands are experiencing extensive soil and fertility loss. ▪ Carbon Sequestration: Soil depletion diminishes or reverses the capacity of systems to absorb and hold carbon.

Racial Equity Plan (2021)



This plan was the result of a collaborative effort among city staff and several organizations to advance racial equity within the City of Boulder government and to transform Boulder into a more inclusive, safe, and welcoming environment for all who live, work, learn, or recreate in the community. Logic models were developed to determine desired short-term (2022), mid-term (2025), and long-term (2030) outcomes for the plan. Additionally, goals and strategies for staff, boards, City Council, as well as coordination with the community were developed to advance racial equity.

Progress will be reported annually with the opportunity for amendments to the plan to reflect changes in circumstances and community desires every three years. It is anticipated that this plan will be updated annually to include accomplishments and results, how racial equity priorities determined budget decisions, challenges faced, proposed next steps, and adjustments to the short-term, mid-term, and long-term outcomes.

Goal	Description/Strategies
Goal 1 Everybody gets it	▪ The city will normalize and operationalize understanding of institutional and structural racism among people who work for or represent the City of Boulder, including city staff, City Council, Boards and Commissions, and ongoing program volunteers. ▪ Strategies include developing equity-focused leadership at all levels, developing workplace-based equity teams, and providing racial equity training.
Goal 2 Justly do it	▪ The city will take action to end racial disparities in city services. ▪ Strategies include achieving commitment at the department level, use of the Racial Equity Instrument, integrating racial equity into master and strategic plans, focusing on racial equity in stewarding public funds, and racial equity programming and city financial processes.

Goal	Description/Strategies
Goal 3 Community commitment	▪ The city will strengthen partnerships and collaborate with community members and organizations that demonstrate a commitment to ending racism. ▪ Strategies include partnering with the community, building community organizational capacity, seeking opportunities to support and promote the value of diversity and multiculturalism, and recognizing history of institutional racism within the City of Boulder.
Goal 4 Power to *all* people	▪ The city will build and maintain trust, expanding the influence of community members of color through inclusive and responsive engagement. ▪ Strategies include improving access to decision-makers, supporting city-community relationships through staffing, focusing on high-quality community engagement, valuing lived experience, and addressing language, cultural and engagement barriers.
Goal 5 Representation matters	▪ The city will eliminate barriers and create opportunities to build a diverse workforce across the depth and breadth of local government including elected officials, boards, commissions, and working groups. ▪ Strategies include addressing boards, commissions and working groups, and developing the City of Boulder's workforce through hiring, recruitment, and retention.

Trends

This section discusses emerging regional and national trends in the topics relevant to this Master Plan. These are to be considered in concert with Boulder's existing policies, initiatives, and master planning efforts. An overarching national trend is toward integrated resource planning of stormwater and flood management capital improvements.

Flood Management

Regionally, many surrounding communities are adopting standards that are more stringent than the state mandated minimum requirements to better suit the needs of the community. Because the National Flood Insurance Program (NFIP) Community Rating System (CRS) is now encouraging nature-based solutions to flood mitigation that overlap with stormwater conveyance and stormwater quality issues, the issues discussed in the sections below also apply to flood management.

Nationally, all communities that participate in the NFIP CRS will be subject to the new program requirements that are part of the 2021 Addendum to the 2017 CRS Coordinator's Manual which went into effect January 2021. Additionally, a more comprehensive update to the NFIP is expected to follow. While the City of Boulder currently receives more than 50% of the possible credit for its stormwater management program under CRS Activity 450 (Stormwater Management), this is expected to decrease with the revised requirements, and this decrease could impact Boulder's community rating and the discounts that the community received on NFIP policies.

Additional flood management activities that are occurring nationally include accounting for the varying effects of climate change. Examples of this include modification to runoff hydrographs and estimation of debris flows caused by drought and significant forest fires in impacted watersheds. Some cities with significantly forested watersheds are requiring that hydrologic conditions account for effects of forest fires by producing hydrographs that reflect 100% deforestation. Management strategies for increased sediment and debris that may be generated from burned areas are used to increase resilience. Boulder has completed similar work related to source water protection for drinking water.

Climate change has also resulted in an increase of frequency and intensity of storm events in United States. Houston, TX, has experienced a 500-year flood event three times since 2015, and Hurricane Harvey caused more than $180 billion in damage. Both Harris County and the City of Houston have since enacted regulations that require new construction to build to the current 500-year base flood elevation (BFE). Examples of regulations to increase resilience include requiring new construction and additions larger than one-third of the existing footprint to be at least 3 feet above the 500-year BFE in the floodway, 2 feet above the 500-year BFE in the 100-year and 500-year floodplains, and restrictions on fill within the 500-year floodplain.

In areas across the United States that deal with alluvial floodplains and deep glacial till, channel migration zones have been mapped using historic data and soil type. These migration zones are characterized as either severe or moderate, and development within these zones is regulated accordingly. Additionally, channel migration is considered a special hazard under the CRS program. By mapping and regulating these zones, additional credit is available as part of the CRS program.

Stormwater Management

The main trend in stormwater drainage is a continued emphasis on reliable, resilient, and sustainable urban drainage systems.

Adaptation for changing rainfall patterns due to climate change is a global trend in stormwater drainage management. Engineers and climate change scientists should collaborate to observe and model climate, weather, and extreme events. This would serve to improve the relevance of the modeling and observations for use in the planning, design, operation and maintenance, and renewal of the built and natural environment.

There is a trend toward the use of stormwater control measures that provide greater benefits. Multi-functional practices to achieve water quality benefits for an increasing range of precipitation events (including flood management) is gaining traction. One green infrastructure trend is to increase co-benefits to meet multiple community goals (e.g., enhance wetlands, reduce heat island effects, etc.) and mitigate the effects of climate change.

Stormwater Quality

The city's stormwater quality plans and programs are generally aligned with regional and national trends. In Colorado, most Phase II MS4 permittees, like Boulder, focus on the required programs necessary to maintain compliance with their MS4 permits. Municipalities such as Fort Collins and Denver are increasingly focusing on, and gaining experience with, green infrastructure strategies, considering not only the water quantity and quality benefits of green infrastructure but also other co-benefits to the community. This is in line with national trends, where communities are using green infrastructure to target not only permit requirements and consent decrees, but also to focus on maximizing other community co-benefits that these practices typically offer.

One significant area in which the city is less stringent than some other Front Range communities, is the threshold at which post-construction stormwater quality requirements beyond Low Impact Development standards are triggered. “Applicable development sites” are based on a one-acre disturbance threshold, which is consistent with the MS4 permit. However, a growing number of communities are using much lower thresholds, such as 10,000 square feet, to trigger implementation of some level of stormwater quality controls. Given that much of the development occurring in the city is smaller-scale redevelopment, many sites are anticipated to fall below the one-acre threshold. Over time, the increases in imperviousness from small projects that fall below the threshold for requiring SCMs will be significant due to the amount of small-lot redevelopment that will occur in Boulder.

Based on trends in recently drafted MS4 permits for Denver and Non-Standard Phase 2 MS4 permits, the city should expect increasingly stringent requirements driven not only by TMDLs, but also by impairment designations on the Colorado 303(d) List. This also includes stream standards for nutrients, specifically total phosphorous and total nitrogen. The city’s work related to the *E. coli* TMDL for Boulder Creek is generally more advanced than what has been implemented in many other Front Range communities with *E. coli* impaired streams, with the possible exception of Denver. Because *E. coli* originates from human as well as natural sources, it can be difficult to determine which set of controls will be sufficient to attain instream standards. The extent to which homeless encampments affect instream *E. coli* exceedances has not been fully characterized but represents a broader social issue in the city that extends beyond the realm of stormwater controls.

Nationally and regionally, there is increased recognition that stream health is affected not only by discharges to the stream, but also the condition of the stream channel itself. Historically, master drainage plans have focused more significantly on flood-related problems and solutions. However, more recently, stormwater quality and “greener” strategies for stream health are being implemented in master plans. Over the last several years, Mile High Flood District has significantly revised guidance related to channel improvements that are more holistic, integrating both instream and upland strategies to protect streams.

3 Stormwater Quality

In built urban environments, stormwater runoff must be actively managed to minimize adverse impacts to streams and drainageways. The city's Stormwater Quality Program works to preserve, protect, and enhance stream water quality and habitat by implementing a multi-faceted program to control pollutants at their source, attenuate and treat stormwater runoff from frequently occurring storm events, and implement stream health improvements. The major goals of the program include:

1) Reduce pollutant loading to streams. At a minimum, this includes complying with the city's Municipal Separate Storm Sewer System (MS4) permit certification and addressing Total Maximum Daily Load (TMDL) requirements such as those in place for *E. coli*. This also includes watershed improvement program measures that go beyond the minimum requirements of the MS4 permit.
2) Educate the public on the role they play in preventing and addressing pollution in Boulder.
3) Maintain and enhance urban waterbodies, including streams, riparian areas and wetlands. This includes collaborating across city teams and departments to implement a greenways[1] management program that improves and maintains the health of stream channels, wetlands and the riparian corridor, as well as provide enjoyable public spaces for the Boulder community.
4) Monitor and evaluate urban surface water quality. This goal recognizes the importance of evidence-based decision-making to guide assessment of water resource health, priorities and effectiveness of programs, capital improvements and maintenance approaches.
5) Adaptively manage the Stormwater Quality Program. Evolving regulatory requirements and environmental conditions require that the Stormwater Quality Program be managed in an adaptable and collaborative manner that engages in broader regional efforts and lessons learned related to stormwater quality.

1 The City of Boulder Greenways system is comprised of a series of corridors along riparian areas including Boulder Creek and 14 of its tributaries, which provide an opportunity to integrate multiple objectives, including habitat protection, water quality enhancement, storm drainage and floodplain management, trails, recreation and cultural resources.

Policy Discussion

Many aspects of Boulder's Stormwater Quality Program are mandated by regulatory requirements under its MS4 Permit. The city also routinely looks for and takes opportunities to optimize the existing program and go beyond minimum permit requirements. Effective policies, therefore, are those that support meeting regulatory requirements; align with community needs and values; and incorporate flexibility to meet changing demands related to regulatory requirements, climate change, resiliency, and other considerations.

Policy and Program Goals

The mission of the city's Stormwater Quality Program is to preserve, protect, and enhance stream water quality and habitat by implementing a multi-faceted program to control pollutants at their source, attenuate and treat stormwater runoff for frequently occurring storm events, and implement stream health improvements. A series of working meetings among city staff, Community Working Group representatives, and the consultant team, resulted in the development of four overarching program goals, ten supporting goals (sub-goals) and associated objectives as summarized below. Recommendations to achieve each programmatic goal follow.

Mission:

Preserve, protect, and enhance stream water quality and habitat by implementing a multi-faceted program to control pollutants at their source, attenuate and treat stormwater runoff for frequently occurring storm events, and implement stream health improvements.

Reduce Pollutant Loading to Streams	Maintain and Enhance Urban Waterbodies (Streams, Riparian Areas, and Wetlands	Monitor & Evaluate Urban Surface Water Quality	Adaptively Manage Stormwater Quality Program
Maintain compliance with current MS4 requirements Reduce sources of E. coli in Boulder Creek to meet TMDL requirements Promote the effective design, implementation, and maintenance of low impact development (LID) & green infrastructure approaches to stormwater management	Protect & enhance water quality and urban stream health through strategic collaboration, data collection, programmatic planning & implementation of water quality projects Support the preservation, restoration, & maintenance of greenways, creek corridors, and wetlands for the protection and improvement of water quality	Support compliance related to surface water permitting and regulations Seek to better understand surface water quality, dynamics, and impacts related to stream health and regulations	Actively engage in water quality planning, policy, and regulation in Colorado Actively engage in regional collaboration efforts and research related to stormwater quality Adaptively manage Boulder's stormwater program to maintain regulatory compliance and adapt to changing climate conditions

1. Reduce pollutant loading to streams

GOAL: Maintain compliance with current MS4 permit requirements.

Objective:	Meet or exceed regulatory requirements for minimum control measures.

Compliance requirements for the city's Stormwater Quality Program are clearly defined under its MS4 permit certification. Requirements include public involvement, public education and outreach, illicit discharge detection and elimination, construction-related erosion and sediment control, post-construction stormwater control measure (SCM) installation and maintenance, and municipal good housekeeping. The program is also clearly described in the program description document (PDD) and annual reports. It is recommended that the city continue with the current approach to MS4 compliance as the baseline for controlling stormwater-related polluted loading to streams. Opportunities to go above and beyond these minimum requirements are discussed further below.

In 2022-2023, Colorado's Standard Phase 2 stormwater MS4 permit is expected to undergo a substantive update that will likely include a series of more prescriptive "clear, specific and measurable" permit requirements. It is recommended that the city actively engage in stakeholder meetings and public comment on the draft permit to provide input to Colorado Department of Public Health and Environment (CDPHE) regarding expected benefits of potential new requirements so that efforts remain focused on actions that are most effective in reducing pollutant loading to streams. The city should anticipate increased administrative and monitoring requirements under the forthcoming MS4 permit renewal.

GOAL: Reduce sources of *E. coli* contributions to Boulder Creek to meet TMDL requirements.

Objective:	Work to identify potential *E. coli* sources and determine controllability.
Objective:	Identify and implement strategies to reduce controllable sources of *E. coli* in stormwater runoff entering Boulder Creek.
Objective:	Implement studies, policy initiatives and projects in coordination with other city initiatives that improve urban stream conditions and reduce *E. coli* loading to Boulder Creek.

Experience in Boulder and in other communities across the country has shown that there are no easy answers for *E. coli*. For more than 10 years, the city has actively engaged in *E. coli* source identification studies and implementation of appropriate abatement strategies to control *E. coli*. The city's program is relatively advanced in comparison to other communities in Colorado and on par with communities in other states that are faced with similar challenges to comply with *E. coli* TMDLs. Based on the results of both outfall and instream monitoring, the city has begun developing and implementing sewershed management plans, as laid out in the Boulder Creek *E.coli* TMDL Implementation Plan, to target storm drainage outfall networks with persistently elevated *E. coli* concentrations (GEI, 2019). Additionally, the city has used the latest scientific techniques such as using human DNA markers (e.g., Bacteroides HF183) to identify areas where possible sanitary sources could be contributing to elevated *E. coli*. The city should continue to use this science-based approach to prioritize areas for further investigation, focusing first on dry weather sources and highest risk sources such as sanitary sewage leakage from aging infrastructure or illicit discharges (WWE and Geosyntec, 2016). It is recommended that the city address potential water quality impacts from encampments through continued coordination with the citywide encampment abatement approach[2], through expeditious clean-up of trash and debris along waterways and further analysis of other potential water quality impacts.

Based on outcomes of sewershed management plans and monitoring efforts, the city should work to address controllable sources of *E. coli* discharged from the city. Solutions for *E. coli* load reductions are likely to be iterative. In some cases, *E. coli* loading may be reduced, but it is unrealistic to remove all *E. coli* loading due to natural sources (e.g., birds, raccoons) present in the watershed. While there are examples of *E. coli* load reduction strategies that can help to reduce *E. coli* loads, there are few, if any, examples of urban streams that have 100% compliance with *E. coli* TMDL targets. In summary, it is recommended that the city continue with source identification and load reduction strategies as dictated in the TMDL Implementation Plan. Completion of this systematic approach should trigger an update to the implementation plan that evaluates regulatory requirements, limited resources, and overall water quality improvement opportunities combined with realistic expectations of what may be achievable.

Currently, the city's MS4 permit has prescriptive *E. coli*-related requirements that apply to Boulder Creek between 13th St and the confluence with South Boulder Creek. The city should continue to evaluate *E. coli* impairments and sources on stream segments outside of the current TMDL reach, including Boulder Creek upstream of 13th St and South Boulder Creek between Highway 93 and the confluence with Boulder Creek, and should anticipate the need for outfall monitoring for these stream segments. If revised permits or new TMDLs are proposed, the city should actively participate in regulatory processes to share information and assist the state in developing meaningful requirements that recognize the advanced status of the program and avoid duplicating prior monitoring and investigation efforts. The city should actively participate, where the opportunity allows, in research and state and national policy discussions related to *E. coli* to stay current with various trends and know best how and when to engage.

GOAL: Promote the effective design, implementation, and maintenance of green infrastructure approaches to stormwater management.

Objective:	Promote infiltration/green infrastructure as the preferred stormwater management strategy through policies for capital project and private development implementation.
Objective:	Conduct education/training both internally and externally to improve SCM design and installation.
Objective:	Enhance SCM maintenance and inspection program.
Objective:	Evaluate options for implementation of SCMs for small sites <1 acre.

Given that most of the city's developable area has been developed, some of the most significant opportunities for improving stormwater quality are through incorporating SCMs into redevelopment sites, capital projects, and sites with less than one acre of disturbance, which is the threshold of applicability of MS4 permit requirements. Infiltration-based strategies that incorporate use of receiving pervious areas and filtration-based practices such as bioretention are particularly well suited to smaller sites. These practices are part of green infrastructure and low impact development (LID) approaches that provide stormwater quality benefits and often have other co-benefits for the community such as green space, cooling effects, and can assist the city in meeting its climate action goals. As Front Range developers and contractors are still gaining experience with design and

[2] *Regulations governing camping bans are codified in BRC 8-3-21.*

implementation of such approaches, the Utility has identified an ongoing need for training for designers and installers so that these systems are properly designed and constructed. Additionally, existing, poorly maintained SCMs can become public nuisances and export pollutants. For this reason, focusing on enhanced maintenance and inspection of SCMs, with emphasis on educating owners on appropriate operation and maintenance practices is expected to reduce stormwater related pollutant loading, even without the construction of new control measures.

The city should explore the benefits of adopting SCM requirements for areas with less than one acre of disturbance in the city code. Currently, the city uses a review checklist approach to encourage use of LID on all development projects. However, formally defined upper and lower thresholds for which the city requires LID or green infrastructure could help to promote more widespread implementation of these approaches. Several other cities of comparable size to Boulder now require runoff reduction approaches to be implemented for development and redevelopment projects less than one acre. The thresholds of added impervious area triggering these requirements vary (e.g., 500 square feet to 5,000 square feet) and would warrant further analysis prior to adoption of revised thresholds in the city. Additionally, the city's Green Infrastructure Strategic Plan (Wood, 2019) provides a solid framework for the city to continue moving forward with green infrastructure implementation and should continue to be used as a guiding document for green infrastructure. A special emphasis for the incorporation of green infrastructure should be placed on projects constructed on city owned properties and as part of future capital improvements.

Colorado Municipality with Recently Updated Criteria	Threshold Triggering Stormwater Quality Control Measures*
Fort Collins	> 1,000 square feet impervious area increase
Denver**	Project > 0.5 acre
Commerce City	Projects with a cumulative disturbed area of > 5,000 square feet
Greenwood Village	> 500 sf impervious area increase

**Some exceptions apply.*
***Draft; proposed threshold.*

2. Maintain and Enhance Urban Waterbodies (Streams, Riparian Areas, and Wetlands)

GOAL: Protect and enhance water quality and urban stream health through strategic collaboration, data collection, programmatic planning, and implementation of water quality projects.

Objective:	Identify and track the health and function of Boulder's urban streams.
Objective:	Develop and implement stream management plans that identify in-stream and riparian maintenance protocols and restoration needs by stream reach.
Objective:	Implement studies, policy initiatives, and construction projects in coordination with other city initiatives and work groups that improve urban stream conditions.

In 2021, the city initiated the Boulder Urban Stream Health program. This innovative program provides a substantial opportunity to improve water quality, enhance habitat for aquatic life and increase community enjoyment of local waterways throughout the city. For effective maintenance and enhancement of urban streams, an orderly, watershed-based approach is essential — basing stream improvement plans on scientific and engineering analysis so that needed stream improvements are prioritized and implemented in a manner that is sustainable and integrated in the overall stream network. The plan to first develop a scientific approach to assess and document stream conditions enables an objective and holistic evaluation of potential stream enhancement projects. Nationally, the water quality benefits of stream restoration are increasingly recognized as part of a sound water quality improvement strategy (Bledsoe et al., 2022); as such, it is recommended that the city continue to pursue this program. Implementation of the program should be an iterative and adaptive process. Regular, periodic evaluation of the program's benefits is recommended, with recognition that the benefits of stream management occur over a longer timeframe than other types of projects.

As a baseline understanding of urban stream health and as a framework for interdepartmental collaboration on stream enhancement projects is developed, it is recommended that the city continue to collaborate with external organizations, and in particular the Mile High Flood District to:

- formulate restoration plans for consistency with regional master planning efforts
- identify funding opportunities, and
- confirm eligibility for maintenance support

Through this collaboration, the city benefits from experience gained regionally with High-Functioning Low-Maintenance Stream (HFLMS) design approaches.

The urban stream health program should include a framework to track effects of climate change and actions that can minimize and/or respond to climate change in the context of stream health. Examples of impacts include increased water temperature; changes in spring runoff patterns and lower instream flows; effects of drought on riparian vegetation; insect damage to riparian trees, changes in species composition, including invasive species; increased frequency of extreme runoff events; and wildfire-related impacts to stream health. Given that the city is located at the wildland-urban interface, planning for wildfire-related impacts includes coordination with Boulder County to reduce debris flows, water quality pollutants and increased flood risk (Williams, et al, 2022). Efforts include previous risk evaluations (JW Associates, 2012) and Boulder County's Wildfire Hazard Identification and Mitigation System.

GOAL: Support the preservation, restoration, and maintenance of greenways, creek corridors, and wetlands for the protection and improvement of water quality.

> Objective: Support management of greenways and riparian zones to protect ecological function and community values.

> Objective: Protect and preserve wetlands.

Currently, the city's organizational structure includes several separate programs related to urban stream health, greenway maintenance and wetland programs. These programs are important given the interrelated nature of instream conditions, riparian corridors, and wetlands and warrant further coordination. Additionally, as stream enhancements are planned and implemented, long-term sustainability requires maintenance such as weed control, trash pickup and removal of dangerous conditions (e.g., eroded banks, fallen trees) that can arise periodically from hydrologic events.

Protection of wetlands for their water quality and ecological benefits is a priority for multiple city departments. The city has adopted stream, wetland and water body regulations that are administered through the city's Planning and Development Services (P&DS) Department. The city's program goes above and beyond baseline federal regulations by protecting both the wetland area in addition to buffer zones around the wetland. The city also maintains open data layers in GIS identifying the location and boundaries of regulated wetlands known to exist within the city and provides public outreach to homeowners related to minimizing impacts to wetlands. In support of the city's existing efforts related to the protection and preservation of wetlands, it is recommended that the Utility incorporate these efforts as part of the Boulder Urban Stream Health program and in conjunction with stormwater quality project planning initiatives.

3. Monitor and Evaluate Urban Surface Water Quality

GOAL: Support compliance related to surface water permitting and regulations.

> Objective: Collect and evaluate water quality data in support of surface water permits and regulations.

The city maintains a long-term surface water monitoring program, including water chemistry, flow measurements and biological health assessments (benthic macroinvertebrates). This long-term monitoring program provides valuable information on current water quality and changes to water quality over time. This program also provides a scientific basis for assessment of stream impairments and informed input regarding future water quality regulations and permits. The monitoring program is one of several advanced long-term monitoring programs in the state, and should be continued, including regular data analysis and synthesis to determine long-term water quality trends. Additionally, integration of stormwater outfall special project monitoring with instream data is an important aspect of assessing the extent to which the MS4 program affects instream water quality, as well as providing an opportunity to link SCM performance with receiving water benefits.

The sampling program parameters, locations and frequencies should be periodically reviewed to ensure that the monitoring program is meeting applicable regulatory and science-based objectives. For example, if the city implements a runoff control or stream improvement project, then upstream-downstream (or before-after) monitoring related to such projects could be beneficial for quantifying the benefits of the projects.

GOAL: Seek to better understand surface water quality, dynamics, and impacts related to stream health and regulations.

Objective: Implement projects and studies to inform regulatory decisions related to city surface water permits.

The Stormwater Quality Program will benefit from special projects, studies and/or modeling efforts that evaluate the effectiveness of stormwater quality improvements. For example, the city can take advantage of regional and national SCM performance studies, but the program could benefit from watershed-scale modeling to evaluate the expected benefits of stormwater improvements implemented at scale in Boulder. The city should continue to promote the use of green infrastructure approaches on capital projects and should consider revisiting the water quality modeling efforts and recommended water quality installation projects listed in the stormwater master plan to incorporate infiltration-based approaches. Additionally, the city may want to monitor SCM installations to obtain locally based data on SCM performance, particularly if data gaps are identified for certain SCMs. Boulder has also participated in national nutrient-related modeling research with the Water Research Foundation; such projects can provide an opportunity to leverage directed research for the benefit of the city. Research projects, if implemented, should have well defined, hypothesis driven work plans and study objectives.

From time to time, the city has conducted special studies on pollutants of concern such as neonicotinoids. The Stormwater Quality Program should maintain flexibility for studies related to emerging contaminants (with PFAS as a recent example), microplastics, and other topics. The city has a history of partnering with the U.S. Geological Survey and other research entities on such topics.

4. Adaptively Manage Stormwater Quality Program

GOAL: Maintain a dynamic and compliant stormwater management program by engaging in state and regional regulatory and research efforts.

Objective: Actively engage in water quality planning, policy and regulation in Colorado.

Objective: Actively engage in regional collaborative efforts and research related to stormwater quality.

Objective: Adaptively manage Boulder's Stormwater Quality Program to maintain regulatory compliance and adapt to changing climate conditions.

The city should continue its active involvement in regional stakeholder groups including the Colorado Stormwater Council, the Mile High Flood District, and targeted stakeholder groups related to water quality and permit issues through the Colorado Department of Public Health and Environment and the Water Quality Forum. Early and active participation in these efforts helps to ensure that the city's interests are represented in regulatory actions. Additionally, regionally collaborative research can fill data gaps on topics such as the role of urban stormwater in nutrient loading to streams, design and performance of SCMs in space-constrained sites, evaluation of maximum extent practicable (MEP) performance standards for pollutants such as *E. coli*, and other topics. Such regionally collaborative efforts enable higher quality studies to be conducted through pooled resources and generally leverage regional knowledge to avoid duplication of efforts. For example, in Washington State MS4 permit requirements included SCM monitoring; however, a regionally coordinated approach resulted in each MS4 monitoring a specific type of SCM to fill specific data gaps, which minimized cost and provided a more complete data set.

Climate resilient infrastructure is a priority for the Stormwater and Flood Management Utility and should be incorporated into the Stormwater Quality Program to minimize risk and adapt to the impacts of climate change. Analysis of factors that lead to resiliency and sustainability in SCMs is a topic of national research. Ongoing planning and evaluation are occurring to develop tangible recommendations for SCM design, implementation and maintenance (e.g., vegetation selection, irrigation requirements). The city should continue to participate in regional efforts to develop low-regret adaptive strategies and support SCM maintenance.

It is recommended that the Utility evaluate its programs to identify changes needed to maintain regulatory compliance and to properly resource active programs. For example, the impact of climate change on urban streams is a rapidly evolving topic, and may require adjustment to policies, practices, and research priorities related to stormwater quality.

Climate Change and SCMs

Heat stress on vegetation and greater evapotranspiration is expected from wetlands and ponds with permanent water surfaces due to warming temperatures caused by climate change. Other potential system stresses include more frequent summer runoff events and reduced inter-event time. Consequently, increased maintenance may be required.

Temperature has many effects on biological, chemical and physical processes in green infrastructure stormwater controls. Temperature increases are expected to modify the plant palette for many green infrastructure practices. Furthermore, runoff temperature moderation effects and non-stormwater urban heat island benefits are likely to become increasingly important if temperatures increase. Increased runoff frequency and extended dry periods and/or heat waves have the potential to affect vegetation and maintenance (from Earles et al., 2015).

Recommendations

The city's Stormwater Quality Program has a solid approach in place to comply with MS4 permit requirements. Additionally, the program has a clear vision to improve stormwater quality and stream health and provides a framework that allows flexibility to use evidence-based decision-making to refine specific actions.

It can take some time for the efficacy of stormwater quality measures within a watershed to be demonstrated. Non-point source treatment requires numerous SCMs across the watershed; and, given the diffuse and episodic nature of stormwater pollution, results are more likely to be observed as gradual improvements.

It is recommended that the Stormwater Quality Program conduct the following high priority actions to further enhance the program beyond regulatory compliance efforts:

- Increase the number of green infrastructure facilities on capital projects by participating and co-sponsoring projects to incorporate a runoff control component. This effort should aim for early integration of stormwater quality objectives into projects at the planning and conceptual stage and consider the co-benefits of green infrastructure approaches to develop multifunctional drainage solutions on city-led projects.
- Update the stormwater quality section of the Stormwater Master Plan to incorporate updated stormwater quality modeling techniques and identify priority stormwater quality treatment areas and projects using green infrastructure and infiltration-based approaches. Currently, the Stormwater Master Plan focuses on underground SCM water quality project locations which should not be considered the only possible approach.
- Develop and implement a systematic approach to evaluating and managing Boulder's urban streams and riparian areas through monitoring, management planning, and restoration/maintenance project completion. This effort should aim to integrate with flood management planning and consider the hydrology, hydraulics, vegetation, geomorphology, and community values functions of urban streams.
- Evaluate *E. coli* load reduction goals for Boulder Creek based on feasibility and cost-benefit of control measure implementation. This effort should be conducted following the completion of monitoring and evaluation efforts conducted as part of the TMDL Implementation Plan and consider the controllability of sources, risk to public health, and regulatory requirements.
- Encourage the community to take action in their neighborhoods and on their own properties to reduce stormwater runoff and mitigate pollutant sources through robust education and outreach programs.

Corresponding with the goals and objectives of this chapter, the following stormwater quality policies and supporting actions are recommended for incorporation into the Master Plan:

- Maintain compliance with current MS4 permit requirements.
  - Meet or exceed regulatory requirements for minimum control measures.
- Reduce sources of *E. coli* contributions to Boulder Creek to meet TMDL requirements.
  - Work to identify potential *E. coli* sources and determine controllability.
  - Identify and implement strategies to reduce controllable sources of *E. coli* in stormwater runoff entering Boulder Creek.

  - Implement studies, policy initiatives and projects in coordination with other city initiatives that improve urban stream conditions and reduce *E. coli* loading to Boulder Creek.
- Promote the effective design, implementation, and maintenance of green infrastructure approaches to stormwater management.
  - Promote infiltration/green infrastructure as the preferred stormwater management strategy through policies for capital project and private development implementation.
  - Conduct education/training both internally and externally to improve SCM design and installation.
  - Enhance SCM maintenance and inspection program.
  - Evaluate options and feasibility for implementation of SCMs for small sites <1 acre.
- Protect and enhance water quality and urban stream health through strategic collaboration, data collection, programmatic planning, and implementation of water quality projects.
  - Identify and track the health and function of Boulder's urban streams.
  - Develop and implement stream management plans that identify in-stream and riparian maintenance protocols and restoration needs by stream reach.
  - Implement studies, policy initiatives, and construction projects in coordination with other city initiatives and work groups that improve urban stream conditions.
- Support the preservation, restoration, and maintenance of greenways, creek corridors, and wetlands for the protection and improvement of water quality.
  - Support management of greenways and riparian zones to protect ecological function and community values.
  - Protect and preserve wetlands.
- Support compliance related to surface water permitting and regulations.
  - Collect and evaluate water quality data in support of surface water permits and regulations.
- Seek to better understand surface water quality, dynamics, and impacts related to stream health and regulations.
  - Implement projects and studies to inform regulatory decisions related to city surface water permits.
- Maintain a dynamic and compliant stormwater management program by engaging in state and regional regulatory and research efforts.
  - Actively engage in water quality planning, policy and regulation in Colorado.
  - Actively engage in regional collaborative efforts and research related to stormwater quality.
  - Adaptively manage Boulder's Stormwater Quality Program to maintain regulatory compliance and adapt to changing climate conditions.

References

Bledsoe, B., Lammers, R., Clary, J., Jones, J., Earles, A., Leisenring, M., Struck S., and Strecker, E. 2022. *Stream Restoration as a BMP: Crediting Guidance*. The Water Research Foundation: Denver, CO.

City of Boulder (n.d.) Boulder Targeted Homelessness Engagement and Referral Effort. https://bouldercolorado.gov/services/boulder-targeted-homelessness-engagement-and-referral-effort

City of Boulder (n.d.) Wetland Permits. https://bouldercolorado.gov/services/wetland-permits

City of Boulder (2021). Wetland Tips for Homeowners. April 7. https://bouldercolorado.gov/news/wetland-tips-homeowners

Boulder County (n.d.). Wildfire Hazard and Mitigation System. https://www.bouldercounty.org/disasters/wildfires/mitigation/wildfire-hazard-identification/

Earles, T.A., MacKenzie, K., Bennetts, D., and Traylor, J. (2015). Planning for Variability and Uncertainty: Climate Change and UDFCD Urban Drainage System. Accessible at: https://mhfd.org/wp-content/uploads/2019/12/Climate_Change_and_the_Urban_Drainage_System.pdf.

GEI. (2019). *E coli* TMDL Implementation Plan, City of Boulder.

JW Associates Inc. (2012). Saint Vrain Wildfire/Watershed Assessment. Accessible at: https://www.jw-associates.org/projects/saint-vrain-wildfirewatershed-assessment

Washington Department of Ecology (n.d.). Stormwater Action Monitoring. Accessible at: https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring

Williams, A. P., Livneh, B., McKinnon, K. A., Hansen, W. D., Mankin, J. S., Cook, B. I., Smerdon, J.E., Varuolo-Clarke, A.M., Bjarke, N.R., Juang, C.S. & Lettenmaier, D. P. (2022). Growing impact of wildfire on western US water supply. *Proceedings of the National Academy of Sciences*, 119(10). Accessible at: https://www.pnas.org/doi/full/10.1073/pnas.2114069119

Wood Environment & Infrastructure Solutions, Inc. (2019). City of Boulder Green Infrastructure Strategic Plan. Prepared for the City of Boulder.

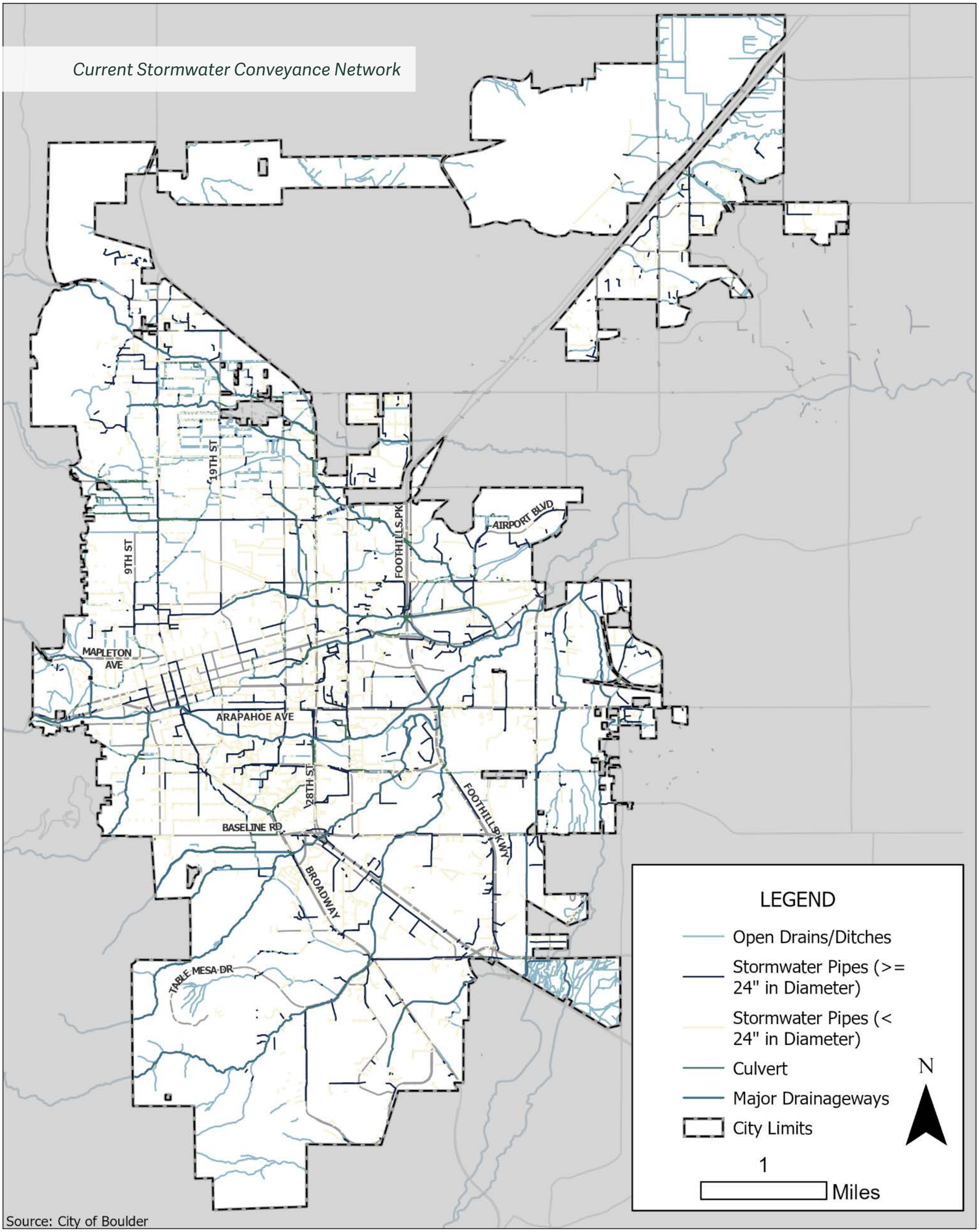
Wright Water Engineers and Geosyntec Consultants. (2014). Colorado *E. coli* Toolbox: A Practical Guide for MS4s. Prepared for Mile High Flood District. Accessible at: https://mhfd.org/wp-content/uploads/2019/12/Denver-E-coli-Toolbox-08-5-2016.pdf

4 Stormwater Drainage

Urbanization increases direct stormwater runoff caused by land use change and must be actively managed to minimize local flooding and impacts to streams and drainageways. Stormwater drainage systems traditionally consist of a *minor system* for modest size rainfall events and a *major system* for emergency flows. The City of Boulder follows Mile High Flood District policy for the sizing of stormwater drainage systems. This includes sizing the minor system to convey the 2-year storm event in residential areas and the 5-year storm event along collector and arterial roads and in commercial areas. The minor system is the conventional drainage system designed to minimize disruptions and safely allow the movement of pedestrians and traffic. This system includes gutters, roadside ditches[3], culverts, catch basins, storm drains, detention ponds, and open channels. Minor systems have been expanding in recent years to include green infrastructure elements such as bioretention practices and porous pavements. Green infrastructure components are often focused on meeting stormwater quality improvement and climate objectives; however, many communities also include meeting hydrologic objectives for small storms.

Boulder's history of flash flooding associated with the major drainageways often overshadows the fact that flooding can happen anywhere, regardless of proximity to waterbodies. When extreme rainfall events occur, stormwater runoff can cause localized flooding on streets and in neighborhoods that happens independent of an overflowing waterbody. Major systems are designed to convey flows from the 100-year storm event in Boulder and include the use of streets, urban streams and drainageways, and larger detention ponds. While the major system is intended to direct and route these emergency flows, residents and businesses also have a role in protecting their properties and ensuring the safe flow of water around structures when storm events result in unusually long or intense rainfall.

[3] *Sometimes called a "borrow" ditch, a roadside channel is dug for drainage purposes. These are different from irrigation ditches, which deliver water associated with water rights to a downstream beneficial use.*


Current Stormwater Conveyance Network
19TH ST
9TH ST
FOOTHILLS PK
AIRPORT BLVD
MAPLETON AVE
ARAPAHOE AVE
28TH ST
FOOTHILLS PKWY
BASELINE RD
BROADWAY
TABLE MESA DR
LEGEND
Open Drains/Ditches
Stormwater Pipes (>= 24" in Diameter)
Stormwater Pipes (< 24" in Diameter)
Culvert
Major Drainageways
City Limits
N
1
Miles
Source: City of Boulder

Policy Discussion

The current policies related to stormwater drainage are mostly contained within the Boulder Valley Comprehensive Plan and in the Stormwater Master Plan. Since the Mile High Flood District sets policy standards for the communities it serves, variations between the two sets of policies will be evaluated and updated where necessary. The CFS Master Plan establishes standards and considerations that inform the development of project specific planning efforts, including updates to the Stormwater Master Plan. The following section discusses issues and approaches to address identified improvement actions from a policy perspective.

Policy and Program Goals

The policy and program evaluation (Appendix A) identified a set of goals and objectives that could be used to evaluate the existing programs within the Utility. As part of the analysis on stormwater drainage policy, these goals and objectives were reviewed and refined where necessary to meet the current and future needs of the Utility.

Stormwater Collection System

GOAL: Provide an adequate stormwater collection and conveyance system for existing and future development within the city

Objective: Size the stormwater collection and conveyance system to convey runoff from a 2-year storm event in residential areas, and from a 5-year storm events for collector and arterial roadways and in commercial areas

Objective: Focus on problem areas created by smaller storms to address localized flooding

GOAL: Control the rate and volume of stormwater runoff from development and redevelopment projects to minimize impacts of localized and downstream flooding and stream bank and channel erosion

Objective: Limit post-development peak flow conditions to match pre-development[4] peak flow conditions

GOAL: Provide a connected and continuous stormwater collection and conveyance system that does not discharge into irrigation ditches, where practical.

Objective: Identify stormwater connections into irrigation ditches

Objective: Identify irrigation ditches having insufficient capacity for stormwater conveyance

Objective: Identify and manage modifications that may impact irrigation ditches in partnership with irrigation ditch companies

[4] *Pre-development peak flow conditions refer to existing conditions prior to redevelopment, not green field conditions.*

Operations and Maintenance

GOAL: Ensure the stormwater collection and conveyance system functions properly and yields expected capacity to protect public safety and the city's investment in the system

Objective:	Provide routine inspections and assessments of the entire system
Objective:	Provide routine maintenance of pipes, structures, natural and man-made channels including irrigation ditches, and public detention facilities
Objective:	Provide minor repairs to existing pipes and structures

GOAL: Provide maintenance accessibility to the entire stormwater collection and conveyance system

Objective:	Identify reaches of the stormwater collection and conveyance system lacking adequate maintenance access
Objective:	Provide permanent access to reaches of the stormwater collection and conveyance system, detention facilities, and other drainage facilities for routine and major maintenance activities

GOAL: Provide irrigation ditch maintenance per existing maintenance agreements with irrigation ditch companies

Objective:	Identify tasks for irrigation ditch maintenance in current asset management system to develop a predictive maintenance plan in partnership with irrigation ditch companies

GOAL: Ensure resources are available to provide emergency maintenance on the stormwater collection and conveyance system

Objective:	Identify resources required to provide emergency maintenance during and after storm events

Level of Service Standards

It is often not economically feasible to design stormwater collection and conveyance systems to fully manage extreme precipitation events without overflow. For that reason, it is necessary to determine what level of service this system will provide. During storm events that occur frequently, but result in moderate and more manageable flow rates, it is expected that the stormwater system will collect and convey excess stormwater runoff in a way that provides public convenience, minimally interferes with traffic, and prevents property damage caused by excess ponding of stormwater runoff. This system is often referred to as the initial drainage system, or the minor system. When larger storm events occur, some degree of flooding is expected, and major systems then convey runoff that exceeds the capacity of the minor system. Major systems are not always intentionally designed and are often incorrectly assumed to consist only of the major drainageways. During major storm events, flooding can occur anywhere in the watershed when emergency overflows are not intentionally designed to safely convey excess runoff to the major drainageways. When this happens, flooding impacts property and can threaten the health, safety, and welfare of the community. Major drainage systems, regardless of type, should be capable of conveying water without flooding buildings or impacting life safety and remain relatively stable during major runoff events. Major systems should provide the same level of service irrespective of whether the cause of flooding is rainfall or out-of-bank river flooding.

Design storm frequencies are selected to determine the peak flow rate that should be managed by various parts of the stormwater drainage system for both the minor storm and the major storm. It is recommended that design storm frequencies be reported in the city's Design and Construction Standards.

Stormwater Master Plan

The city's Stormwater Master Plan (SMP), last updated in 2016, serves as a long-term guide to address existing and future stormwater drainage and stormwater quality issues. It contains a plan for the stormwater drainage system to alleviate current capacity and flooding problems. It also evaluates the existing stormwater infrastructure with respect to system analysis criteria created as part of the master plan. The SMP also recommends further improvements to address future conditions more thoroughly and evaluate the impacts of stormwater runoff on the entire watershed.

Data Collection and Continuous Improvement. Section 3 of the 2016 Stormwater Master Plan notes several limitations with the input data. For example, limited survey information was available for the major roadside ditches and the irrigation ditches. Today's hydrologic and hydraulic models are highly integrated with geographic information systems. This plan recommends that a GIS database containing the conveyance assets be continuously improved in a format directly compatible with the hydraulic model. Updates to the model can then be processed quickly and efficiently and become a continuous improvement process as well. The recommended long-term goal should be to include the entire collection system and irrigation ditches in the model.

Model Calibration. Calibration of the hydrologic and hydraulic model to both measured flow data in the collection system and reported flooding complaints provides increased accuracy. Data collection and calibration efforts can be costly. However, when the estimated investments needs are over $114M, consideration of model calibration may be warranted. Synergies with outfall monitoring efforts conducted by the stormwater quality program could be explored to use collected flow data for environmental monitoring and model calibration purposes.

Model Approach. Incorporate a 2-dimensional (2-D) modeling approach to combine a 1-D model of the minor conveyance system (storm sewer pipes) and a 2-D surface model which routes overland flow. There are several benefits to using a 2-D stormwater model. The primary benefit is to map the overland flow like a floodplain along a river. Mapping the overland flow improves the overall understanding the system which leads to better alternative improvement analysis. Mapping the overland flow is also beneficial for communicating with decision makers and the community to convey risk. Additionally, areas of the city which do not have storm sewers, and hence are not included in typical 1-D model analyses, are easily included in a 2-D model approach. This approach would also allow for the incorporation of irrigation ditches into the model to improve the understanding of the relative importance of irrigation ditches for urban drainage and alternatives analysis. Furthermore, knowledge of irrigation ditch conveyance would inform stormwater carriage agreement negotiations with irrigation ditch companies.

Analyze a Range of Scenarios. As part of the hydraulic analysis, a range of design storms up to and including the 1-percent chance recurrence interval (100-year) should be modeled. The resilience of the system should also be evaluated over a range of scenarios. This could include modeling a range of tailwater conditions as part of a sensitivity analysis and evaluating the system response to historical storm events either as discrete events or as a continuous simulation. In the evaluation of alternatives, increasing the level of service provided should be evaluated. Often going up a single pipe size for conveyance of the minor storm event has a significant impact on the level of service provided but only results in a marginal impact on the capital costs.

Multifunctional Solution Approach. Look for ways to provide community benefits beyond just drainage, such as recreational value, biodiversity, social resilience, improved microclimates, environmental sustainability, and vibrant economic growth. Look for synergistic solutions with other projects in the city. The identified water quality improvement projects in the Stormwater Master Plan are predominantly manhole treatment devices that prevent pollutants from entering into the stormwater collection and conveyance system. These improvements do not incorporate multifunctional benefits like low impact development and green infrastructure approaches and should be revisited.

Climate Change and Resilience

Climate model projections for Colorado agree on a warming average annual temperature, with temperatures already rising by about 2.5 degrees Fahrenheit since the beginning of the twentieth century (Frankson, et al., 2022). There is a high degree of uncertainty in precipitation projections. Urban drainage systems are designed using rainfall intensity, and when rainfall events become more intense, the system's level of service will decrease. Engineers and climate change scientists must work collaboratively to observe and forecast changes in intensity-duration-frequency estimates and develop strategies to make infrastructure more resilient.

Examples of strategies from around the country and world include:

- *Change the level of service criteria:* Madison, WI, increased their target level of service standards for culverts, drainage of enclosed depressions, detention basins, and road surfaces as an interim step while a state initiative evaluates climate change impacts. Another similar approach is to add an additional level of service criteria, for example Copenhagen, Denmark, added a criterion for considering cloudbursts (defined as a 100-year storm event for Copenhagen).
- *Apply confidence intervals to precipitation frequency estimates:* Another approach which relies only on historical rainfall data, is to consider the confidence intervals associated with the precipitation frequency estimates rather than just the most frequently occurring number. For example, NOAA publishes 90% confidence intervals with the estimates (NOAA, 2013).
- *Implement a risk management approach in design:* The American Society of Civil Engineers (ASCE) promotes a risk-based approach where climate analysis is based on the infrastructure design life and the use or occupancy of buildings and structures served by the drainage infrastructure. Communities like Boston, MA, New York, NY, and Washington, DC, have incorporated risk management components into their programs and commonly associate this with critical infrastructure or critical facilities.

Due to significant uncertainty and variability in climate change science along the Front Range, best engineering practices to account for the uncertainty associated with climate change impacts are recommended over specific design requirements for all stormwater drainage infrastructure. A risk management approach that considers the design life of infrastructure and the use or occupancy of buildings and structures served by the drainage infrastructure is recommended. This approach places increased analysis and informed decision making in areas where the consequences of flooding are high and are commonly associated with critical infrastructure (ASCE, 2018).

In general, agencies are finding that the current codes are inadequate both in coverage and applicability for their assets and many are navigating through the effort to write standards and guidelines (ASCE, 2018). A comprehensive assessment should be undertaken to understand and reshape the guidance as it relates to stormwater and flood mitigation.

Operation and Maintenance

All infrastructure requires maintenance. However, there is no industry standard on the recommended frequency of maintenance within a stormwater collection and conveyance system. Rather inspection and maintenance should be done at a frequency that is necessary to keep the system functioning as intended. This may start at a set schedule but is often adjusted based on repeated findings through the use of an asset management system. In 2021, Boulder's Utilities Maintenance work group continued to make major changes to increase maintenance efficiency and frequency by splitting into two separate groups, one of which is solely responsible for the maintenance of the stormwater drainage infrastructure. Additional staffing resources were dedicated to support this area of maintenance, which also includes responding to customer complaints related to the stormwater drainage system. Current policies do not definitively define all roles and responsibilities related to operations and maintenance of the stormwater drainage system, including defining what constitutes public maintenance responsibilities and what constitutes private maintenance responsibilities in some cases. It is recommended that operations and maintenance policies be included in the CFS Master Plan to achieve the following:

1) Define what constitutes the public stormwater drainage system versus a privately owned stormwater drainage system
2) Support the city staff in making maintenance and capital improvement decisions related to the city's stormwater collection and conveyance system
3) Define public and private maintenance responsibilities for stormwater drainage systems
4) Clarify that the city may conduct emergency maintenance operations when warranted
5) Ensure that property owners understand their operation and maintenance responsibilities

The specification of detailed maintenance activities, including frequency of occurrence, is best discussed in an operation and maintenance manual instead of at the policy level.

Customer Input from Inquire Boulder

Resources needed to address customer inquiries places a significant demand on many communities. Records of comments and complaints should be centralized into one dataset, which the city has done with the Inquire Boulder system. For the five-year period from 2015 through 2019, a total of 469 storm drain problems were recorded in the Inquire Boulder system (**Figure 4.1**). The frequency of records is highest in May (18 per month) and June (14 per month) and the least frequent in September thru February (averaging 3 to 6 per month). This Master Plan recommends that a policy be included to specify how inquiries will be handled and what response will be provided. Target times for response to inquiries will vary based on the volume and severity of issues raised.

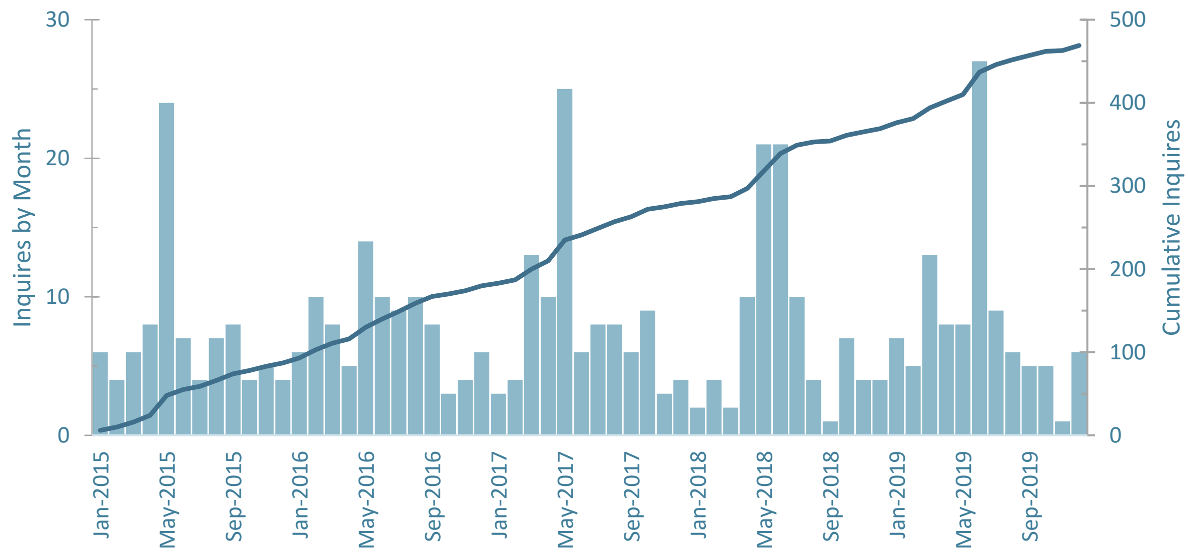


Figure 4.1 – 2015 to 2019 Stormwater Drainage Complaints from Inquire Boulder

It is recommended that Inquire Boulder be expanded to include links for more information like upcoming storm conditions, what residents need to do to prevent local flooding, quick facts, requesting assistance, opportunities to volunteer, and general education about stormwater which is tied to the MS4 permit. This could also include information such as where to route downspouts and sump pump discharges along with legal implications if runoff is mismanaged. The city's website for snow and ice removal already contains examples of this, as does Seattle Public Utilities' website focused on Wet Weather Preparation Tips.

Continuous Improvement

Maintaining information on the stormwater infrastructure is best thought of as a continuous improvement process. All data associated with surveys, inspections, assessments, hydrologic and hydraulic modeling, design, construction, and maintenance should have a process by which data is continuously updated in a master database. To accomplish this, contracts with outside agencies should include provisions of deliverables to provide the data in a compatible format. To aid with this process, it is beneficial to have a standardized data format. Coordination with Planning and Development Services (P&DS) will be required for projects related to private development.

Additionally, hydrologic and hydraulic models should be the property of the Utility and should be clearly stated as such in all contract documents. It's often beneficial for a community to adopt modeling guidelines which specify modeling requirements, methods, naming conventions, submittal requirements, and other technical details. The Metropolitan Sewer District of Greater Cincinnati (MSDGC) has a robust example of modeling guidelines.

Hydrologic and hydraulic modeling software packages are continuously evolving and updating. Standardizing the software package(s) used is often desirable but can be challenging. Most of the modeling software makes use of GIS data, often directly linking with the GIS files. Data collected as part of the model analysis (e.g., surveyed pipe and channel data) should be updated in the master database. Model results such as pipe capacity information, peak flow rates from design storms, and other pertinent data should also be included in the GIS database format for sharing and storing information.

Staggering and Sequencing Project Work

The existing Stormwater Master Plan is a good overarching plan with conceptual designs and project prioritization. Prior to construction of the prioritized projects, additional modeling will be necessary to refine the designs. Oftentimes, the accepted approach is to collect the data necessary to understand the condition of the existing infrastructure followed by a period of monitoring to refine and calibrate the hydraulic and hydraulic models, which then become the basis for design. Not every project will require model calibration. However, based on the substantial investments needs, collecting monitoring data to calibrate the model is often cost effective. Additionally, the collected data can also be used to update the city's asset management database. Since these phases can take a significant amount of time, it is prudent to stagger multiple projects at different points within their individual sequence. By developing a formal sequence, projects can be staggered to account for public engagement, coordination between departments, budget cycles, and typical timeline required for each project phase. A formal project flowchart may be beneficial which identifies all the various steps and coordination required (**Figure 4.2**).

Project	Time						
1	Data Collection	Monitoring	Model	Design	Construction		
2		Data Collection	Monitoring	Model	Design	Construction	
3			Data Collection	Monitoring	Model	Design	Construction

Figure 4.2 – Example Project Staggering and Sequencing

Recommendations

The following stormwater drainage policies and general suggestions are being recommended:

Stormwater Drainage System

- Provide a comprehensive and integrated stormwater drainage system for existing and future development to adequately convey and manage stormwater runoff. This includes systems to mitigate safety hazards, protect property, and minimize disruption during and after minor and major storm events.
  - Design storm frequencies for the minor and major storm events and associated design criteria shall be as defined in the latest edition of the Design and Construction Standards.
  - Minor storm event criteria are designed to maintain travel on public streets and provide public convenience, minimally interfere with traffic, and prevent property damage during frequently occurring storms.
  - Major storm event criteria are designed to prevent building flooding and minimize danger to human life when the rate or volume of runoff exceeds the capacity of the system designed for the minor storm event.
- Manage a GIS database related to stormwater collection and conveyance assets to be maintained in a format that is directly compatible with the hydraulic model for the stormwater drainage system and current asset management software.
  - Develop guidelines related to data quality
  - Identify necessary information needed to update the GIS database to be requested upon completion of construction projects, inspections, or repairs to the system.
  - Require projects that include modifications or additions to the public or a private stormwater drainage network to provide updated GIS stormwater network files conforming the city's GIS database guidelines as part of project closeout information.
- The stormwater drainage system is not a standalone network but is a subsystem of the city's overall stormwater and flood management system. Stormwater system planning and design should include evaluation of broader impacts to interrelated systems and functions, such as stormwater quality, protection of natural drainageways, and flood mitigation. Multifunctional solutions should be considered to benefit the quality and performance of the overall drainage infrastructure.
- The city will strive to minimize flooding, stream bank and channel erosion within the major drainageway system by controlling the rate and volume of stormwater runoff from development and redevelopment projects.
- Adaptive risk management should be used to achieve climate resilience of infrastructure. It is recommended that the city adopt a policy that adaptive risk management be considered for inclusion in currently used standards.
- Uncertainty associated with future climate conditions is not completely quantifiable, leading to considerable engineering judgement to balance the cost of mitigating risk through adaptation against the potential consequences of failure. Stakeholders should be informed about the

uncertainty of the projections and the reasons for the uncertainty as described by the climate science community.

- Acknowledge that there is a high degree of uncertainty and consider the feasibility to use low-regret adaptive strategies to make a project more resilient to future climate and weather extremes.
- Continue to identify critical infrastructure that is most threatened and evaluate the costs and benefits for projects and strategies to protect this infrastructure (including the use of the Project Prioritization Framework, which provides significant opportunity to identify and discuss the merits and priority of projects to protect critical infrastructure).

Stormwater Master Plan

- For the purposes of evaluating and improving the stormwater drainage system's performance during both the minor and major storm events, the Utility will maintain and update a stormwater master plan, also known as a master drainage plan. This plan must identify the infrastructure required to provide for the drainage and management of surface waters within the city's watersheds in a way that protects people, prevents property damage, minimizes interference with traffic, mitigates increases in stormwater runoff due to land use changes, and prevents increases in flooding, by carrying such waters to designated points without overflow or discharge.
  - Include the entire collection system and irrigation ditches in a hydrologic-hydraulic model that is calibrated to both measured flow data in the collection system and reported flooding complaints.
  - Model the system with a 2-dimensional (2-D) approach, which combines a 1-D model of the minor conveyance system (storm sewer pipes) and a 2-D surface model which routes overland flow.
  - Analyze a range of design storms up to and including the 1-percent chance recurrence interval (100-year event).
  - Adopt modeling guidelines which specify modeling requirements, methods, naming conventions, submittal requirements, and other technical details. Require that the hydrologic and hydraulic models become the property of the Utility as part of submittal requirements.

Operation and Maintenance

- Public stormwater drainage infrastructure consisting of stormwater inlets including catch basins, storm sewers, and storm sewer appurtenances such as manholes, junctions, etc., are considered part of the public stormwater system and shall be maintained by Utilities. Staff shall conduct periodic inspections and routine maintenance of the public stormwater drainage infrastructure at a frequency necessary to ensure its continuing and proper function. Privately owned stormwater drainage infrastructure, the major drainageway system, irrigation ditches, and irrigation laterals are not part of the public stormwater drainage infrastructure and are to be maintained by others except in the case of a contractual obligation.
  - Clearly define infrastructure that shall be maintained by the Utilities Maintenance work group.
  - Clearly define infrastructure that shall be maintained by private property owners.

- Information collected during inspection and maintenance activities will be used to support the Utility's asset management system, by evaluating the condition of the assets and setting priorities for operational and maintenance work, as well as identifying capital improvement project needs.
  - Inspection, cleaning, and maintenance frequencies will be updated as needed based on system needs, the probably of failure, and the consequence of failure.
  - Identify the information to be included in the stormwater drainage GIS database and when it is to be updated
- Property owners are required to maintain culverts that extend under private driveways and natural or artificial drainageways conveying open channel flow contained within drainage easements or within public rights-of-way free from obstruction to ensure maximum designed flow may pass at all times. Property owners may not alter drainage improvements, drainageways contained within drainage easements or within public rights-of-way. Under current practice, property owners are required to maintain the roadside ditches adjacent to their properties in areas without curb and gutter and should not block such drainages. (B.R.C. 9-12-12(c)).
- The Utility may perform emergency maintenance on privately owned stormwater drainage systems when necessary to protect the common good. Emergency maintenance applies to conditions which may be potentially damaging to life, property, or public roads and rights-of-way. Emergency maintenance should not be construed as the city accepting maintenance obligations for privately maintained infrastructure.
- Reports for maintenance requests received by phone or through Inquire Boulder will be relayed to on-call personnel for response and recorded for use by the Utility's asset management system. Maintenance necessary during large-scale events with high volumes of maintenance requests may be contracted to private contractors through existing service contracts to respond to situations that require immediate attention.
  - Stormwater problem investigations (i.e., local ponding or flooding). City crews will investigate reported problems. Develop a timeline for contacting the individual regarding the complaint and schedule an investigation time as appropriate. Problems originating in the public drainage system are addressed by the city in a prioritized fashion. Some solutions may be the property owner's responsibility. When solutions are the responsibility of the property owner, city staff may offer available resources for more information.
  - Street flooding during, or immediately after, a storm event. City crews will respond and alleviate maintenance-related street flooding as soon as possible. Residents should be informed that they may not be contacted directly or observe crews working on problems during heavy storm events, as crews are moving quickly to resolve issues.
  - Dry weather conditions problem reporting, such as blocked storm drain inlet, or broken, dislodged or missing inlet grates and manhole covers. City crews will respond and address problems as necessary. Residents may not receive a call-back.
- The city may elect to not respond to complaints regarding privately owned drainage systems, e.g., a detention or retention basin that is the responsibility of a subdivision or neighborhood. From a public relations standpoint it is often good to respond to these types of complaints and a phone call should be sufficient over an on-site visit.

References

ASCE. (2018). *Manuals and Reports on Engineering Practice No. 140, Climate-Resilient Infrastructure, Adaptive Design and Risk Management.* American Society of Civil Engineers Committee on Adaptation to a Changing Climate.

City of Boulder and Boulder County. (2015). *Boulder Valley Comprehensive Plan. 2015 Major Update. Adopted 2017.*

FEMA. (2017). *National Flood Insurance Program Community Rating System Coordinator's Manual.* Federal Emergency Management Agency.

Frankson, R., Kunkel, K. E., Stevens, L. E., Easterling, D. R., Umphlett, N. A., Stiles, C. J., . . . Goble, P. E. (2022). *Colorado State Climate Summary 2022. NOAA Technical Report NESDIS 150-CO.* Retrieved from NOAA National Centers for Environmental Information: State Climate Summaries 2022: https://statesummaries.ncics.org/chapter/co/

HDR. (2016). *City of Boulder 2016 Stormwater Master Plan.* City of Boulder, Colorado.

Mahoney, K., Lukas, J., & Mueller, M. (2018). *Colorado - New Mexico Regional Extreme Precipitation Study: Summary Report, Volume VI. Considering Climate Change Estimation of Extreme Precipitation for Dam Safety.* Colorado Division of Water Resources.

MHFD. (2021). *Urban Storm Drainage Criteria Manual, Volumes 1, 2, & 3.* Mile High Flood District.

NOAA. (2013). *Precipitation-Frequency Atlas of the United States. NOAA Atlas 14, Volume 8, Version 2.0: MIdwestern States (Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Wisconsin).* National Oceanic and Atmospheric Administration.

NOAA. (2022). *Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates: Assessment Report.* National Oceanic and Atmospheric Administration, National Weather Service Office of Water Prediction.

URS. (2004). *Comprehensive Flood and Stormwater Utility Master Plan.* City of Boulder.

Wobus, C., & Bash, R. (2020, December 31). Memorandum to Coleman, B., City of Boulder. *Incorporating Climate Change into Flood Control Along South Boulder Creek: Summary of Federal, State, and Local Guidance*. Lynker Technologies.

5 Groundwater

Much of the City of Boulder is built in areas where groundwater can be within a few feet of the ground surface, depending on the season. This can present issues with short-term dewatering during construction and longer-term dewatering associated with permanent, subterranean structures (i.e., basements and underground parking garages). In the latter instance, the most common method to limit water damage is a permanent footing drain system connected to a sump pump. Water is collected by the footing drains and then either pumped to the surface where it is discharged at grade or pumped into a nearby storm sewer. Although not all sump pump discharge is a problem, it can become a nuisance when improperly discharged. Note that for the purposes of this document, the word "groundwater" is used generically to mean any underground water which is not exclusively regulated by the State.

Groundwater

Groundwater exists in the voids present in the layers of soil and rock and is typically defined by areas where all the spaces and cracks are completely filled with water, also called the zone of saturation. Locating and mapping depths to groundwater can be tricky because the composition and depths of soil and rock can vary substantially, even within a few lateral feet.

The Colorado Department of Public Health and Environment (CDPHE) issues permits related to groundwater discharge that focus on discharge volume and water quality[5]. Activities associated with single family residential buildings are generally exempt from these permits, which make a distinction between infiltration from stormwater and groundwater. If stormwater infiltrates into the ground and is dewatered prior to reaching the zone of saturation, it is not considered groundwater by the State. Therefore, it is presumed that if a typical residential basement construction requires dewatering, it is in direct response to precipitation events and the pumped water is assumed to be stormwater; thus, requiring no permit. Discharging stormwater comingled with groundwater does require a state Colorado Discharge Permit System (CDPS) discharge permit and is not required to meet the criteria and provisions of WQP-27, Low Risk Discharges Policy when discharging to the surface.

Per City of Boulder regulations, infiltrated stormwater or uncontaminated groundwater can either be discharged to grade with no permit or to the city storm sewer with a city permit[6] as long as the discharge complies with state regulations. City of Boulder permitting includes a review of system capacity among other considerations. Discharges to grade must generally follow historic drainage patterns and should not leave the property in such a way that it creates adverse impacts to adjacent properties or the public right-of-way[7]. The improper discharge of sump pumps can create nuisance drainage that may negatively impact adjacent properties and create hazards in the rights-of-way, such as the formation of ice and slime on sidewalks and roads.

[5] General Permit No. COG603000 for Discharges from Subterranean Dewatering Activities
[6] BRC 11-5-5 (d)(2) relates to storm sewer discharge regulations
[7] *BRC 8-2-8 details water discharges that are prohibited, required remediation, and city enforcement actions*

Policy Discussion

Both the Boulder Valley Comprehensive Plan and the 2004 CFS Master Plan recommended the consideration of additional regulations related to groundwater. This section identifies and compares potential regulation and policy options to address the identified issues.

Policy and Program Goals

The policy and program evaluation (Appendix A) identified goals and objectives that could be used to evaluate the existing groundwater programs within the Utility. As part of the analysis on groundwater policy, these goals and objectives were reviewed and refined to meet the current and future needs.

GOAL: Mitigate impacts on groundwater or surface water quantity and quality, groundwater recharge, local water wells, wetlands, and ecosystems

Objective: Minimize subsurface structures that require ongoing dewatering

GOAL: Address the unintended consequences created by dewatering activities that cause harm to adjacent properties or create hazards in the public right-of-way

Objective: Reduce the number of complaints related to improper groundwater discharge

Objective: Identify and publish mitigation and remediation measures that can be implemented by private property owners to encourage compliance with state and local regulations

The following section includes discussion of approaches used in other locations throughout the United States to address issues similar to the identified improvement actions.

Right-of-Way Hazard Created by Improper Discharge

Regulating Groundwater

The city has given much consideration to the regulation of groundwater dewatering activities[8]. However, nuisance problems persist due to limited options for lawful discharge of pumped subsurface water. Small lot sizes or lots with little pervious area are common to Boulder and result in a lack of space for onsite infiltration of sump pump discharge that leads to nuisance runoff. Residents may be unaware of regulations and/or effective means to discharge sump water. This runoff can cause private property damage, both at the discharge site and to properties adjacent to the discharge site, especially during times of high groundwater or large precipitation events. Nuisance runoff that crosses the public right-of-way creates resource demands on city staff who are frequently called to investigate sump pump discharge complaints. Additionally, groundwater in Boulder naturally contains elements like arsenic, silver, and selenium that could be considered pollutants at higher concentrations. Increasing discharge of sump pumps into the storm sewer system raises concerns about whether these storm sewer inputs may create future problems with the city's Municipal Separate Storm Sewer System (MS4) permit. While individual sump pump discharge locations may not require State permitting, the cumulative effects of these discharges could become significant contributors of future pollutants that the city would be required to manage.

Many other communities across the United States experience similar issues with both short-term and long-term dewatering activities and have tried increasing dewatering regulations to address the problem. In 2016, the City of Palo Alto, California, began requiring groundwater dewatering mitigation measures as part of their construction dewatering regulations. These measures include either constructing a cutoff wall or undergoing a hydrogeologic study, installation of a groundwater monitoring well, a dewatering plan, and a groundwater use plan to address the method and location of discharge. Although Palo Alto is seeing some initial benefit from such measures, the long-term groundwater impacts are still unknown. Additionally, building construction costs have increased substantially due to the significant costs associated with the cutoff wall and hydrogeologic study.

Elsewhere, communities have considered enacting a wholesale prohibition of subterranean structures for all new construction to reduce issues associated with dewatering. However, no successful examples of implementing this type of citywide regulation were found. For example, West University Place, Texas, proposed banning the construction of all residential basements in 2011, but met opposition from the community and was ultimately unsuccessful in getting the measure passed. Therefore, they instead passed a regulation limiting the size, location and use of new basements below residential and commercial structures.

Lastly, there is also precedent for regulating basement depths based on the widespread presence of high groundwater. Multiple cities in Wisconsin and in coastal areas have regulations that require basement floors to be constructed one or two feet above the seasonal-high groundwater elevation. Within the City of Boulder, the claim is often made that building height restrictions limit the final construction size, and therefore, basements are necessary to increase livable area beneath houses. The cities mentioned above do not have the same height restrictions as Boulder. Therefore, their regulations may not be as limiting in terms of final construction size.

In Boulder, the construction of residential subterranean structures is currently prohibited within the 100-year floodplain. This regulation could potentially be expanded to include other areas with high groundwater outside the 100-year floodplain, but determining these areas can be problematic. Mapping Boulder's groundwater depths would provide an increased degree of accuracy in determining areas of high groundwater but is resource- and cost-prohibitive such that the gain achieved in reducing nuisance sump pump discharges does not justify the

[8] *Until 2019, the city had a groundwater discharge permit that was subsequently discontinued due to its duplicative nature with State permits.*

cost. Boulder could consider whether the application of more stringent regulations on groundwater impacts should be applied on a case-by-case basis dependent on engineering reports. However, this approach may not achieve consistent, equitable, or practical resolution to groundwater discharge issues.

Alternatives to Regulations

There are, of course, areas of the U.S. where basements are not commonplace. This practice is often driven not by regulations, but rather by foundation and constructability issues. For example, areas with excessively high groundwater or expansive clays such as “caliche” soils can experience interior flooding and problems with damp walls. Dewatering systems in these areas can often prove inadequate in handling the high volume of water and are not reliably covered by insurance when they fail. These issues are frequently avoided altogether by eliminating construction of subterranean structures in these areas.

In locations where soil and groundwater conditions make the construction of basements unfavorable, cities may find it necessary to educate builders and the community about challenges and potential risks related to subterranean construction. Education efforts result in more informed home buyers and potentially a diminished desire to construct a home with a basement. However, this approach does not eliminate the problems altogether. Rather, dewatering activities become something to manage versus something to eliminate.

Recommendations

Ongoing dewatering activities associated with subterranean construction including those from single family residential basements can create unintended consequences that can harm adjacent properties or present hazards in the public rights-of-way. The location and movement of groundwater varies significantly throughout the city, and mapping and identifying the depths of seasonally high groundwater can be costly and impractical. Increasing regulations may be marginally effective in reducing dewatering issues but can increase construction costs and raise equity concerns. Therefore, because of the questionable benefit and potential for limited return on investment, this Master Plan does not recommend that Boulder pursue further regulation at this time.

It is therefore recommended that Boulder enhance education of the community on the public and personal hazards associated with subterranean construction in an equitable manner, including:

- Educate the community on groundwater risks, dewatering systems, and to give a better understanding of operation and maintenance requirements for a dewatering system.
- Update and keep current education materials related to localized options for addressing sump discharges and share interdepartmentally to ensure consistent messaging.

Knowledge about the proper discharge from dewatering systems may lead to a reduction in nuisance drainage and associated damage to private property and hazards in the public rights-of-way. New construction of subterranean features could be discouraged in an education campaign. Additionally, private property owners with sump pumps and those looking to build can be made aware of the hazards associated with improper discharge and could be encouraged or incentivized to properly discharge. The desired outcome of this policy is to discourage new subterranean construction and to correct problems associated with existing improper sump pump discharge.

6 Floodplain and Hazard Mapping

The City of Boulder is situated at the base of the Rocky Mountain Foothills where large drainage areas associated with the city's major floodways are predominantly located. These drainage areas can generate considerable stormwater runoff that is conveyed through steep canyons prior to entering the city limits. As a result, Boulder is highly susceptible to flash floods that carry large volumes of sediment and debris, resulting in hard to predict flooding conditions.

Boulder's current floodplain mapping studies meet or exceed the Federal Emergency Management Agency (FEMA) Guidelines and Standards in compliance with the National Flood Insurance Program (NFIP) and are based on inundation potential as is typical for standard flood hazard maps. This floodplain mapping forms the basis for the city's floodplain management and mitigation, floodplain regulations, and the NFIP. Therefore, it is important that current floodplain maps accurately reflect existing conditions. The community has expressed a desire for access to a higher level of hazard mapping that more accurately represents the flooding conditions and hazards within the city for flood-preparation and decision-making purposes.

**Programs and Initiatives
Supported by Floodplain and Hazard Maps**

- National Flood Insurance Program (NFIP)
- NFIP Community Rating System (Flood Insurance Premium Reductions)
- Federal, State, and Regional Funding
- Future Land Use Planning
- Flood Hazard Risk Assessment
- Floodplain Regulations
- Floodplain Mitigation Efforts
- Outreach and Education
- Flood Preparedness, Response, and Recovery

Debris Carried by Flooding in 2013

Policy Discussion

Although the city's floodplain mapping must meet FEMA standards, the city has discretion about which methods to use to develop these maps. For example, the city takes guidance provided by FEMA, Colorado Water Conservation Board, and Mile High Flood District (MHFD) into consideration when setting modeling and mapping standards. Although this flexibility still meets federal regulations, the resulting variability can present challenges when comparing and prioritizing flood mitigation needs across Boulder's drainages. Improvements in the accuracy of available data and modeling software will continue to add further options for mapping procedures and parameters. Therefore, policies and practices that promote consistent methodologies and uniform mapping are recommended to better support comparison of flood risk across drainages.

Policy and Program Goals

The policy and program evaluation (Appendix A) identified a set of goals and objectives that could be used to evaluate the existing policies and programs related to floodplain and hazard mapping within the Utility. As part of the analysis, these goals and objectives were reviewed and refined to meet the current and future needs. The following policy analysis and recommendations support the goals and objectives listed below.

GOAL: Provide floodplain mapping throughout the city to inform land use decisions

Objective:	Comply with current FEMA and city standards for updating and adopting regulatory floodplain maps
Objective:	Identify areas subject to the greatest risk of flooding within the city

GOAL: Inform the community of floodplain risks and areas prone to hazards

Objective:	Identify areas subject to flood-related hazards to reflect flood risks in Boulder

Hydraulic Modeling

Hydraulic modeling incorporates simulation and analysis to identify how likely it is for an area to flood. For example, areas within the delineated 100-year floodplain have 1 percent chance or higher of experiencing a flood each year, whereas the delineated 500-year floodplain represents a 0.2 percent chance or higher of experiencing a flood each year. This information is then used to design mitigation approaches to reduce the negative impacts of flooding. Hydraulic models can be either one-dimensional (1-D) or two-dimensional (2-D) for flood hazard studies, and the decision of which to use depends on a variety of factors including technical and regulatory considerations. In general, 1-D models are most appropriate where flood flows are oriented along streamlines that run approximately parallel to the primary stream channel. Two-dimensional models are most appropriate where there is significant flow in both the streamwise and cross-stream directions, there are multiple flow splits[9], and/or overbank flows are disconnected from the main channel. The vast majority of existing Special Flood Hazard Areas

[9] A flow splits exists when floodwater junctions with one upstream reach and multiple downstream reaches. "Junctions and Flow Splits". USACE. https://www.hec.usace.army.mil. Accessed 14 Feb 2022.

(SFHAs)[10], which define areas where floodplain management regulations must be enforced, were developed based on 1-D modeling. Two-dimensional models have, however, become more prevalent over the past few decades with continued refinement of modeling techniques and increases in computational and data management capability. Whereas 2-D models can more accurately reflect the flooding hazard in reaches with the conditions mentioned previously, the structure to support their regulatory use is relatively new and is still being refined. Therefore, Boulder primarily uses a 1-D modeling approach when identifying Special Flood Hazard Areas. Modifying this approach by using new mapping technologies and methodologies that are not currently included in FEMA's Guidelines and Standards has historically delayed construction of flood and storm projects on the order of years. It is therefore recommended that the city prepare for the adoption of 2-D modeling procedures. This includes following FEMA's most recent guidance for 2-D modeling at the time of the project.

Climate Change

The Utility recognizes that it has a role in addressing uncertainty due to climate change, including changes in frequency and magnitude of precipitation events. The hydrologic analysis required for regulatory mapping is based on an approach that minimizes uncertainty in data and engineering calculations. How these maps are applied to inform flood mitigation planning and other Utility activities should account for uncertainties related to climate change. Approaches to best address this uncertainty are addressed by the Utility through infrastructure resilience in design, as discussed in Chapters 4 and 8.

As global temperatures continue to rise, the resulting effects of a changing climate should be incorporated into mapping practices based on the best available science. Most global and regional climate models project increased warming, droughts, and wildfires in this region (Lukas, et al, 2014).

Mapping Update Frequency

The frequency of mapping updates should be driven by the need to have accurate flood hazard data for the community and the public. Information concerning the flood hazard on riverine systems within the city influences multiple aspects of the city's long-range planning. Flood risk is constantly changing due to physical and climatic changes. As data collection and methods of assessment change, the understanding and accuracy of flood risk also changes. However, there is not a timeline on which hydrologic and hydraulic analyses become inaccurate, and as such, a frequency for mapping updates is not recommended. Instead, the Utility should consider implementing a map review schedule to confirm whether existing maps still best represent current conditions. FEMA's Coordinated Needs Management Strategy (CNMS) provides an approach to evaluate physical and method changes that should inform the determination of when to update existing maps. The CNMS Map Viewer provides information on assessments already being completed at the national level for streams within Boulder.

Regulatory Mapping

FEMA publishes standards and guidelines that apply to floodplain mapping used for the NFIP. Although floodplain maps produced by the city must ultimately be accepted by FEMA, there are varying ways to accomplish this. The Utility should clearly outline the process for developing, reviewing, and adopting regulatory data and products to limit unintended variations between studies and to support prioritization of projects based on common

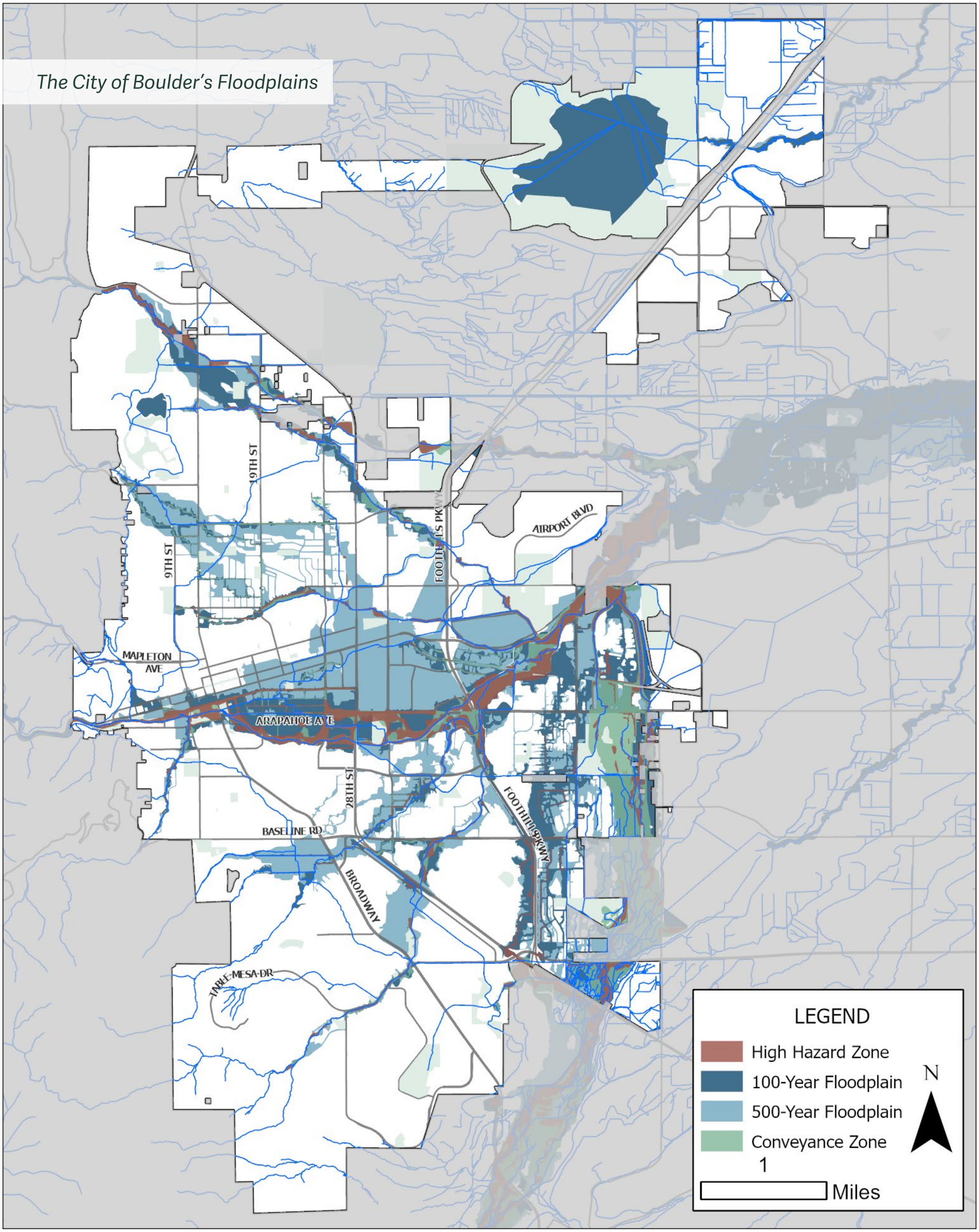
[10] The SFHA is the area where the National Flood Insurance Program's (NFIP's) floodplain management regulations must be enforced, and the area where the mandatory purchase of flood insurance applies. "Special Flood Hazard Area". FEMA, https://www.fema.gov/glossary/special-flood-hazard-area-sfha. Accessed 14 Feb 2022.

parameters. Documentation of methodologies and assumptions for floodplain mapping products would build consistency for comparison across the city's watersheds. Additionally, referring to guidelines that are recommended or required by MHFD and FEMA would minimize the need for a lengthy document while still identifying the Utility's preferences for data sources and methods. To simplify the review process and use of resulting floodplain analyses, the following guidelines should be considered for identification:

1) Products to be developed for each project type
2) Requirements for evaluating or updating hydrologic studies
3) Preferred used of 1-D or 2-D hydraulic models, including preferred or approved software for hydraulic modeling
4) Hydraulic modeling assumptions, including culvert blockages and breakaway bridge structures
5) Requirements for High Hazard Zone calculations
6) Return periods of flood events to be mapped

Adoption of floodplain mapping by the city for floodplain regulation or submittal to FEMA to update the FIRMs should be an identified decision point for each floodplain assessment after preliminary results are available. As the process can delay timelines and require additional internal resources, the regulatory adoption process should be completed when it supports flood risk reduction and should not be completed without evaluation. The decision should be informed by how the results of the new floodplain mapping product support the city's goal of flood risk reduction. For example, when the results do not indicate a significant increase or decrease in risk has occurred, it may better serve the city to complete the FEMA regulatory floodplain mapping process after a mitigation project has been completed. On the other hand, if base flood elevations have significantly increased but mitigation projects are anticipated to have a long duration, adoption of the mapping by the city for regulatory purposes would support the Utility's hazard reduction objective.

On average, it takes the city about a decade of mapping activity in a watershed to provide a full update to the floodplain maps using the current process. However, without significant changes in land use and development, topography, channel modification or hydrology, updates to the regulatory floodplain maps may not be necessary.


The City of Boulder's Floodplains
MAPLETON AVE
9TH ST
19TH ST
FOOTHILLS PKWY
AIRPORT BLVD
ARAPAHOE AVE
28TH ST
BASELINE RD
BROADWAY
FOOTHILLS PKWY
TABLE MESA DR
LEGEND
High Hazard Zone
100-Year Floodplain
500-Year Floodplain
Conveyance Zone
N
1
Miles

Sediment Deposition along Fourmile Canyon Creek

Hazard Mapping

Property damage and other flood-related public safety issues can result from a variety of factors, including inundation, deposition of sediment and other debris, and erosion. Although mudslide and erosion hazards were added to the NFIP by Public Law 91-152 in 1969 and Public Law 93-234 in 1973 respectively, standard flood hazard (SFHA) maps are typically based only on inundation potential caused by clear water flooding, with erosion and deposition rarely included. The extraordinary flooding that occurred along the Colorado Front Range in September 2013 exposed a key limitation of over-reliance on inundation-based SFHA mapping to identify community risk. While the resulting peak discharge frequencies at many locations within the City of Boulder were generally below the adopted 100-year peak flow rates (WWE, 2014), 63 percent of insurance claims paid by FEMA's National Flood Insurance Program were outside of the delineated 100-year floodplain. Much of the damage in the areas outside this floodplain not related to groundwater or sewer backups resulted from flood-related debris deposits and inundation due to flow diversions by the debris deposits.

Although they may by laterally stable, channels that transition from a confined valley to an alluvial fan surface near the western city limits (e.g., Bear Canyon Creek, Twomile Canyon Creek, and Fourmile Canyon Creek), are subject to debris flows that can cause blockage which limits capacity and send floodwaters and debris into unexpected paths away from the primary channel. While FEMA provides guidance and technical procedures for mapping areas subject to uncertain flow paths (i.e., alluvial fan flooding) (44 CFR 65.13; FEMA, 2016), the procedures do not generally apply to urbanized areas where development has altered the pre-development flooding characteristics (Fuller, 2013, p30). FEMA (2016, Sect 2.3.4) recognizes this limitation by noting that two-dimensional models may be appropriate for determining flood hazards on alluvial fans, particularly those involving complex urban flooding. Because of the uncertainty in where debris deposits and debris blockages will occur during any particular flood, worst-case analyses that sequentially block different, possible blockage locations should be considered in identifying the limits of the fluvial hazard zone in these areas.

The Colorado Water Conservation Board (CWCB) Fluvial Hazard Zone Delineation Protocol (Blazewicz, et al., 2020) defines the fluvial erosion hazard zone (FHZ) as *the area a stream has occupied in recent history, may occupy, or may physically influence as it stores and transports water, sediment and debris*. The FHZ, thus, includes not only the areas subject to inundation, but also those outside the inundation zone subject to erosion or deposition of sediment and other debris.

Recommendations

Mitigation projects often drive the priority of when floodplain analyses occur. Consistent procedures and timelines for assessing the basis of selection of hazard mitigation are beneficial in understanding existing hazards. Confirming that current flood hazard assessments accurately represent existing conditions ensures mitigation efforts address the most significant risks. In addition to identifying the need to update existing studies, a policy to assess and update flood hazards should include a review of new community issues and priorities. A review of non-mapped urban and riverine flood hazard areas and the future climate impact on flood hazards are examples of flood hazards that could be included in the process.

It is recommended that the Utility evaluate and clearly document the parameters and methods used for current hydrologic and hydraulic analyses and floodplain mapping the city uses for planning and flood risk mitigation on a 5-year interval. A decision to update the mapping can be made whenever significant changes are encountered. This will ensure that decisions are based on an updated flood hazard assessment and that consistent practices are being followed.

The following mapping policies are recommended:

- Adoption of new floodplain mapping for regulatory purposes will be evaluated and completed when new flood hazard information supports flood risk reduction and mitigation. Unless physical changes within the watershed (i.e., land use, topography) or channel (i.e., flood mitigation improvements, changes to hydraulic structures) result in a change that modifies the extent of the floodplain more than 10 percent or the depth of the base flood elevation by more than 0.5 feet, regulatory floodplain maps may not be updated.
- Provide a uniform method of mapping that identifies the greatest risks to people and property to support mitigation planning; floodplain management; public awareness; and flood preparedness, response, and recovery efforts.
  - Consider identifying site-specific hazards that may require additional mapping (i.e., fluvial erosion, avulsion, sedimentation, channel blockages, modifications to hydrologic analyses to include future conditions scenarios like effects from wildfires).
- Review existing maps to evaluate when hydrologic and hydraulic analyses or physical changes to a watershed may result in a substantive difference in the current flood hazard of a major drainageway.
  - Develop an evaluation cycle and framework to evaluate potential changes in flood hazard that indicates what warrants the need to update flood hazard analysis and map updates.
  - Standardize floodplain analysis and mapping procedures to uniformly incorporate local guidance with regional, state, and federal requirements.
  - Incorporate information on data and assumptions used as part of current floodplain mapping studies into the city's online Map of the Floodplains and printed maps.
- Continue to address the effects of climate change on floodplain delineation based on the best available scientific data.
- Due to the devastating effects that can be caused by climate-related disasters, the Utility should proactively incorporate floodplain mapping guidance produced by state, regional, and local organizations related to climate change.

- Continue to use one-dimensional (1-D) models for floodplain hazard mapping to regulate floodplain development where a reach assessment indicates a 1-D model is appropriate
- Prepare for adoption of 2-D modeling for regulatory mapping when reach based evaluation indicates a 2-D analysis is appropriate and when following FEMA Guidelines and Standards can be efficiently incorporated into the project. Preparation could include:
  - Adopting FEMA guidance on defining the regulatory floodway using 2-D models as it continues to evolve
  - Identifying how to evaluate floodway development with 2-D models
  - Developing a list of city-approved hydrologic and hydraulic models
  - Aligning any approach with MHFD and FEMA requirements
  - Stay abreast of developments in this area and provide input, as appropriate, to ensure that challenges specific to conditions in the city are reflected in forthcoming standards and guidance.

References

Blazewicz, M., K. Jagt and J Sholtes, 2020. Colorado Fluvial Hazard Zone Delineation Protocol Version 1.0, Colorado Water Conservation Board, 212 pp.

Department of Natural Resources, Colorado Water Conservation Board, DRAFT Rules and Regulations for Regulatory Floodplains in Colorado, November 19, 2021. 2 CCR 408-1 Floodplain Rules_FINAL REDLINES.pdf (state.co.us)

Federal Emergency Management Agency (FEMA), 2019. Coordinated Needs Management Strategy (CNMS) Technical Reference, CNMS Database User's Guide.

Federal Emergency Management Agency (FEMA), 2016. Guidance for Flood Risk Analysis and Mapping, Alluvial Fans, November, 36 pp.

Federal Emergency Management Agency (FEMA), 2015. Final Report Reducing Losses through Higher Regulatory Standards Best Practices and Cost-Effective Strategies Report, FEMA-DR-4145-CO, March, 97 pp.

Federal Emergency Management Agency (FEMA), 2016. Guidance for Flood Risk Analysis and Mapping, Alluvial Fans, November, 36 pp.

Federal Emergency Management Agency (FEMA), 2019. 2D Models and Floodways: Challenges, Benefits and Considerations- DRAFT Version 0.1

Federal Emergency Management Agency (FEMA), 2020. Guidance for Flood Risk Analysis and Mapping, Hydraulics: Two-Dimensional Analysis Hydraulics Two-Dimensional Analysis Guidance (fema.gov)

Federal Emergency Management Agency (FEMA), 2020. Guidance for Flood Risk Analysis and Mapping, Floodway Analysis and Mapping Floodway Analysis and Mapping Guidance (fema.gov)

Federal Emergency Management Agency (FEMA) Website accessed December 2, 2021. Announcements for Flood Risk Analysis and Mapping Activities | FEMA.gov

Fuller, J.E., 2013. Gaps in FEMA Guidance for Delineating Flood Hazards on Active Alluvial Fans, Journal of Flood Engineering, 4(1), June, pp 29-38.

Lukas, J., Barsugli, J., Doeksen, N., Rangwala, I., and Wolter, K. 2014. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation, Second Edition. Colorado Water Conservation Board.

Mile High Flood District, Flood Hazard Area Delineation (FHAD) Guidelines, Website accessed December 2, 2021. NONSTRUCTURAL BEST MANAGEMENT PRACTICES (mhfd.org)

Wright Water Engineers, Inc., 2014. Rainfall-Runoff Analysis for September 2013 Flood in the City of Boulder, Colorado, prepared for City of Boulder Utilities, October, 79 pp.

Wobus, C. and Bash, R., Lynker Technologies to Coleman, B., City of Boulder. December 31, 2020. Incorporating Climate Change into Flood Control Along South Boulder Creek: Summary of Federal, State, and Local Guidance.

7 Modifications to Regulations

The Boulder Revised Code (BRC), first published in 1981, is the official book of laws of the City of Boulder that is updated quarterly by City Council. Updates to the BRC are approved by City Council through the adoption of ordinances. Draft flood and stormwater management ordinances are informed by extensive community engagement and Water Resources Advisory Board (WRAB) and Planning Board recommendations. If approval is recommended, the draft is submitted to City Council for a study session to debate the merits and content of the ordinance. If changes to the draft are recommended by Council, they must be incorporated and reviewed by WRAB and Planning Board again. The draft ordinance is then presented to the public for a comment period lasting fifteen days. Following public comment, adjustments may or may not be made, and the ordinance must then be adopted by City Council and approved by the city attorney prior to publishing in the BRC.

The Design and Construction Standards (DCS) is an extension of the BRC used to provide minimum standards for the construction of public infrastructure and private improvements that either connect to or may impact public infrastructure. Currently, any updates to the DCS, including modifications, additions, or clarifications, must also go through the same approval process prior to being adopted through an ordinance by City Council.

Flood and stormwater regulations have the primary function of protecting public health, safety and welfare, and endeavor to reflect community values. Oftentimes, floodplain management regulations face the challenge of balancing competing interests including environmental protection, recreation, preservation of open space, individual property rights, and economic impacts. Instituting new regulations involves careful consideration of the proposed change and any potential unintended consequences, which takes time.

Code:
Compilation of municipal ordinances

Ordinance:
Local law adopted by a municipality

Regulation:
Official rule that supports the enforcement of a law

Regulatory Discussion

The introduction of new regulations or modification to existing regulations requires thorough evaluation of anticipated positive and negative impacts and outcomes. Generally, the process to vet regulatory proposals begins with understanding the need and goals of the regulatory action. Regulatory alternatives are then developed and evaluated both quantitatively and qualitatively against a 'no change' scenario based on benefits, costs, and consequences. Of specific importance are anticipated burdens, fiscal impacts, legal ramifications, and the distribution of these impacts. Benefits are then weighed against the initial goals to determine whether there will be an appreciable effect and if the costs or burdens are justified. Additionally, reasonable alternatives that might achieve the same or similar goals without the need for added regulation should also be evaluated. The reason for this rigor is to fully understand the benefit and burden of regulatory changes.

The following section identifies regulatory modifications to either the BRC or the DCS for future consideration by the city. Examples of potential impacts and desired outcomes are discussed, but a full regulatory impact analysis is beyond the scope of this Master Plan and should be conducted prior to formal proposal.

Boulder Revised Code, 1981

Ordinances that relate to the function and operation of the Utility are contained in a few locations within the BRC, as shown in the table below. During recent public engagement, community members asked whether strengthening floodplain regulations is warranted. This concept was investigated from a regulatory standpoint to determine if gaps are present in existing regulations. A discussion of possible regulations to address gaps follows the table.

Boulder Revised Code Chapter	Summary of Relevant Content
Title 8: Parks, Open Spaces, Streets, and Public Ways	
Chapter 2: Streets and Sidewalks	▪ Requires property owners to maintain ditches and drainage ponds ▪ Prevents the discharge of water onto sidewalks, streets, alleys, or rights-of-way ▪ Describes enforcement actions
Title 9: Land Use Code	
Chapter 3: Overlay Districts	▪ Identifies floodplains and wetlands as overlay districts[11] ▪ Includes regulations for development within regulatory floodplains and within streams, wetlands, waterbodies and associated buffer zones
Chapter 12: Subdivision	▪ Requires the provision of utility, drainage, irrigation ditch, and maintenance easements for subdivisions and lots
Chapter 16: Definitions	▪ Defines relevant terms used throughout Chapter 9 (mostly relates to floodplain, stream, wetland, and waterbody regulations)

[11] *Overlay districts provide restrictions or additional requirements for all development within a geographic area, irrespective of the basic zoning standards. These districts "overlay" or can cross existing zoning.*

Boulder Revised Code Chapter	Summary of Relevant Content
Title 11: Utilities and Airport	
Chapter 5: Stormwater and Flood Management Utility	▪ Establishes the Stormwater and Flood Management Utility as an enterprise and allows for the collection of fees ▪ Describes functions of the Utility ▪ Establishes land development regulations for stormwater quality and conditions regulating the use of the stormwater utility system ▪ Authorizes the Utility to inspect private property ▪ Requires the provision of construction and maintenance easements on natural drainageways as a condition of issuing building permits ▪ Requires property owners to maintain flood channels ▪ Describes enforcement actions ▪ Provides MS4 permit required regulatory language related to illicit discharge, pollution prevention, enforcement, etc.

Floodplain Regulations

Floodplain regulations restrict or prohibit certain uses within the city's regulatory floodplains. These regulations should periodically be reviewed and updated to reflect changing community needs and to ensure that floodplain management and National Flood Insurance Program (NFIP) objectives are achieved. To accomplish this, existing floodplains regulations could be reviewed against higher regulatory standards discussed under the Community Rating System (CRS) Activity 430. It is not recommended that increases in regulations be made solely for the purpose of receiving CRS credits. However, the CRS Coordinator's Manual is often viewed as a resource for nationally accepted floodplain best practices. Resources and recommendations found in Activity 430 could be used to identify potential areas where higher standards may support community values and the intended purpose of the city's floodplain regulations.

Addressing Development in the Floodplain

Highly developed floodplains present community-wide challenges. Prevention and regulation of development within the floodplain results in significant burdens and impacts on private property owners, developers, and local economies. However, the benefits to public health, safety, and welfare can outweigh the costs and impacts when they have the intended effect. Communities must therefore carefully consider the many complexities surrounding floodplain regulations prior to adopting or amending regulations to ensure they best fit a community's needs and values and to analyze the tradeoffs and unintended consequences that accompany these types of restrictions.

Prevention of all new construction within regulatory floodplains can work well in communities that have a fair amount of privately-owned, undeveloped land remaining in floodplains. The city of Fort Collins, for example, prevented the construction of new residential structures in the Poudre River 100-year floodplain following the 1997 flood. As a result, only eight structures were damaged during the 2013 flood, even though nearly 14,000 structures had been constructed between the two floods (Pew Charitable Trusts, 2019). Boulder has different circumstances that would likely make increased regulations less effective. Extensive development already exists in Boulder's floodplains, and current day construction primarily consists of redevelopment and expansions to existing structures versus new construction. As noted in the policy and program evaluation (Appendix A), the area of building footprint within the 100-year floodplain only increased by 0.1% between the years of 2014 and 2018. Further regulations on new development activities, therefore, would not play a major role in achieving regulatory goals of floodplain management, and the result would likely be a small cumulative benefit at the cost of relatively large regulatory and administrative burden.

The community has also wondered whether stricter limitations on redevelopment of the approximately 2,600 structures in the regulatory 100-year floodplain would be worthwhile. Imposing such regulations on redevelopment may offer limited flood risk benefit and the move could exacerbate Boulder's current housing challenges and further narrow the demographic of who is able to live in Boulder. Additionally, the effect of more stringent regulations on entities like churches, schools, or medical care facilities may be unmanageable such that they choose to relocate outside of Boulder. The city's Racial Equity Tool provides a structured approach to considering benefits and burdens of any proposed regulatory changes and is for recommended for future use when evaluating new regulations.

Legislative Intent

Section 9-3-2(a) of the BRC defines the legislative intent of Boulder's floodplain regulations, which includes protecting health, safety, and welfare by focusing on property protection and minimizing danger to human life. While other functions are mentioned, the legislative intent may not fully capture community values or policies within the BVCP that focus on preservation of natural floodplains and the associated social and economic benefits. The city may consider whether to add these elements.

500-Year Floodplain

In 2011 the WRAB and Planning Board both unanimously voted to approve a draft ordinance for critical facilities and mobile populations in the 500-year floodplain. Mobile populations refer to groups of people who may be present in a location that is not their place of permanent residence, such as hotel guests or convention attendees. This draft ordinance included language that required facilities used for group assembly located in the floodplain to develop emergency management plans and provide a flood warning system to ensure that flood protection information is disseminated to facility users. Group assembly typically includes gathering for the purposes of social, civic, religious, or other functions. City Council raised concerns about the ordinance's potential impact on the business community and provided feedback for modifications in 2012. In 2013, the modified draft ordinance that exempted facilities used for group assembly was approved by City Council. Evacuations during emergency situations are often complicated and can become hazardous when large numbers of people are present. It is recommended that language removed from the 2011 draft ordinance be reevaluated for inclusion into the standards for critical facilities and lodging facilities in the 500-year floodplain ordinance. This evaluation should also include a review of an occupancy threshold to reduce impacts to the business community while still protecting vulnerable groups.

100-Year Floodplain

Development in the 100-year floodplain is permitted as long as required flood protection measures are provided. However, the addition of structures and fill materials reduces floodplain storage capacity and can deflect waves onto neighboring properties. While storage losses are likely minimal on individual properties, the cumulative impacts of continued development can cause rises in flood depths and potentially increase the extents of the 100-year floodplain boundaries. It is recommended that provisions to limit or reduce flood storage losses be evaluated. Approaches often used include prohibiting fill or requiring compensatory storage (meaning no net storage loss). These restrictions can be quite difficult to implement, regulate, and enforce on smaller sites, which may not be practical if the anticipated future flood storage losses are minimal.

High Hazard Zone

Currently, the regulations for BRC 9-3-8 (b) state that in the event of a flood, any structure located in the High Hazard Zone intended for human occupancy that is damaged more than 50 percent of its pre-flood market value cannot be repaired, reconstructed, or used for human occupation. For example, housing units valued at $200,000 cannot sustain more than $100,000 worth of damage, and a $5 million house cannot sustain more than $2.5 million worth of damage and be reconstructed or inhabited. The even application of this 50 percent standard across all home values may unfairly disadvantage lower income populations, who may already possess fewer resources to recover from natural disasters. Across the United States and within the City of Boulder, marginalized populations have historically been pushed to the least desirable or higher risk locations for housing. Meaning that people of color and lower-income populations often live in floodplains[12]. Therefore, to meet the intent of the city's racial equity policy, it is recommended that alternative metrics or socio-economic weighting factors be evaluated to assess whether a structure can be repaired or reconstructed. For example, FEMA's Benefit-Cost Analysis program uses a Depth-Damage Function, or Depth-Damage Curve to express damage based on the percentage of the structure, contents, and functions impaired or destroyed and not the percentage of market value (FEMA, 2009).

Additionally, BRC 9-3-8 (b) also states that the city may contract or purchase flood-impacted land at its fair market value *after* damage has occurred. In instances where flood insurance does not fully cover losses, this has the function of dissolving pre-flood equity. It is recommended that programs or modifications to the purchase price of flood damaged land be investigated to address equity and the disproportionate effects associated with this regulation.

Drainage Ditches and Drainage Ponds

In some locations within the city, drainage ditches convey stormwater. Where these ditches exist, BRC 8-2 states that any required maintenance is the responsibility of the adjacent property owner. This includes the requirement that no person who owns a ditch or drainage pond shall fail to maintain it in good repair and in a safe and unobstructed condition (BRC 8-2-8). Chapter 8-2 also includes requirements of property owners to maintain sidewalks, including the removal of hazards such as snow, ice, and improper discharge of water. In these instances, the code includes enforcement provisions for required corrective actions by the property owner and subsequent fines and actions the city may take to correct the violation. It is recommended that similar provisions for corrective actions and associated fines be evaluated for failure of property owners to maintain roadside ditches and drainage ponds.

Design and Construction Standards

The Design and Construction Standards apply to the comprehensive design and construction of adequate and functional public improvements associated with development, redevelopment, and subdivision of lands; and providing necessary right-or way, transportation, and utility services. The document also provides minimum standards required for the design and construction of privately owned transportation and utility improvements that are connect to or impact public infrastructure.

Chapter 7 of the DCS covers stormwater and provides design requirements for a stormwater utility system to mitigate safety hazards and minimize property losses and disruption during heavy stormwater runoff or flooding events. The intent is to maintain travel on public streets during storm events, enhance water quality of

[12] *See redlining practices discussed in the city's Racial Equity Plan.*

stormwater runoff, manage increased runoff due to development, establish long-term management of natural drainageways, and provide for ongoing and emergency maintenance of the public stormwater system.

Modifications to the DCS

Per BRC Section 9-9-4 (a), the DCS is adopted as a part of code by reference, meaning that it functions as though it were written into the BRC. Therefore, it subject to the same process of adoption as the BRC for additions, revisions, or corrections, however minor. Section 1.05 of the DCS states that the Director of Public Works (referred to in this document as the Director of Utilities) may alter or modify standards in the DCS when specific practical difficulties are involved in their execution. However, it is often the case where corrections are needed for minor errors, or revisions are warranted for the purposes of clarification or to better conform with the intent of existing standards and policies. In instances where additions, revisions, and corrections are consistent with existing policies and do not alter the intent of the standard nor the cost of its implementation, it is recommended that the Director of Public Works be given the authority approve these changes.

Some municipalities elect to allow departments to update design standards without needing City Council approval, as long as the design standards are in support of the ordinances that govern those activities. This is especially useful in instances where changes in in federal or state regulations require modifications to design standards for compliance. While this option was considered for stormwater design standards, especially as they relate to MS4 permit requirements, it was recommended for the purposes of regulatory transparency that the existing process requiring City Council approval still be followed whenever changes to the DCS substantively modify existing standards, impose new standards, or result in modifications that would increase the cost of implementation.

As-Built Drawings

Section 1.03 of the DCS details submittal requirements for construction approval, including as-built drawing submittal requirements. Section 7.17(B), "Stormwater As-Built Drawings" is also referenced in this section for drawings pertaining to the construction of stormwater control measures. It is recommended that as-built submittal requirements include the submission of GIS files to Information Services for all stormwater quality, stormwater collection and conveyance, and flood mitigation improvements on both private and public property. Submittal requirements should include standardized data formats for the inclusion into the city's existing GIS database. Additionally, the inclusion of materials, invert elevations, date of installation, inspections, peak flow rates from design storms, and hydraulic design capacities could further assist in the updating of hydrologic and hydraulic modeling as well as the city's asset management system.

Stormwater Design Standards

A general review of Chapter 7 is recommended for correction of minor errors, clarity, specificity, and intent. Recommendations include the following:

- Review for consistency in terminology. Multiple terms are used interchangeably to refer to the same design standard or system infrastructure and could be clarified. For example, the use of initial storm and minor storm, and various labels for the stormwater collection and conveyance system and associated subsystems. Terms used include stormwater drainage system, stormwater utility system, stormwater drainage facilities, open stormwater systems, open drainageway system, and minor stormwater system.

- Further define the term historic conditions. Historic runoff volume and runoff rates are currently used as the basis for the design and sizing of detention practices. However, it is not clear whether historic conditions refer to what existed prior to any development on the site, as used by MHFD, or if it refers to the conditions present prior to the start of the proposed construction.
- Further define materials and installation methods in Section 7.06, "Materials and Installation." As currently written, the section allows the use of all materials and methods that have adequate strength to support trench and AASHTO HS-20 loadings. Some materials may not be suitable for use in the city, and preferred materials should be indicated where necessary.
- Review sections that overlap with the Urban Storm Drainage Criteria Manual (USDCM) published by the Mile High Flood District (MHFD). The USDCM is used as a referenced standard that is applied when standards for design and construction of stormwater improvements are not specified directly in the DCS. There are instances where information in the USDCM is repeated directly in the DCS and should be referenced to eliminate conflicts as the USDCM is updated. Additionally, some language in the USDCM often reflects a suggestive rather than definitive tone, making standards difficult to interpret and enforce. Clarification should be provided in the DCS where this occurs.

Detention

It is recommended that design requirements in Section 7.12, "Detention" be reviewed. There are significant differences between the DCS and the USDCM for both detention pond design and exemptions for detention requirements. The USDCM recommends the use of full spectrum detention design, whereas the DCS requires detention be sized to contain 110 percent of the difference between the historic runoff and the initial and major storm runoff projected for the ultimate developed conditions. It is not clear from this requirement whether release rates must also be controlled to match historic conditions.

Applicable Development Site

Currently, the city's MS4 Permit requires that any new development or redevelopment site resulting in land disturbance greater than or equal to one acre must comply with the city's stormwater quality design standards. Several other cities of comparable size to Boulder now require runoff reduction approaches to be implemented on sites disturbing less than one acre. It is recommended that the current one-acre threshold be evaluated to determine if a lower threshold is warranted, as discussed in Chapter 3, Stormwater Quality.

Recommendations

Modifications to regulations can be a lengthy task involving thorough evaluation of the benefits and tradeoffs experienced by all who will be impacted. Therefore, recommended modifications to regulations are not within the scope of this document. However, the identified areas below are recommended for further evaluation through regulatory impact analyses to better determine whether additional regulations may be warranted.

It is recommended that the following regulations be further evaluated, including use of the city's Racial Equity Tool, for potential modification. Additionally, code development and revision cycles should spring-board off of current applied knowledge (i.e. 2013 Flood and other "lessons learned").

Boulder Revised Code, 1981

- Evaluate existing floodplain regulations to consider the following:
    - Refine the legislative intent of floodplain regulations to incorporate community values associated with flood mitigation, response, and recovery
    - Include assembly group facilities in the 500-year floodplain regulations for emergency management plans and flood warning systems
    - Evaluate regulations that would prevent or limit flood storage losses in the 100-year floodplain
    - Consider limiting or preventing fill within stream buffers to preserve the natural and beneficial functions of floodplains, with consideration for potential exemptions, such as ditch company operations and maintenance practices
- Evaluate the incorporation of enforcement actions and fees for the failure to maintain drainage ditches and drainage ponds.

Design and Construction Standards

- Allow the Public Works Director to make minor changes to the DCS that do not increase cost or alter the intent of the Standards.
- Review Chapter 7, "Stormwater Design" for correction of minor errors, clarity, specificity, and intent.
- Require as-built submission of GIS files for all stormwater quality, stormwater collection and conveyance, and flood mitigation improvements on both private and public property.
- Review detention pond design standards and design exemptions for consistency with MHFD requirements.
- Consider regulation of sites creating less than one-acre of disturbance and applicability of associated stormwater quality design standards.
- Incorporate more stringent stormwater quality design and construction requirements for city projects to lead by example.

8 Flood Mitigation, Property Acquisition, and Watershed Management

Floods are one of the costliest natural disasters in terms of economic losses and human hardship. One of the principal functions of the Stormwater and Flood Management Utility is to reduce risk and losses caused by floods. A variety of tools are employed by the Utility to achieve this. The construction of major drainageway flood mitigation projects is one of the primary ways in which this is accomplished. The Utility has been working for many years to reduce the threat of floods through the implementation of flood mitigation projects by first planning, evaluating, and then constructing these projects through the city's Capital Improvement Program. Additionally, it is understood that floodplains provide several natural and beneficial functions for both humans and surrounding ecosystems. As Boulder's population expanded rapidly, development was pushed further into the floodplains. Because the majority of this development happened prior to the existence of floodplain regulations, it became increasingly difficult to provide floodplain protections while adequately addressing societal needs and challenges. Therefore, Boulder uses a combined approach involving a variety of programs to identify and address the tradeoffs associated with comprehensive floodplain management.

Flood Impacts

- Injury or loss of life
- Property damage
- Infrastructure damage and road closures
- Economic losses
- Housing displacement
- Erosion and landslides

In addition to flood mitigation projects, the Utility also seeks to manage flood risk through property acquisition and watershed management. Property acquisition seeks to reduce the exposure of flooding to high-risk structures by removing them from the flood path. This further reduces flood risk to life and property in dangerous flood prone areas. Watershed management, on the other hand, manages increases in stormwater runoff caused by development such that flood risks do not increase. When unmanaged, stormwater runoff from new development and redevelopment in a watershed can result in more frequent flooding, greater flood depths, and longer-lasting floods. Watershed master planning is a progressive way to address these issues, providing a plan of action to address current and expected problems and a tool to make decisions based on the data and science of a watershed's behavior.

Policy Discussion

The City of Boulder's policies are aimed at supporting proactive flood management projects and programs that can adapt to changing conditions. Many of the improvement actions identified during the policy and program evaluation point to a need to formulate specific policies that support and formalize work currently performed by the Utility. The following section discusses issues and approaches to address the identified improvement actions from a policy perspective.

Policy and Program Goals

The policy and program evaluation (Appendix A) identified a set of goals and objectives that could be used to evaluate the existing policies and programs related to flood mitigation, property acquisition, and watershed management within the Utility. As part of the analysis, these goals and objectives were reviewed and refined to meet the current and future needs. The following policy analysis and recommendations support the goals and objectives listed below.

GOAL: Identify, evaluate, design, and construct improvements within the floodplain to mitigate damages to property and protect the public.

- **Objective:** Develop flood mitigation plans for major drainageways in the city
- **Objective:** Provide standardized guidance for the creation of mitigation plans
- **Objective:** Select, design, and construct flood mitigation projects that incorporate nature-based solutions to remove people and property from the floodplain

GOAL: Remove structures and acquire privately owned properties in areas prone to flooding, especially within the city's High Hazard Zone, for the purposes of flood mitigation

- **Objective:** Develop a prioritized list of high-risk properties to inform property acquisitions
- **Objective:** Prevent reconstruction of structures that have sustained significant flood damage
- **Objective:** Retain undeveloped high hazard flood areas in their natural state whenever possible

GOAL: Ensure that major drainageways are maintained to accommodate the passage of floodwaters

- **Objective:** Routinely clear nuisance vegetation and sediment from channels and debris buildup from culverts and bridges
- **Objective:** Provide satisfactory maintenance access and public access easements or rights-of-way for the purposes of maintenance activities

GOAL: Preserve and protect the natural resources and beneficial functions of floodplains

Objective: Preserve undeveloped floodplains through public land acquisition, private land dedications and multi-agency coordination

GOAL: Reclaim and restore floodplains and their functions

Objective: Incorporate floodplain restoration measures into flood mitigation projects

Objective: Restore habitat for native species

GOAL: Protect cultural and recreational resources associated with stream corridors and floodplains

Objective: Identify and protect historic resources within the floodplain

Objective: Limit open space development to trails, trail linkages, and open recreational facilities that do not impede flood flows

Boulder Creek Improvements at Eben G. Fine Park

Flood Management

As part of the flood management planning process, floodplains are first mapped prior to implementing any mitigation strategies. It is the Utility's policy to first implement nonstructural measures whenever feasible to mitigate risks associated with flooding. A particular advantage of nonstructural measures is their ability to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement. Once viable nonstructural solutions have been implemented, the Utility then identifies reaches of mapped creeks where structural modifications are most feasible for the mitigation of flood risk. When implementing structural measures, the Utility does not consider the use of concrete lined channels, dams, levees, or floodwalls unless there is a clear threat to life safety and other mitigation alternatives have been determined infeasible. In close coordination with community members and partner organizations like the Mile High Flood District, flood mitigation plans are developed to identify and evaluate the benefits and costs of potential major drainageway mitigation projects for design and construction. Due to the city's high risk for flash flooding and many tradeoffs associated with flood risk mitigation, it is not feasible to eliminate all risk within the City of Boulder. The Utility implements nonstructural systems and programs to further reduce risk where more targeted approaches are not warranted. However, flood risk reduction is most effective when community members also understand their responsibility and take action to continue to proactively address individual risk. This includes implementing nonstructural measures as needed to further protect themselves from harm and their property from damage.

Nonstructural Measures for Flood Risk Management

A set of techniques that do not change the physical shape of natural drainage channels and have little to no impact on the characteristics or extent of the flood itself. Methods are designed to alter the impact or consequences of flooding by eliminating exposure (i.e., removing structures) or reducing vulnerability of people and the built environment within the floodplain as it currently stands. Examples include:

- Advanced flood warning systems
- Flood preparedness education
- Floodplain regulations
- Obtaining flood insurance
- Floodproofing structures
- Removing structures from the floodplain

Structural Measures for Flood Risk Management

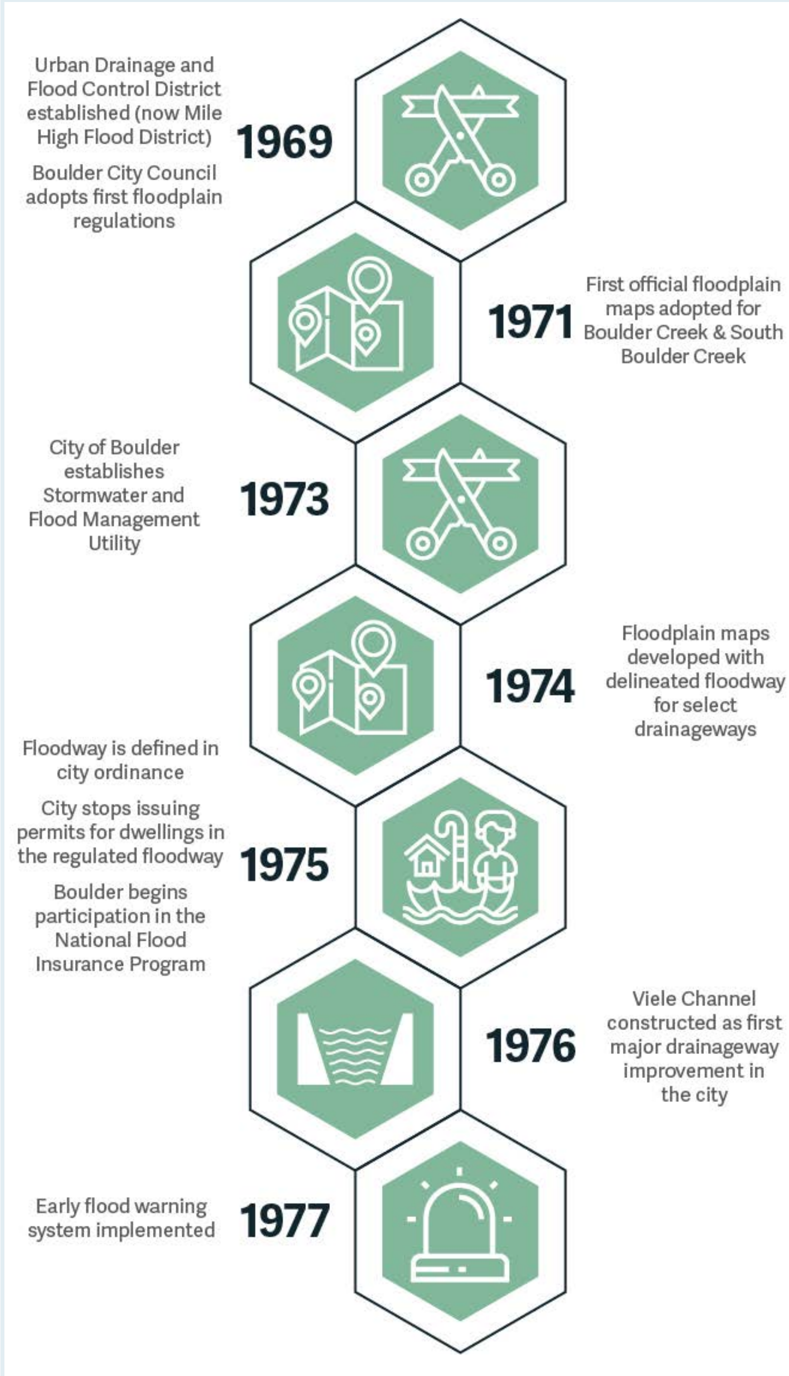
A set of techniques that modify the natural channel and/or associated riparian (overbank) area to reduce flooding extents and allow adequate room for the passage of floodwaters for the purposes of protecting people and property. Examples include:

- Channel and overbank modifications: widening, deepening, or straightening
- Dams
- Floodwalls
- Levees
- Concrete lined channels

Boulder's History of Floodplain Management

The City of Boulder has a history of destructive flooding, and Boulder Creek is considered to have the highest flood risk in the State of Colorado based on population and property values (Pettem 2016, Truby and Boulas 1983). Throughout this history, the city has been both praised for a progressive and proactive stance on flood management and criticized for not doing more to heed early recommendations and warnings to limit development in the floodplains. During the first three quarters of the 20th century, more than twenty flood studies were conducted in which recommendations to either cease all building in the floodplains or to construct structural modifications to the creeks themselves were made to prevent future losses (Pettem 2016). However, without floodplain regulations in place, development in the floodplains continued. Following a series of floods in 1965 and 1969, many communities along the Front Range, including the City of Boulder, began to shift their approach to floodplain management (see timeline). The establishment of a Flood and Stormwater Utility and the development of floodplain regulations enhanced protections for people and Boulder's valuable environmental resources while still meeting the needs of a growing population. The Utility continues to strive for balance when planning for flood mitigation while recognizing that achieving all values may not be possible under any particular circumstance. Therefore, careful consideration of tradeoffs is necessary.

Boulder Floodplain Management: 1969-1977



Many of the early flood mitigation plans proposed in Boulder included structural measures such as channel straightening and widening, concrete floodwalls, and levees. These plans were rejected due to a lack of local support for structural modifications to Boulder Creek (U.S. Army Corps of Engineers 1977). As a response, the city adopted several policies to recommend nonstructural mitigation strategies that would preserve the existing character of creeks and associated flooding patterns.

Property Acquisition

The removal or relocation of structures from the floodplain is an example of a nonstructural measure implemented by the Utility. The Utility's property acquisition program has been successful in acquiring multiple high-risk properties comprising over 200 dwelling units. However, as property values continue to increase within the city, the effectiveness of this program will decrease without significant increases in funding sources. At most, current funding allocation under this program only allows the pursuit of potentially one or two opportunities per year. This limited funding does not provide the latitude to pursue multiple property acquisition opportunities when opportunities arise, and opportunities are assessed only after targeted properties come on the market for sale. With the availability of additional funding, the program could expand significantly and allow a shift to a more proactive approach by actively engaging target property owners ahead of time for more large-scale or impactful acquisitions. One way to do this would be to leverage the Utility's available funding for this program by continuing to evaluate whether grants such as FEMA's suite of Hazard Mitigation Assistance grant programs, or the United States Department of Housing and Urban Development's Community Development Block Grant Disaster Recovery (CDBG-DR) and Mitigation (CGBG-MIT) programs could be used to significantly increase the overall funding for the program.

An example of a city that has shown great success with this approach is Portland, Oregon. In 1997, the city's department of Environmental Services developed the Johnson Creek Willing Seller Program to help move people and property out of areas that frequently flood. Restoration projects on land acquired through the program are used to increase flood storage, improve fish and wildlife habitat, restore wetlands, and create passive recreational activities for city residents. Portland staff contacts targeted property owners and offers willing sellers fair market value for their property. Owners are under no obligation to sell to the city. Following property purchases, the city uses deed restrictions to designate properties as open space in perpetuity, ensuring no future expenditure of federal disaster assistance funds in those locations. The Johnson Creek Willing Seller Land Acquisition Program is an implementation strategy for the 2001 Johnson Creek Restoration Plan, which addresses nuisance flooding, water quality problems, and fish and wildlife declines as related issues. The plan identifies common solutions to restore natural floodplain functions. Environmental Services land-banks acquired properties while designing floodplain management projects and securing funding. Through the Johnson Creek willing seller program, Portland has acquired over 100 acres of land at a cost of $8.48 million since 1997 by leveraging local, state, and federal funding.

Nonstructural and Non-Containment Policies

1977: Resolution No 141 Nonstructural Flood Control Policies for Boulder Creek

City Council adopts a policy that recommends guidelines for preservation and restoration over structural changes to Boulder Creek's channel or floodplain. Includes flood proofing, early warning systems, flood insurance, land use management, and floodplain filling restrictions.

1978: Boulder Valley Comprehensive Plan

City Council adopts "non-containment" policy for Boulder Creek to restrict development within the floodplain of Boulder Creek and its tributaries.

Flood Mitigation

Due to development patterns that started prior to the enactment of floodplain regulations and continued within the confines of existing regulations, flood mitigation solutions must now balance a wide range of community interests with public safety needs. To allow adequate room for the passage of floodwaters to protect people and property, natural channels are enlarged to reduce flooding extents. By reducing flooding extents, the floodplains are then reduced in size. Flood mitigation alternatives that preserve existing floodplains without altering the shape of the creek channel often require extensive removal of existing structures to increase the space needed for floods to spread out as they naturally do within the city. Existing structures that remain within the floodplain can be floodproofed to a certain degree, but this approach frequently does not address protection of the public infrastructure required to serve these areas during and after flood events.

Therefore, flood mitigation plans are completed for the major drainageways to analyze existing drainage conditions within the floodplain, develop mitigation alternatives, and select preferred conceptual designs that oftentimes include structural improvements. Structural flood mitigation includes measures like concrete lined channels, dams, levees, and floodwalls. Additionally, methods that refine the shape of the channel or adjacent riparian areas to convey floodwaters more efficiently within the confines of the open space that is available are also considered structural measures. Many organizations including the International Union for Conservation of Nature (IUNC) and FEMA have adopted what are called nature-based solutions for the mitigation and management of floods (FEMA 2021, Miles, et al. 2021). Nature-based solutions incorporate engineering practices to design modified channels and associated floodplains that protect people and property while also restoring or creating adaptive ecosystems. MHFD has similarly adopted high-functioning and low maintenance stream design to mimic natural processes through the design of engineered channels and floodplains. These approaches generally align with Boulder's community values, as space is limited, and ecological improvements can be incorporated into the new channel and riparian design. In the future, a realistic and practical option may be to continue to incorporate nonstructural approaches and emphasize nature-based solutions that change the channel and floodplain but continue to mimic natural processes and incorporate natural systems. This has the added benefit of supporting the city's climate goals.

Conceptual Rendering of Future South Boulder Creek Flood Mitigation Project

Regardless of the specific mitigation alternative, the city would benefit from establishing a more standardized approach to flood mitigation planning to support easy comparison of proposed flood mitigation projects citywide. The 16 major drainageways that run through the city can have significant variations in their physical, hydraulic, and hydrologic characteristics, as well as physical constraints like proximity of structures or important site features to the stream channel. These characteristic differences have led to differences in flood mitigation analysis approaches. Additionally, urban service criteria and standards within the Boulder Valley Comprehensive Plan state that the major drainageway system should be designed to transport the 100-year flood event *unless a modified standard is approved* (City of Boulder and Boulder County 2015). Given the physical and design constraints that are often present in many of the major drainageways, transporting the 100-year event is not always feasible. Therefore, the Utility works with community members to develop mitigation alternatives that best represent channel and floodplain characteristics, as well as community desires. Prioritizing the conceptual designs generated by these basin-specific mitigation plans can be challenging. Therefore, the Utility needs a consistent approach to support uniform evaluation of projects for prioritization that can also accommodate changes in process and methodology as data and technology improve. Chapter 10 provides a set of criteria to be used for city-wide project prioritization that should be incorporated into the mitigation planning process as metrics to provide a consistent basis for comparison. This type of standardization will better allow the Utility to compare future projects and evaluate the functionality of projects once they are constructed.

Climate Change and Infrastructure Resilience

While major flood mitigation projects are typically designed to reduce risks associated with the 100-year flood event, it is also understood that larger events can happen. Boulder should anticipate and proactively address uncertainty due to climate change in engineering design methodology based on the best available scientific data and industry accepted practices. The Utility also recognizes that impacts of extreme weather events attributable to climate change can occur before changing conditions are observed in the data. To address this, infrastructure resilience should become an integral part of the flood mitigation planning process.

Preferred flood mitigation design alternatives should achieve the highest level of protection feasible and be evaluated over a wider range of events to model performance. This should include performance of the system in a 100-year flood event and a 500-year flood event, regardless of design level of service. Whenever possible, exceedance flows should be intentionally routed in areas that are least harmful to people and property. Incorporating a risk management approach that considers the design life of infrastructure and the use or occupancy of buildings and structures served by major flood mitigation projects is also recommended. This approach places increased analysis and informed decision making in areas where the consequences of flooding are high and are commonly associated with critical infrastructure. The intent of a risk management approach is to consider the consequence of exceedance and adjust the design accordingly based on risk.

Maintenance of Major Drainageways

> **Flood Maintenance**
>
> Routine maintenance is necessary to ensure unobstructed flow of water. Such maintenance may include brush and tree removal, dredging, and other cleanup activities.
>
> Major maintenance work may occur once every one or two decades and may include the removal of large trees and more extensive dredging and sediment removal.

Routine maintenance is necessary to preserve the function and conveyance capacity of the major drainageways. The community consistently voiced a desire to increase and enhance flood and storm maintenance activities throughout the public engagement process associated with this Master Plan. City staff also recognize the need for increased maintenance and have been actively investigating ways to more proactively address and resource maintenance of the major drainageways, irrigation ditches[13] and the stormwater collection and conveyance system. In 2021, the Utilities Maintenance work group continued to make changes to increase maintenance efficiency and frequency by splitting into two separate groups, one of which is solely responsible for maintenance of open drainageways, greenways, and irrigation ditch obligations citywide. Shortly thereafter, City Council approved the addition of three new staff positions that allowed for the dedication of five total staff to this area to support enhanced maintenance. Although this staffing level supports the beginnings of more routine open channel maintenance, it is insufficient to perform a complete maintenance cycle of the approximate 37 miles of floodway, 451 acres of greenways, and additional miles of irrigation ditches with contractual obligations on a recurring basis with any regularity. Currently, maintenance is limited to irrigation ditch obligations and known open channel hot spot areas that may or may not be coincident with storm-driven events. While not specifically governed by policies within the Utility, support for the resources required to perform these maintenance functions is essential to achieving maintenance goals. It is recommended that data collected by this newly formed maintenance group be used to track maintenance activities and evaluate further resourcing needs going forward.

The Mile High Flood District (MHFD) contributes to drainageway maintenance throughout Boulder County both through direct maintenance efforts such as mowing, dredging, and vegetation removal, but also through monetary contributions to maintenance efforts. The contributions are in the range of approximately 8-10 % of the city's maintenance workload. The city should continue to look for opportunities to enhance this relationship and leverage MHFD's support wherever possible.

At times, flood and storm maintenance impacts conflict with community expectations. For example, maintenance can include tree, vegetation, and sediment removal. Such activities can result in resident calls to stop or intervene in the maintenance, often requesting that trees remain. Engagement and outreach efforts should include information on what to expect during flood maintenance for both the community and decision makers to minimize conflict.

Of important note, the city does not have access easements to all reaches of Boulder's major drainageways. The city typically receives easements as part of annexations, development, redevelopment, or by voluntary participation by landowners, but easement acquisition is not possible in all cases. Maintenance crews may only access creeks with easements or with landowner permission, and lack of access can delay or prohibit maintenance activities. Additionally, to be effective, creek maintenance should occur in a continuous fashion,

[13] *City maintenance of private irrigation ditches occurs when there is a contractual obligation in place. Otherwise, the irrigation ditch maintenance obligation remains with the irrigation ditch company.*

versus sporadically along the length of a creek. Therefore, it is recommended that a plan and approach be developed for how to address obtaining outstanding easements along Boulder's 47 miles of stream so easements can be secured.

Watershed Management

Watershed management encompasses the functions of many programs within the Utility and does not fit neatly under any specific topic area. While discussed in this Chapter for its contribution to flooding reduction, many stormwater conveyance and stormwater quality benefits are also incorporated into watershed management and planning. Managing increases in stormwater volume and peak flow caused by urbanization is one of the biggest problems in floodplain management. To address future flood risk, flood management and mitigation needs to take a holistic approach to excess stormwater runoff generated by the entire watershed. Floodplain management is typically understood as the programs and activities that address riverine flooding which happens when streamflow overtops adjacent banks. However, excess stormwater runoff that originates in urban areas floods stormwater management infrastructure, which ultimately increases the extent and duration of flooding associated with the city's major drainageways. For this reason, the National Flood Insurance Program's Community Rating System (CRS) includes a Class 4 prerequisite of a watershed master plan that accounts for the management of increased runoff from a developing watershed. Essentially, it is the management of all flooding sources within a major drainageway's contributing watershed, regardless of where they originate.

The CRS Program encourages watershed management planning and provides guidance on best practices for watershed-based master planning. The objective is to provide guidance on how to reduce increased flooding from future conditions, including new development, redevelopment, and the impact of climate change throughout a watershed or community. Best management practices include:

- Evaluation of future conditions and long-duration storms
- Evaluation of the impact of climate change
- Identification of wetlands and natural areas
- Protection of natural channels
- Provision of a dedicated funding source for implementing the plan

The CRS Program requires that a watershed master plan, at a minimum, address future development and redevelopment within the watershed and the impact of these activities on flows during a 100-year event. These plans go a step beyond stormwater regulations in locating and addressing existing problems and identifying potential future problems. Associated modeling may show that different standards are needed for different watersheds, or for different parts of the watershed. Communities may also discover that existing stormwater management regulations are adequate or need to be more stringent to prevent development from increasing the frequency and severity of existing and future problems.

For the purposes of the CRS Program, stating that both the Comprehensive Flood and Stormwater Master Plan and the Stormwater Master Plan are linked as pieces of an inclusive watershed management plan is recommended for future CRS technical review and scoring under the Watershed Master Plan element. Pierce County, Washington, also has a similar basin planning approach that it has implemented for over 15 years. This program has many similarities with the City of Boulder's basin-wide flood mitigation planning and has received credit for the Watershed Master Plan prerequisite with CRS.

Recommendations

Many of the components necessary for a well-rounded flood mitigation, property acquisition, and watershed management program are already in place within the Utility. Ensuring that these components are well-integrated, standardized, and consistently proactive will strengthen the work that is already being done. The following policies and supporting actions are recommended:

Flood Mitigation

- Identify flood mitigation measures using standardized methodology and a robust public engagement process in a way that incorporates best practices identified by MHFD and the CRS.
  - Standardize inputs, methods, and outputs from mitigation studies to reflect current available data and industry accepted standards. Provide requirements that allow for comparison of alternatives between drainage basins. Examples of standardized outputs include floodplain models, GIS files for selected design concepts, and metrics for city-wide prioritization.
  - Incorporate future conditions into hydraulic and hydrologic models, including recommendations related to climate change based on scientific evidence and relevant climate science data.
  - As part of flood mitigation planning, assess flood mitigation resilience measures in extreme flood events. Evaluate impacts of selected alternatives, regardless of design level of service, over a range of flood events up to and including the 500-year flood event.
- Emphasize the use of nature-based solutions for flood mitigation to protect people and property in a way that preserves or restores the ecological functions of creek and riparian corridors while offsetting the city's carbon footprint.
- To address uncertainty related to climate change, preferred flood mitigation design alternatives should achieve the highest level of protection feasible.
- It is the policy of the Boulder Valley Comprehensive Plan that the major drainageway system will be designed to transport the 100-year flood event or a modified standard in an approved plan. All mitigation plans are required to model and evaluate the 100-year flood event. However, physical characteristics vary greatly by major drainageway such that 100-year flood protection may not be feasible. In these situations, proposed mitigation alternatives shall strive to mitigate to the highest degree feasible based on drainageway characteristics and community preference.

Property Acquisition

- Promote open space uses of floodplains by removing existing structures through pre-flood and post-flood property acquisition. Purchases should be prioritized in locations that threaten the health, safety, and welfare of the community.
  - Identify, target, and seek funding from outside sources (i.e., state or federal grant funding such as FEMA's suite of Hazard Mitigation Assistance grant programs) to leverage existing funding for larger scale property acquisition.

- Create a prioritized list of structures to make the best use of existing funds and resources. Prioritization criteria should include consideration for racial and economic equity as well as risk to life safety.
- Develop and deploy an outreach program to targeted properties that promotes "willing sellers". Maintain a list of properties willing to participate should funding become available.
- Include the identification of properties that would be useful for flood mitigation as part of mitigation planning efforts. Maintain an updated list of properties targeted for acquisition to include value of property and how much the city would be willing to pay for this property. Proactively track real estate market to identify when these properties will be available before they come on the market.

Watershed Management

- Flooding occurs when the volume and rate of stormwater runoff exceeds the capacity of the infrastructure intended to convey runoff. The Utility is committed to a comprehensive and interconnected approach to watershed management in all 16 of its major drainage basins that identifies and mitigates both sources of excess runoff and damaging effects of flooding, regardless of where they occur.
  - Continue to advance basin-wide flood mitigation studies. Include an intentional integration of the stormwater collection and conveyance system and natural drainageways in flood mitigation planning.
  - Evaluate the impact of future conditions on watersheds and the receiving major drainageways for multiple storm events, including the 100-year storm.
  - Establish an evaluation protocol every 5 years to evaluate whether the data used for watershed master planning are still appropriate and whether the plan effectively manages stormwater runoff.
- Remain aware of major changes that occur in watersheds, such as droughts, invasive species, and fires. Coordinate with stakeholder agencies within the watersheds to proactively address these conditions.

References

City of Boulder and Boulder County. 2015. "Boulder Valley Comprehensive Plan. 2015 Major Update. Adopted 2017."

City of Boulder. 2020. "City of Boulder Flood Management Program."

Committee on Adaption to a Changing Climate. 2018. *Climate-Resilient Infrastructure: Adaptive Design and Risk Management.* Reston, VA: American Society of Civil Engineers.

Environmental Services, City of Portland, OR. 2022. *The Johnson Creek Restoration Plan In Action: Willing Seller Program.* Accessed January 27, 2022. https://www.portlandoregon.gov/bes/article/106234.

FEMA. 2021. "Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities." Federal Emergency Management Agency.

FEMA. 2017. *National Flood Insurance Program Community Rating System Coordinator's Manual.* Federal Emergency Management Agency.

MHFD. 2021. *Urban Storm Drainage Criteria Manual, Volumes 1, 2, & 3.* Mile High Flood District.

Miles, L., R. Agra, S. Sengupta, A. Vidal, and B. Dickson. 2021. *Nature-Based Solutions for Climate Change Mitigation.* United Nations Environment Programme and International Union for Conservation of Nature.

Pettem, Silvia. 2016. *Boulder's Floods and Flood Management: Past & Present.* Boulder, CO: City of Boulder.

Pierce County, WA. 2022. *Pierce County Document Center.* Accessed January 27, 2022. https://www.piercecountywa.gov/DocumentCenter/Index/4522.

Truby, J., and L. Boulas. 1983. *Colorado's Vulnerability to Very High Risk Natural Hazards, Revised.* Division of Disaster Emergency Services.

U.S. Army Corps of Engineers. 1977. "Boulder's Flood Protection Decision: A choice to live with." Omaha, NE.

URS. 2004. *Comprehensive Flood and Stormwater Utility Master Plan.* City of Boulder.


DEERE

9 Flood Preparedness, Warning, Response, and Recovery

The City of Boulder is one of the highest flash flood risk communities in Colorado (Pettem 2016, Truby and Boulas 1983). Floods can happen at any time with little or no warning. City floodplains and stormwater infrastructure are designed to convey water during storm events in a way that reduces flood risk to the community. Infrastructure alone cannot eliminate all dangerous flooding conditions, however, and it is important for the city and community members to prepare in advance and be able to respond when conditions warrant. This Chapter summarizes roles, responsibilities, and community resources available for the various phases of a flood, including:

- The city's flood education and outreach efforts
- Flood insurance
- Emergency warning and alert resources
- Emergency operations and associated organizational structure
- Recommendations

Roles, Responsibilities and Resources

Many structures within the City of Boulder were constructed prior to the mapping of Boulder's floodplains, the enactment of floodplain regulations, and the development of a Stormwater and Flood Management Utility. Because the city is prone to flash flooding along with various other hazards, flood preparedness, flood warning, and emergency response are all critical for life safety and property protection. National and regional agencies generally identify four levels of flooding as defined below, and the city and community members both have a role to play in each phase.

1. **Normal Operations** || *Be aware and prepare*
2. **Heightened Readiness or Low Impact Flooding** || *Be aware and prepare – flooding is possible and/or low impact flooding is imminent or occurring*
3. **Flash Flood Watch** || *Life-threatening flash flood may occur*
4. **Flash Flood Warning** || *Life-threatening flash flood is imminent or occurring*

Under **Normal Operating Conditions**, city staff review emergency response plans and functions, and participate in emergency preparedness exercises.

Community members should consider buying flood insurance, develop and discuss personal emergency response plans and evacuation routes, sign up for emergency alerts and ensure contact information is up to date, and take floodproofing precautions such as those described by the National Weather Service (NWS) in this resource.

When a potential flood scenario is developing, the Office of Disaster Management for City of Boulder & Boulder County (ODM) coordinates with Mile High Flood District (MHFD), Skyview Weather, the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS), and others on weather forecasting, patterns, predictions, and probability of impact information. Primary data sources used by these agencies include radar, lightning detection software, gauge-adjusted radar rainfall software, rain gauges, streamflow gauges, and topography, including drainage boundaries. Key severe storm characteristics of concern include slow moving storms, the presence of lightning indicating convection-based thunderstorms, rain intensity of two inches or more per hour, and storm events that cause ground saturation. Additionally, MHFD has developed a Flash Flood Prediction Program (F2P2) which runs April through September in the Denver/Boulder metropolitan area. This program uses information from MHFD's partnership with NWS and local governments to provide notifications of heavy rain and flood threats.

These agencies may issue a Flood Advisory indicating a **Heightened Readiness** stage, which typically indicates nuisance flooding conditions. Both City of Boulder and ODM staff monitor conditions and NWS and MHFD activity during this stage. Additionally, city staff respond to nuisance flooding and other issues as they arise and begin flood response preparations. Preparations include referring to flood action plans, ensuring resources and materials are readily available, and identifying critical system components that may be impacted and/or may need to be operated.

> Community members should stay aware, review preparedness plans, and sign up for emergency notifications.

In a **Flood Watch**, where weather conditions are favorable for flooding and life-threatening flash flooding may occur, city preparation activities increase. City staff continue to respond to nuisance flooding and additionally prepare to shut valves and headgates, set up barricades, and identify critical system components that may be impacted and/or may need to operate. These activities are largely performed by Utilities Maintenance staff, with support from technical experts as needed.

> Community Members should continue to monitor weather, prepare household members (including pets) for possible evacuation or moving to higher ground, and charge electronic devices to stay connected to alerts and other notifications. Community members should also identify potential evacuation routes and be prepared to re-route if flood waters are encountered.

Under a **Flood Warning** where life-threatening flash flood is imminent or occurring, a more comprehensive response and event management structure is needed. In this situation, ODM activates the Emergency Operations Center (EOC) to coordinate flood response efforts with the support of Emergency Support Functions (ESF) described below. During such an event, city public works personnel staff the *ESF 3 – Public Works* position in the EOC. Utilities staff responsibilities and involvement are largely situationally dependent, as no two events are the same. As a guide, Utilities has established high-level actions and duties for various departmental workgroups including the Engineering / Flood and Stormwater team for different flood threat levels. This guide and set of actions are summarized under the Emergency Operations Plan and the Public Works' operational response plans, as defined by the city in conjunction with ODM. Specific actions and tasks in the response plan should be annually reviewed and updated as needed to stay current and practiced. The internal emergency operational plans utilize an All-Hazard Alert (AHA) framework to assist with defining roles and responsibilities and providing clarity for the four levels/phases of flooding.

When either **Flood Watch** or **Flood Warning** conditions are issued by the weather agencies, or demonstrated conditions warrant, the City of Boulder Police and Fire Communication Center (BPFC) will send a message to the Boulder Fire Department and Boulder Police to indicate flood status. The BPFC issues emergency notifications to the public and activates the public warning sirens as directed by incident command. ODM will activate the Emergency Operations Center if a flash flood warning is imminent or issued and provide coordination and manage capabilities that are needed to support response and the community. Depending on the scale of flooding, alerts may be issued city-wide or to a specific area. BPFC has pre-planned polygon maps in Everbridge associated with flooding in areas. Additionally, Wireless Emergency Alerts (WEA) may also be broadcast to anyone with a WEA capable cell phone within a geographic radius of a specific area. The alerting systems described in **Table 9-1** below can be tied to polygons if alerts are issued to a particular area and wireless emergency alerts will bleed over beyond the intended polygons at least 1/10 of a mile- and as far as citywide, depending on individuals' cellular handset technology.

As noted above, one important distinction once active flooding is occurring, is that the response management structure varies depending on the magnitude of the storm. City staff take the lead in small to medium-scale flood events involving low impact, localized flooding. For such events, Boulder's Utilities staff response includes providing engineering expertise, construction management, technical support, and maintenance services to alleviate the impacts of flooding.

Utilities also has a key supporting role in larger flood emergencies. In such events, ODM leads disaster response and recovery efforts in coordination with the State Emergency Management Agency. During a large-scale event, ODM activates the EOC with support from various ESFs. City of Boulder Utilities staff support *Emergency Response Function 3: Public Works and Engineering Annex* during EOC activation, including providing flood modeling information upon request during an emergency. The other roles described for a small to medium event are also provided. **Table 9-1** below summarizes the various roles and responsibilities described in this section.

Table 9-1 – Flood Preparation and Response Roles and Responsibilities

Flooding Phase	City Utilities Staff Responsibilities*	Community Member Responsibilities	Other Key Agency Contributions	Available Community Resources
Normal Operations *Be aware and prepare*	1. Update and maintain Emergency Response Plans, including updating contact lists and confirming /clarifying roles 2. Perform Emergency Response Exercises 3. Update and maintain public education and outreach materials 4. Maintain equipment and supplies needed for emergency response 5. Perform routine maintenance on flood and storm infrastructure and systems	1. Prepare and know your risk 2. Obtain flood insurance 3. Sign up for alerts 4. Have an emergency preparedness kit ready 5. Ensure your sump pump is functioning properly	1. ODM supports emergency response training and planning. Monitors for developing situations. 2. MHFD manages stream gages and related data, provides flood preparedness and response materials, and coordinates with municipalities on flood maintenance projects. 3. NWS monitors weather and provides weather-related information, provides flood preparedness and response materials.	1. Boulderfloodinfo.net 2. Community Guide to Flood Safety 3. Flood Awareness Flash Drive (handed out at various city events) 4. City of Boulder and related flood preparedness information 5. NWS Before a flood actions

Flooding Phase	City Utilities Staff Responsibilities*	Community Member Responsibilities	Other Key Agency Contributions	Available Community Resources
Heightened Readiness or Low Impact Flooding *Be aware and prepare - flooding is possible and/or low impact flooding is imminent or occurring*	1. Respond to nuisance flooding and issues 2. Alert work groups of potential needs and EOC staffing assignments 3. Identify critical system components that may be impacted	1. Account for all members of your household (including pets) 2. Stay tuned to local weather networks 3. Be prepared to evacuate or seek higher ground	1. ODM, MHFD, and NWS monitor weather and provide weather-related alerts and notifications as situation warrants. 2. ODM staff monitor conditions and NWS and MHFD activity under these conditions.	1. Report non-emergency flooding on Inquire Boulder 2. NWS radio weather reports
Flash Flood Watch *Life-threatening flash flood may occur later in the day*	1. Oversee resource acquisition for Utilities Maintenance 2. Employ specific plan of action: i.e., bridges to monitor, water valves to shut down, evaluate conditions of water resources, monitor dam safety, and implement dam emergency action plans as needed. 3. Coordinate with ditch companies for head gate closures and/or emergency operations by ditch company personnel. 4. Monitor water quality and quantity issues. 5. Staff ESF3 if EOC is activated.	1. Account for all members of your household (including pets) 2. Stay tuned to local weather networks 3. Be prepared to evacuate or seek higher ground (there may be only moments to react)	1. ODM coordinates with Boulder Police and Fire to indicate flood status. Police and Fire determine the need for emergency notifications. 911 center issues the emergency notifications to the public and activate sirens as situation warrants. 2. ODM activates the EOC as needed to coordinate flood response and recovery activities, including coordination with local, State, and Federal agencies. 3. MHFD and NWS continue to monitor weather and provide weather-related alerts and notifications as situation warrants.	1. NWS radio weather reports 2. City communication networks, including social media accounts

Flooding Phase	City Utilities Staff Responsibilities*	Community Member Responsibilities	Other Key Agency Contributions	Available Community Resources
Flash Flood Warning *Life-threatening flash flood is imminent or occurring*	1. Oversee resource acquisition for Utilities Maintenance 2. Oversee damage/repairs to water distribution and wastewater collection systems. 3. Assess immediate and residual field damages; assists and prioritize crews as needed. 4. Employ specific plan of action: i.e., bridges to monitor, water valves to shut down, evaluate conditions of water resources, monitor dam safety and implement dam emergency action plans as needed. 5. Coordinate with ditch companies for head gate closures and/or emergency operations by ditch company personnel. 6. Monitor water quality and quantity issues. 7. Provide staffing and situational awareness for ESF3 at the EOC .	1. Stay tuned to local weather networks 2. Follow any evacuation orders 3. Seek higher ground (never walk or drive through floodwaters) 4. Practice electrical/gas safety, particularly at night. Have battery operated flashlights available as part of your preparedness kit.	1. Same as Flash Flood Watch	1. City communication networks, including social media accounts 2. Emergency services, such as ODM 3. NWS during a flood actions

** This table primarily focuses on City Utilities staff responsibilities. Numerous other city departments also have significant roles in natural disasters.*

Fire/Flood – One element of emergency response not covered in the above table relates to runoff and debris flow following a wildland fire. Post-fire drainage evaluation is necessary when a fire occurs in drainages in and surrounding Boulder. Fires of different magnitude involve different scales of incident management. Large fires will likely be managed by state or federal agencies, including resources to manage runoff and debris flow. For such significant events, city staff may play a minor supporting role in providing drainage information to the managing agencies. For events of smaller scale, city staff may play a more direct role in evaluating the situation and making and implementing recommended erosion control measures. Staff from Utilities Flood and Stormwater Engineering and/or Water Quality in cooperation with Open Space and Mountain Parks staff and ODM, among other departments will often need to coordinate on recommended erosion control measures.

Dam Safety - Boulder is situated downstream of water supply dams. Dam owners, including Boulder, coordinate with the State of Colorado and other regulatory agencies on dam safety, emergency preparedness exercises and other management activities. Dam safety is a component of infrastructure management and is outside the scope of this master plan. The responsibility for flood preparedness remains the same for dams and hydrologic flooding. Community members should refer to recommendations in this chapter.

Public Outreach and Education

In the preparedness phase of flooding, the Utility engages in extensive public outreach and education efforts to educate the community about flood risks. However, demographics change, and the need is ongoing, particularly considering the significant number of renters. The 'Be Heard Boulder' questionnaire launched at the beginning of the master plan update process identified the following community concerns and perceptions about flooding:

- Who is at risk?
- How big is the risk?
- Preparation is key
- Warn the community earlier

The CFS Community Working Group echoed these same themes by noting the importance of focusing on equity and in reaching traditionally hard to reach populations. To do this, the Utility should routinely use the city's new Racial Equity Instrument and continue to investigate effective and creative outreach strategies and develop a mechanism to understand the efficacy of outreach and education efforts being conducted.

1. The public outreach and education strategy should be updated to provide structure and process for aligning activities with the overall CFS Master Plan goals. The city's approach currently aligns with Community Rating System (CRS) Activity 330. The city should maintain this approach and continue to identify and evaluate additional applications that could result in broader public awareness and involvement.

As part of a public outreach and education strategy, the following actions should be considered for inclusion:

7) Identify goal and objective evaluation metrics, including outputs (i.e., administrative and programmatic activities) and anticipated outcomes (i.e., changes in awareness and behavior).
8) Conduct a target audience characterization to identify subgroups of the community that have shared characteristics and communication needs/preferences/capabilities. These audiences exist within different geographic areas of the community that require targeted messaging based on flood risk, vulnerability and neighborhood. The use of existing or new survey tools could be used to determine awareness and communication preferences.
9) Align with city's Racial Equity Plan and consider the following outreach strategies for Spanish-speaking residents[14]:

[14] *Recommendations developed by the CWG Community Connectors*

a) Maximize in-person outreach opportunities, including having a presence at community events, manufactured housing communities, and through partnerships, such as those with Boulder's Neighborhood Services team, Boulder Housing Partner, Intercambio de Communidades, El Centro AMISTAD, and schools
b) Offer opportunities and assistance for people to sign up for emergency alerts during community events/ informational sessions
c) Where possible, hold public meetings in Spanish, versus using Spanish language interpretation
d) When using interpretation services in a Community Working Group setting, have a dedicated interpreter for the duration of the outreach period, that is embedded in the team and learns the technical terms
e) Provide translated infographics, flyers, and pamphlets
f) Consider developing short, catchy informational videos and social media posts

10) Identify communication channels, stakeholders, and partners that can help tailor and disseminate messaging. Specifically, develop a concrete approach for how the city and response agencies will reach non-English speaking residents when ordering evacuations. Identify and disseminate resources for the Spanish-speaking and other non-English speaking communities to access in an emergency.
11) Develop key messaging which can be tailored by theme (i.e., preparedness, response, and recovery) and by key target and sub-target audiences. Identify messaging gaps. Specifically include information about how these efforts relate to personal safety, and how this subject is relevant to residents. For example, flood mitigation and preparation can save lives, and can keep access to places like schools and hospitals open.
12) Organize existing messaging by format and distribution channel (i.e., print, electronic, in-person events, virtual events, innovative formats) by phase and by sub-target audiences to identify messaging gaps or oversaturation. Schedule routine debriefs related to these efforts to establish continuous improvement.

Additionally, the city should update its annual flood communications plan and schedule to include lessons learned during the COVID-19 pandemic, including effective distribution methods, guidance and guidelines on hosting in-person or virtual events, evaluation methods, and associated costs.

Flood Insurance and the Community Rating System

Another preparedness activity involves flood insurance. The City of Boulder participates in the National Flood Insurance Program (NFIP) by adopting and enforcing floodplain management ordinances and providing public education to reduce future flood damage. In exchange, the NFIP makes federal government-backed flood insurance available to homeowners, renters[15], and business owners regardless of whether they are in the floodplain. The NFIP also has a voluntary incentive-based program called the Community Rating System (CRS), which ranks communities on a 1-10 scale (Class 1 being the 'best') and allows communities to obtain discounts on flood insurance premiums if community floodplain management activities exceed minimum NFIP standards. Participation in the CRS Program generally involves receiving points for performing flood management activities that reduce and avoid flood damage to insurable property and that foster comprehensive floodplain management in exchange for insurance discounts. Boulder first entered the CRS Program in 1992 as a Class 9 community, which provided a 5% discount on flood insurance premiums. Since then, the city has maintained an active floodplain

[15] Typically, renters or mobile home insurance policies do not cover flood damage, so community members should be aware of what coverage is provided under individual policies.

management program and now holds a CRS Class 5 rating, providing NFIP flood insurance policy holders with up to a 25% discount[16].

Ability to recover from flood damages can be a major consideration for residents who do not have access to Federal insurance programs, and/or who lose childcare, income, or struggle to pay for flood repairs on top of monthly bills. The city should use the Racial Equity instrument to evaluate how best to support residents who do not, or cannot, qualify for FEMA backed flood insurance after a flood.

In addition to providing communities with discounts on flood insurance rates, FEMA's CRS program is nationally recognized as being a comprehensive guide for best practices related to floodplain management, stormwater drainage, and stormwater quality. The city's commitment to implementing diverse and comprehensive programs in this arena is recognized through its current Class 5 rating under the CRS program. The Community Working Group has expressed a desire to maximize insurance benefits. One option would be to move to a Class 4, which would increase reductions by approximately 5% to a total of up to 30% on NFIP flood insurance premiums for community members. A significant hurdle for communities in achieving the Class 4 rating is the prerequisite requirement for Watershed Master Planning (WMP) under CRS Activity 450, which entails completing a unified plan that addresses both storm and flood management. Approval of the CFS Master Plan update would likely meet this "CRS Activity 450 WMP" criteria. However, additional prerequisites and 500 additional CRS points would be needed to achieve a Class 4 rating. Significant additional staff and financial resources would be needed to refine existing programs or implement new programs that would garner the necessary Class 4 credit points. Therefore, these improvements should be considered when implementing priority flood and storm projects and programs based on staff capacity and in comparison to community benefits associated with other work plan priorities.

Emergency Warning Dissemination

Early warning systems are a critical life-safety aspect of flood management, some of which require community member sign-up, which ideally would occur in the preparedness phase of a flood. Boulder Police and Fire use the Emergency Warning alerts summarized in **Table 9-2** below in coordination with ODM when forecasted or actual current conditions warrant. Evaluation of how to optimize emergency warning dissemination, including addressing language access issues, should continue to be considered and refined to ensure coverage in areas where most needed, particularly when considering socially vulnerable individuals who may be less likely to receive warning messages.

Table 9-2 – Emergency Alert Systems

Mechanism	Audience	Benefits	Drawbacks
Everbridge (Auto)	Landline phones	The communications centers/ dispatch centers receive quarterly updates on landlines from Century Link and Comcast to ensure landline numbers are current.	Few residents have landlines; if solicitor-block features are present, the emergency telephone notification will not go through to warn the resident.

[16] *The maximum discount for CRS applies to properties in the FEMA defined Special Flood Hazard Area, generally in the 100-year flood plain. Other properties receive a lower discount of 10%.*

Mechanism	Audience	Benefits	Drawbacks
Everbridge (Opt-In)	Residents and commuters	Notifications are received by cell, home, and work phones; text message; and email. Can sign up for multiple locations (i.e., work and home). Webpage for signup is available in multiple languages Allows for Spanish messaging	Requires action from the public to sign up online; those wary of providing personal information, may not be inclined to opt-in; if cell phone numbers or locations registered in the system change, then the residents may not get the notifications as expected. Spanish messaging may depend on cell carrier
Integrated Public Alert Warning System (IPAWS) / Wireless Emergency Alerts (Auto)	Anyone with a WEA capable cell phone, television, radio, or NOAA weather radio.	Wireless Emergency Alerts (WEA) Broadcasts messages to anyone located in the city or a specified polygon with a WEA capable cell phone. Allows for Spanish messaging Emergency Alert System (EAS) broadcasts notifications to television and radio stations. NOAA Weather Radio broadcasts to weather radios in the range of the radio system.	A cell phone tower must be within the polygon. Therefore, the locations of all cell phone towers should be linked into the Everbridge system. Spanish messaging may depend on cell carrier EAS only reaches viewers or listeners of TV and radio stations and is not required to be transmitted by the stations once received. NOAA Weather Radio will only be received by public who have a NOAA weather radio turned on. The system also can be used by proprietary platforms and apps causing changes to the notification content and warning areas.
Sirens (Auto)	People outdoors or in cars	Notifies people recreating in or near waterways and commuters	May not be heard indoors (particularly in apartment buildings); can be difficult to decipher audio message associated with the alert; depending on location relative to the siren, the sound may not be heard and/or the message can sound distorted

Mechanism	Audience	Benefits	Drawbacks
Door-to-Door Notifications (Auto)	Local residents	Experience demonstrates that during an emergency, residents may not get the warning even if all systems are used. First responders will need to deploy to the hazard area to set up roadblocks and go door to door, if possible, to warn and assist residents.	There will be areas inaccessible to first responders and door-to-door notifications will not be made. Spanish speaking residents may not understand English-only evacuation directions.
Note: (Auto) indicates no community member action is needed to receive an alert; (Opt-In) requires community member registration.			

Everbridge

Currently, the city has access to and uses the Everbridge platform, which is recognized as a top platform across the country. The redundancy and speed are currently unmatched by competitors, as the total number of activations "pushed out" by phone, email, text to the community far exceeds any other platform. Additionally, when an alert message is acknowledged by the intended recipient, the system does not continue to send same message. This keeps the system from duplicating unwanted messages to an inbox, phone or text. Although this system is currently the most successful at sending targeted alerts, the "opt-in" feature can be a challenge as it requires community member action to register. The city should keep apprised of technological improvements to all alert systems and consider upgrades as they become available.

Wireless Emergency Alerts (WEA)

In early 2022, Boulder gained new emergency alert capability that allows police and fire departments to send Integrated Public Alert Warnings (IPAWS), including Wireless Emergency Alerts (WEA), to the public. These messages activate all enabled cell phones in a specific geographic area with sounds and text, similar to Amber Alerts and National Weather Service emergency notices, without requiring users to opt-in or subscribe to the service in advance. When possible, these alerts include direction from emergency responders on what steps to take. While the city still strongly encourages individuals to register through Everbridge opt-in notifications for the most targeted emergency messaging, the use of WEA will allow officials to reach out-of-town visitors, unhoused individuals, and people outside of their opt-in addresses during a life-threatening emergency. ODM holds the administrative responsibility for the WEA service, which can be activated by individual jurisdictions that are part of sender groups. In Boulder, the sender group is led by the 911 Communications manager with input from Public Safety PIOs and other communications staff.

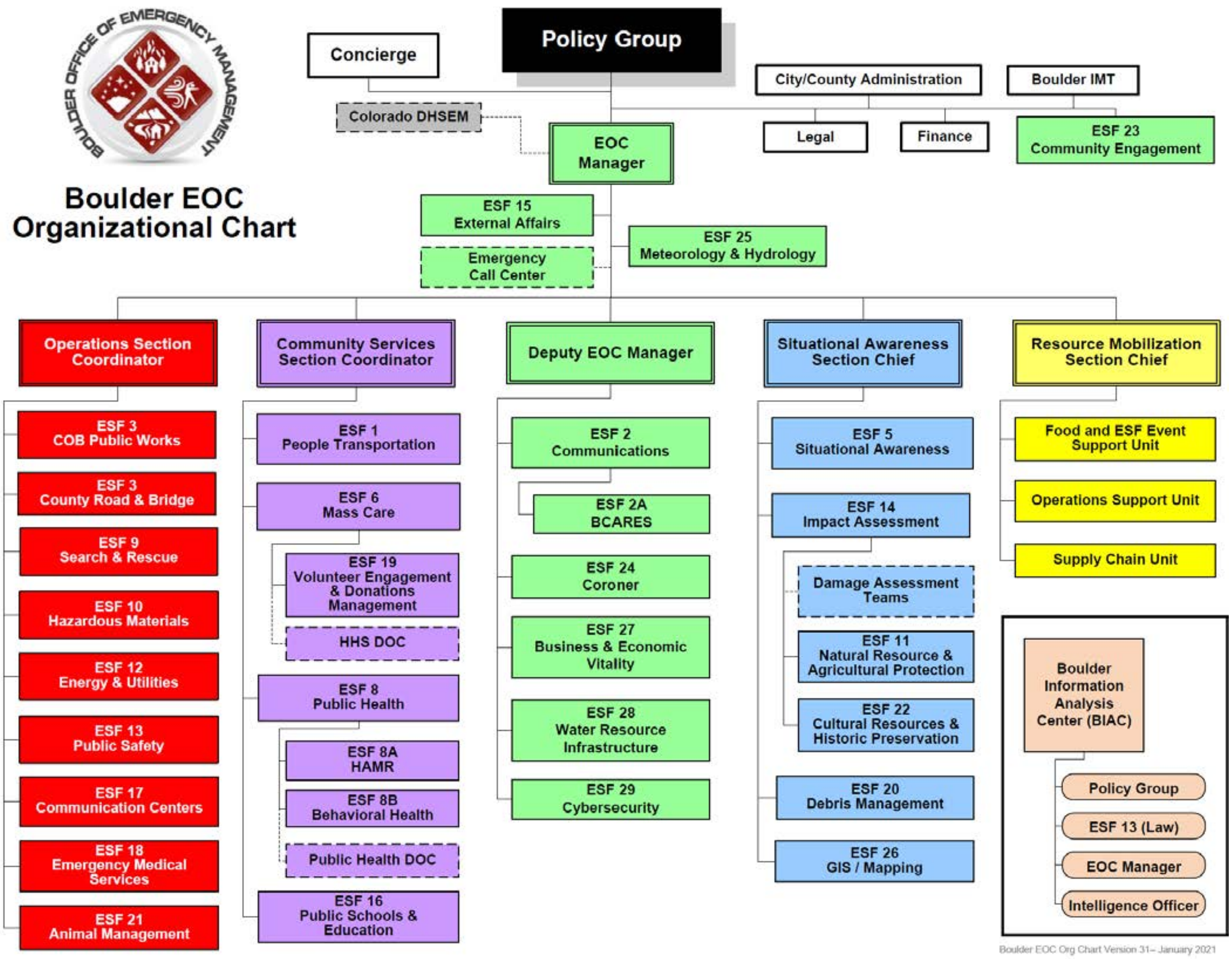
Outdoor Warning Sirens

The ODM coordinates with BPFC for activating the outdoor warning sirens in the event of an outdoor emergency. These sirens are owned and maintained by the City of Boulder. Boulder's current sirens are aging, and some are approaching the end of their useful life. The city should investigate potential upgrades to newer outdoor warning systems, as well as available federal funding sources, which can be used to help offset purchase costs if new sirens are warranted. Additionally, siren coverage is currently determined using a proximity function that sets a fixed distance surrounding each siren. Since these sirens are intended to warn people who are outdoors at the time of an emergency, variables such as weather conditions, prevailing wind directions, and building and terrain heights should all be incorporated into an updated coverage analysis.

Flood Response Operations

As noted previously, once an emergency event reaches a certain threshold, a more formal and comprehensive incident management structure is necessary and requires an activation of the EOC. The overarching EOC framework and comprehensive set of ESFs are shown in the figure below. For the Utilities Department, main duties and responsibilities fall under ESF 3 – Public Works. ESF 3 duties are described as:

> *ESF 3 is structured to provide public works / public utilities and road and bridge-related support for the changing requirements of incident management, to include preparedness, prevention, response, recovery and mitigation actions. Public utilities includes city-provided water, wastewater, and stormwater/flood systems and infrastructure. Activities within the scope of this function include conducting pre-and post-incident assessments of public works and infrastructure and reporting damage; executing emergency contract support for life-saving and life-sustaining services; providing technical assistance to include engineering expertise, construction management, contracting and real estate services; providing emergency repair of damaged infrastructure and critical facilities; recovery programs including coordinating the restoration and recovery of the transportation and public utility infrastructure; and coordinating and supporting prevention, preparedness and mitigation among transportation infrastructure stakeholders at the local and State levels.*


BOULDER OFFICE OF EMERGENCY MANAGEMENT
Boulder EOC Organizational Chart
Policy Group
Concierge
City/County Administration
Boulder IMT
Colorado DHSEM
EOC Manager
Legal
Finance
ESF 23 Community Engagement
ESF 15 External Affairs
Emergency Call Center
ESF 25 Meteorology & Hydrology
Operations Section Coordinator
Community Services Section Coordinator
Deputy EOC Manager
Situational Awareness Section Chief
Resource Mobilization Section Chief
ESF 3 COB Public Works
ESF 3 County Road & Bridge
ESF 9 Search & Rescue
ESF 10 Hazardous Materials
ESF 12 Energy & Utilities
ESF 13 Public Safety
ESF 17 Communication Centers
ESF 18 Emergency Medical Services
ESF 21 Animal Management
ESF 1 People Transportation
ESF 6 Mass Care
ESF 19 Volunteer Engagement & Donations Management
HHS DOC
ESF 8 Public Health
ESF 8A HAMR
ESF 8B Behavioral Health
Public Health DOC
ESF 16 Public Schools & Education
ESF 2 Communications
ESF 2A BCARES
ESF 24 Coroner
ESF 27 Business & Economic Vitality
ESF 28 Water Resource Infrastructure
ESF 29 Cybersecurity
ESF 5 Situational Awareness
ESF 14 Impact Assessment
Damage Assessment Teams
ESF 11 Natural Resource & Agricultural Protection
ESF 22 Cultural Resources & Historic Preservation
ESF 20 Debris Management
ESF 26 GIS / Mapping
Food and ESF Event Support Unit
Operations Support Unit
Supply Chain Unit
Boulder Information Analysis Center (BIAC)
Policy Group
ESF 13 (Law)
EOC Manager
Intelligence Officer
Boulder EOC Org Chart Version 31– January 2021

Recommendations

To proactively address Boulder's flood risk, the following recommendations for emergency preparedness and response activities should be considered:

- **Emergency Response and Roles** - Review and update existing city emergency response plans. Confirm and clarify city Utilities staff response roles internally and with partnering agencies for small to medium events (no EOC activation) and for large events (full EOC activation) and update accordingly in the Emergency Operations Plan and operational response plans.
- **Education and Outreach** – City staff should periodically review and update city resources available to the community. Consider education and outreach goals and objectives; target audiences (especially vulnerable and non-English speaking audiences); communication channels, stakeholders, and partners that can help tailor and disseminate messaging.
- **Emergency Alert Systems** – City staff should periodically review and update emergency alert systems and references available to the community and should investigate potential upgrades to newer outdoor warning systems.
- **Equity –** City staff should apply the city's Racial Equity Plan and Instrument to emergency preparedness and response plans and activities and consider whether identifying and evaluating outside resources, programs or partnerships could provide support to community members that don't qualify for FEMA programs because of lack of information, documentation, or immigration status.
- **Community Members** – Consider buying flood insurance, develop and discuss personal emergency response plans and evacuation routes, sign up for emergency alerts and ensure contact information is up to date, and take floodproofing precautions such as those described by the National Weather Service (NWS) in this resource.

Targeted Outreach

One of the most important aspects of the city's education and outreach program should be to connect with community members that will most likely require additional support before, during, and after a flood with equitable distribution of tools and resources for flood preparedness.

Traditional outreach strategies and media often overlook or miss such populations, and it is important for the city to develop and implement effective strategies such as in-person community meetings and include tools to remove language barriers, which is particularly important for the Spanish-speaking community.

References

Boulder County CO use of alert notification system. Emergency Mass Notification System - Boulder County

Federal Emergency Management Agency (FEMA), 2003. Homeland Security Presidential Directive-5, To enhance the ability of the United States to manage domestic incidents by establishing a single, comprehensive national incident management system.

FEMA's Community Rating System (CRS) 2017 Manual and 2021 Addendum. The CRS Coordinator's Manual - CRSresources

Pettem, Silvia. 2016. Boulder's Floods and Flood Management: Past & Present. Boulder, CO: City of Boulder.

Truby, J., and L. Boulas. 1983. Colorado's Vulnerability to Very High Risk Natural Hazards, Revised. Division of Disaster Emergency Services.

10 Project Prioritization Framework

The process to bring a major flood project from planning and design to approval can take over a decade, and numerous projects have had more than a 20-year span from concept to construction. While these processes afford ample time to engage stakeholders and consider various project aspects, they are a contributing factor to the extensive timeframes associated with implementation of capital projects that protect the public and prevent property damage. The question then arises of which projects to tackle first. This Master Plan seeks to establish a defensible Project Prioritization Framework that supports prioritization of projects in a way that fairly meets community needs.

Identified projects undergo extensive assessment and refinement to determine location, function, and design alternatives (reference **Figure 10.1** – "Major Flood Project Planning and Development"). Smaller, straightforward projects often go through the Project-Specific Community Process, which is a mechanism to construct the projects in a timely manner. Major flood project approval is more thorough due to the larger impact and costs. These projects benefit from a systematic approach to analyze the project portfolio against multiple criteria and prioritize projects in keeping with community values.

To guide project prioritization framework development, the project team distilled information collected from the policy review and issues identification work with the CWG into ***Stormwater and Flood Management Project Prioritization Goals***:

Stormwater and flood management projects should…
Protect people from harm, educate the community, reduce risks, and…
Preserve, protect, and restore the natural resources associated with creeks and wetlands for the multiple benefits they provide to support a resilient community
Provide resilient infrastructure that addresses uncertainty, including climate change considerations
Provide access for emergency response and recovery efforts
Minimize property damage
Provide efficient and cost-effective solutions
… in ways that are mindful and equitable to our entire community.

These Goals serve as guiding principles for the Project Prioritization Framework, and a multi-criteria decision analysis tool has been developed to aid in the prioritization decision making.

Figure 10.1 – Major Flood Project Planning and Development

The process for review and approval of individual projects is identified in the annual Capital Improvement Plan (CIP) and budget approval process. Currently, various processes may be required for a specific project. For example:

Concept Plan and Site Review: Concept Plans and Site Plans are reviewed by the interdepartmental staff Development Review Committee, departmental Advisory Boards, Planning Board, and City Council (call-up option).

Community and Environmental Assessment Process (CEAP): The CEAP provides a framework for balanced and thoughtful consideration of environmental and social issues in the preliminary planning and design of capital projects. It also provides a forum for public discussion of broad level project issues relative to master plans and overall community goals. It is a tool to aid in the development and refinement of project design and impact mitigation options.

Project-Specific Community Process and Design: Many projects are not required to go through concept and site review and would not benefit from a CEAP process. These typically have a project-specific design and public process to efficiently and appropriately identify community needs, concerns, and preferences. Many projects have been assessed through facility studies, area or facility planning processes, mitigation plans, or other studies. The processes are collaborative with multiple city and/or county departments.

Major Flood & Stormwater Projects — The CIP

The city has developed a capital improvement program (CIP) that includes 32 projects in the 16 major drainageways and incorporates local drainage and collector system improvements from the 2016 Stormwater Master Plan (**Table 10-1**). After final approval and adoption of the CFS Master Plan, staff will apply the Project Prioritization Framework to major flood projects as part of routine Utilities operations beginning with the 2024 CIP budget cycle. The Prioritization Framework will be applied to the projects included in **Table 10-1** below. As additional mitigation plans are completed and approved by City Council, the identified projects from approved mitigation plans will be added to the list of CIP projects, and the updated list of projects will be reprioritized. With a quick review of this list, it is easy to understand the value of employing a logical method to prioritize projects.

Table 10-1 – Boulder's Major Flood and Stormwater CIP to be Prioritized

Major Drainageway	Proposed Project	Flood Mitigation Plan
Bear Creek	Culvert Improvements	Bear Canyon Creek (2016)
	Channel Improvements	
Bluebell Canyon Creek	Bluebell-01	Skunk Creek, Bluebell Canyon Creek and King's Gulch Flood Mitigation Plan (DRAFT 2020)
	Bluebell-02	
Boulder Creek		*Mitigation Plan not Completed*
Boulder Slough		*Mitigation Plan not Completed*
Dry Creek		*Mitigation Plan not Completed*
Elmer's Two Mile Creek	*Completed*	*Completed*

Major Drainageway	Proposed Project	Flood Mitigation Plan
Fourmile Canyon Creek	Fourmile @ Broadway Fourmile @ 19th Street Safer Schools Access Fourmile Upstream of 26th Fourmile Broadway to 19th	Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning (2017)
Goose Creek	Goose-01 Goose-02 Goose-03 Goose-04 Goose-05 Goose-06	Upper Goose Creek and Twomile Canyon Creek (DRAFT 2020 – *subject to change/pending approval*)
Gregory Canyon Creek	*Arapahoe to Pennsylvania** Upstream of Pennsylvania	Gregory Canyon Creek Flood Mitigation Plan (2015)
King's Gulch	King's-03 King's-04	Skunk Creek, Bluebell Canyon Creek and King's Gulch Flood Mitigation Plan (DRAFT 2020 – *subject to change/ pending approval*)
Skunk Creek	Skunk-05 Skunk-06 Skunk-07 Skunk-08	Skunk Creek, Bluebell Canyon Creek and King's Gulch Flood Mitigation Plan (DRAFT 2020)
South Boulder Creek/Dry Creek Ditch No. 2/Viele Channel	*SBC Phase 1** SBC Phase 2 SBC Phase 3	South Boulder Creek Major Drainage Plan (2015)
Sunshine Canyon Creek		*Mitigation Plan not Completed*
Twomile Canyon Creek	Twomile-01 Twomile-02 Twomile-03 Twomile-04	Upper Goose Creek and Twomile Canyon Creek (DRAFT 2020)
Wonderland Creek	Foothills to Valmont 26th to 28th Street 19th Street	Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning (2017)
Stormwater Local Drainage Improvements	Tier I Local Drainage System CIP Projects	Stormwater Master Plan (2017)
Stormwater Collector System Improvements	Collector Storm Sewer System Tier 1 Hydraulic and Combined Hydraulic/Water Quality CIP Projects	Stormwater Master Plan (2017)

*Note: Projects currently in the design and construction phase of the project lifecycle will be shown in the context of the prioritization framework among all the other prioritized projects for transparency but will progress as currently planned without delay as they have been in progress for some time and are nearing the end of the project cycle.

Multi-Criteria Decision Analysis

Multi-criteria decision analysis (MCDA) is a general term to describe a set of methods used to support decision-making processes by considering multiple and often conflicting criteria through a structured framework. This framework can then be used for the prioritization of complex alternatives. The use of an MCDA tool for prioritization of the city's major flood capital projects provides numerous advantages, including:

- The ability to accommodate multiple stakeholders for enhanced public participation
- The ability to analyze multiple alternatives with complex benefits and attributes
- Allows for evaluation of the impact that criteria weighting have on outcomes and perform real-time sensitivity analyses
- Provides a robust, defensible tool that allows fair and equitable decision making

Project Prioritization Framework

The purpose of the Project Prioritization Framework is to aid in good decision making, build projects that align with community values, and meet the Utility's goals and objectives. Characteristics of an effective framework include:

- A clear and defensible framework
- Incorporation of community values identified through stakeholder engagement and constructive dialog
- Ability to rank major capital projects that have been developed from multiple studies, CEAP, and master plan outcomes

Public input was sought by inviting residents to participate through Be Heard Boulder, six basin-specific meetings, and several in-person meetings (e.g., National Night Out, Duck Race, Hometown Festival, Farmer's Market), as well as input from the Community Working Group and WRAB members, to confirm the criteria of greatest importance. In total, about 90 people participated in a ranking exercise to provide input on the criteria: this included 18 Spanish-speaking public; 55 English-speaking public, four WRAB members, and 12 CWG members.

Project prioritization criteria are shown in **Figure 10.2**. The addition of racial equity considerations, as described in Boulder's Racial Equity Plan, to project prioritization metrics is one of the primary objectives of this Master Plan update. The methodologies of the past used a "losses avoided" approach to calculate project benefits resulting in Benefit/Cost ratios that typically favor projects in areas with the highest property values as opposed to where the life safety risk and community needs are highest.

Figure 10.2 – Initial Project Prioritization Criteria

Criteria voting was done using a "dotstorming exercise" where community members were asked to rank project prioritization criteria with respect to their importance (reference **Figure 10.3**). The results of the Dotstorming exercise provided weighted values for each attribute are shown in **Figure 10.4**. To simplify the model outputs and to limit double counting of criteria, "protection of critical facilities" was tucked under the Life Safety category; "infrastructure resilience" and "protect property" were combined under an Effectiveness category; and "environmental" and "cultural" resources were combined into one category (with each being a sub category).

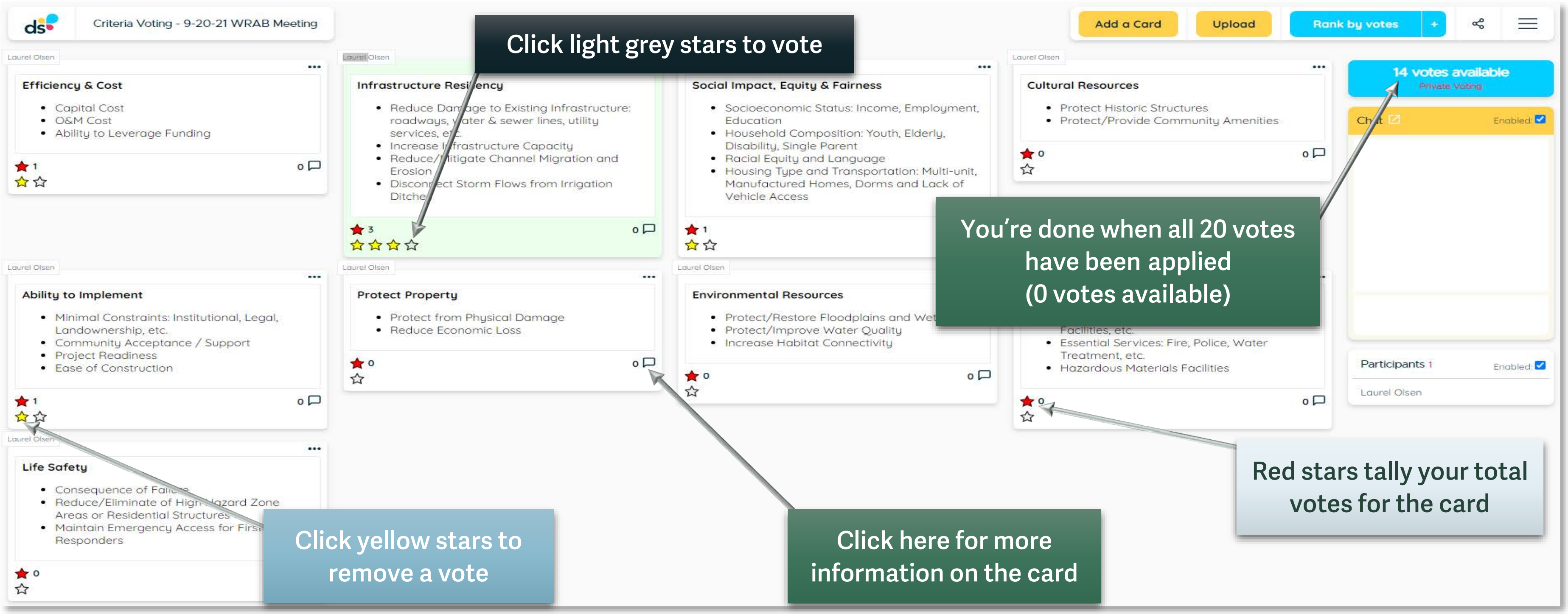


Figure 10.3 – Project Prioritization Criteria Voting using the Dotstorming Tool

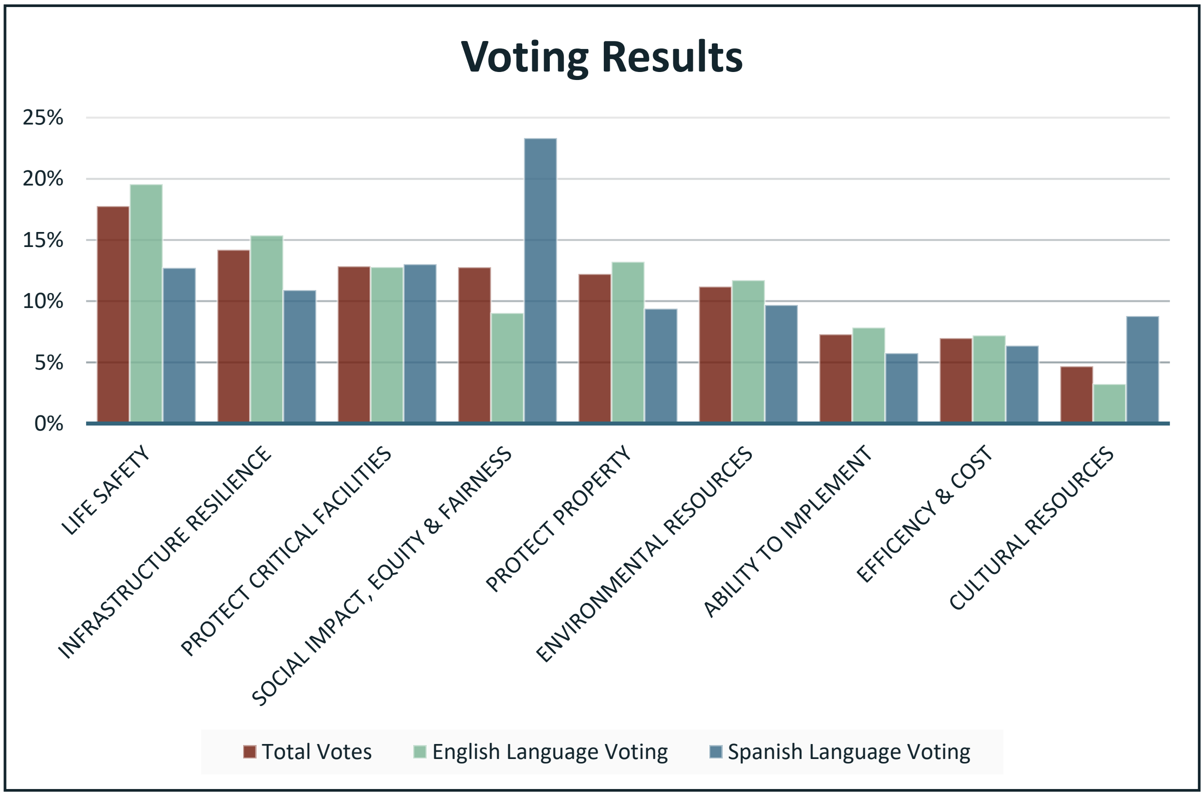


Figure 10.4 – Voting results from stakeholder engagement meetings (n = 89, total votes = 1240)

Criteria Selection and Weighting

The city reviewed the weighting criteria to ensure strategic alignment with the overall mission of the Utility. Acknowledging that public health, safety, and welfare are fundamental project goals, as well as the highest ranking attribute from the community, the city embarked on building the multi-criteria decision analysis (MCDA) tool to provide a Project Prioritization Framework. The framework will enable sound decision-making around the effectiveness and efficiency, equity, and environmental/cultural aspects of each project along with the ability to implement — attributes that are also critical to the success of the Utility and the community.

A basic MCDA tool was used to compare projects by taking the relative weight of multiple criteria (including quantitative, qualitative, and semi-quantitative information). The community scoring was used to assign the relative weight of each criterion in terms of importance to the community, and the overall "score" of a project is derived from totaling the weighted sums for all of the criteria. The ordering of a project's benefit is taken to be the project ranking by preference. The following sections further describe the criteria, the metrics used to compare each project, and the scoring framework. Criteria shown in the table are described in more detail below. **Table 10-2** outlines the units used in the MCDA model.

Table 10-2 – Ranking Criteria by Attribute and Input Metrics to Decision Model

Attributes Placed in Model for Assessment	Associated Units (Quantitative, Qualitative or Semi-Quantitative)
LIFE SAFETY	

Attributes Placed in Model for Assessment	Associated Units (Quantitative, Qualitative or Semi-Quantitative)
Protect Critical Facilities	
Critical Facilities removed from HHZ	# of Structures removed
Critical Facilities removed from 500-yr floodplain	# of Structures removed
Remove Residential Units from HHZ	# of Structures removed
Road Level of Service	Average Annual Daily Traffic (AADT)
COST	
Capital Costs	$
O&M Costs	$
EFFECTIVENESS	
Protect Property	
Reduction in Physical Damage Potential	# of Structures removed from 100-yr floodplain
Reduction in Damage to Structures (from Hazus[17])	$
Level of Service	% Increase
ENVIRONMENTAL/CULTURAL RESOURCES	
Protection/Restoration of Environmental Resources	
Protect Existing Natural Features & Habitat	Acres
Restore/Reclaim Natural Features	Acres
Protection of Cultural Resources	1 to 5 ranking (5 is important)
SOCIAL IMPACT, EQUITY AND FAIRNESS	
Social Vulnerability (from Social Vulnerability Index[18])	0 to 1 ranking (1 is vulnerable)
ABILITY TO IMPLEMENT	
Constraints	Easy / Neutral / Difficult
Community Acceptance & Support	1 to 5 ranking (5 is full support)
MULTIPLE BENEFITS	
Protect Critical Facilities	1 to 5 ranking (5 is important)

[17] *Hazus, a nationally standardized risk modeling methodology managed by FEMA's Natural Hazards Risk Assessment Program, is a GIS-based desktop software with a collection of inventory databases across the U.S. Hazus identifies areas with high risk for natural hazards and estimates physical, economic, and social impacts of floods. What is Hazus? | FEMA.gov*

[18] *The Social Vulnerability Index (SVI) uses 15 U.S. census variables to help local officials identify communities that may need support before, during, or after disasters. Social vulnerability refers to the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. CDC/ATSDR's Social Vulnerability Index (SVI)*

Cost

Evaluation of a project's cost includes all costs incurred by the Utility through the duration of the life of the project.

Capital Cost

Capital cost represents estimated cost of construction incurred by the Utility. To determine this, proposed cost, including contingency factors, of a project is obtained from the most recent planning or design document. Typically, this information will be found in the mitigation plan for the proposed alternative. Any anticipated or secured funding through grants, federal, regional, or city partners will be deducted from the proposed cost of construction.

Ranking Factor	Capital Cost ($)
Quantitative Metric	Capital cost to the Utility in present year dollars

Operations & Maintenance (O&M) Cost

Operations and maintenance costs represent a significant portion of the Utility's annual budget. The O&M costs for a project are estimated costs to occur annually, with the annual O&M cost calculated as 0.5% of the constructed cost. The present worth of a uniform recurring annual O&M cost is:

PW (Present Worth) = O&M cost x UPW (uniform present worth, conversion factor)

$$UPW = \frac{(1+r)^n - 1}{r * (1+r)^n}$$

Where: r = 2.7% discount rate (based on the annualized ENR Construction Cost Index from 2010 to 2020)

n= 50 years (average useful life of major flood projects)

Ranking Factor	Estimated Present Worth ($)
Semi-Quantitative Metric	Present worth of annualized O&M cost to the Utility

Effectiveness

Flood mitigation studies typically use a Benefit/Cost ratio to determine the effectiveness of a project. These 'benefits' are often calculated by determining the present-day dollar value of losses avoided. Therefore, flood mitigation projects constructed in areas with high property values score very well. Often, these are the same areas that possess the greatest means for recovery in the event of flood losses. To distribute this benefit more equitably, the value of losses mitigated was separated from the number of structures protected. Additionally, the city strives to provide conveyance of the 100-year flood event through each of the major drainageways. The Utility endeavors to make the greatest practicable progress toward this benchmark as is feasible for these projects.

Property Protection

Reduction of flood risk to property is one of the main drivers for the construction of flood mitigation projects. Between the years of 2010 and 2018, floods have caused approximately $17 billion dollars of damage annually in the United States (Duguid, 2021). Additionally, flooding disproportionately affects individuals with lower incomes and lower levels of economic security, as they possess less means to recover losses.

Physical Damage Reduction

Physical damage reduction is calculated based on the number of structures that a project removes from the 100-year floodplain. A combination of publicly available GIS data and proposed floodplain limits delineated as part of flood mitigation studies or design projects are used to calculate this value.

City of Boulder Datasets. The City of Boulder maintains a Building Footprints GIS dataset that is housed on the city's Open Data Hub. Information in this dataset includes building type, building height, building area, and a ground elevation value. This information is reduced to include only the structures located within the regulatory floodplains in question through the city's following datasets: Current High Hazard Zone, Current 100-Year Extent, and Current 500-Year Extent. This results in a number of structures identified for potential flooding impacts and damage/benefit calculations.

Ranking Factor Quantitative Metric	**Number of Structures Removed from 100-Year Floodplain**

Economic Loss Reduction

RECOMMENDED:

GIS-based flood modeling outputs are used to prepare HAZUS reports — a Federal Emergency Management Agency (FEMA) assessment tool that estimates losses associated with floods. HAZUS provides a quantification of the loss of essential structures as well as a total monetary loss due to structural damage and resulting effects on commerce for a given flood inundation area.

Ranking Factor Quantitative Metric	**Flood Damage Avoidance ($)**

A NOTE ABOUT FLOOD MITIGATION PLANS:

Mitigation Plans provide data for the alternatives of major flood improvements and their proposed impacts. Hydraulic floodplain models provide an estimate of existing flooding and "with project" proposed conditions that include flooding extents, inundation depths, and flooding impacts to properties and buildings. The information contained in the Mitigation Plans can be used for some of the project data as described below.

Damage Assessment Approach. Damage assessments are completed for existing and proposed conditions to determine the potential benefits of implementing a flood mitigation project. This analysis is limited to calculating damages related to buildings and content value. Additional damages such as displacement costs and loss of function impacts, and non-traditional damages (landscaping and agricultural equipment, outbuildings, vehicles, traffic function, and public safety or loss of life) are not included in the analysis. The approach to assessing damages typically follows FEMA Benefit-Cost-Analysis (BCA) guidance, with modifications to best consider the unique landscape within the watershed.

Annualized and Present Value Damages. Typically, the mitigation plans provide the total damage to each structure for the 10-, 50-, 100-, and 500-year events are annualized to estimate the expected damages per year. Expected annualized damages are used to estimate the total damages that would be expected over project lifetime. The present value (PV) of damages represents the total damage value over the life of the project in current day value. The standard FEMA discount rate of 7% and a useful life of a major drainage system of 50-years are used for these calculations.

Flood risk reduction benefits were calculated based on the number of structures as well as the value of structures. Benefit cost ratio metrics are provided in each mitigation plan, which equals the value of losses avoided divided by the mitigation costs. A ratio of less than 1 indicates a project with costs that exceed the benefits, while a ratio greater than 1 indicates a project with costs that are less than the benefits. However, for the Project Prioritization Framework it was determined that using the benefit cost ratio alone provides the greatest benefit for those who own/occupy the most expensive structures. These are also often the population who have the greatest means to recover. As a proxy to benefit cost, the Project Prioritization uses the number of structures removed and economic loss reduction metrics.

Level of Service

The level of service (LOS) standards discussed in the BVCP goals are for protection from a 100-year storm event. The calculation for the improvement in LOS is:

*[(Proposed LOS — Existing LOS) / Recommended LOS] * 100 = percent improvement in LOS*

This attribute is expressed as a percentage.

Ranking Factor	**Percent Increase (%)**
Quantitative Metric	From 0 to 100

Environmental & Cultural Resources

Criteria voting showed a high interest in projects that protect and restore wetland, floodplain, and riparian areas; protect and improve water quality; protect threatened and endangered (sensitive) species, and increase habitat connectivity. In addition, the community values protection of cultural resources including structures listed on the National Register (includes National Landmark and Listed Historic District); centennial farms, local landmarks, and other eligible sites as defined by the Colorado Office of Archaeology and Historic Preservation.

Environmental Resources

The Utility is committed to working with local and regional partners to protect and restore environmental resources within the city. In addition to recognizing the benefits of protecting riparian, floodplain, and wetland habitat, projects will also strive to protect threatened and endangered species habitat.

Protect Existing Natural Features

Areas considered as existing natural features include wetlands, floodplains, and riparian areas based on City of Boulder GIS data; and threatened and endangered species habitat based on Boulder County GIS data. If locations of natural features were surveyed for a project, the use of project-specific survey data is preferred. Area quantities reported for protection of existing natural features must be based on net protected values. The calculation for this value is as follows:

Acres Protected = Existing natural features protected (acres) – Existing natural features disturbed or lost (acres)

Ranking Factor Quantitative Metric	**Acres Protected** Net area of natural features protected in acres; value may be negative if net losses are incurred

Restoration or Reclamation of Natural Features

Areas considered restored or reclaimed include natural features that were disturbed and restored during construction, as well as any additional restoration or reclamation areas included as part of a project.

Ranking Factor Quantitative Metric	**Acres Restored or Reclaimed**

Cultural Resources

Inundation zone maps from the mitigation plan are submitted to Colorado Office of Archaeology and Historic Preservation (OAHP) for query of their GIS cultural data (previously recorded sites and conducted surveys within each inundation area). After the OAHP provides this data, each site and survey are queried in OAHP's COMPASS online database to obtain site forms and survey reports. From this, chronological information as well as the National Register for Historic Places status can be obtained for sites as well as the survey report information.

Each site is ranked based on three important criteria: degree of impact, the significance of the resources, and land management. Individual site rankings are on a 10 to 1 scale, 10 being the most important and 1 as the lowest importance. An explanation of the individual site ranking is provided below.

Impact

The potential impact on cultural resources ranked based on where they fall within the inundation zones. The ranking of the potential impact is as follows:

- 10 — "Full" impact
- 5 — "Partial" impact
- 1 — "Near" the inundation zone – This ranking identifies important resources that are close to the inundation zone that could potentially be impacted.

Eligibility

Eligibility is a field or official assessment assigned to professionally inventoried sites. Eligibility will be extracted from the data based on the location of cultural resources relative to the inundation zones. The ranking of these assessments are as follows:

5 — Listed on the National Register; National Landmark; Listed Historic District.

4 — Listed on the State Register; Centennial Farms; Local Landmark; Supports Linear Resource; Contributing to Existing District.

3 — Eligible (Officially and Field)

2 — No assessment; Needs Data (Officially and Field)

1 — Not Eligible (Officially and Field); Does not support linear resource; Delisted

Land Management

Land management is determined by the laws and regulations that each land manager is obligated to follow to appropriately preserve and protect cultural resources. The ranking based on land management is as follows:

5 = State Parks; BLM; USFS

4 = State Wildlife Areas (SWA); State Land Board (SLB)

3 = Land Trust (Nature Conservancy); City and County

2 = Department of Defense (DoD)

1 = Private

Step-by-step project ranking procedures based on their potential benefit to protect cultural resources in the path of the current inundation zones is provided below.

1) Once sites were pulled from the GIS data, they were then grouped by current inundation zone and a calculation was performed to determine how many sites would be protected.
2) Many sites are within properties that are managed by more than one entity; as a result, some sites were duplicated during the land management analysis.
   a) The average for each duplicated individual site was calculated and the duplicates were then removed (only the average for each duplicated site was used in the following steps).
3) An average for all the cultural resources within each current inundation zone was then calculated to determine the resources that would be protected by the Project.
4) Each project was then grouped based on:
   a) The **Sum of High Priority Significant Resources** in the path of the current inundation zone and how many would be removed from the inundation area.
   b) If there was more than one project that had the same number of significant resources within each of these groups, the **Sum of Eligible (Field or Officially) Resources - Potentially Significant Sites** was then used to further sort the Projects.
   c) Similarly, if there was the same number of eligible sites within each of these groups the **Site Ranking Average for Each Project** was used for the final ranking of each capital project.

NOTE: Field and officially not eligible, no assessment, and no data sites are *only* used during the average ranking for each site and therefore, the **Site Ranking for Each Project**. It is assumed that not eligible, no assessment, and no data sites are not as significant as the Eligible sites, nor are they as significant as the **High Priority Significant Resources**, which were given a "5" or a "4" in the individual **Eligibility** site ranking. While the methods for ranking the projects are somewhat subjective, an exclusively quantitative ranking is not possible at this time.

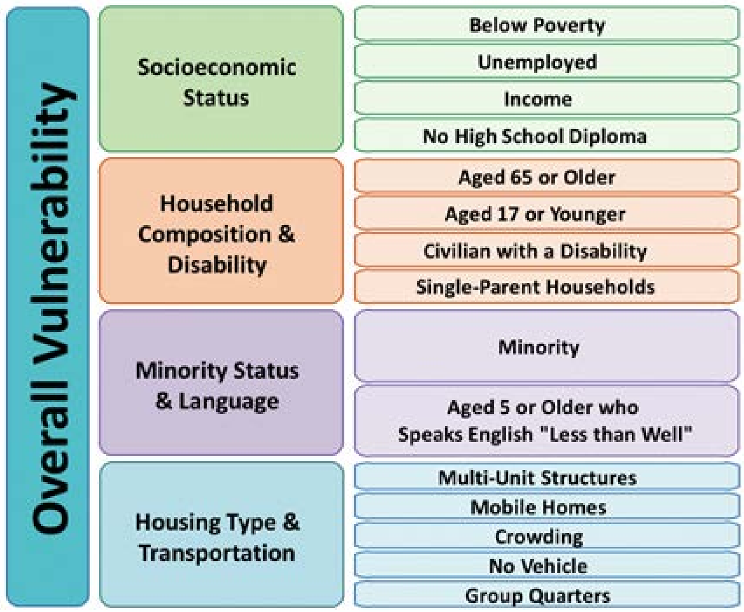
Ranking Factor Semi-Quantitative Metric	**Scale of 1 to 10** 0 indicates slightly important; 10 indicates significantly important

Social Impact, Equity and Fairness

Flood damages have different impacts across the community, and people do not have the same ability to recover when impacted. Understanding these differences will help identify the areas with the highest needs and assist in prioritizing these projects.

Social Vulnerability

Social vulnerability refers to the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss. Several factors, including poverty, lack of access to transportation, and crowded housing may weaken a community's ability to prevent human suffering and financial loss in a disaster (CDC, 2021). The Centers for Disease Control / Agency for Toxic Substances and Disease Registry Social Vulnerability Index (CDC/ATSDR SVI) uses U.S. Census data to determine the social vulnerability of every census tract. Census tracts are subdivisions of counties for which the Census collects statistical data. The CDC/ATSDR SVI ranks each tract on 15 social factors and groups them into four related themes (shown below). Each tract receives a separate ranking for each of the four themes, as well as an overall ranking.



Source: CDC/ATSDR SVI Fact Sheet | Place and Health | ATSDR

Ranking Factor Quantitative Metric	**SVI Range 0 to 1** 0 indicates least vulnerability; 1 indicates greatest vulnerability

Ability to Implement

Design and construction projects can encounter many obstacles that can prevent a project from happening or greatly lengthen the time it takes to fully complete a project. This criterion identifies whether a project is expected to encounter obstacles that would hinder or prevent its design and construction, such as institutional, legal, or other practical constraints; ability to permit; whether the city owns the land/holds easements or rights-of-way; and if there is political will and community acceptance and support. These factors are described in more detail below.

Project Constraints

Typical project constraints that increase the difficulty of bringing a project to fruition include institutional, legal, or other practical constraints; ability to permit the project or how long it may take for permitting on a local, state, or federal level; whether the city owns the land/holds easements or rights-of-way; anticipated difficulty obtaining privately owned land or easements for construction; or others.

Ranking Factor Qualitative Metric	**Easy / Neutral / Difficult**

Community Acceptance & Support

The Utility relies on robust community engagement throughout the flood mitigation planning process to develop selected alternatives that align with community needs and values. The community acceptance & support criterion evaluates the results of these engagement efforts.

Ranking Factor Qualitative Metric	**Scale of 1 to 5** 1 indicating little community support; 5 indicating broad community acceptance

Life Safety

City of Boulder GIS building datasets include: basic information on each structure including a building type and a ground elevation value. This information is reduced to include the structures located within the High Hazard Zone, the 100-year floodplain, and the 500-year floodplain, and results in a number of structures identified for potential flooding impacts and damage/benefit calculations.

Protect Critical Facilities

In 2014, the city enacted new floodplain regulations to ensure community safety, protect vulnerable populations, and maintain essential services during and after a major flood. Critical Facilities are defined as: at-risk populations such as schools, daycares, and senior care facilities; essential services such as fire and police stations, and water and wastewater treatment facilities; and hazardous materials facilities located within the 500-year floodplain.

Critical Facilities Removed from the High Hazard Zone (HHZ)

The High Hazard Zone is defined as the area of the floodplain that has the greatest risk for loss of life. Critical facilities identified through City of Boulder GIS data will be used in conjunction with the existing and proposed HHZ boundaries to determine the number of critical facilities anticipated to be removed due to project improvements.

Ranking Factor Quantitative Metric	**Number of Facilities Removed from High Hazard Zone**

Critical Facilities Removed from the 500-Year Floodplain

Critical facilities identified through City of Boulder GIS data will be used in conjunction with the existing and proposed 500-year floodplain boundaries to determine the number of critical facilities anticipated to be removed due to project improvements.

Ranking Factor Quantitative Metric	**Number of Facilities Removed from 500-Year Floodplain**

Removal of Residential Units from the High Hazard Zone (HHZ)

The High Hazard Zone is defined as the area of the floodplain that has the greatest risk for loss of life. Residential units identified through City of Boulder GIS data will be used in conjunction with the existing and proposed HHZ boundaries to determine the number of residential units anticipated to be removed due to project improvements.

Ranking Factor Quantitative Metric	**Number of Residential Units Removed from High Hazard Zone**

Road Level of Service

Annual Average Daily Traffic (AADT) data were collected from the Colorado Department of Transportation (CDOT) Online Transportation Information System (OTIS). AADT represents the average daily traffic count for a particular highway segment, in both directions, representing an average 24-hour day in a year and was used as an indicator of road usage and quality. These data were queried against the “without project” inundation maps to characterize the effects of flooding to road closures and road loss due to flooding. AADT is entered into the decision model with values ranging from less than 10,000 to more than 75,000.

County counts are 24-hour daily volumes taken mid-week (Tues – Thurs) on county roads during the summer months. An adjustment factor is applied to each raw count based on the time of the year the count was taken (using factors from CDOT).

Additional data was collected from the City of Boulder to ascertain the AADT information within city limits.

Ranking Factor Quantitative Metric	**Highest AADT Value** Nearest proximal AADT value of road segment receiving benefit from project improvements

Multiple Benefits

Some projects provide multiple benefits over and above recognized attributes. Examples of multiple benefits may include:

- Incorporation of water quality or stormwater drainage project components
- Multi-agency benefits
- Piloting of emerging technologies or demonstration projects
- Alternative transportation (steer residents in a particular direction such as walking/cycling instead of driving)
- Co-benefits with other proposed projects (e.g., building a project when another project will already be performing road reconstruction)
- Incorporation of recreation or education components
- Enhanced permit compliance (water quality)

Ranking Factor Qualitative Metric	**Range 1 to 5** 0 indicates few benefits; 5 indicates greatest high level of benefits

Table 10-3 – Criteria Scoring (Dotstorming and Model Inputs to Decision Model)

Dotstorming	Votes	% of Vote	Criteria	*Possible Weight*	Sub Criteria	Weight	Sub Sub-Criteria	Weight	Overall Weight
Ability to Implement	**92**	**7%**	**Ability to Implement**	*7%*					
					Constraints	50%			3.5%
					Community Support	50%			3.5%
Efficiency & Cost	**88**	**7%**	**Cost**	*10%*					
					Capital Cost	60%			6.0%
					O&M Cost	40%			4.0%
			Effectiveness	*20%*					
Protect Property	**154**	**12%**			Protect Property	80%			
							Reduce Physical Damage	60%	9.6%
							Reduce Economic Loss	40%	6.4%
Infrastructure Resilience	**179**	**14%**			Level of Service	20%			4.0%
			Environmental/ Cultural Resources	*11%*					
Environmental Resources	**141**	**11%**			Protection/ Restoration of Environmental Resources	70%			
							Protect Existing Natural Features	75%	5.8%
							Restore or Reclaim Natural Features	25%	1.9%

Dotstorming	Votes	% of Vote	Criteria	*Possible Weight*	Sub Criteria	Weight	Sub Sub-Criteria	Weight	Overall Weight
Cultural Resources	**59**	**5%**			Protect Cultural Resources	30%			3.3%
Social Impact, Equity, Fairness	**161**	**13%**	**Equity**	***18%***					
					Social Vulnerability	100%			18.0%
Life Safety	**224**	**18%**	**Life Safety**	**29%**					
Protect Critical Facilities	**162**	**13%**			Protect Critical Facilities	40%			
							Critical Facilities Removed from HHZ	60%	6.9%
							Critical Facilities Removed from 500-yr floodplain	40%	4.6%
					Remove Residential Units from HHZ	40%			11.6%
Infrastructure Resilience Metric					Road Level of Service	20%			5.8%
			Multiple Benefits	**5%**					5.0%

MCDA Tool

The decision hierarchy (**Figure 10.6**) illustrates the structure used to support decision-making, outline the criteria and sub-criteria used to rank one project to another.

Example projects were placed into the MCDA tool to ascertain its usefulness in assessing project prioritization. An example of how this tool is applied, as discussed in the July 18, 2022, Water Resources Advisory Board meeting, is provided in **Appendix D**. The model provides a ranking of projects by overall score and can show the respective contribution of the different criteria as shown in **Figure 10.5**. In this instance, Project D scores higher in Life Safety and Effectiveness categories, and when all scoring is considered, it scores highest. However, Project E2 scores nearly as well, due to its relatively high score in Effectiveness, Equity, and Cost.

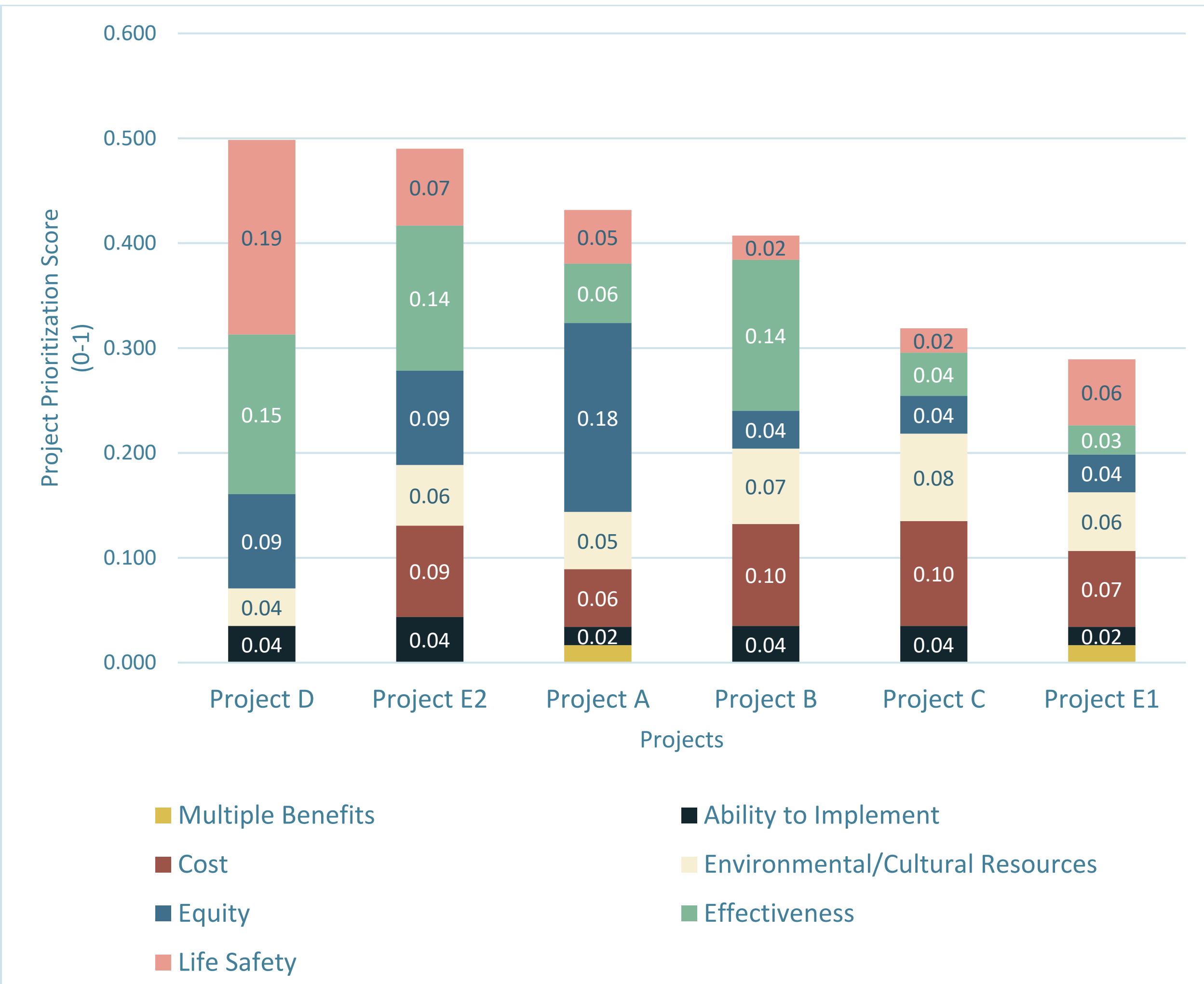


Figure 10.5 – Example MCDA Tool outcome showing criteria contribution by project

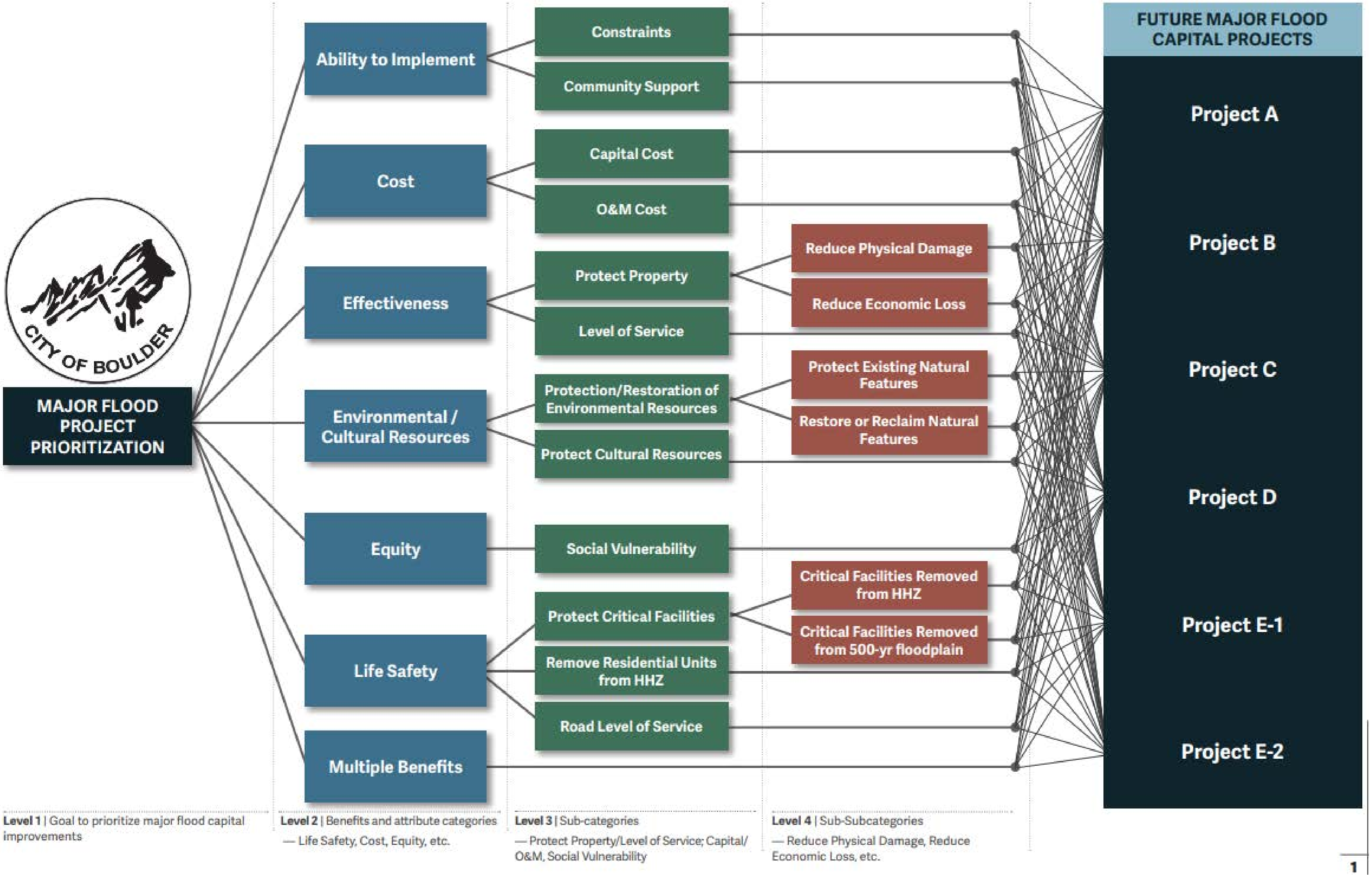


Figure 10.6 – Decision Model Main Criteria and Sub criteria

As mentioned earlier, historically project alternatives were considered from a Benefit/Cost ratio (BCR) aspect with priority given to those projects that had the highest ratios. In the example projects, if the historic BCR were used to prioritize this suite of projects, Project B would rank higher (as opposed to Project D, which is shown as a second preference, below).

Figure 10.7 – Example ranking using BCR as primary criteria for project prioritization

Table 10-4 shows the difference in scoring between the revised MCDA Tool vs a straight Benefit/Cost ratio method:

Table 10-4 – Scoring – revised MCDA Tool vs straight Benefit/Cost ratio

Project	Priority using BCR	Priority using MCDA Tool
Project D	2	1
Project E2	3	2
Project A	6	3
Project B	1	4
Project C	4	5
Project E1	5	6

Figure 10.8 through **Figure 10.12** provide further granularity regarding scoring on a project-by-project basis as demonstrated for some of the criteria, below.

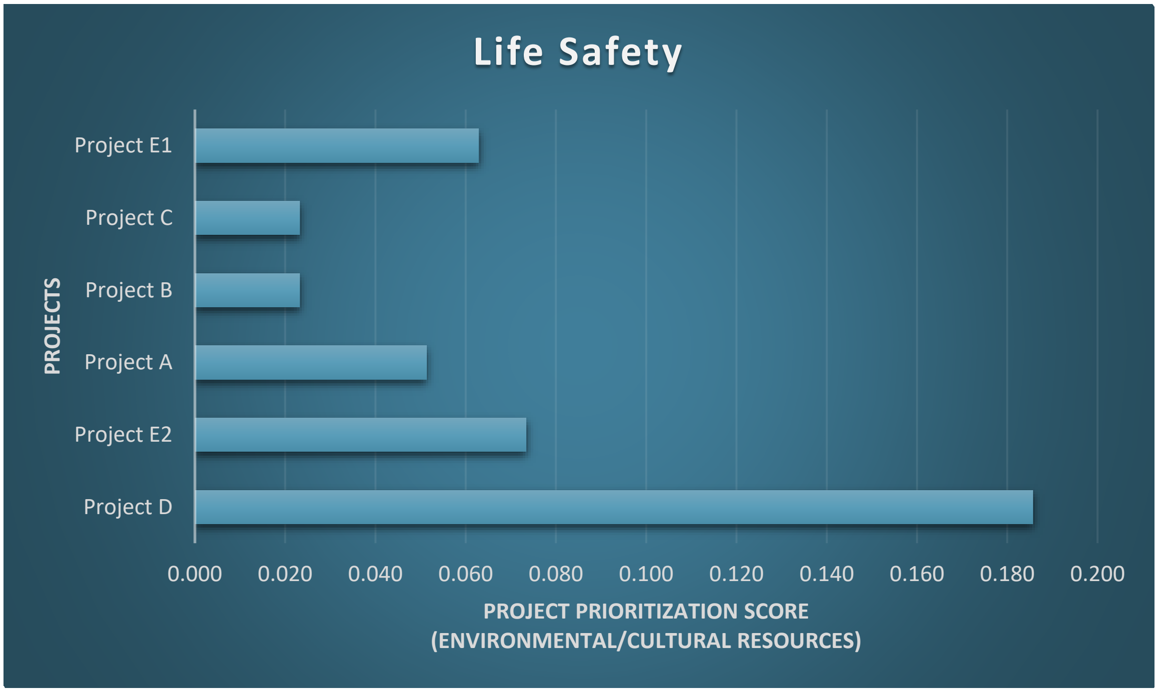


Figure 10.8 – Life Safety criteria scoring by project

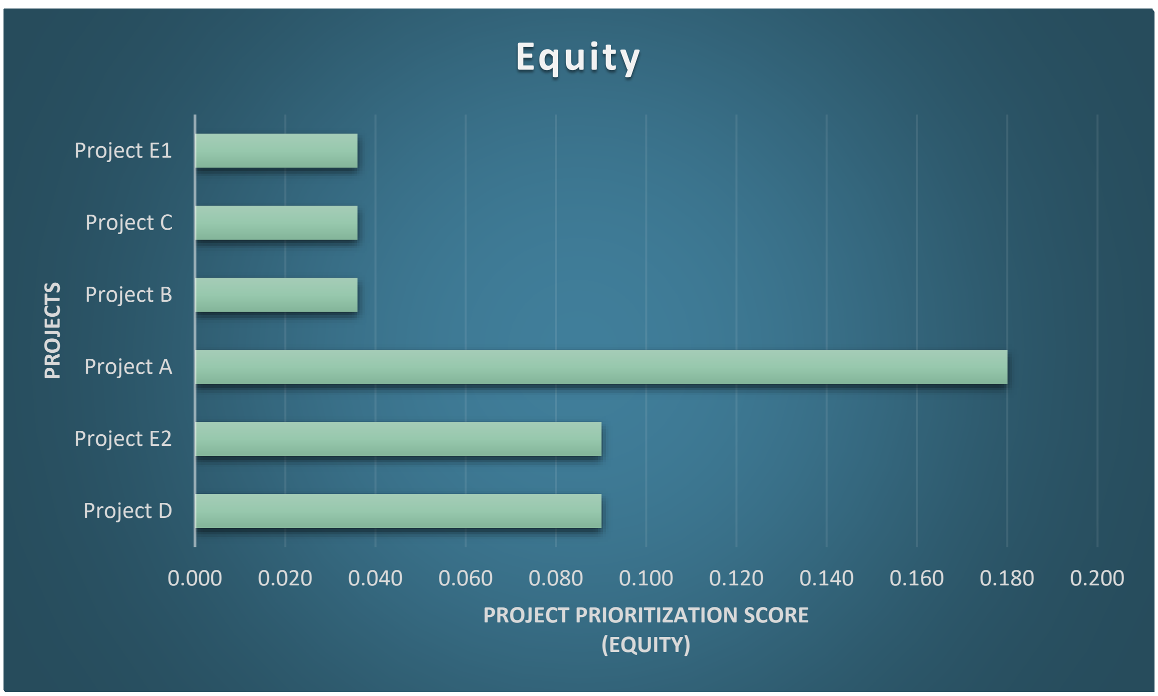


Figure 10.9 – Equity criteria scoring by project

Figure 10.10 – Effectiveness criteria scoring by project

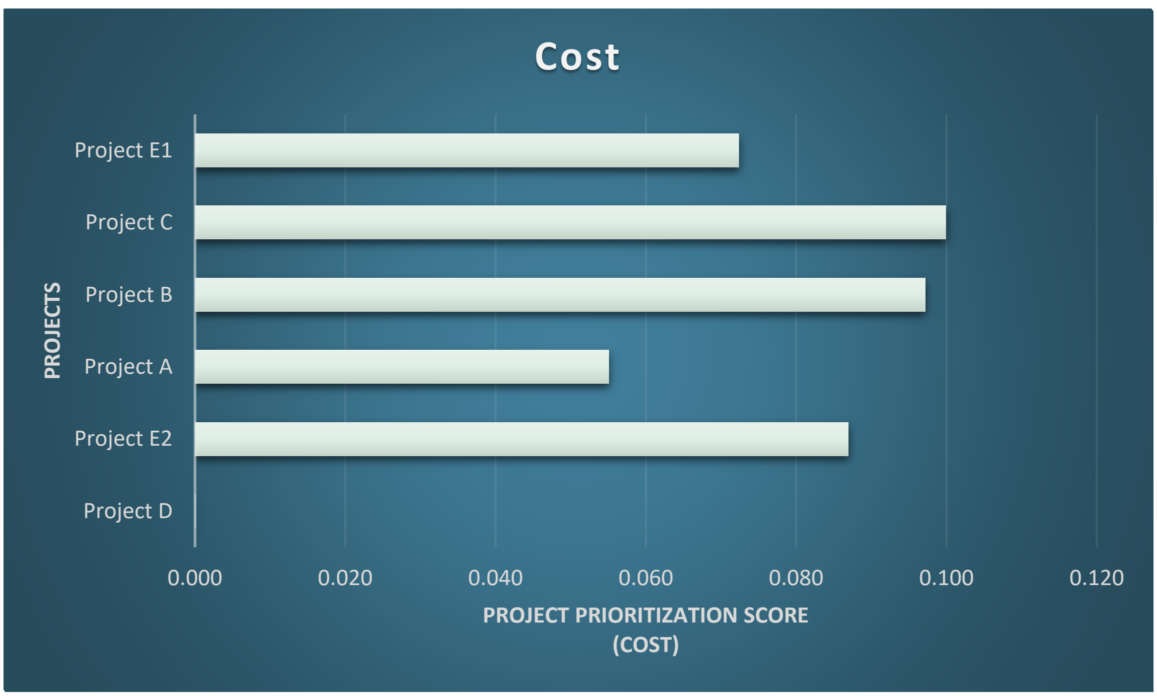


Figure 10.11 – Equity criteria scoring by project

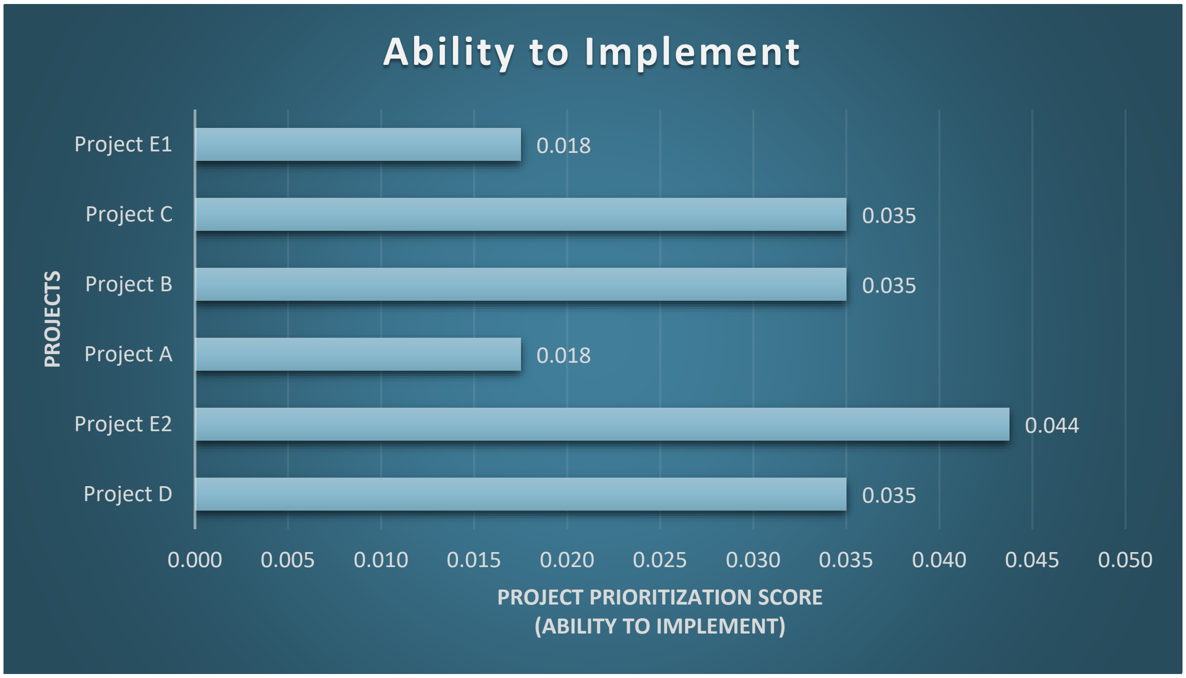


Figure 10.12 – Ability to Implement criteria scoring by project

Figure 10.13 portrays the overall contribution by criteria for each Project for a quick assessment of "why" one project scored better than another.

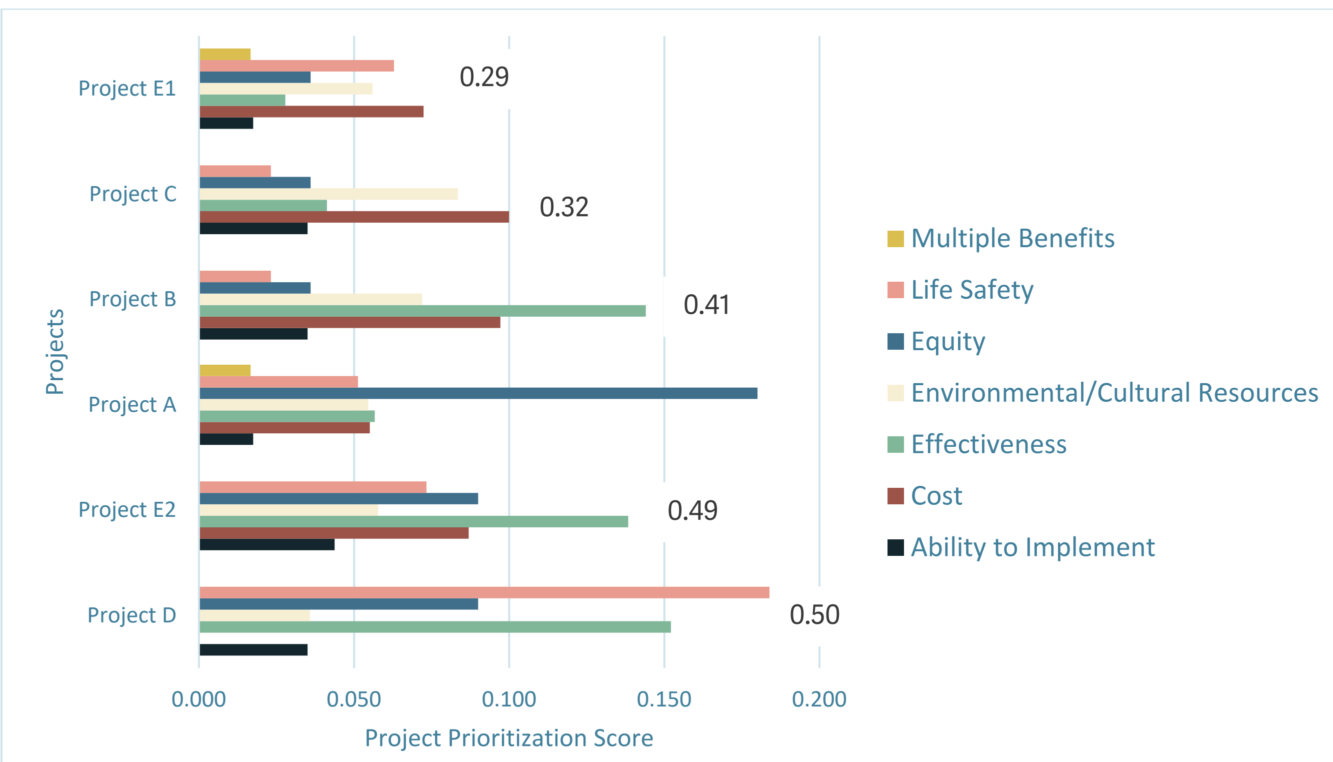


Figure 10.13 – Overall Contribution by Criteria for each Project

The decision model is dynamic, and weighting values can be easily modified to create "what if" scenarios. As additional information becomes available for major flood projects, the model will be further developed to inform the proposed capital improvement expenditure priorities and budget.

References

Boulder County Traffic Counts. Retrieved on February 16, 2022 from Boulder County Traffic Counts (arcgis.com)

Centers for Disease Control/Agency for Toxic Substances and Disease Registry. (CDC/ATSDR). Retrieved on February 16 from CDC/ATSDR's Social Vulnerability Index (SVI)

City of Boulder Traffic Count Data. Retrieved on February 16, 2022 from Boulder Traffic Count (bouldercolorado.gov)

Deguid, Kate. (2021, February 21). Cost of Flood Damage to US Homes Will Increase by 61% in 30 Years. Rueters. https://www.reuters.com/business/environment/cost-flood-damage-us-homes-will-increase-by-61-30-years-2021-02-22/

Federal Emergency Management Agency (FEMA). Hazus Program retrieved from Hazus | FEMA.gov

Madruga de Brito, M., M. Evers. (2016). "*Multi-criteria decision-making for flood risk management: a survey of the current state of the art*," Natural Hazards and Earth System Sciences, 16, 1019–1033, 2016. Accessed at www.nat-hazards-earth-syst-sci.net/16/1019/2016/ doi:10.5194/nhess-16-1019-2016

Mustajoki, J., M. Marttunen. (2017). *"Comparison of multi-criteria decision analytical software for supporting environmental planning processes",* Finnish Environment Institute, 2017. Accessed at http://dx.doi.org/10.1016/j.envsoft.2017.02.026 1364-8152.

Water Research Foundation. (2018). "Recommended Operation and Maintenance Activity and Cost Reporting Parameters for Stormwater Best Management Practices Database," 2018.

11 Financial Considerations

There are many critical factors which may either facilitate or limit the Utility's ability to adequately manage stormwater runoff and mitigate the effects of floods. The Utility requires administrative, planning, engineering, operational, regulatory, and infrastructure management functions that demand a substantial financial investment. Drivers for additional capital requirements include aging infrastructure, escalating construction costs, community values, and new regulations. This Chapter discusses financial considerations including the types of costs likely to be incurred by the Utility in the future.

Since approval of the 2004 Flood and Stormwater Master Plan, the Utility has completed flood mapping for nearly all of Boulder's 16 major drainageways, constructed major flood improvements on Elmer's Two Mile ($9M), Wonderland Creek ($30M), and Gregory Creek ($735K), among others, and completed 75 percent of remaining flood mitigation studies. These mitigation studies are prepared to identify the preferred flood mitigation projects to be designed and constructed.

Using information from the completed mitigation plans and the Stormwater Master Plan (2016), Utilities has estimated that the cost to complete the remaining storm and flood mitigation capital improvements across the city's 16 drainageways is roughly $355 million (2022 dollars). This accounts for construction of over $47M in stormwater projects and $308M in major flood projects. In implementing past projects, the time required to perform permitting, approvals, and the community engagement process has resulted in completion of a major flood project about every seven to ten years.

Simply put, if the pace for construction of major flood projects remains the same, it could take more than 50 years to complete the current list of capital projects that have been identified through the mitigation plans and Stormwater Master Plan. Impediments to CIP construction include: staff resources (additional Project Managers and/or consultant staff are required); the project lifecycle requirements (permitting, approvals and community engagement); need for community support (at the project level, and for rate increases); and continued ability to bond the work.

A public engagement process was conducted during the spring of 2015 in support of the latest Utility Rate Study (Raftelis, 2017). In June 2015, the Water Resources Advisory Board (WRAB) was provided the results of the public engagement process, and the WRAB, followed by the City Council, adopted the following Utility rate guiding principles (Boulder, City of, 2017):

- Be effective in yielding total revenue requirements
- Provide revenue stability and predictability for the utilities
- Fairly allocate the total cost of service across customer classes to attain equity
- Encourage low-impact development to decrease stormwater impacts

Funding Sources

Stormwater and flood management are critically important city functions, reflecting the city's standing as a highly flood-prone community. The Utility serves a customer base of 29,579 properties (as of December 31, 2021) and provides a multi-million dollar operational and capital infrastructure program, at about $10 to $15 million annually.

Rates and fees are annually assessed to fund activities of the Utility and to ensure that required reserves are maintained and debt service coverage requirements are met. Adequate reserves are required for bond issues and for other outstanding liabilities. The Utility strives to maintain a 25% operating reserve over a six-year planning period. Current reserves are estimated to be above 25% over a six-year planning period. In addition, the Utility also has a $1,050,000 reserve available for the property acquisition program.

Debt service coverage requirements are established as part of the Utility's bond covenants. Planning for issuing debt for projects includes consideration of maintaining coverage ratios as required by bond covenants and maintaining strong bond ratings to keep interest rates and costs low. On an annual basis, the Utility is required, per bond covenant requirements, to generate net revenues (before debt service) equal to 1.25 times its annual debt service requirements. The Utility currently generates net revenues that average about four times this requirement.

In addition to the City's annual review of rates and fees, a financial and rate consulting firm is hired periodically to conduct a comprehensive rate and fee review. The last rate review was completed in 2017 by Raftelis Financial Consultants (Raftelis, 2017). Results of this rate study included a revision to the fee calculation methodology for non-single family residential customers to include a simple fixed charge in addition to a charge for each square foot of impervious area. The fee and rate structure went into effect on January 1, 2018. A comparison of monthly stormwater utility fees for Colorado municipalities is presented in **Figure 11.1.** Of particular note is that, prior to the 2013 flood, average utility fee was markedly lower (about $8 per month), but a substantial rate increase was enacted in 2014 to cover community investment in flood mitigation and reduce risk. This is further illustrated in **Figure 11.4**.

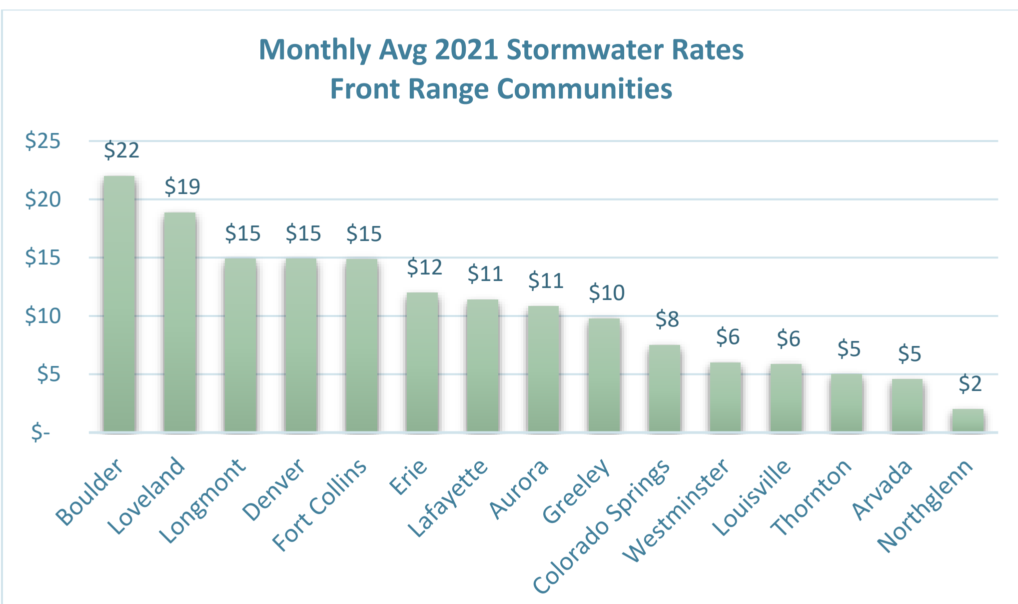


Figure 11.1 – Monthly Average 2021 Stormwater Rates

Funding Sources

The Utility's funding is comprised of service fees, Plant Investment Fees (PIF), bond proceeds, funding for limited purposes from the regional Mile High Flood District (MHFD), and occasional grants, loans, and cost sharing. The charges to commercial, industrial, and institutional properties are based on their impervious coverage and gross property area in relation to that of the average conditions present on single-family residential properties. Basically, more heavily developed properties pay more. The charges to non-residential properties vary significantly, as there exists a wide variation in impervious coverage and property area. In total, the charges to customer classes reflect the demands imposed by existing land conditions on the stormwater and flood management infrastructure and associated programs.

Monthly User Fees

Monthly Utility service charges (fees) are the primary source of funding for the Utility. Initially set in 1973 at $1.00/month for residential customers, service charges were intended to recover the costs of administration, operations, maintenance, and system replacement over time, plus construction of additional infrastructure. However, revenue collected in the early years of the Utility was insufficient to fully fund those needs. To address this deficit, service charges were allocated to new construction and General Fund appropriations were used to fund operational programs as the Utility programs were established. To allow the Utility to fully fund its operations and construction, the Utility's service charge rates were increased in 1982, 1987, 1989, 1990, and repeatedly thereafter.

The Utility's current rate methodology consists of a fixed service charge and an area charge which are billed to customers within the city limits. The area charge for single-family residential customers is based on their lot size. All other customers pay an area charge based on the impervious area (driveways, parking lots, roofs, etc.) contained on their lot. These fees are codified in the Boulder Revised Code (BRC), under Section 4-20-45 Stormwater and Flood Management Fees. The 2022 fixed service charge for all accounts is $3.53 per month. Residential area charges average $22.00 per month, and owners of all other parcels pay an area charge of $0.008005 per square foot of impervious area.

Plant Investment Fees

In 1989, the city adopted a Stormwater and Flood Management Plant Investment Fee (PIF) to assist in the funding of growth or expansion-related facilities for the collection and conveyance of stormwater runoff. The PIF is a one-time fee collected when an annexed, developed, or redeveloped property requires access to flood control or stormwater collection and conveyance infrastructure. From 1989 to 1996, the PIF was calculated in a manner similar to the non-residential monthly user fees. In 1998, the PIF calculation was adjusted to more accurately reflect the wide range of residential development happening in the community. Prior to 1998, residential property paid a PIF using a sliding scale dependent only upon property size. In 2001 this was modified so that each residential property paid a PIF based upon both its calculated runoff coefficient and property size.

The PIFs are calculated based upon the new replacement value of the Utility assets less depreciation and are found in BRC 4-20-46 Stormwater and Flood Management Utility Plant Investment Fee. The PIF is currently set at $2.39/square foot of impervious area (2022). As the city sees less net new impervious area in development projects, it is anticipated that these fees will diminish in their overall contribution to revenue.

Bonds

The Utility issues bonds to pay for major flood improvements that typically have long useful life, so that the debt can be spread out over several years (usually over a 20-year period). The Utility continues to maintain a high bond rating, most recently Aa1 from Moody's and AAA from Standard and Poor's. The ratings report for the 2018 Water and Sewer Bonds stated this is due in part to "strong fiscal management" and maintaining sufficient reserves.

Other Funding Sources

The Utility is also supported by funding from the MHFD for certain qualifying expenditures. MHFD funds are generated by a special mill levy (property tax), with the objective that they be returned proportionally to their geographic area of origin over time. Apportionment of the funds across the MHFD is not required to reflect revenue origin in any given year. It is estimated that funding from MHFD will average between $1M to $2M annually in the next six years.

A general breakdown of funding sources is shown in **Figure 11.2** below.

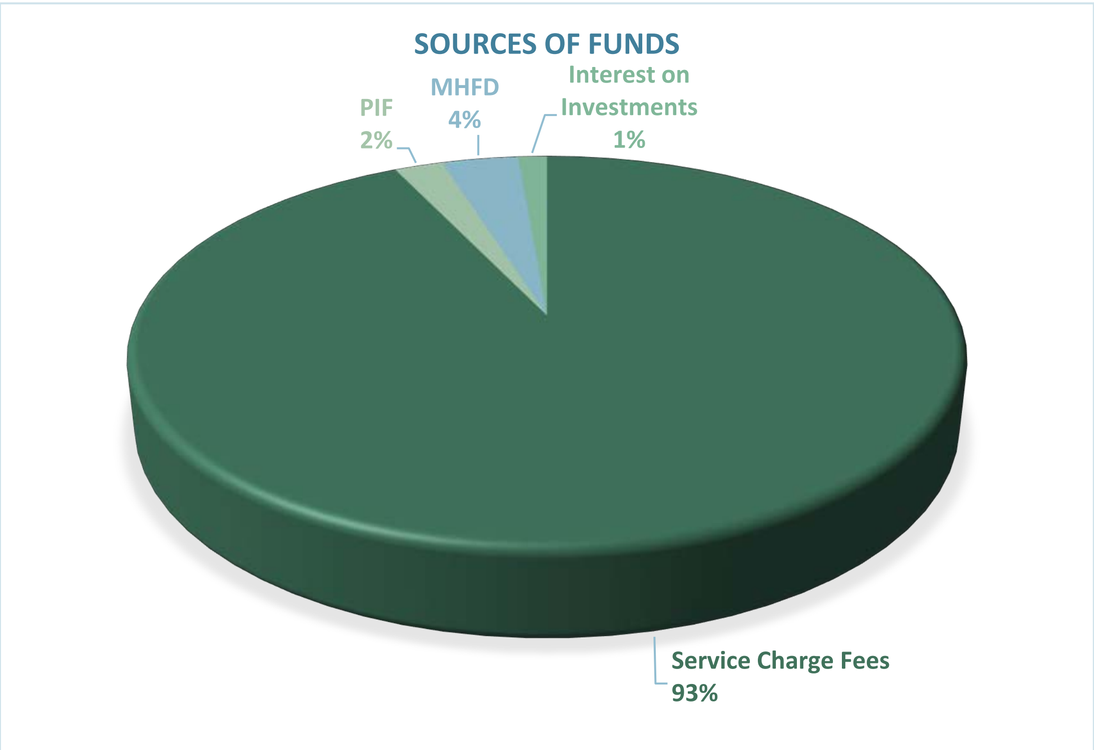


Figure 11.2 – Sources of Funds

Rate Comparisons & Methodologies

The current method of apportioning the Utility's costs across the community supports the program's initial focus on stormwater collection and conveyance and flood management. Although refinements have been enacted from time to time, the funding structure and resulting cost apportionment have remained relatively constant. Increases to service charges and PIF have kept pace with program growth.

Residential service fees in Boulder have increased significantly since the 2013 flood. **Figure 11.3** provides a comparison of Colorado-based programs and shows that Boulder, followed by Loveland, Longmont, Denver, and Fort Collins have the highest flood utility fees in comparison with other Front Range municipalities. In comparison, in 2003 Fort Collins had the highest reported average annual residential fee at about $155 per year as they had adjusted their rates following to a major flood event (1997). Over the past two decades, Fort Collins invested substantial resources into their program, gaining a National Flood Insurance Program (NFIP) Community Rating System (CRS) Class 2 rating, which provides a significant reduction in flood insurance premiums for the community's property owners, among other benefits. The 2013 flood in Boulder came 16 years after the 1997 flood in Fort Collins, and the Utility continues to make strides toward financing major flood improvements.

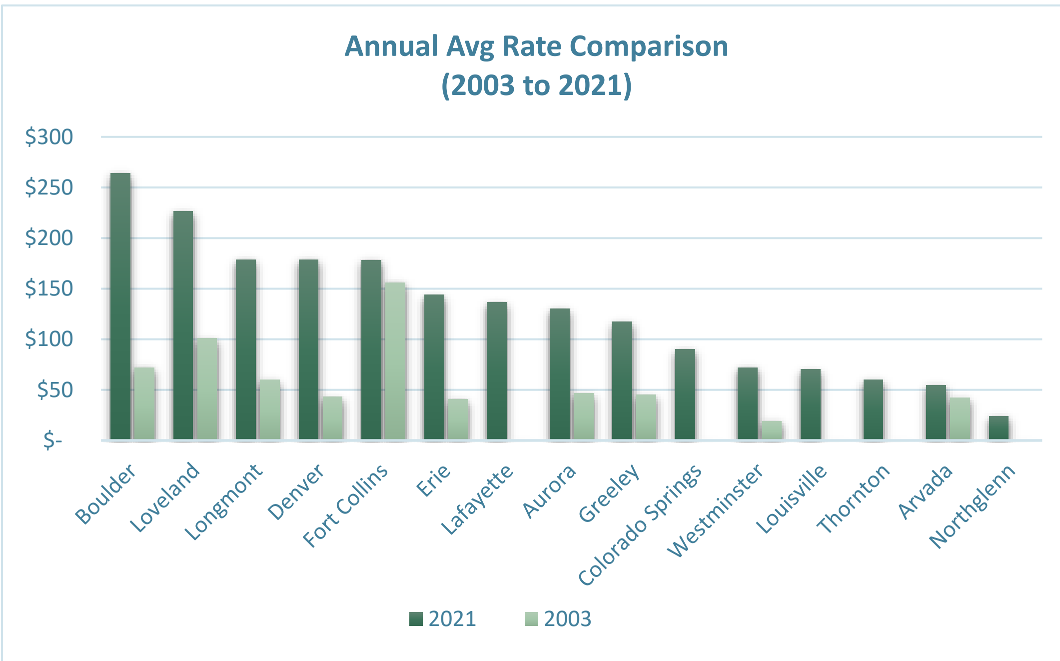


Figure 11.3 – Annual Average Rate Comparison (2003 to 2021)

Subsequent to the 2013 floods, Boulder similarly embarked on a program to systematically and consistently raise rates to provide additional flood protection, including mapping and mitigation studies, and construction of flood infrastructure. A one-time, significant rate increase of 75% occurred in 2015 and annual rate increases have averaged about 8% since then. **Figure 11.4** shows the historic Utility rate increases since the previous Comprehensive Flood and Stormwater Utility Master Plan was prepared.

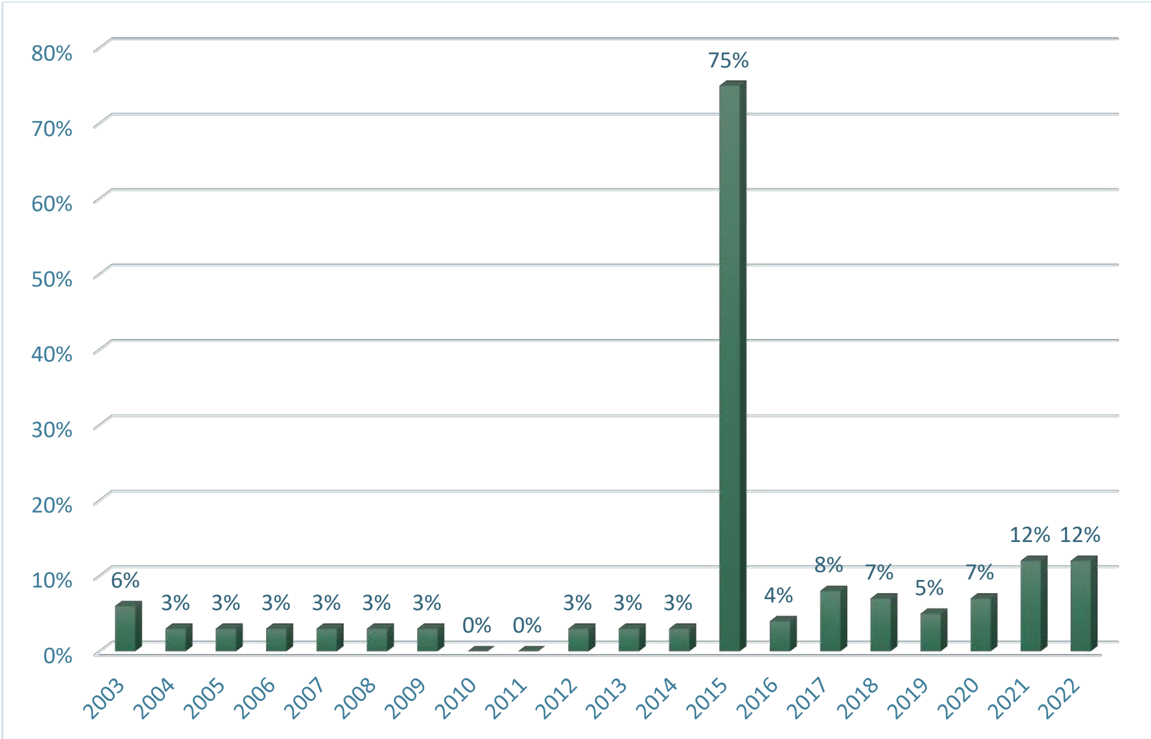


Figure 11.4 – Historic Stormwater and Flood Management Utility Rate Increases by Year

Recent and proposed rate increases are included in **Table 11-1**.

Table 11-1 – Stormwater and Flood Utility Recent and Proposed Rate Increases

	2020	2021	2022	2023	2024
Rate Increases (Current / Proposed)	7%	12%	12%	12%	12%

Boulder's service charge rate methodology is generally consistent with industry practices. PIFs ensure that over time, new development financially participates in the cost of capital infrastructure that was built in anticipation of the storm and flood management demands created by the increase in impervious surfaces. The basic parameters employed in the Utility's service fee and PIF rate methodologies are impervious area and, to a lesser degree, gross property area. Both factors increase the rate and volume of stormwater runoff, especially in severe storms when the initial mitigating effects of vegetation and soil absorption are overwhelmed.

Historically, the Boulder community has consistently supported increases in utility service charges and plant investment fees to meet demonstrated needs. A public engagement process was conducted during the spring of 2015 in support of the latest Utility Rate Study (Raftelis, 2017). It included the city mailing 26,000 postcards to notify customers of the opportunity to provide input. The resulting feedback did not indicate the need to make largescale changes to the rate structures. As such, the Utility has opted to ramp rates up each year; this smoothing rate setting approach is preferred as it avoids large one-time rate increases in any given year which can shock ratepayers. Stepping up service charge rates infrequently also demands that a substantial fund balance be created in the first few years after a rate is in place. The accumulated fund balance would subsequently erode as expenditures overtake and eventually exceed revenues.

Budget

The Utility's approved budget in 2022 fiscal year was about $17.67M (reference **Table 11-2**). This includes $6.58M for operational expenses, $8.64M for capital expenditures, $0.86M for departmental transfers, and $1.59M for debt service on existing bonds (essentially long-term loans that are paid off over time). Operating and emergency reserves are budgeted at $5.25M. The Utility's fund balance at year's end is projected to be $13.2M.

A summary of the breakdown of the Utility's recent and projected budget/expense categories is shown in **Figure 11.5**, below. The percentages are an average of actuals (2020, 2021); approved (2022); and projected (2023 through 2027) expenses.

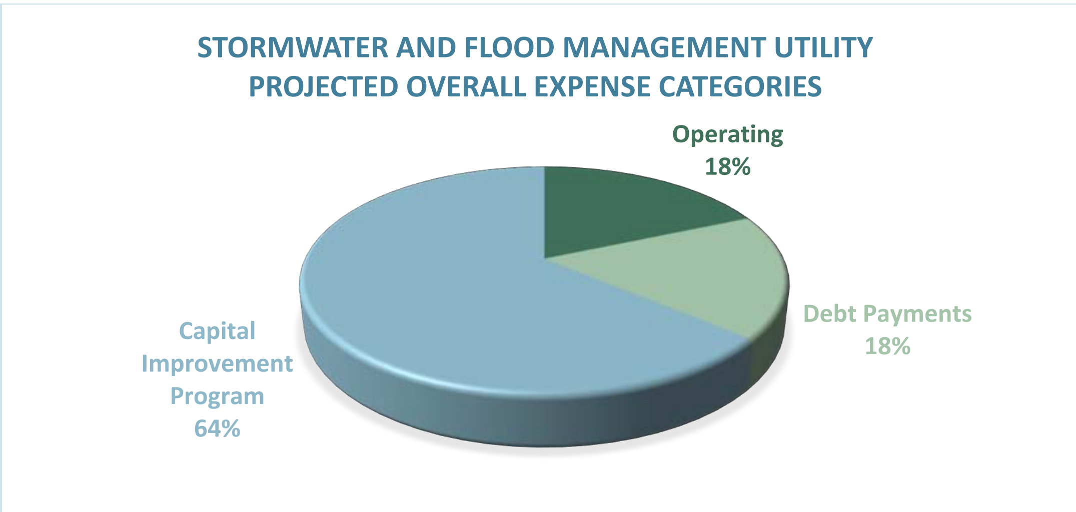


Figure 11.5 – Stormwater and Flood Management Utility Projected Overall Expense Categories

As shown above, the budget is primarily used for capital improvement program expenses. A further breakdown of the Utility's current operating budget/expenses is shown in **Figure 11.6**, below. The percentages are an average of actuals (2020, 2021); approved (2022); and projected (2023 through 2027) operating expenses.

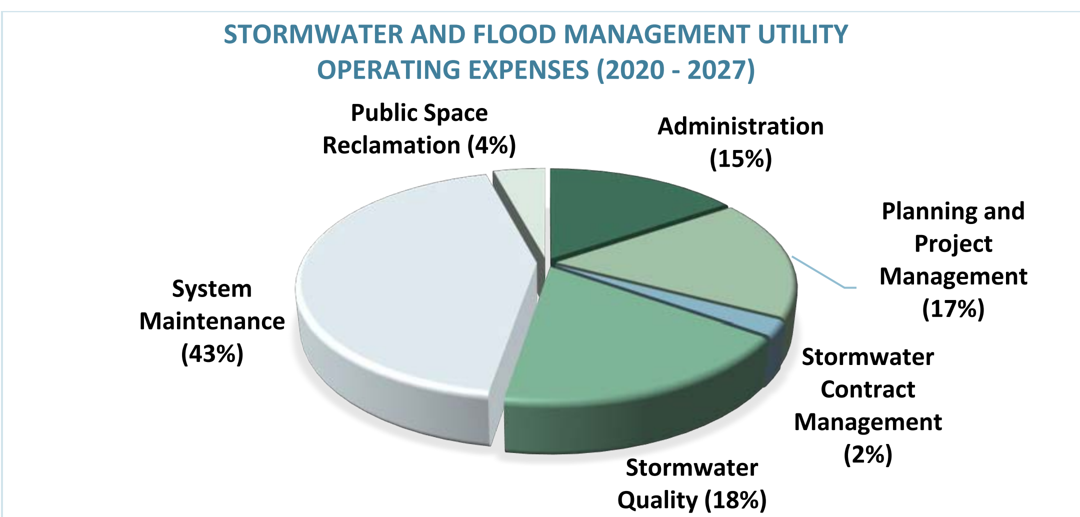


Figure 11.6 – Stormwater and Flood Management Utility Operating Expenses (2020-2027)

Table 11-2 provides the Stormwater and Flood Management Utility 2022 fund financial information (Source*: Approved 2022 City Budget).*

Table 11-2 – Flood and Stormwater Utility Actual and Projected Expenditures

	2020 Actual	2021 Revised	2022 Approved	2023 Projected	2024 Projected	2025 Projected	2026 Projected	2027 Projected
Operating Uses of Funds	$ 4,410,085	$ 5,180,622	$ 6,579,730	$ 6,321,515	$ 6,447,945	$ 6,582,630	$ 6,720,732	$ 6,862,349
Debt Services	$ 1,589,163	$ 1,591,688	$ 1,590,188	$ 1,588,088	$ 10,165,776	$ 10,167,726	$ 10,168,626	$ 10,167,476
Transfers Out	$ 665,902	$ 985,714	$ 857,957	$ 874,794	$ 892,049	$ 914,150	$ 936,826	$ 960,092
Capital Projects**	$ 2,703,640	$ 31,004,029	$ 8,637,500	$ 16,787,500	$ 96,190,700*	$ 4,117,500	$ 4,297,500	$ 5,517,500
Total Uses of Funds	$ 9,368,790	$ 38,762,053	$ 17,665,375	$ 25,571,897	$ 113,696,470	$ 21,782,006	$ 22,123,684	$ 23,507,417
Total Reserves	$ 4,646,321	$ 4,922,021	$ 5,252,168	$ 5,204,138	$ 13,818,235	$ 13,760,296	$ 13,812,848	$ 13,866,443
ENDING FUND BALANCE (after Reserves)	**$ 35,947,434**	**$ 13,309,182**	**$ 13,189,050**	**$ 8,703,734**	**$ 308,573**	**$ 1,347,391**	**$ 3,085,425**	**$ 4,661,370**

** This is predominately capital outlay with bond proceeds.*
***Capital projects also include capital carry-over from multi-year projects.*

In past years, the CIP program has emphasized major drainageway improvements and property acquisition. Over the next five years, capital expenditures for major drainageways are projected to be the highest outlay (>60%) of the budget followed by stormwater management (>30%), as shown in **Figure 11.7,** below.

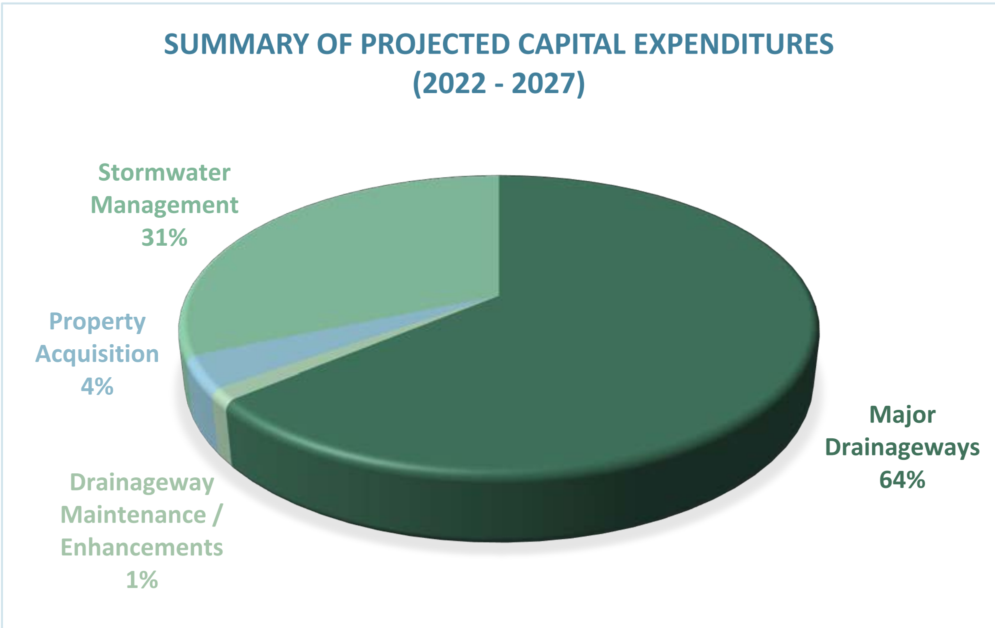


Figure 11.7 – Summary of Projected Capital Expenditures (2022-2027)

Funding Analysis

Underlying factors, such as inflation and construction costs, aging of legacy stormwater infrastructure, and new regulations will influence the Utility's future programs. Evolving risks due to climate change uncertainty and the city's sustainability and resilience objectives may justify significant changes in Utility funding. Additional factors that must also be accounted for include: 1) the community's ability and willingness to pay for program expansion and upgrades of both physical systems and operational capability, and 2) practical limits on the Utility's ability to mount and manage the increasing effort required.

Financial Implications and Scenarios

The following provides a starting point for examining the strategic decisions and implications on the future Stormwater and Flood Management Utility. A highly detailed program strategy supported by a refined cost of service analysis is required (often presented in a rate analysis) to provide a current financial template of stormwater and flood management costs and revenues.

Project-Level Funding Scenarios

Flood mitigation projects undergo extensive assessment and refinement to determine location, function, design alternatives, and preferred design approaches. Smaller, straightforward projects often go through the Project-Specific Community Process, which is a mechanism to construct the projects in a timely manner. Major flood mitigation project approval is more thorough due to the larger impact and costs. These projects benefit from a multi-criteria decision making process (Project Prioritization Framework) to analyze the project portfolio and prioritize projects in keeping with community values.

Master plans within the city lay out strategic objectives that will be pursued at differing levels based upon the amount of additional investment appropriated by the City Council through the annual budget process. The levels of funding for most city projects fall in to three categories: Fiscally Constrained, Action, or Vision.

Funding Scenario	Description
Fiscally Constrained	This funding level provides approximately $5M in capital funds and reflects what is needed to maintain basic Utility services over the short term. This includes minimal rate increases (that keep up with the Consumer Price Index). Minor investment is made in capital improvement projects and maintenance and operations would be a priority. The city had generally maintained this funding level prior to 2015. Under this funding scenario the CIP might take 75 or more years to complete.
Action	This funding level assumes an average of $7M annually in 2022 dollars, and accounts for annual fluctuations and associated rate increases. Some capital improvements are debt-financed so debt service is included in utility rates. In addition, this funding level includes six Engineering/Project Managers as currently approved in the 2022 Budget Book (Figure 11.8). Under this funding scenario it may take more than 50 years to complete the CIP. This is where the city funding has been since 2015.

Funding Scenario	Description
Vision	This funding level provides approximately $11M in annual capital funds and augments resources with additional engineers, project managers and/or consultants and capital available to complete one to two major flood projects per year. This level of funding supports an acceleration of the stormwater and major flood Capital Improvement Program and Utility maintenance so that the CIP can be completed within 30 to 35 years. These funds would be realized through a combination of continued rate increases to fund bond issuances; higher than estimated Plant Investment Fees; one-time federal grants; and higher interest on investments. This level requires sustained larger rate increases and additional staffing and resources to implement the projects.

Fund Balance and Reserves

The Utility maintains an adequate fund balance year-over-year (reference **Table 11-2**) but the carry-over balance will diminish when large capital projects are constructed. The fund balance in a utility's accounting unit is a critically important management tool for strategizing the pace and form of the evolution of the program and associated funding. Because a fund balance carries over from one year to the next, the Utility's budgeted income does not have to match projected expenditures in any given year. The unrestricted fund balance, along with reserves, allows flexibility from the impact of one-time costs incurred in a given year (particularly emergency responses and cash-expensed capital improvement spending), and maintains reserves that are required under the bond covenants.

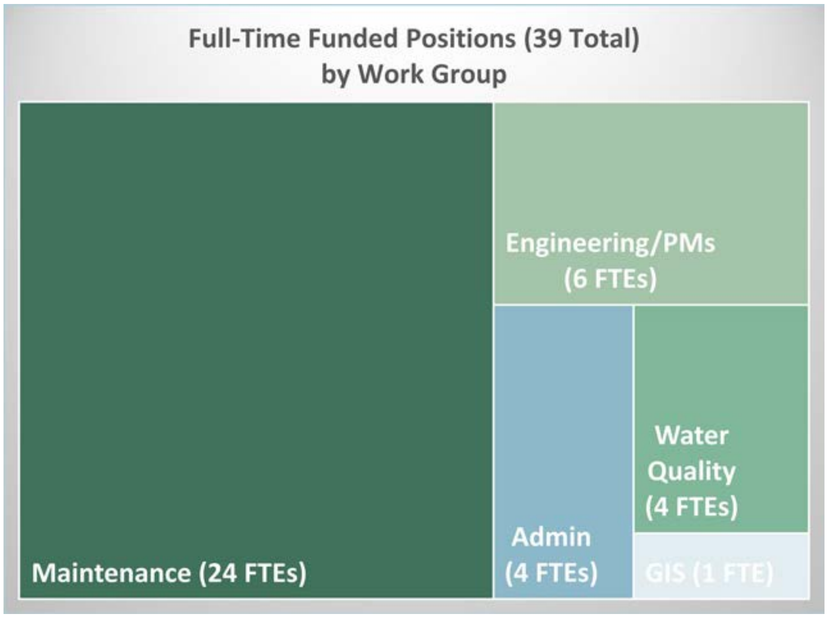
Stormwater and flood management is a recognized "high risk" activity. The Utility must have adequate reserves to deal with evolving, inconsistent, and uncontrollable natural forces. Legacy stormwater and flood management systems constructed decades ago remain in place today in much of the city, but the possibility of extreme storm events and associated design standards have changed. In such an environment, both adequate operational and emergency reserves are prudent along with a fund balance that provides an additional layer of resilience which could be appropriated during a natural disaster.

Staffing Resources

The Utility has budgeted for adequate staffing levels, which are currently set at 39 full-time equivalents (FTEs)[19] (reference **Figure 11.8** for an overview of personnel by Work Group), an increase of 8 FTEs over the prior year. The latest increase is in Stormwater maintenance in response to increased MS4 permit requirements and in the addition of five Public Space Reclamation staff. However, like other utilities across the U.S., there are a number of open, un-filled positions that cause additional workload for the existing staff. Additionally, although the piped stormwater is now adequately resourced to complete a 15-year system maintenance cycle, open-channel flood, greenways, and irrigation ditches are currently only resourced to address contractual obligations, known hot-spots, and/or coincident with storm-driven events. Although the two systems have similar volumes of maintenance demands, they are not similarly allocated staff and equipment resources and would benefit from resources that would allow a complete preventive and proactive maintenance cycle every 10 to 15 years.

[19] *Does not include support staff in neighboring departments such as Planning and Development Services*

The Utility has budgeted for six project engineers and project managers and current staffing level is three FTEs. The Utility is endeavoring to fill these positions and can use additional consultant support as a stopgap measure. However, the Utility may not be able to advance the planned capital improvement program unless the engineering staffing complement is augmented (i.e., several open positions must be filled).



Source: Approved 2022 City Budget

Figure 11.8 – Full-time Funded Positions (39 Total) by Work Group

Financial Policy Issues

Stormwater and flood management are critically important city functions, reflecting the city's standing as a highly flood-prone community. The Utility provides a multi-million dollar operational and capital infrastructure program, at about $20 million annually. Four attributes of effective utility funding are:

- Funding must be *stable* over time so a reasoned and efficient program can be delivered
- Funding must be *adequate* to meet the identified needs
- Funding must be sufficiently *flexible* to serve the diverse elements of the program and, especially, changing priorities over time
- Funding must *equitable* to ensure long-term community acceptance and support

Policy Discussion

The level of funding, resources, and tools needed to carry out the required functions of the Utility is a fundamental consideration. Three aspects should be considered:

- How much is currently spent on operations, capital infrastructure improvement, debt financing, allocations to operating and emergency response reserves, and bond debt coverage? Is that level of funding adequate to get the job done?
- What type and amount of funding will be needed in the future to accomplish the goals and objectives set forth in this and the Stormwater Master Plans?
- In the context of future program expectations, management policies, and risk exposure, what is a prudent / appropriate year-end balance in the Utility's accounting fund?

The purpose of funding policy is to provide funding guidance and ensure associated financial management resources are available to carry out the stormwater and flood management program. Policy recommendations in furtherance of these objectives is included below.

Future Funding Methods and Mechanisms

Additional funding methods and financial management tools may be available that could buttress the Utility's funding, such as cooperative cost sharing and federal and state grants and loans. With the service fees providing over 90% of the Utility's revenue, these remain the singular most stable and robust revenue source.

Grants and Loans

There are continued and new opportunities for federal and state grants and loans, which can augment the Utility's funding capacity. For instance, the Utility recently obtained grant funding from HUD and the Federal Highway Administration for approximately 35 percent of the Wonderland Creek flood mitigation project. Other grants and loans that the city may wish to pursue include:

BRIC Grants

City staff routinely evaluate and apply for federal grants like the Building Resilient Infrastructure and Communities (BRIC) grant through FEMA. BRIC is FEMA's pre-disaster hazard mitigation program that replaces the existing Pre-Disaster Mitigation (PDM) program.

IIJA Loans and Grants

The Infrastructure Investment and Jobs Act (IIJA) is a five-year, $1.2 trillion infrastructure package that was signed into law in November 2021. The first-year allotment of the nearly $43.5 billion in total SRF funding that has been provided to the State of Colorado is a total of $121,347,000 with $14,354,000 dedicated to the Clean Water State Revolving Fund (CWSRF). EPA encourages states to strategically use funds from the Bipartisan Infrastructure Law (BIL) as a catalyst to continue building and maintaining a robust project pipeline of SRF projects. EPA recommends states use practices already exemplified in some SRF programs, such as simplifying and streamlining their application process and encouraging integrated and regional approaches (Bipartisan Infrastructure Law | US EPA). High-level outcomes of the law include:

- **WIFIA.** Reauthorizes the Water Infrastructure Finance & Innovation Act (WIFIA) loan program at $50 million annually for U.S. projects.
- Provides $1.4 billion over five years for **Sewer Overflow and Stormwater Reuse** municipal grants.
- **Storm Act.** Provides $100 million annually, over five years for the Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act. The STORM Act was enacted earlier this year and creates a Resilience Revolving Loan Fund.
- **BRIC Funding.** Makes an additional $1 billion available in grants for the FEMA BRIC Program.

All of these are highly competitive grants or loans, and staff endeavor to apply for these when a project is well positioned for award. Before applying, the city considers how the grant is structured and evaluated and applies when positioned to submit a qualified/competitive proposal. Staff will continue to monitor city projects for funding program applicability and apply when appropriate.

Rate Methodologies

The Utility conducts regular rate methodology reviews and adopts updates as needed. In the case of utilities (e.g., water, wastewater, stormwater) that provide a commodity or service, utility service charges are based on the ratepayers' service demands which means the more demand or use a customer makes of the services, the more they should pay.

Service charges can also be augmented with modifications and other funding methods. Similar to the city, some utilities use a combination of a fixed base charge per account with variable charges that reflect differences in service demands across customer classes (e.g., single-family residential versus commercial, industrial, and institutional groups). Fixed base charges may also vary among different classes of customers. Many stormwater utilities provide a system of credits and offsets against service charges to recognize unusual property conditions or activities that reduce the demands imposed on the utility program and facilities and it's cost of service.

Data associated with each class of customer, and even individual customers, can be manipulated in various ways in a service charge calculation. Over eighty percent (80%) of stormwater utilities use impervious coverage as the primary, or even sole, parameter for calculating stormwater service charges. Some have just one customer class encompassing all single-family residences. Others group residential customers in tiers. Customers may be grouped in a few classes, or several dozen.

Impervious area has been the primary parameter employed in Boulder since the initial rate methodology was adopted in 1973. The manner in which impervious area is measured, estimated, or calculated and how it is treated in the service charge calculation has evolved over the past fifty years. The city needs to periodically reassess how the service charge and PIF rate methodologies fit with the changing program and costs.

Annual Service Charge Rate Adjustment / Biannual Update Analysis

The city's primary financial management tool is the annual budget process, which addresses both costs and revenues. The city's approach is to conduct the analyses and formally appropriate funding for the following calendar year. In addition, the city forecasts future operating, capital budgets, and revenues for a six-year period in less detail for financial planning purposes, providing a glimpse of the future budget but only locking in the first year by formal City Council adoption.

The city has routinely adjusted service charge and/or PIF rates annually (ramping) rather than on a longer interval (stepping), consciously integrating the rate analysis process into the budget process. Management of the Utility during the year benefits from linking rate management with budgeting. To maintain that connection with the city's budget process, an annual rate evaluation should also incorporate a projection for the next year.

Debt Versus Expensed Funding for Major Capital Infrastructure

The city employs both annually budgeted (cash funded) and debt-financed funding of major capital infrastructure. The latter allows the Utility to expedite property and equipment acquisitions and to make costly improvements to the stormwater and flood management facilities. When very costly improvements must be built, like major flood improvements, bonding is the practical funding mechanism.

Debt funding can enhance the equity of cost apportionment over time by extending the payment period for capital infrastructure that has a service life over several generations and future land development conditions. Given that the Utility's stormwater and flood management service charges are limited to developed properties with impervious area, undeveloped properties don't participate financially. The city normally sells revenue bonds with a twenty-year repayment schedule, which allows the Utility to spread costs across both currently developed properties and those that will be developed during that bonding period.

Incorporating Sustainability and Resilience as Financial Considerations

Leadership in fiscal resilience is making the city better equipped to respond to and recover from economic shocks, whether this is withstanding a global recession or responding to a major event (Boulder, 2016). One of the city's primary financial policies is that one-time revenues shall only be used to cover one-time expenses and that ongoing costs should not be greater than ongoing revenues.

Recognizing that the utilities around the world are facing a volatile, uncertain, complex, and ambiguous landscape, creating and maintaining a sustainable and resilient community requires a keen understanding of current impact and future financial implications over the long-term. Sustainability and resilience require both the capacity to respond quickly and the ability to do so over years.

The functionality of stormwater and flood management systems must be maintained over time, which requires a complex and dynamic set of activities ranging from inspection to cleaning, repair, and replacement. However, the sustainability of a stormwater and flood management program is not solely a matter of ensuring that the systems and services provided continue to function effectively; it also involves financial sustainability. Income from various sources must be sufficient to pay for operational and capital costs and meet operating and emergency reserve objectives far into the future.

For example, the asset management system has illuminated the challenge of maintaining and replacing legacy stormwater systems. The asset management system should be elevated as a priority with continued resources applied to the stormwater and flood management facilities as soon as practicable.

Refinement of the Future Program Budgets through Cost of Service Analyses

Cost of service analyses serve other purposes beyond budgeting and program management. Reasonably detailed and accurate cost projections are essential when service charge and PIF rate studies are conducted. They also foster effective use of the Utility's asset management system.

This Master Plan provides abundant information that would inform a cost of service analysis, including both the current functions performed by the Utility as well as major trends in flood management, stormwater drainage, and stormwater quality. That look into the future illuminates emerging issues and opportunities that may impact the city and the Utility in the future. Future costs can be more easily and reliably forecast with regular updates.

Recommendations

The Utility's financial strategy is to provide adequate resources to support the planning, construction, and operations and maintenance of capital improvement projects and meet regulatory compliance requirements. Revenues are tied to a "user pays" model largely around the amount of impervious surface area.

The recommendations presented herein address funding and financial management. They support the Stormwater and Flood Management Utility, policy issues addressed above, and the goals and objectives of the Master Plan.

20-year CIP Development

- Apply the Prioritization Framework to remaining projects to develop a 20-year CIP for the Utility, including evaluation of external funding sources.
- Annually update the Prioritization Framework and, upon City Council approval of the Budget Book, commence design and construction of the approved, prioritized, projects.

Future Funding Methods and Mechanisms

- Assess a range of potential funding methods and mechanisms to optimize and diversify funding sources.

Rate Methodologies

- Continue to review and update service charges and rate methodologies to: 1) maintain currency of the structure with industry practice and standards; 2) reflect strategic objectives and costs; and, 3) ensure that apportionment of costs across the community equitably reflect the service demands and impacts.

Annual Service Charge Rate Adjustment / Biannual Update Analysis

- Adjust service charge rates annually as part of the budget process to meet program strategy, expenditure, and fund balance objectives.
- Conduct an analysis of the rates on an annual planning timeframe to assess short-term revenue sufficiency to meet strategic, operational, capital investment, and fund balance objectives.
- Reassess the technical structure of the service charge rate methodology and the PIF methodology every five to eight years to determine consistency with city policies, evolving functions of the Utility, availability of other funding mechanisms, other policy objectives, and the BVCP requirements.

Debt Versus Expensed Funding for Major Capital Infrastructure

- Use revenue-bonded debt funding for an increasing portion of the Utility's capital infrastructure needs, reducing reliance on the Utility's annually budgeted expenditures to fund capital infrastructure, expediting improvements in operational functions, improving asset management, and enhancing the temporal equity of capital infrastructure cost apportionment.

Incorporating Sustainability and Resilience as Financial Considerations

- Incorporate the city's sustainability and resilience objectives and their impact on financial considerations in the Utility's policies, strategic program planning, budgeting process, and operations.
- In coordination with the city's budget process, the Utility should perform a regular assessment of possible service charge and PIF rate adjustments necessary to maintain a sustainable utility.

Refinement of the Future Program Budgets through Cost of Service Analyses

- Undertake a long-range but relatively detailed cost of service analysis to refine future financial planning and budgeting.
  - Examine a five to eight-year time frame on cost of service analyses.
  - Include a level of detail that is sufficient to support annual service charge and PIF rate reviews.
- Cost of service projections should be reassessed every two years in coordination with city's annual budget process (which provides a one-year appropriation with a subsequent 5-year CIP projection) and refined as needed through service charge and PIF rate studies.

References

Barnes, G. (2015). *Key Financial Indicators for Water and Wastewater Systems: Debt Service Coverage Ratio*. Accessed at: Key Financial Indicators for Water and Wastewater Systems: Debt Service Coverage Ratio - Environmental Finance Blog (unc.edu).

Boulder, City of. (2021). City of Boulder 2022 Approved Budget. Accessed at Budget | City of Boulder (bouldercolorado.gov)

Boulder, City of. (2021). Prior Year Budgets. Accessed at Prior Year Budgets | City of Boulder (bouldercolorado.gov)

Boulder, City of. (2021). Water Resources Advisory Board Agenda Item "Draft Proposed 2022-2027 6-year Capital Improvement Program (CIP) Water, Wastewater and Stormwater/Flood Management.

Boulder, City of. (2017). City Council Agenda Item, "Utility Rate Structures Study Update", Meeting date May 2, 2017.

Boulder, City of. (2016). City of Boulder Resilience Strategy

Boulder, City of (1981, as revised). Boulder Charter and Revised Code. Accessed February 2, 2022 at BOULDER CHARTER AND REVISED CODE | Municipal Code | Boulder, CO | Municode Library.

Boulder, City of. (2004). Comprehensive Flood and Stormwater Master Plan. Chapter 7 – Financial Considerations, 6 pp.

McCartney, A. (2019). *Enhancing Your Utility's Long-Term Financial Sustainability & Resilience through Cash Reserves.* Water Finance and Management. Accessed from: *Enhancing Your Utility's Long-Term Financial Sustainability & Resilience through Cash Reserves* - Water Finance & Management (waterfm.com). Enhancing Your Utility's Long-Term Financial Sustainability & Resilience through Cash Reserves - Water Finance & Management (waterfm.com)

McCartney, A. (2019). *Capital Reserves, Debt Service & Rate Stabilization Reserves.* Water Finance and Management. Accessed at: *Cash Reserves Pat. 2: Capital Reserves, Debt Service & Rate Stabilization Reserves* - Water Finance & Management (waterfm.com). Cash Reserves Pt. 2: Capital Reserves, Debt Service & Rate Stabilization Reserves - Water Finance & Management (waterfm.com)

National Association of Flood and Stormwater Management Agencies. (2006). Guidance for Municipal Stormwater Funding. Accessed at: Guidance for Municipal Stormwater Funding (epa.gov).

Raftelis Financial Consultants. (2017). Draft Memorandum entitled "Utility Rate Analysis Phase 2 – Analysis of Wastewater and Stormwater Rate Alternatives, dated January 9, 2017.

Royster, S. (2013). *More on Reserve Funds: How Much is Too Much*, accessed at: More on Reserve Funds: More on Reserve Funds: How Much Is Too Much? - Environmental Finance Blog (unc.edu)

12 Glossary of Terms

Acronym	Term	Definition
	100-Year Flood/ Base Flood / 1% Annual Chance	A flood event that statistically has a 1 out of 100 (or one percent) chance of being equaled or exceeded on a specific watercourse in any given year. The term does not imply that the flood will necessarily happen once every one hundred years.
	100-Year Floodplain	All land areas subject to inundation by floodwaters in a flood event having a one percent chance of being equaled or exceeded in any given year. A structure in the 100-year floodplain has a 26 percent chance of flooding at least once over a 30-year mortgage.
	500-Year Floodplain	All land areas subject to inundation by floodwaters in a flood event having a 0.2 percent chance of occurring in any given year.
	Alluvial Fan	A geomorphologic feature characterized by a cone or fan-shaped deposit of boulders, gravel, and fine sediments that have been eroded from mountain slopes, transported by flood flows and then deposited in the valley floors and which is subject to flash flooding, high velocity flows, debris flows, erosion, sediment movement and deposition, and channel migration.
	As-Built Plans	A community may require submission of “as-built” plans to certify that a project was built in accordance with the permit. A registered professional architect or engineer certifies the actual construction.
	Atlas 14	Precipitation frequency estimates for selected durations and frequencies based on statistical analysis performed by NOAA. Eleven volumes are published and updated for the United States and selected territories. This information is used in the sizing and design of stormwater and flood infrastructure.
BFE	Base Flood Elevation	A base flood elevation is the height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum o f1929, the North American Vertical Datum of 1988, or other datum referenced in the Flood Insurance Study report, or the depth of the base flood, usually in feet, above the ground surface.
BMP	Best Management Practice	Methods for preventing or reducing non-point source pollution from entering adjacent water bodies.
	Borrow Ditch	A roadside drainage ditch. (*see Channel*)
BRC	Boulder Revised Code	A document that contains ordinances adopted by City Council, including the City’s floodplain regulations and the Stormwater and Flood Management Utility.

Acronym	Term	Definition
BVCP	Boulder Valley Comprehensive Plan	A comprehensive plan that includes policies to guide decisions about growth, development, preservation, environmental protection, economic development, affordable housing, culture and arts, urban design, neighborhood character, and transportation within the Boulder Valley. It serves to inform decisions about the manner in which urban services are provided, including water utilities and flood control.
	Braided Stream	A stream whose flow is divided at normal stage by small islands.
	Capacity	The volume of water stored by a dam at the emergency spillway elevation, usually expressed in acre-feet. It differs from storage, which is the volume of water stored at any specific elevation.
CIP	Capital Improvement Program	A six-year plan for all City departments which identifies physical public projects or equipment purchases, provides a planning schedule, estimates costs, and forecasts available funding.
	Catch Basin	A chamber or well, usually built at the curb line of a street, for the admission of surface water to a storm sewer or sub-drain.
	Channel	An open conveyance of surface stormwater having a bottom and sides in a linear configuration. Channels can be natural or man-made. Channels can have levees or dikes along their sides to build up their depth. Constructed channels can be plain earth, landscaped, or lined with concrete, stone, or any other hard surface to resist erosion and scour.
CDPHE	Colorado Department of Public Health and Environment	A State department that serves Coloradans by providing public health and environmental protection services that promote healthy people in healthy places. CDPHE is responsible for services related to this Plan, such as water quality protection, emergency preparedness, and pollution prevention.
CRS	Community Rating System	A program administered by FEMA that recognizes and rewards communities working to reduce flood damages through a variety of approved floodplain management and flood awareness activities. Through the program, a community can reduce the flood insurance premiums that flood prone property owners pay. Discounts can range from 5% to 45% based on CRS credit points that are awarded under 19 public information and floodplain management activities.
CFS	Comprehensive Flood and Stormwater Utility Master Plan	Document that provides a framework for implementing various programs in projects in the Stormwater and Flood Management Utility.
	Conveyance Zone	The areas in the floodplain that are reserved for the main passage of the entire 100-year flood flow when the 100-year floodplain is artificially narrowed until a maximum six-inch increase in flood water depth is created. This zone is delineated to allow development to occur up to the narrowed floodplain and still provide passage of 100-year storm flows.

Acronym	Term	Definition
cfs	Cubic Feet per Second	Typical unit of measure to quantify the flow rate of water or the amount of flow in a wash. One cubic foot is equivalent to 7.5 gallons of water. Thus, 1 cfs is 7.5 gallons of water passing by a reference point every second.
	Culvert	A hydraulically short conduit which conveys surface water runoff through a roadway embankment or through some other type of flow obstruction.
	Delineation	Defining the physical boundaries of a stream, floodplain, jurisdictional wash, etc.
	Design Discharge	The nth-year storm for which it is expected that the structure or facility is designed to accommodate.
	Detention Basin	A basin or reservoir where water is stored for regulating a flood. It has outlets for releasing the flows during the floods.
	Discharge	The amount of water that passes a specific point on a watercourse over a given period of time. Rates of discharge are usually measured in cubic feet per second (cfs).
	Drainage Basin	A geographical area which contributes surface water runoff to a particular point. The terms “drainage basin”, “tributary area”, and “watershed” can be used interchangeably.
	Drainage Ditch	(*see Channel*)
	Ecosystem Services	Benefits provided to the human population by functioning and healthy ecosystems. Examples of benefits include access to clean water, temperature regulation, and resistance to the effects of climate change.
	Elevation Certificate	The Elevation Certificate is an important administrative tool of the National Flood Insurance Program (NFIP). It is to be used to provide elevation information necessary to ensure compliance with community floodplain management ordinances, to determine the proper insurance premium rate, and to support a request for a Letter of Map Amendment or Revision (LOMA or LOMR-F). Download the Elevation Certificate Instructions or Form from FEMA.
	Embankment	A man-made earth structure constructed for the purpose of impounding water.
	Emergency Spillway	An outflow from a detention/retention facility that provides for the safe overflow of floodwaters for large storms that exceed the design capacity of the outlet or in the event of a malfunction. The emergency spillway prevents water from overtopping the facility.
	Encroachment	The result of placing a building, fence, berm or other structure in a floodplain in a manner that obstructs or increases the depth (or velocity) of flow on a watercourse.

Acronym	Term	Definition
	Evapotranspiration	Evapotranspiration is the sum of water lost to the air via transpiration by plants and evaporation from water surfaces and soils.
FEMA	Federal Emergency Management Agency	An independent federal agency established to respond to major emergencies that state and local agencies don't have the resources to handle. FEMA seeks to reduce the loss of life and protect property against all types of hazards through a comprehensive, risk-based emergency management program. FEMA website
	FEMA Flood Zones:	
	Zone A (unnumbered)	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones. Mandatory flood insurance requirements apply.
	Zone AE and A1-30	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. In most instances, base flood elevations derived from detailed analyses are shown at selected intervals within these zones. Mandatory flood insurance requirements apply.
	Zone AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones. Mandatory flood insurance requirements apply.
	Zone AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones. Mandatory flood insurance requirements apply.
	Zone B, C, and X	Areas outside the 1-percent annual chance floodplain, areas of 1% annual chance sheet flow flooding where average depths are less than 1 foot, areas of 1% annual chance stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 1% annual chance flood by levees. No Base Flood Elevations or depths are shown within this zone. Insurance purchase is not required in these zones.
	Zone D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

Acronym	Term	Definition
	FEMA Special Flood Hazard Areas	A flood prone area that has been mapped and accepted by FEMA as the result of a flood insurance study (FIS) for a watercourse and surrounding areas. Mapped floodplains are used for flood insurance needs and for other regulatory purposes.
	Fill Material	Any material used for the primary purpose of replacing an aquatic area with dry land or for changing the bottom elevation of a waterbody. This includes both natural materials (silt, sand, gravel, rock, and wood) and manufactured materials (concrete, plastic, steel, treated wood).
	Flood Mitigation Measures, Nonstructural	A set of techniques that do not change the physical shape of natural drainage channels and have little to no impact on the characteristics or extent of the flood itself. Methods are designed to alter the impact or consequences of flooding by eliminating exposure (i.e., removing structures) or reducing vulnerability of people and the built environment within the floodplain as it currently stands.
	Flood Mitigation Measures, Structural	A set of techniques that modify the natural channel and/or associated riparian (overbank) area to reduce flooding extents and allow adequate room for the passage of floodwaters for the purposes of protecting people and property.
	Floodplain	Areas adjacent to a stream or river that are subject to flooding during a storm event.
	Floodplain Management	A program that uses corrective and preventative measures to reduce flood and erosion damage and preserve natural habitat and wildlife resources in flood prone areas. Some of these measures include: adopting and administering Floodplain Regulations, resolving drainage complaints, protecting riparian habitat communities, and assuring effective maintenance and operation of flood control works.
	Floodplain Regulations	Adopted policies, codes, ordinances, and regulations pertaining to the use and development of lands that lie within a regulatory floodplain.
	Floodplain Development Permit	An official document which authorizes specific activities within a regulatory floodplain or erosion hazard area.
	Floodway	The channel of a watercourse and portion of the adjacent floodplain that is needed to convey the base or 100-year flood event without increasing flood levels by more than one foot of floodwater.
	Floodway Fringe	The areas of a delineated floodplain adjacent to the Floodway where encroachment may be permitted.
	Flow Split	When floodwater junctions with one upstream reach and multiple downstream reaches.
	Fluvial Flooding	Flooding that occurs due to water overtopping the banks of rivers and creeks.

Acronym	Term	Definition
FHZ	Fluvial Hazard Zone	The area a stream has occupied in recent history, may occupy, or may physically influence as it stores and transports water, sediment, and debris.
	Grade Control Structure	A structure used across a stream channel placed bank to bank to control bed elevation, velocity, pressure, etc.
GI	Green Infrastructure	An approach to stormwater management that protects, restores, or mimics the natural water cycle.
	Greenways	The City of Boulder Greenways system is comprised of a series of corridors along riparian areas including Boulder Creek and 14 of its tributaries, which provide an opportunity to integrate multiple objectives, including habitat protection, water quality enhancement, storm drainage and floodplain management, trails, recreation and cultural resources.
	Groundwater	Water within the earth that supplies wells and springs; water in the zone of saturation where all openings in rocks and soil are filled; the upper surface of which forms the water table.
	High Hazard Zone	The area of the floodplain where water depth and velocity pose a threat to life and safety. This area is delineated for areas in the floodplain where water velocity multiplied by water depth equals or exceeds the number four or where flood waters are predicted to be over four feet deep.
	Hydraulic Structures	The facilities used to impound, accommodate, convey, or control the flow of water, such as dams, intakes, culverts, channels, and bridges.
	Hydraulics	A field of study dealing with the flow pattern and rate of water movement based on the principles of fluid mechanics.
	Hydrograph	A graph of flow, or discharge over time.
	Hydrology	A field of study concerned with the distribution and circulation of surface water, as well as water dynamics below the ground and in the atmosphere.
	Hyetograph	A graph of rainfall intensity over time.
	Impoundment	Floodwater stored in a basin or behind a dam. It can be described in terms of a water depth (ft) or a volume (acre-ft).
	Infiltrated Stormwater	Precipitation that infiltrates into the ground but is located above the zone of saturation.
	Infiltration	The downward movement of water from the surface into the soil, as contrasted with percolation which is the movement of water through soil layers.
	Intensity	When applied to rainfall, intensity is the depth of rain in a specified time. Examples are 1 inch per hour or ½ inch in 20 minutes.

Acronym	Term	Definition
	Irrigation Ditch	A channel owned by a private irrigation company to deliver water associated with water rights to a downstream beneficial use.
	Lateral Stream Migration	Change in position of a channel by lateral erosion of one bank and simultaneous deposition on the opposite bank.
LOMA	Letter of Map Amendment	An official amendment of a current Flood Insurance Rate Map (FIRM) accepted by FEMA for a property or a structure. The LOMA verifies that the structure or portions of the property have been removed from a designated-floodplain area.
LOMR	Letter of Map Revision	An official revision of a current Flood Insurance Rate Map (FIRM) accepted by FEMA, which reflects changes in mapped areas for flood zones, floodplain areas, floodways and flood elevations.
LOMR-F	Letter of Map Revision Based on Fill	An official revision of a current Flood Insurance Rate Map (FIRM) accepted by FEMA, based on the placement of fill outside of the regulatory floodway (Conveyance Zone). Often used to remove an area of land from an existing regulatory floodplain.
	Levee	A man-made structure, usually an earthen embankment often reinforced with soil cement, that is designed to contain or divert the flow of water.
	Low Flow Channel	A channel within a larger channel which typically carries low and/or normal flows.
LID	Low Impact Development	Stormwater management and land development strategies that emphasize conservation and the use of onsite natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-development hydrologic functions.
MHFD	Mile High Flood District	An independent, special district that assists local governments in the Denver metropolitan area with multi-jurisdictional drainage and flood control challenges. MHFD offers numerous services that cover flood management, stream mitigation, stormwater, research, and more. (Previously called Urban Drainage and Flood Control District, UDFCD).
MS4	Municipal Separate Storm Sewer System	A single conveyance or a network of conveyances such as storm drains, pipes, gutters, streets, ditches, and others owned by a public entity which is designed or used to collect or convey stormwater runoff to be discharged into local water bodies.
NFIP	National Flood Insurance Program	A federal program that allows property owners to purchase insurance protection against losses due to flooding. In order to participate in this program, local communities must agree to implement and enforce measures that reduce future flood risks in special flood hazard areas.

Acronym	Term	Definition
NOAA	National Oceanic and Atmospheric Administration	A federal agency established to forecast weather, monitor oceanic and atmospheric conditions, and perform other functions related to the exploration and protection of oceans. NOAA is responsible for the National Weather Service, publishing Atlas 14, and researching climate change.
NPDES	National Pollutant Discharge Elimination System	A permit program established by the Clean Water Act which addresses water pollution by regulating point sources that discharge pollutants into waters of the United States. The program is administered and enforced by states under the direction of the EPA.
	Nature-Based Solutions	Structural flood mitigation measures that incorporate engineering practices to design modified channels and associated floodplains to protect people and property while also restoring or creating adaptive ecosystems.
O&M	Operations and Maintenance	Required maintenance activities and measures associated with infrastructure.
	Outlet Structure	A hydraulic structure placed at the outlet of a channel, spillway, pipe, etc., for the purpose of dissipating energy and providing a transition to the channel or pipe downstream.
	Pre-Development Conditions	Existing conditions that are present prior to pending development or redevelopment on a site. Does not refer to fully undeveloped conditions that existed prior to any previous development.
	Pluvial Flooding	Localized flooding that is independent of an overflowing water body, often caused by intense precipitation events.
	Point Source Pollution	Any discernible, confined, or discrete conveyance such as a pipe, ditch, channel, tunnel, or other, that discharges an industrial, municipal or agricultural waste into a water of the United States.
ROW	Right-of-Way	The entire width of land between the public boundaries or property lines that is acquired for or devoted to the construction of roads.
TM	Technical Memorandum	
TMDL	Total Maximum Daily Load	The total amount of a pollutant that a stream can contain in a day. TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.
TSS	Total Suspended Solids	The total amount of particulate matter that is suspended in the water column.
	Peak Flow	The maximum rate of flow through a watercourse for a given storm.
	Percolation	The movement of water through the subsurface soil layers, usually continuing downward to the groundwater or water table reservoirs.
	Precipitation	All forms of water that fall to the earth's surface - including rain, snow, sleet, and hail.

Acronym	Term	Definition
	Regulatory Floodplain	A portion of the geologic floodplain that may be inundated by the base flood where the peak discharge is 100 cubic feet per second (cfs) or greater. Regulatory floodplains also include areas which are subject to sheet flooding, or areas on existing recorded subdivision plats mapped as being flood prone.
	Retention Basin	A basin or reservoir where water is stored for regulating a flood. Unlike a detention basin, it does not have outlets for releasing the flows, the water must be disposed by draining into the soil, evaporation, or pumping systems. These facilities are not used in Boulder.
	Recurrence Interval / Return Period	The average time interval between occurrences of a hydrological event of a given or greater magnitude, usually expressed in years. It is a statistical measurement typically based on historic data denoting the average recurrence over an extended period of time. Technically, it is the inverse of the probability that the event will be exceeded in any one year.
	Riparian Habitat	Plant communities that occur in association with any spring, cienega, lake, watercourse, river, stream, creek, wash, arroyo, or other body of water. Riparian habitats can be supported by either surface or subsurface water sources.
	Riparian Zone	A stream and all the vegetation on its banks.
	Runoff	The portion of precipitation on land that ultimately reaches streams, especially water from rain or melted snow that flows over ground surface.
	Sediment	Soil particles, sand, and minerals washed from the land into aquatic systems as a result of natural and human activities.
	Sheet Flow	Very shallow overland discharge.
SFHA	Special Flood Hazard Area	The area where NFIP floodplain management regulations must be enforced, and where the mandatory purchase of flood insurance applies for federally backed mortgages.
	Spill	A predicted flow of water that escapes the stream channel and flows in a different direction.
	Spillway	An outlet pipe or channel serving to discharge water from a dam, ditch, gutter, or basin.
	Storage	The volume of water stored in a basin or behind a dam – usually expressed in acre-feet. It differs from capacity, which is the volume of water stored at the emergency spillway elevation.

Acronym	Term	Definition
	Stormwater	Precipitation mostly from rain or snow that that falls onto the land's surface where it either infiltrates into the soil, accumulates in depressed areas, or contributes to surface runoff. In urban areas, this surface runoff is collected and conveyed in a stormwater drainage system to a natural or man-made watercourse or conveyance system.
SCM	Stormwater Control Measure	Any structure, feature, or practice that is designed, constructed, operated, practiced, or adopted to reduce the quantity, lower the rate, improve the quality, or otherwise control stormwater runoff through detention, infiltration or other stormwater management techniques. Synonymous with best management practice (BMP)
	Stormwater Drainage System	Drainage facilities, both natural and constructed, designed to collect and convey stormwater runoff to a receiving waterbody or point of infiltration. The system includes municipal streets, catch basins, curbs, gutters, storm sewers, ditches, culverts, detention basins, and others. The system is designed to minimize disruptions and safely allow the movement of pedestrians and traffic.
	Stormwater and Flood Management Utility	City utility responsible for the administration of the city's flood management, stormwater quality, and stormwater drainage programs.
	Surface Water	Water that flows in streams and rivers and in natural lakes, in wetlands, and in reservoirs constructed by humans.
	Tailwater	The water surface elevation in the channel downstream of a hydraulic structure.
	Thalweg	The line of maximum depth in a stream. The thalweg is the part that has the maximum velocity and causes cut banks and channel migration.
	Trash Rack	A metal bar or grate located at the outlet structure of a detention or retention basin which is designed to prevent blockage of the structure by debris.
	Tributary	A stream that contributes its water to another stream or body of water.
USEPA or EPA	United States Environmental Protection Agency	A federal agency that is tasked with environmental protection through maintaining and enforcing national standards established through environmental law, conducting environmental assessments and research, and developing environmental education programs.
USDCM	Urban Storm Drainage Criteria Manual	A collection of policies, standards, and technical design criteria used by the communities within the Mile High Flood District for flood risk management, stormwater management, stormwater quality, and erosion control.

Acronym	Term	Definition
	Water of the United States (Waters of the State)	Defined by the Clean Water Act as navigable waters, tributaries to navigable waters, interstate waters, and waterbodies used by interstate commerce including recreation, fishing, and industry.
	Water Table	Level below the earth's surface at which the ground becomes saturated with water. The surface of an unconfined aquifer which fluctuates due to seasonal precipitation.
	Watershed	An area from which water drains into a lake, stream, or other body of water. A watershed is also often referred to as a basin, with the basin boundary defined by a high ridge or divide, and with a lake or river located at a lower point.
	Zone of Saturation	Layers of soil and rock where all the spaces and cracks are relatively completely filled with water. Depth may fluctuate with season and in response to precipitation patterns.
	Zoning	A set of regulations and requirements which govern the use, placement, spacing, and size of land and buildings within a specific area (zone). Zoning regulations serve to promote the public health, safety, morals, or general welfare, and to protect and preserve places and areas of historical, cultural, or architectural importance and significance.

APPENDIX A:
Policy and Program Evaluation


Sustainability, Equity & Resilience Framework
Environmentally Sustainable Community
Safe Community
Economically Vital Commuity
Good Governance
Livable Community
Accessible & Connected Community
Healthy & Socially Thriving Community
Boulder Valley Comprehensive Plan
Policy Guidance
Policy Influence*
COMPREHENSIVE FLOOD AND STORMWATER MASTER PLAN
Prioritize & Implement
Stormwater Master Plan
Drainageway Master Plans
Green Infrastructure Strategic Plan
Development Codes & Standards
E. coli Implementation Plan
Capital Improvement Program
Water Quality Strategic Plan
*CITY WIDE STRATEGIES & COMMITMENTS
• Multi-Hazard Mitigation Plan
• Greenways Master Plan
• Resilience Strategy
• Transportation Master Plan
• Climate, Ecosystems & Community
• Racial Equity Plan
• Keep It Clean Partnership
• Mile High Flood District

Policy and Program Evaluation

The Comprehensive Flood and Stormwater (CFS) Master Plan is the overarching planning document for the Stormwater and Flood Management Utility (Utility). This document provides a framework for the implementation and evaluation of the various programs and activities within the Utility. A necessary part of the evaluation is to assess both the effectiveness of these programs and activities and to determine if they are in alignment with current city policies.

Within the City of Boulder, the Community Sustainability + Resilience Framework defines community values which help set policies and priorities for the city. This includes the main guiding document, the Boulder Valley Comprehensive Plan (BVCP), which guides decisions about growth, development, and preservation, as well as what services the city provides, such as utilities and flood mitigation.

Policies are assessed as to whether the programs and activities within the Utility meet the intent of the policies presented in the BVCP and associated community values based on current implementation. An evaluation of the programs themselves will be completed to identify policy gaps to then assess whether the current policies and guiding documents adequately cover the necessary functions of the Utility.

A framework for evaluation will be established with metrics to determine whether the current programs and activities are adequate to meet the objectives of the Utility. This has not been established to date, and this update to the CFS Master Plan includes an initial evaluation framework to assess the current programs with the intent that the goals, objectives, and associated metrics will be refined to reflect the forward-looking needs of the Utility and public sentiment. A Community Working Group has been assembled to assist with the process and provide input on these items.

Policy Evaluation

Each of the BVCP policies identified in Chapter 2 were evaluated to determine whether the programs and activities in the Utility meet the intent of the identified policies. Relevant actions that relate specifically to the Utility were extracted from each policy and grouped under related policy themes to eliminate any redundant actions. As part of this exercise, nine themes were identified that relate to specific programs within the Utility; each of these themes are discussed in greater depth below.

BOULDER VALLEY COMPREHENSIVE PLAN POLICY THEMES

Flood Management Program Themes

- **Floodplain Preservation and Restoration**
- **Flood Mitigation**

Stormwater Quality Program Themes

- **Water Quality Protection**
- **Groundwater Dewatering**
- **Wetland Preservation and Restoration**

Overarching Utility Themes

- **Integrated Planning**
- **Multi-Objective Planning, Design, and Operation**
- **Provision of Services**
- **Public Engagement and Outreach**

Wonderland Creek Greenways Improvements

Floodplain Preservation and Restoration

A large number of policies within the BVCP relate to the preservation and restoration of floodplains, suggesting its importance within the city. In support of floodplain preservation and restoration, the Utility employs multiple approaches that often incorporate floodplain restoration efforts with other floodplain mitigation projects or when partnering with other departments and work groups within the city. Typical partners include the Greenways Program, Open Space and Mountain Parks, Transportation, and Parks and Recreation. Additionally, properties located in areas prone to flooding are actively purchased by the Utility, especially within the High Hazard Zone, for structure removal and use for floodwater conveyance. Restoration of land following removal of structures on these properties typically occurs as part of larger flood mitigation projects.

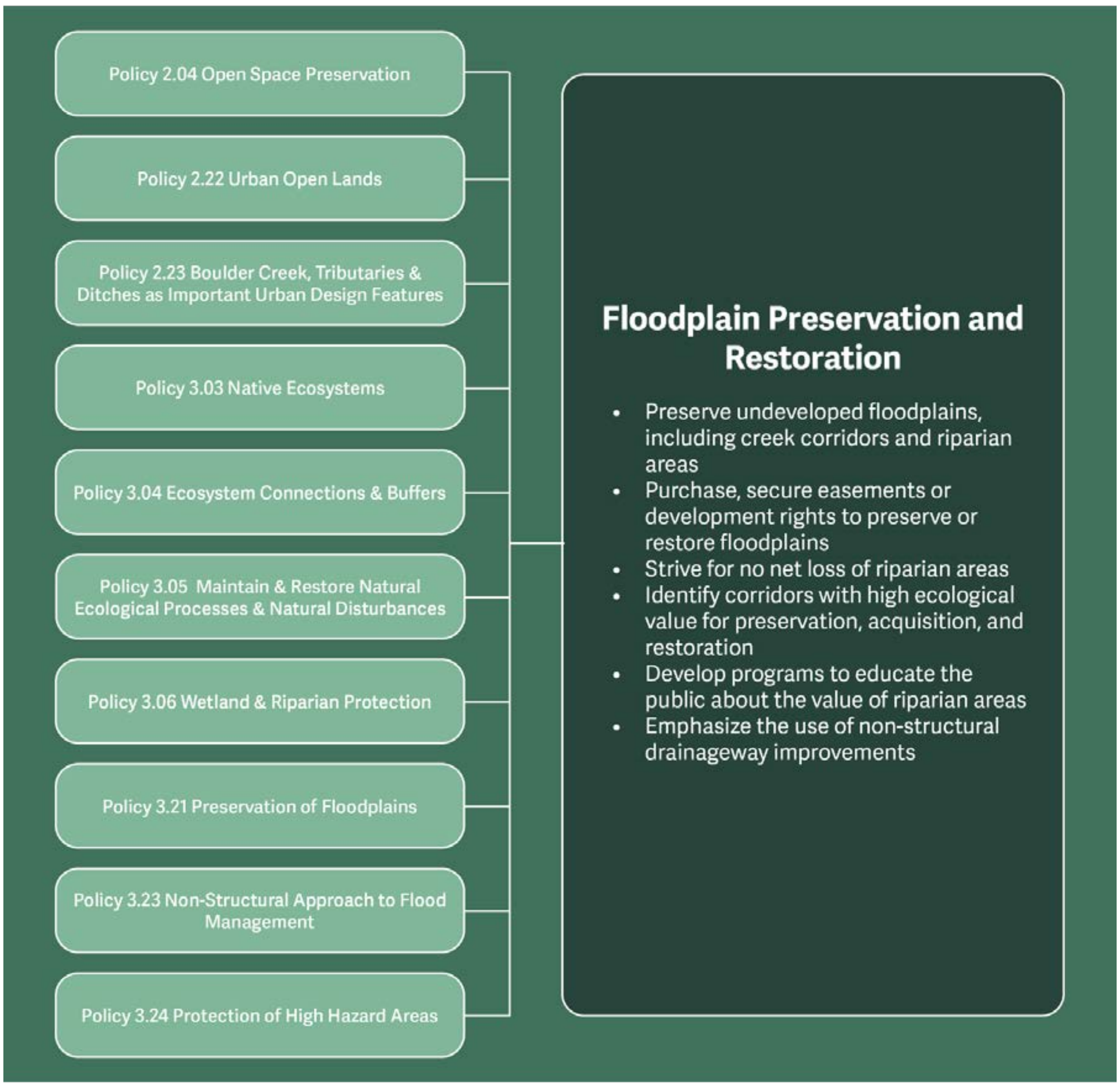
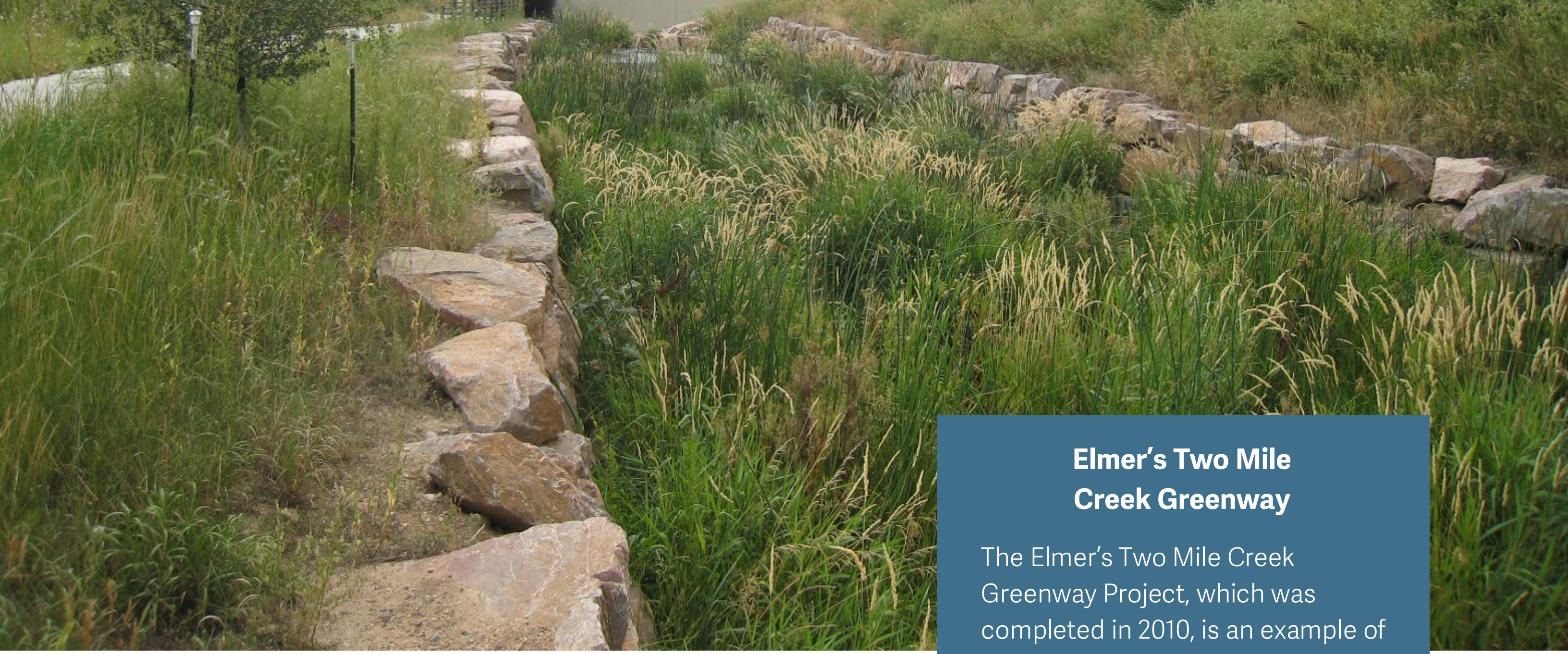


Figure 1 – Floodplain Preservation and Restoration as related to BVCP Policies



Elmer's Two Mile Creek Greenway

The Elmer's Two Mile Creek Greenway Project, which was completed in 2010, is an example of the type of floodplain restoration projects constructed by the Utility. This project was a multi-departmental effort, including assistance from the Mile High Flood District to replace an undersized, fenced-in concrete channel.

The improvements included sections with a widened natural channel bottom and an expanded naturalized floodplain in conjunction with structural drainageway improvements that could convey the 100-year flood.

Floodplain Preservation and Development Regulations

The preservation of natural floodplains, including creek corridors and riparian areas is a clear priority within the BVCP for a multitude of social, environmental, and economic reasons. Currently streams, wetlands, and water bodies are delineated and mapped with an inner and outerbuffer of 25-ft for a 50-ft total buffer area applied outside of the wetland or water body. Riparian areas are not delineated or mapped separately. Riparian areas that are located on city-owned property, on private property with conservation easements, or those with purchased development rights are protected. Creek corridors and associated buffers are protected under the Stream, Wetlands, and Water Body Protection regulations in Chapter 9-3 of the Boulder Revised Code. However, there are no protections for riparian areas that extend beyond the regulated buffers.

Floodplain regulations are used within the city to regulate land use and the type of development activities that can occur within each of the mapped floodplain zones. Current floodplain regulations in Chapter 9-3 of the Boulder Revised Code make no mention of preserving existing undeveloped floodplains or riparian areas. Instead, these regulations are used to guide development within the floodplains in a manner that primarily protects public safety and limits property damage. Regulations governing the High Hazard Zone are by far the most restrictive on development for public safety reasons and prohibit the construction of new structures in this zone. However, construction of new structures, additions onto existing structures, and floodplain fill are allowed in some form within much of the mapped floodplain zones.

In an analysis of city GIS data from 2014 to 2018, approximately 117 additional structures and roughly 1.5 acres of impervious surface area have been constructed within the 100-year floodplain. It was not possible to determine the area of fill permitted within the 100-floodplain from available GIS data.

Table 1 – 2014 to 2018 Change in Buildings and Impervious Cover within Mapped Floodplains

Mapped Floodplain Zone	Building Count		Building Footprint		Impervious Cover	
	Number	% Change	sft	% Change	Ac	% Change
500-Year Floodplain	+206	+3.9%	+396,790	+2.4%	+10.1	+0.9%
100-Year Floodplain	+117	+3.4%	+6,699	+0.1%	+1.5	+0.3%
Conveyance Zone	+15	+2.3%	-53,934	-4.9%	-2.4	-1.0%
High Hazard Zone	+15	+4.2%	-27,074	-6.8%	-2.2	-1.4%

NOTES: The conveyance zone includes the high hazard zone; the 100-year floodplain includes the conveyance zone and the high hazard zone; and the information reported for the 500-year floodplain does not include information within the 100-year floodplain

Use of Non-Structural Drainageway Improvements

Existing policies mention emphasizing the use of non-structural measures over structural methods, such as levees and constructed channels, but there exists no clear guidance within the city as to how non-structural measures are defined and when they should be used. Also, it is not clear whether these types of solutions are emphasized in planning and design or how they are prioritized. Non-structural solutions do not appear within the CIP prioritization goals for mitigation plans used by the city. Since development within these floodplains largely occurred prior to the adoption of regulations, retroactively requiring the use of non-structural drainageway improvements to expand the natural floodplain in fully developed watersheds would be impractical. Because of this, the majority of non-structural practices include floodproofing or raising of existing structures, enhanced warning systems, flood education programs, development of evacuation plans, and flood insurance. Alternatives such as naturalized channels and wide riparian areas where floods are naturally conveyed are often not feasible due to existing development within the floodplain or because the required property acquisition is prohibitive.

Stormwater and Flood Management CIP Prioritization Guiding Principles

- Life Safety (High Hazard) Mitigation
- Flood Emergency Response Capability
- Critical Facility (Vulnerable Population) Hazard Mitigation
- Property Damage Mitigation
- Collaboration with other Greenways Program Objectives
- Potential for Operation and Maintenance Cost Savings
- Accommodating New Growth and Development
- Opportunities to Leverage Outside Funding

Flood Mitigation

The flood management program within the Utility is primarily tasked with the mitigation of damage caused by floods. The BVCP addresses flood mitigation through four separate policies (**Figure 2**). Major activities conducted by the Utility include floodplain mapping, development of flood mitigation plans, design and construction of flood mitigation projects, and review and development of floodplain regulations.

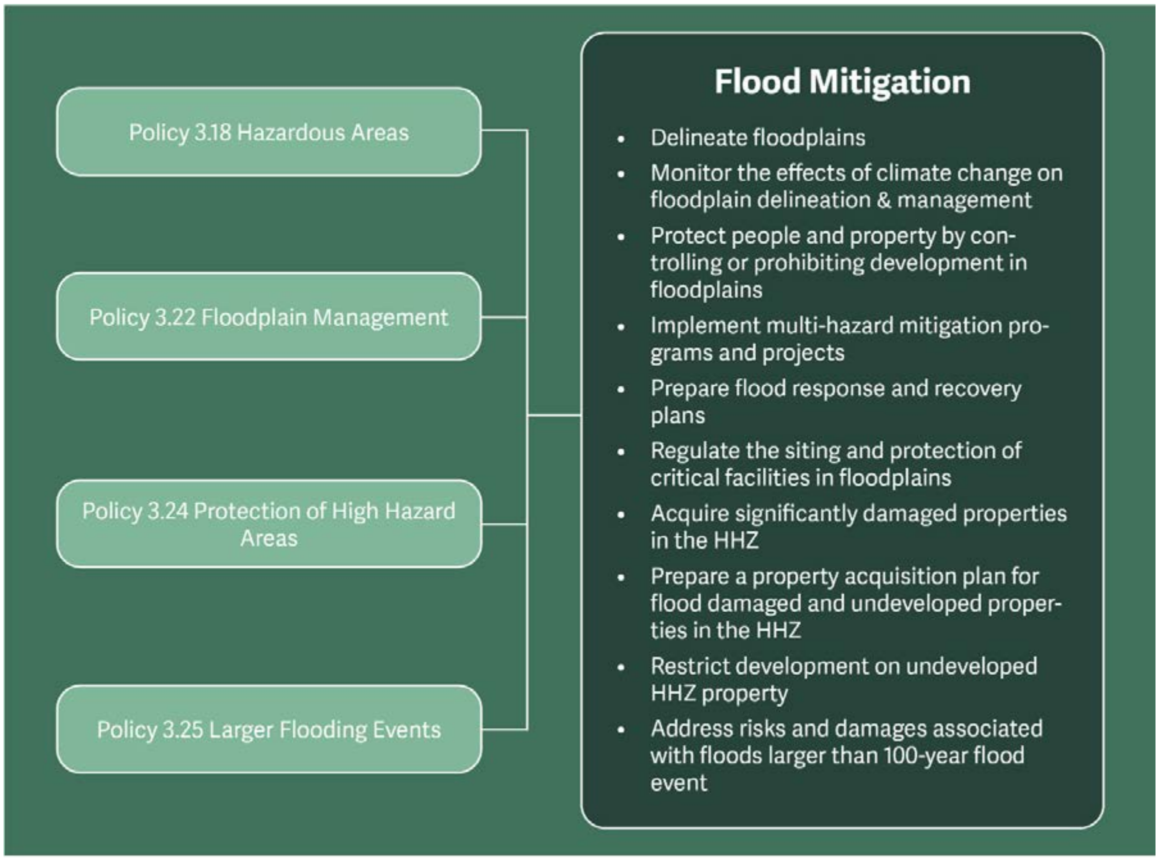
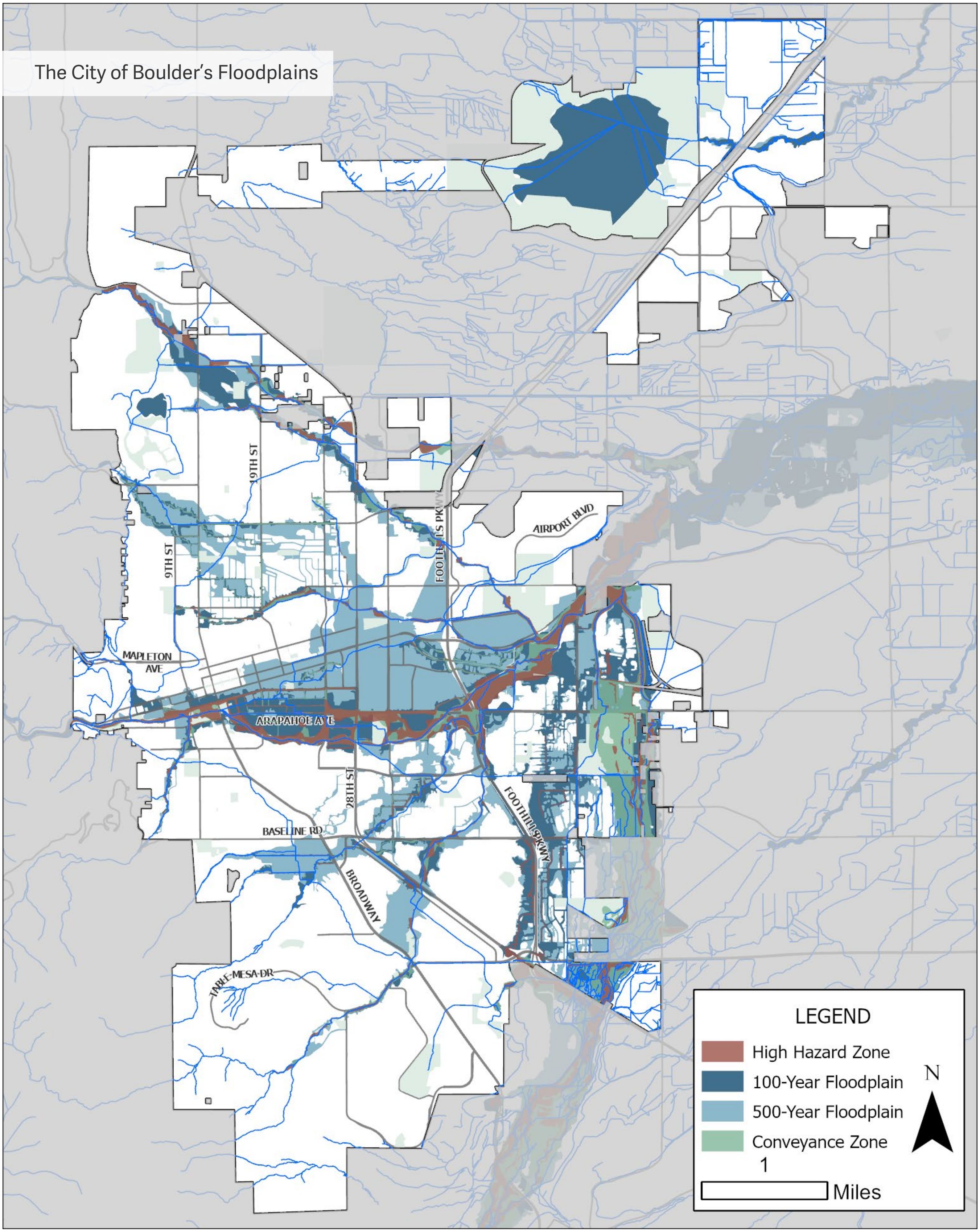


Figure 2 – Floodplain Preservation and Restoration as related to BVCP Policies

Floodplain Mapping and Regulations

The city delineates four distinct flood zones as part of floodplain mapping: High Hazard Zone, Conveyance Zone (Floodway), 100-yr floodplain (1% annual chance of occurrence), and 500-yr floodplain (0.2% annual chance of occurrence). These floodplain maps form the basis for the city's floodplain regulations and flood management program.

The city's floodplain regulations are contained in Chapter 9-3 of the Boulder Revised Code and detail land use regulations intended to reduce risk to people and property in areas along drainageways prone to flooding. In 2014, the city enacted new floodplain regulations to require emergency management plans and provide additional flood protection for critical facilities, such as hospitals, police and fire stations, day care facilities, and water treatment facilities in the 500-year floodplain.


The City of Boulder's Floodplains
19TH ST
9TH ST
FOOTHILLS PKWY
AIRPORT BLVD
MAPLETON AVE
ARAPAHOE AVE
28TH ST
BASELINE RD
BROADWAY
FOOTHILLS PKWY
TABLE MESA DR
LEGEND
High Hazard Zone
100-Year Floodplain
500-Year Floodplain
Conveyance Zone
N
1
Miles

Development of new structures and additions within the 100-year floodplain are permitted as long as the lowest floor of any residential structure is elevated to or above the flood protection elevation, which is two feet above the floodwater surface elevation. Residential basements are not permitted on residential structures in the 100-year floodplain.

Non-residential structures may be constructed below the flood protection elevation as long as floodproofing, not requiring human activation, is installed up to the flood protection elevation. Permitting of new structures requires installation of measures to protect against sanitary sewer backup. Parking lots are allowed in the 100-year floodplain as long as the predicted 100-year flood depths do not exceed 18 inches.

Development within the Conveyance Zone must comply with the 100-year floodplain regulations. Additionally, a private engineering analysis is typically required to ensure that flooding conditions are not worsened (i.e., that the floodplain will not expand or get deeper). Flood mitigation measures may be used to offset these conditions.

Regulations within the High Hazard Zone are the most restrictive due to life safety concerns. No new structures intended for human occupancy are permitted. Additionally, no new parking lots or changes of use from non-residential to residential are allowed. Regulations pertaining to any overlaying zones, such as the 100-year floodplain or the Conveyance Zone, apply as well.

Property Acquisition

The Utility's Capital Improvement Program provides funding for property acquisition in the amount of about $700,000 annually with an escalation for inflation and rising property costs. This fund allows for the purchase of properties in areas prone to flooding, especially in the city's High Hazard Zone. High-risk properties have been identified and prioritized for purchase along each of the city's major drainageways, and the Mile High Flood District has the ability to partner with the city on high-risk purchases through their Property Acquisition Reserve Fund. The city's property acquisition program has been "opportunity-based" in working with willing sellers and targeting properties that become available on the real estate market. Since 2004, seven properties have been acquired with the most recent purchases along Gregory Canyon Creek (**Figure 3**). Purchase of these properties serves to accommodate future flood mitigation improvements. Additionally, floodplain regulations for the High Hazard Zone prevent reconstruction of flood damaged properties if the property has incurred damage equal to an amount that is more than 50% of the structure's pre-flood market value.

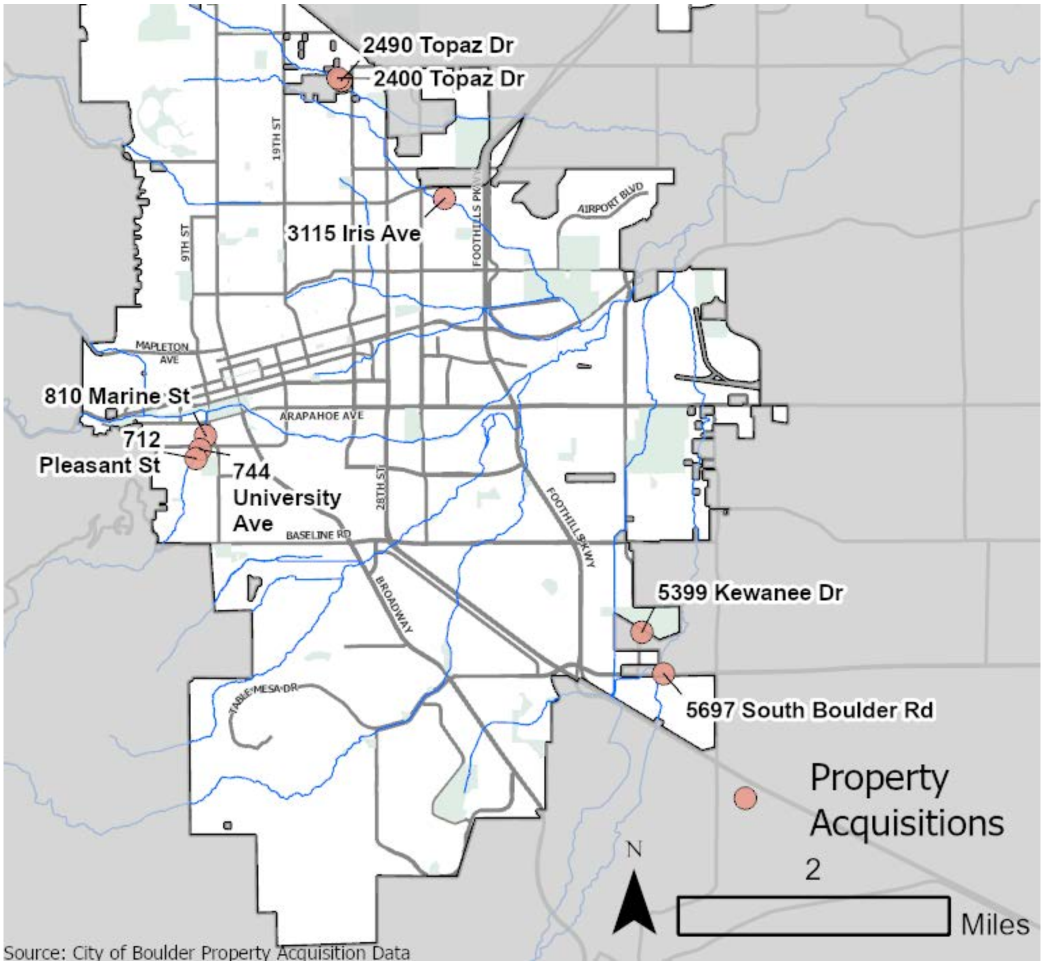
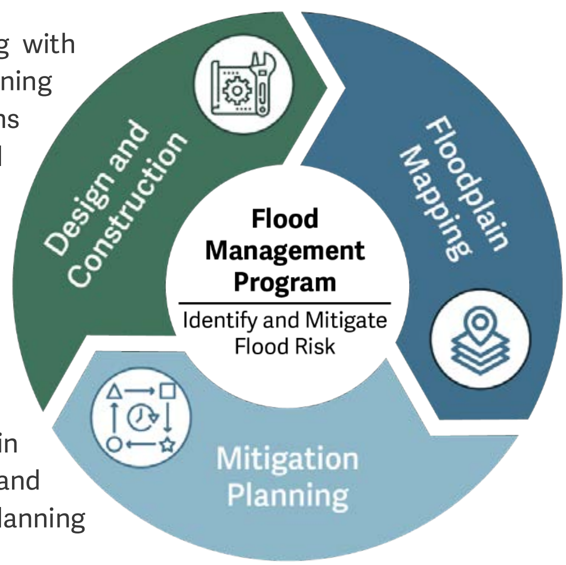


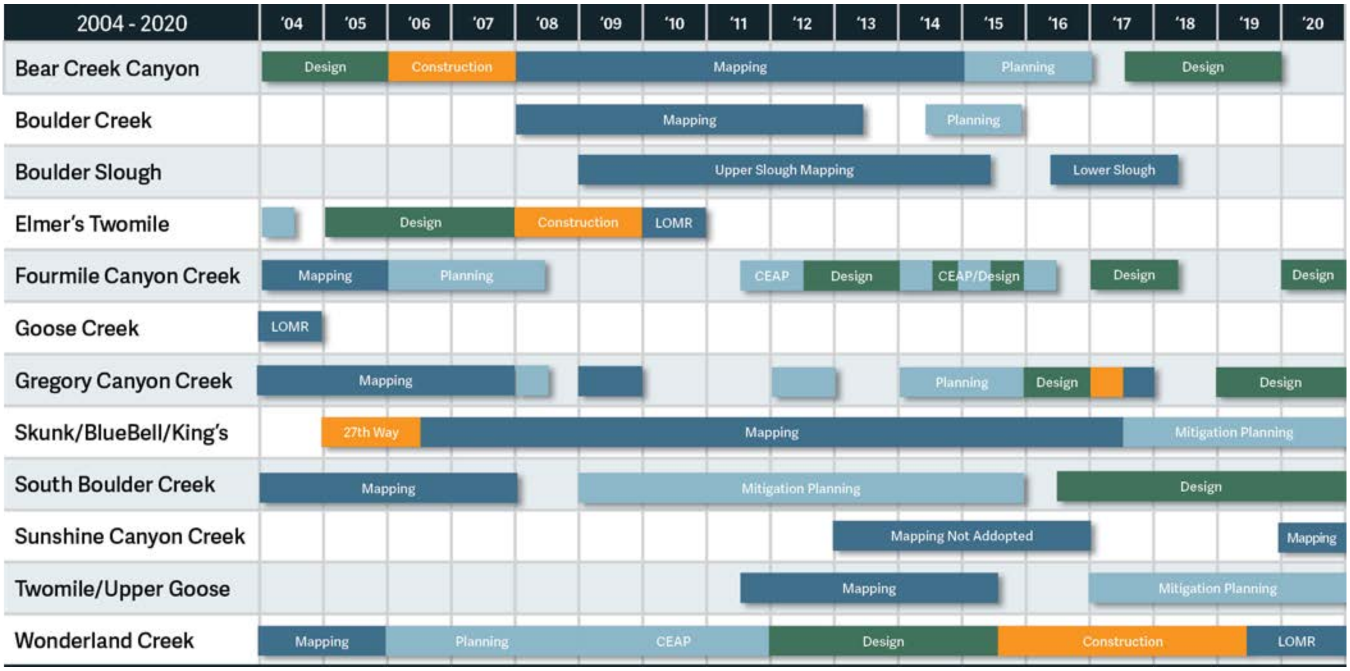
Figure 3 – Locations of Properties Purchased Since 2004

Flood Mitigation Planning Process

The flood management process is cyclical in nature, beginning with floodplain mapping to identify flood risk while mitigation planning identifies measures to reduce these risks. Flood mitigation plans identify and evaluate the benefits and costs of potential improvement projects; subsequently, projects are placed into the Capital Improvement Program for design and construction. Following significant construction projects, floodplain maps are updated to reflect the changes to the flood area.



Since 2004, floodplain mapping updates have been completed on nearly all of the city's 16 major drainageways with several mitigation plans and construction projects either completed or currently in progress. The flood mapping, mitigation planning, design, and construction process takes years to complete due to a thorough planning and public engagement process (**Figure 4**).



Note: Some drainages are grouped for mapping and mitigation purposes. Additionally Dry Creek Ditch No. 2 and Viele Channel are included in the mapping and mitigation studies for South Boulder Creek.

Figure 4 – Floodplain Mapping, Mitigation Planning, Design and Construction Project Life Cycle

Flood Response and Recovery Plans

The City of Boulder works with the Office of Disaster Management for City of Boulder & Boulder County (ODM) to provide emergency response and recovery services. As part of this work, ODM maintains an Emergency Operations Plan that covers the City of Boulder and the All-Hazards Recovery Plan.

Stormwater Quality Protection

The City of Boulder holds a Municipal Separate Storm Sewer System (MS4) permit (No. COR090000), and many of the activities to support the protection and improvement of water quality are governed by MS4 permit regulations. The current MS4 permit includes substantial programmatic and technical requirements for the protection of water quality. These minimum MS4 requirements alone likely meet the intent of the existing policies in the BVCP as shown in **Figure 5**.

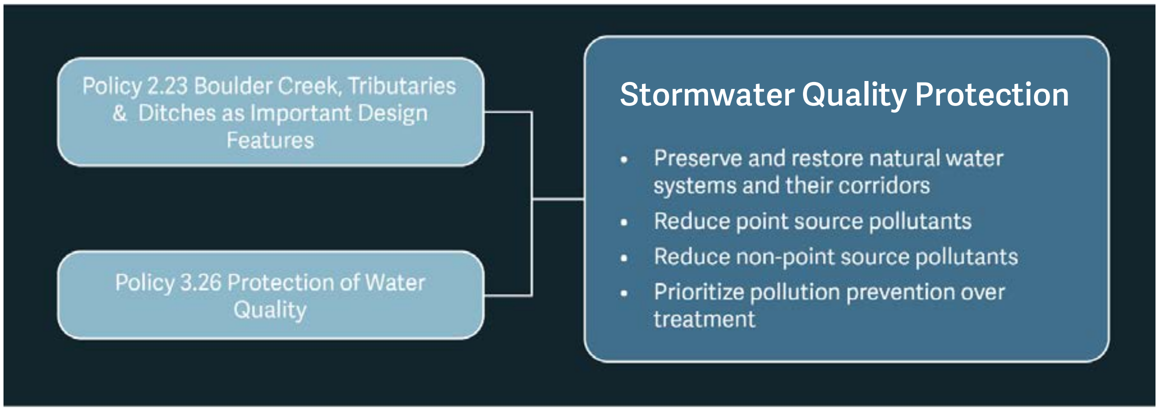


Figure 5 – Stormwater Quality Protection as related to BVCP Policies

In addition to the minimum requirements of the MS4 program, the city is actively pursuing efforts to further stormwater quality initiatives by expanding the green infrastructure program, implementing a multi-pronged adaptive management approach to identify and address sources of *E. coli*, and the Boulder Urban Stream Health Program. This program is a framework for collaboratively identifying and implementing projects to improve urban waterways in the city. The goal of this program is to most appropriately use Utility funds and resources to enhance urban stream health and achieve optimal outcomes through studies, projects, education, and collaboration between Utilities staff and other city partners. The program was initiated in 2021.

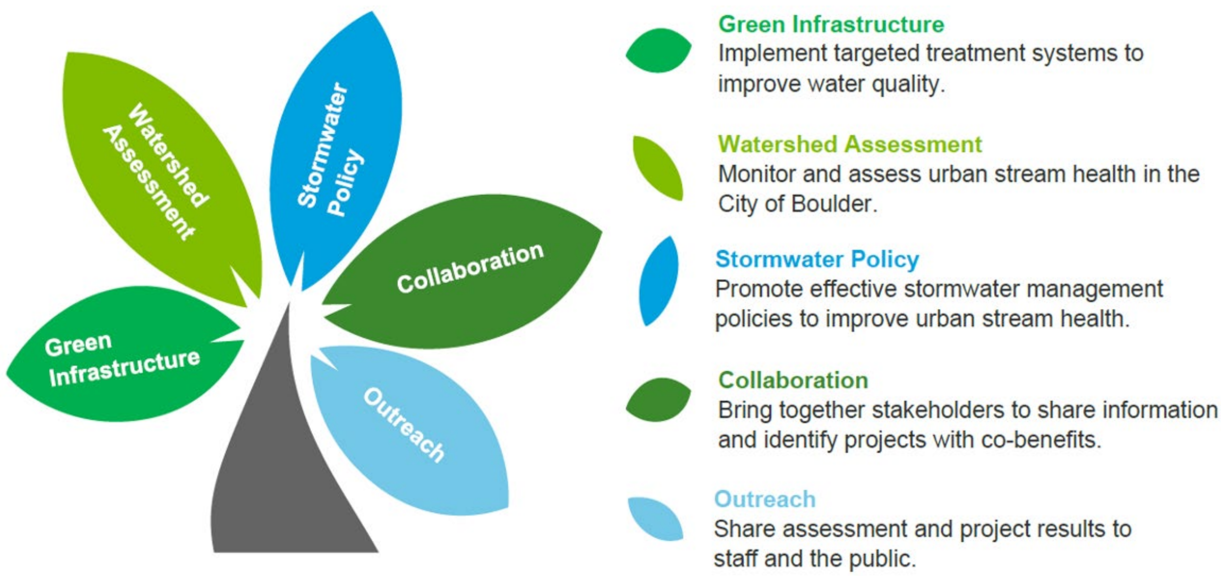


Figure 6 – Boulder Urban Stream Health Program

Groundwater Dewatering

Current BVCP policy guidance suggests the need to address and potentially regulate groundwater dewatering activities. Additionally, the last update to the CFS Master Plan identified recommended actions related to groundwater dewatering and sump systems which have not yet been addressed.

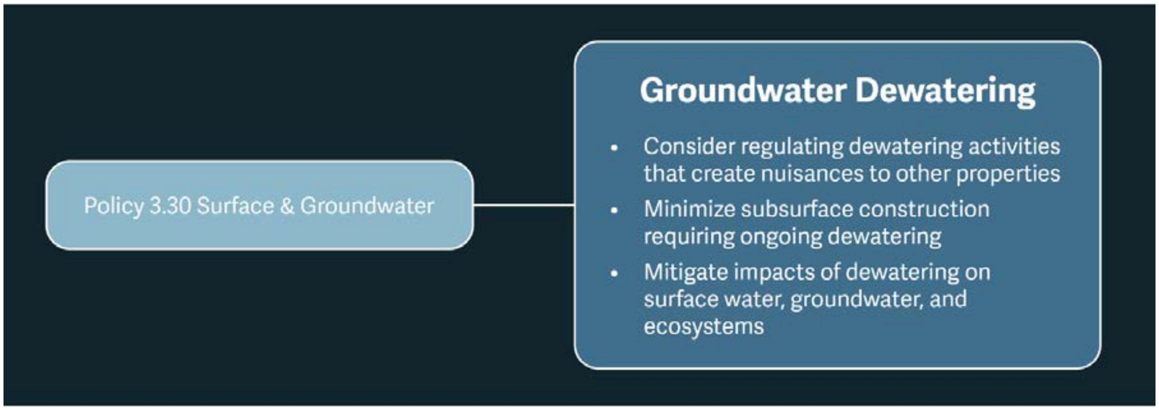


Figure 7 – Groundwater Dewatering as related to BVCP Policies

Wetland Preservation and Restoration

Efforts to preserve and restore wetlands are undertaken by the Planning and Development Services Department (through plan reviews), the Greenways Program, Open Space and Mountain Parks Department, and the Parks and Recreation Department. While the functions of wetlands relate to stormwater quality, their preservation and protection is not currently managed within the Stormwater Quality Program.

Existing regulations governing the protection of wetlands are located in 9-3 of the Boulder Revised Code. These regulations seek to find a reasonable balance between a property owner's desire to make reasonable uses of their property and the public's interest in preserving and protecting wetlands. Therefore, development is discouraged but when it is unavoidable, regulations indicate that impacts should be minimized, and mitigation is required for losses. Construction of buildings, additions, accessory structures, fences, impervious surfaces, and detention or retention facilities are prohibited within regulated wetlands. Additional regulations apply to inner and outer buffer areas based on whether the wetland is considered high functioning. Wetlands less than 400 square feet are exempt from regulations unless a plant, animal, or other wildlife species is listed as rare, threatened, endangered, or as a species of special concern in the BVCP or by a government agency.

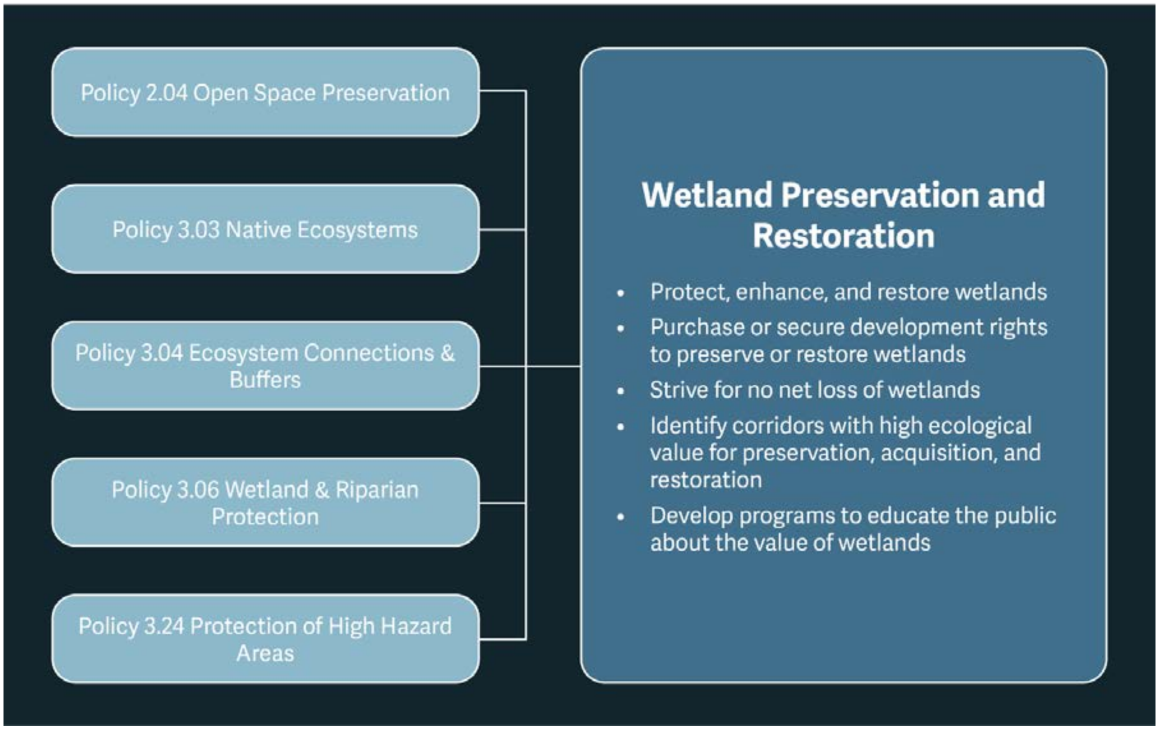
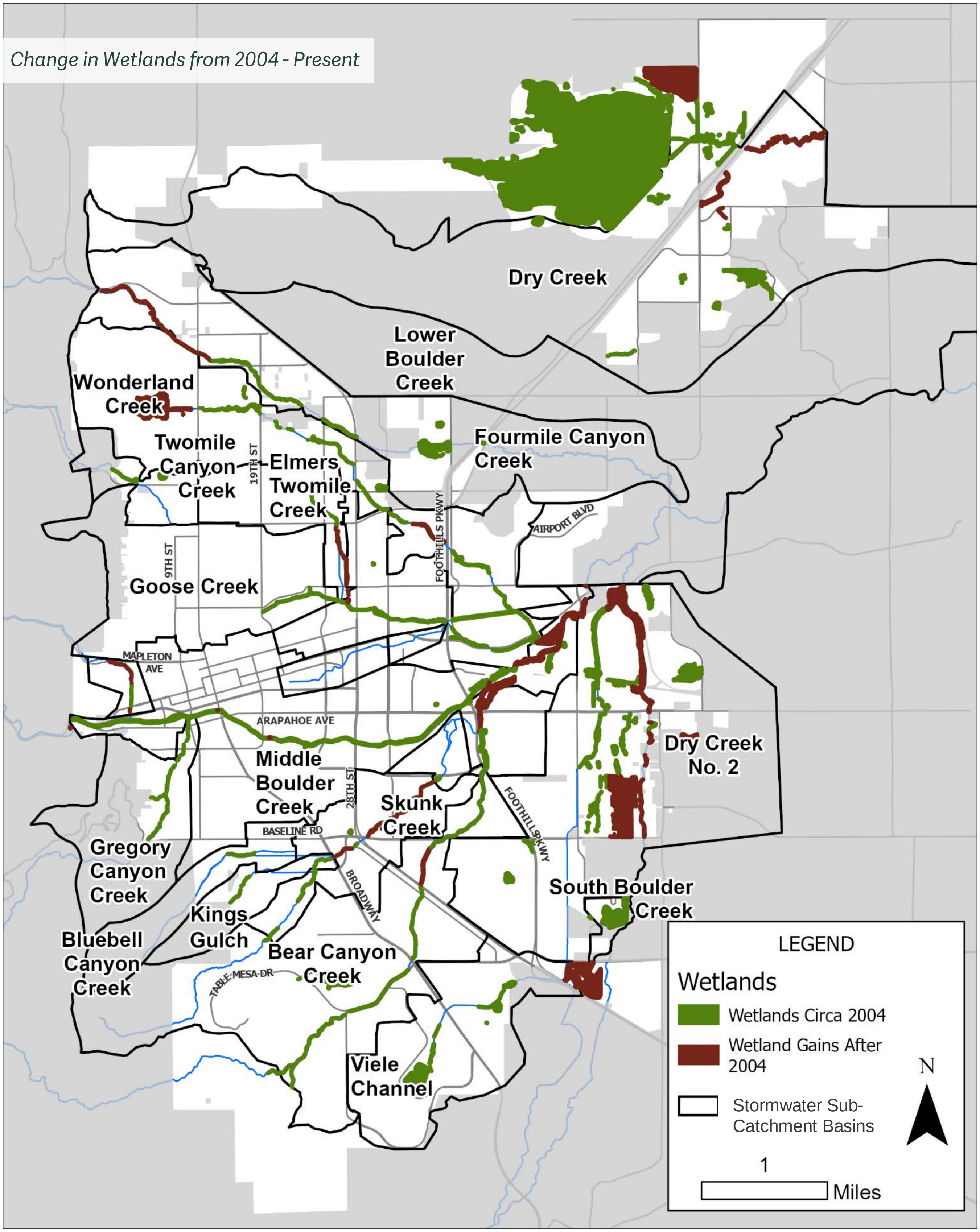


Figure 8 – Wetland Preservation and Restoration as related to BVCP Policies

In 2004, wetlands within the city were mapped and evaluated. Since then, the GIS database has only added records of wetlands that have been annexed, restored, or enhanced, and does not include wetlands that have been lost. Because of this, current data show a 25% increase in wetlands since 2004. However, using an impervious cover dataset from 2018, a roughly 3.5-acre increase of impervious cover in wetlands has occurred. Due to these discrepancies in the data, it cannot readily be determined whether there has been a net loss of wetlands.


Change in Wetlands from 2004 - Present
Dry Creek
Lower Boulder Creek
Wonderland Creek
Twomile Canyon Creek
19TH ST
Elmers Twomile Creek
Fourmile Canyon Creek
AIRPORT BLVD
FOOTHILLS PKWY
9TH ST
Goose Creek
MAPLETON AVE
ARAPAHOE AVE
Middle Boulder Creek
28TH ST
Dry Creek No. 2
Skunk Creek
BASELINE RD
Gregory Canyon Creek
BROADWAY
South Boulder Creek
Kings Gulch
Bluebell Canyon Creek
Bear Canyon Creek
TABLE MESA DR
Viele Channel
LEGEND
Wetlands
Wetlands Circa 2004
Wetland Gains After 2004
Stormwater Sub-Catchment Basins
N
1
Miles

Integrated Planning

The City of Boulder actively works with multiple regional and state organizations to effectively engage on flood management and stormwater quality issues. Partner organizations include the Colorado Department of Transportation, Boulder County, and Keep it Clean Partnership, among others. Additionally, the city is a part of the Mile High Flood District (MHFD), which assists local governments with multi-jurisdictional drainage and flood management issues. The Utility works closely with MHFD on flood mitigation planning, design, construction, maintenance of drainageways, stormwater quality criteria for MS4 Permit requirements, and the Information Services and Flood Warning program. The Keep it Clean Partnership is an organization of seven partner communities within Boulder County that coordinates on stormwater quality activities, including education, outreach, and monitoring to provide an integration of data and studies to analyze long-term water quality trends.

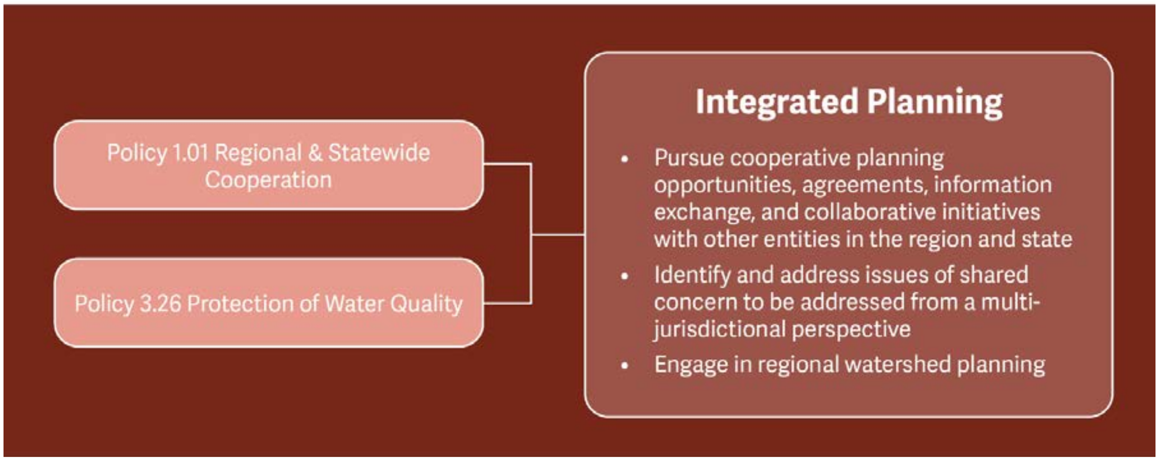


Figure 9 – Integrated Planning activities as related to BVCP Policies

Wonderland Creek Greenways Improvements

Multi-Objective Planning, Design, and Operation

Programs within the Utility often partner with other city departments, regional and state organizations in the design and construction of projects to achieve multiple objectives. A typical example is combining stormwater and flood improvements, stream restoration, and/or trail linkages with transportation projects. Additionally, the Greenways Program is comprised of an interdisciplinary staff work group to integrate multiple objectives along the city's major drainageways. Planning and design for projects along the greenways incorporates objectives such as habitat protection, water quality enhancement, storm drainage and flood mitigation, integration of trails and recreation, and preservation of cultural resources. Additionally, maintenance along the greenways is coordinated between multiple city departments and property managers such as the Boulder Valley School District, University of Colorado, and Boulder County Transportation Department.

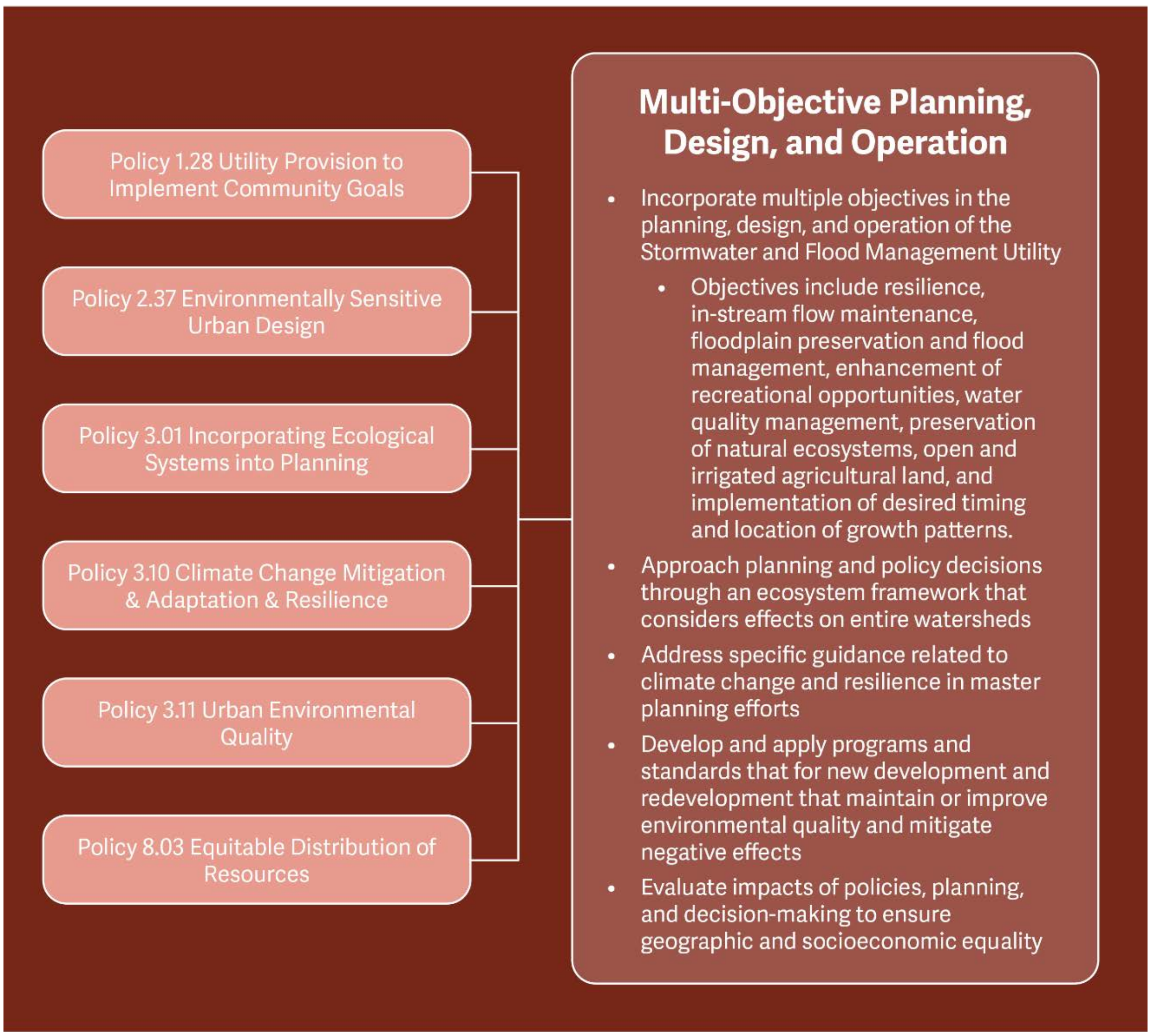


Figure 10 – Multi-Objective Planning, Design and Operation as related to BVCP Policies

Climate change, resilience, and the application of an ecosystem framework are objectives identified in the BVCP (**Figure 10**). It is not clear whether addressing these items and applying an ecosystem framework that considers effects on entire watersheds has been applied in the past, other than following MHFD guidance on floodplain mapping and construction of urban drainage improvements in a way that provides an additional level of conservatism. The Utility has not previously conducted an evaluation of current policies, planning and decision-making through the lens of geographic and socioeconomic equality. The following section on program evaluation incorporates the use of this lens where applicable. This approach is in alignment with the Racial Equity Plan recently adopted by the city and meets the intent of the policies within the BVCP.

Provision of Services

When it comes to the provision of stormwater and flood management services, BVCP policies largely relate to new urban development. However, because the majority of development within the city consists of infill or redevelopment, the construction of stormwater and flood management services for what would be considered new development rarely occurs.

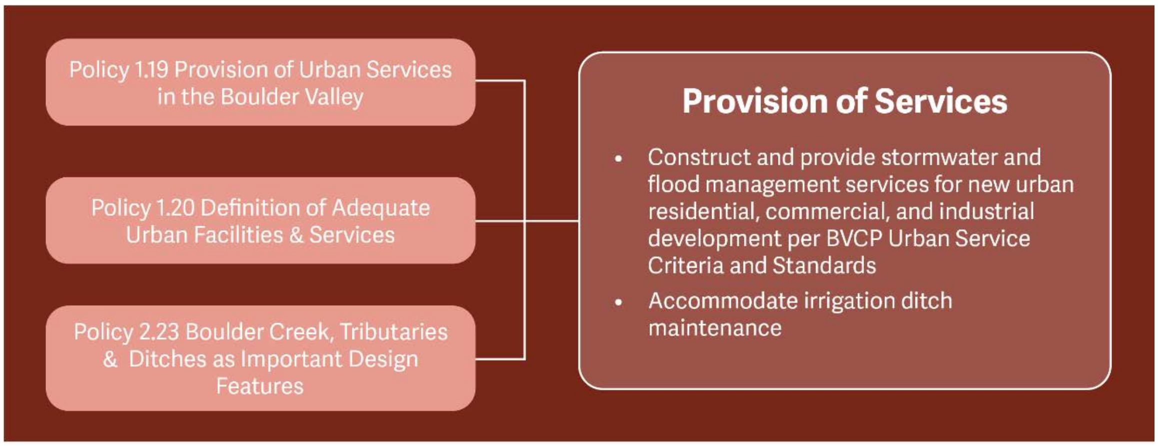


Figure 11 – Floodplain Preservation and Restoration as related to BVCP Policies

Public Engagement and Outreach

Activities related to public engagement and outreach are discussed in Policy 3.22 Floodplain Management that states: "Developing public awareness to flood risks and encouraging the public to proactively implement protective measures that reduce the risk to themselves and their property."

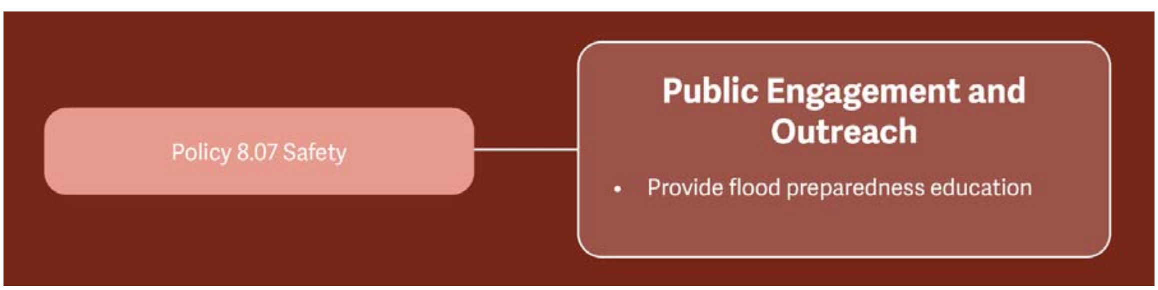


Figure 12 – Floodplain Preservation and Restoration as related to BVCP Policies

The Utility reaches out to community members, boards, commissions, and elected officials in a variety of ways to educate and raise awareness of flood risk and provides resources to help prepare for floods. The table below provides examples of typical education and outreach tools that are often used.

Table 2 – Typical Education and Outreach Tools

Community Guide to Flood Safety	www.boulderfloodinfo.net
Direct mailings to properties in the 100-year floodplain	Flood safety classroom programs for elementary school teachers
Door hangers to University of Colorado off campus housing neighborhoods and high hazard residential properties	Temporary and permanent signage located on underpasses and along creeks
Annual utility bill inserts	Water Festival Flood Safety Presentation
Public events, open houses, workshops	Flood safety sheets for elementary students
Social media posts (Facebook, NextDoor, etc.)	Daily Camera ads
USB devices with flood safety material	Brochures and programs for stormwater outreach

Twomile Canyon Creek Flooding in 2013

Program Evaluation

Program evaluation requires systematic methods to investigate the effectiveness of actions that are aimed at ameliorating stormwater and flooding problems. Unlike the previous master plan, which did not endeavor to evaluate the programs within the Utility, an initial assessment of the Utility's work was conducted to inform the Master Plan going forward and to identify areas where additional information and data would be useful to city staff in the goal of continuous improvement. To conduct this evaluation, goals and objectives were created based on existing policy language, recommendations from other reference documents reviewed in Chapter 2, and conversations with city staff. These goals and objectives were assembled with associated evaluation metrics in a logic model for each program. Current metrics were selected based on the presence of quantitative data and actions that had been completed in support of each objective.

Recognizing that resources to identify flood risk, mitigate flood damage, and maintain flood and stormwater facilities are scarce in comparison with the need, an overarching objective of the evaluation was to assess program outcomes and impact through the following lenses:

- What are the program goals and objectives (as largely outlined in the BVCP)?
- Which program actions drive results?
- Where are the biggest areas of concern, and do the current actions move the needle to solve them?
- What data are available to ascertain effectiveness?

This evaluation included participation by a cross section of city departments and staff, the Office of Disaster Management for City of Boulder & Boulder County, and the Community Working Group (CWG). The CWG provided valuable input regarding community perceptions, values, and program elements of interest including project prioritization; funding; flood warning, response and recovery; public education and outreach; drainage system maintenance; and setting goals that are specific and measurable.

Flood Management Program Evaluation

The City of Boulder has significant flood risk, primarily due to its location at the mouth of the Boulder Creek and its tributaries. With 16 major drainageways, approximately 16 percent of land within city limits — including around 2,600 structures — are located within the regulatory 100-year floodplain. The flood management program is responsible for programs and activities related to local flooding and the floodplain, including floodplain mapping, risk assessments, regulations, flood information and insurance, emergency preparedness, property acquisition, and flood mitigation capital improvements. Capital projects are managed by two full-time engineering project management staff dedicated to both flood management and stormwater drainage. The Utilities Maintenance work group is responsible for maintenance of the floodways with four full-time staff and four part-time staff. The following sections identify the goals and objectives of the existing flood management program that were used as evaluation criteria and to identify program efficacy and opportunities.

Floodplain & Fluvial Hazard Mapping

Floodplain mapping provides the basis for flood management by identifying areas subject to the greatest risk of flooding. This information is essential for determining areas where life safety is threatened and property damage is most likely. Floodplain mapping forms the basis for the city's floodplain regulations and the National Flood Insurance Program.

GOAL: Provide floodplain mapping throughout the city to inform land use decisions

Objective:	Comply with current FEMA, state, and city standards for updating and adopting floodplain maps
Objective:	Identify areas subject to the greatest risk of flooding within the city
Objective:	Identify areas prone to fluvial hazards

All 16 floodplains have been mapped within the city. Since the previous CFS update, ten floodplain mapping projects have been completed and have provided revised and updated maps for 80% of the major drainageways by drainageway length. Current floodplain mapping has been accepted by FEMA. An area for policy analysis includes modeling methods that might better determine flood risk as well as fluvial hazard mapping.

Fluvial Hazard Zone

The area a stream has occupied in recent history, may occupy, or may physically influence as it stores and transports water, sediment, and debris.

Source: *www.coloradofhz.com*

Flood Preparedness, Response & Recovery

Planning and preparation can make a big difference in flood safety and continuing operations after a disaster. The more prepared the community is with pre-flood readiness, ongoing monitoring, effective warning systems, trained response, and post-flood recovery, the better the chances are for management and mitigation of flooding impacts.

GOAL: Provide resources to help people prepare for floods and to recover in the event of a flood

Objective: Ensure people are aware of their flood risk and flood preparation measures

Objective: Maintain a response team within the Utility

Objective: Ensure that adequate resources are provided to socially underrepresented populations for preparedness and response

The Utility currently maintains a robust education and outreach program, and annually performs multiple activities as listed in **Table 2** above to provide information in a variety of forms to the community. Since the City of Boulder has one of the highest flash flood risks of any municipality in the State, the Utility places significant importance on flood education and outreach programs.

GOAL: Provide resources immediately before, during, and after flood emergencies to promote safety and infrastructure resilience

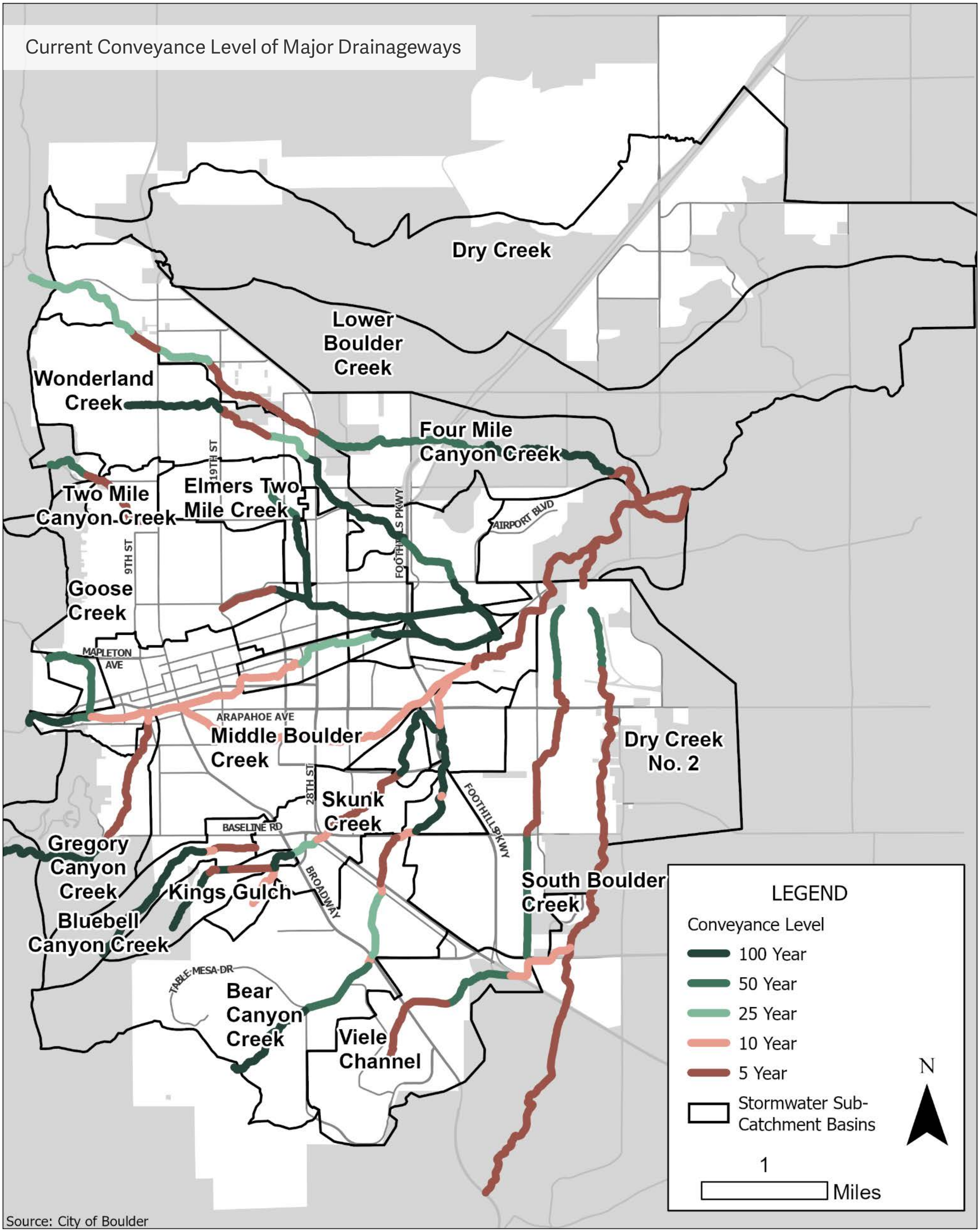
Objective: Ensure adequate and resilient outdoor emergency warning systems are provided throughout the city

Objective: Maintain a current operations plan for response and recovery related to flood emergencies

As its name implies, the purpose of the outdoor warning system is to alert people of flood risk when they are outside. As such, systems are evaluated for coverage using distance-based buffers in GIS. This method does not account for people who are indoors, or impacts caused by physical or environmental factors, such as building obstructions or noise caused by hail or high winds. Additionally, the city maintains a Continuity of Operations Plan in the event of emergencies. Program capacity would be enhanced by routine communication and closer coordination with the ODM, who have resources to support preparedness, response (i.e., the Incident Management Team, Incident Command) and recovery. For greatest impact, it is recommended that city leadership work more closely with the ODM to build capacity.

Flood Mitigation

Most work completed by the Flood Management Program is related to the mitigation of damages to property caused by floods and the reduction of risks to people during flood events. This includes identifying measures for reduced risk through mitigation planning, construction of mitigation projects, regulating development in areas prone to flooding, and ensuring that major drainageways are maintained to accommodate floodwaters.


Current Conveyance Level of Major Drainageways
Dry Creek
Lower Boulder Creek
Wonderland Creek
Four Mile Canyon Creek
Two Mile Canyon Creek
Elmers Two Mile Creek
Goose Creek
Middle Boulder Creek
Dry Creek No. 2
Skunk Creek
Gregory Canyon Creek
Kings Gulch
Bluebell Canyon Creek
South Boulder Creek
Bear Canyon Creek
Viele Channel
19TH ST
9TH ST
MAPLETON AVE
ARAPAHOE AVE
28TH ST
BASELINE RD
BROADWAY
TABLE MESA DR
FOOTHILLS PKWY
AIRPORT BLVD
LEGEND
Conveyance Level
100 Year
50 Year
25 Year
10 Year
5 Year
Stormwater Sub-Catchment Basins
N
1
Miles
Source: City of Boulder

GOAL: Identify, evaluate, design, and construct improvements within the floodplain to mitigate damages to property and protect the public.

Objective:	Develop flood mitigation for major drainageways in the city
Objective:	Provide standardized guidance for the creation of mitigation plans
Objective:	Prioritize flood mitigation improvement projects with an emphasis on the use of non-structural approaches whenever possible
Objective:	Select, design, and construct flood mitigation projects to remove people and property from the floodplain

The Utility is developing mitigation plans for all major drainageways, but it is a lengthy process that often takes many years to fully complete. Since publishing the 2004 CFS Master Plan, mitigation plans have been updated, created, or are in progress for 80% of the major drainageways in the city. These mitigation plans follow general guidance provided by the city to individual consultants. While the hydrologic and hydraulic methodologies used must be based on FEMA approved methods, there is no standardization between the mitigation plans for this or for the development and prioritization of alternatives. Because of this, there are many variations in the methods used; non-structural approaches are sometimes discussed, but do not appear to be prioritized; and conveyance of the 100-year flood event is not always evaluated if it is determined infeasible. Discrepencies between mitigation studies make it difficult to adequately and equitably prioritize projects on a city-wide basis.

After completing mitigation plans, projects are then selected for design and construction as part of the city's CIP process. Since 2004, seven mitigation projects have been completed to increase flood conveyances from less than 10-year event flood capacity to 100-year event flood capacity in some cases. In additon to those seven projects, another seven more are currently in the design or construction phases.

GOAL: Remove structures and acquire privately owned properties in areas prone to flooding, especially within the city's High Hazard Zone, for the purposes of flood mitigation

Objective:	Develop a prioritized list of high-risk properties to inform property acquisitions
Objective:	Prevent reconstruction of structures that have sustained significant flood damage
Objective:	Retain undeveloped high hazard flood areas in their natural state whenever possible

A prioritized list of high-risk structures has been created to inform property acquisitions. Additionally, current floodplain regulations prohibit the redevelopment of flood-damaged structures that are damaged more than 50% of pre-flood market value. They also prohibit construction of parking lots or residential structures in the High Hazard Zone. Review of GIS data from 2014 to 2018 showed that there has been a 6.8% reduction of structures (in square feet) in the high hazard zone and a 1.4% reduction of overall impervious cover.

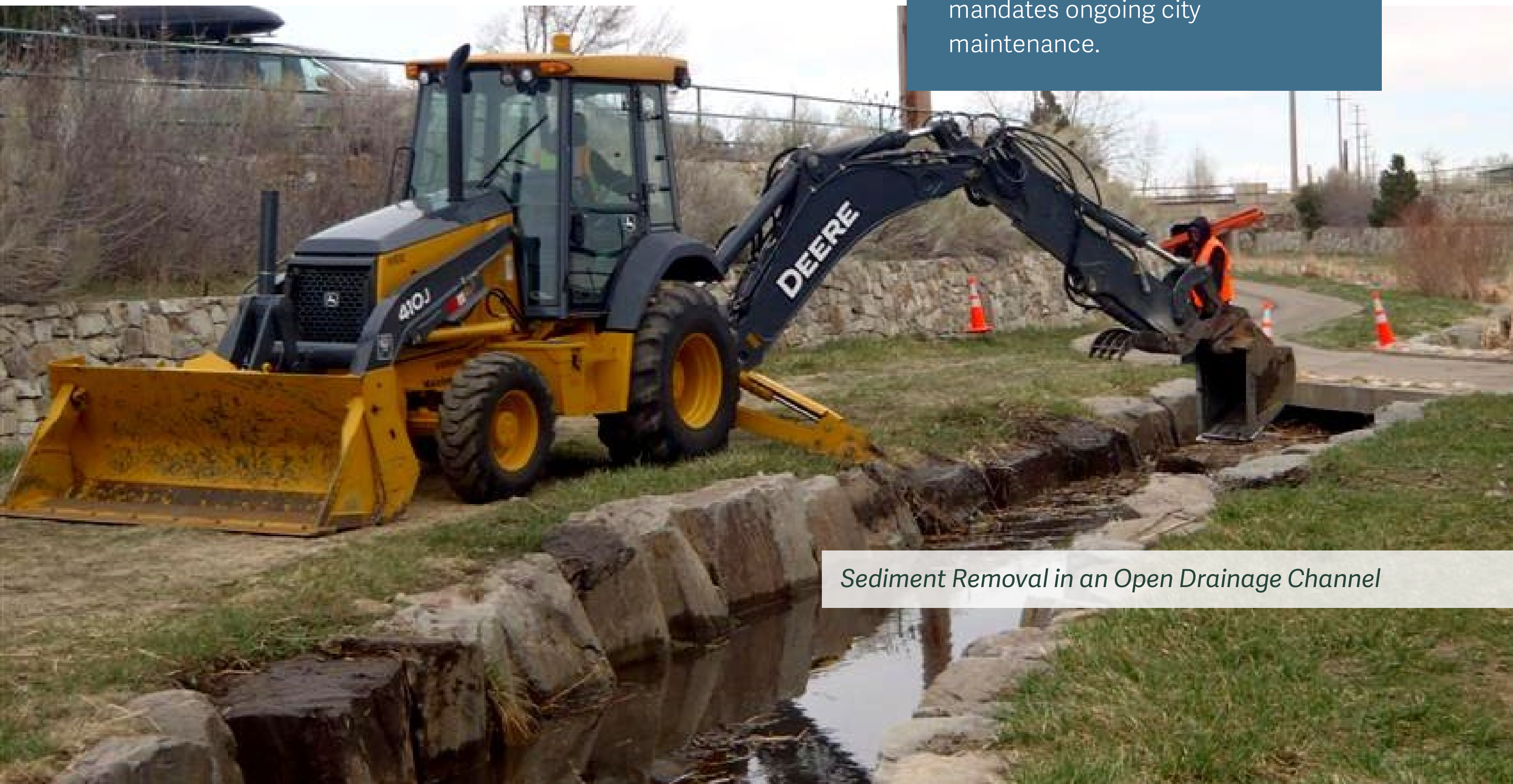
GOAL: Ensure that major drainageways are maintained to accommodate the passage of floodwaters

Objective:	Routinely clear nuisance vegetation from channels and debris buildup from culverts and bridges
Objective:	Provide satisfactory maintenance access and public access easements or rights-of-way, including during annexation, for the purposes of maintenance activities

The Utilities Maintenance work group is responsible for the maintenance of 36.5 linear miles of open drainage channels that make up part of the major drainageways. Maintenance also includes associated structures and floodways, as well as irrigation ditch maintenance where maintenance agreements are in place with private ditch companies. This work is supplemented through the use of contractors and by maintenance projects overseen by the Mile High Flood District. In past years, flood maintenance activities have been predominantly reactive. Responding to emergency maintenance needs, known problematic areas, and irrigation ditches with maintenance agreements has left little time for proactive maintenance. Irrigation ditch maintenance is not a function of the Flood Management Program, but since the activities and required resources are similar, staff maintaining floodways also maintain irrigation ditches, as required. A complete maintenance cycle of city flood facilities has not been completed in recent decades. An asset management system was recently employed to track time and equipment for required tasks. To better address the maintenance needs of the major drainageways, in 2021 the Utilities Maintenance work group was split into a stormwater group and a flood and greenways group, and additional staff have been hired to proactively address maintenance needs of the flood and greenways infrastructure. It is the goal of the Utilities Maintenance work group to complete future maintenance cycles in 10-12 years.

Irrigation Ditches

Since the 1860s, development has occurred near existing private irrigation ditches. As such, ditches located within the City of Boulder have been opportunistically used as default stormwater drainage systems, although not designed for this purpose. This legacy issue, while beneficial in many aspects for stormwater conveyance, also mandates ongoing city maintenance.



Sediment Removal in an Open Drainage Channel

GOAL: Reduce risks to people and property by regulating land use in areas along drainageways that are prone to flooding

Objective:	Regulate development within the 100-year floodplain to mitigate risk of property loss or damage
Objective:	Reduce impacts to critical facilities and services in the 500-year floodplain
Objective:	Evaluate policies intended to address damages caused by floods larger than the 100-year event

Floodplain regulations are in place to meet the intent of the above objectives. However, further review should be undertaken to determine if the regulations and program activities achieve the floodplain management goals listed below. Additionally, these policies have not been evaluated to address damages caused by larger flood events.

Floodplain Management

In addition to protecting people and property from damaging floods, there is a strong community desire to protect the floodplains themselves due to the many social, environmental, and flood mitigation benefits they provide. As part of the community engagement process linked with this Master Plan update, it is clear that public sentiment is aligned with the policies in the BVCP to preserve and protect these floodplains.

GOAL: Preserve and protect the natural resources and beneficial functions of floodplains

Objective:	Define and implement non-structural measures within floodplains
Objective:	Preserve undeveloped floodplains where possible through public land acquisition, private land dedications and multiple program coordination

Non-structural measures have not been defined by the Utility, so it is unclear whether the intent is to naturalize floodplains or if floodproofed structures and enhanced flood warning systems meet this intent. Regardless, non-structural measures are currently incorporated as part of mitigation projects on an opportunistic basis.

Floodplain preservation efforts are a function of the Parks and Recreation Department and the Utilities property acquisition program. While the Utility supports these initiatives, the level of involvement in this activity has not been clearly defined.

GOAL: Reclaim and restore floodplains and their functions

Objective:	Incorporate floodplain restoration measures into flood mitigation projects
Objective:	Restore habitat for native species

Floodplain restoration is often included as part of mitigation projects whenever feasible. Of the mitigation projects that have been constructed since 2004, only the projects involving simple replacements of bridges or culverts did not include some form of habitat or floodplain restoration work. Similar levels of restoration efforts are also proposed in the projects that are still in design and construction phases.

GOAL: Protect cultural and recreational resources associated with stream corridors and floodplains

Objective:	Identify and protect historic resources within the floodplain
Objective:	Limit open space development to trails and trail linkages

Many of the actions completed to achieve these objectives are carried out by the Greenways Program and OSMP. Cultural resources within floodplains were identified in the 2011 Greenways Program Master Plan update. OSMP limits development within the floodplains they manage to trails and other recreational features. However, these limitations on open space development do not currently extend to privately owned properties.

Public Education and Flood Insurance

The City of Boulder participates in the National Flood Insurance Program (NFIP) by adopting and enforcing floodplain management ordinances and providing public education to reduce future flood damage. In exchange, the NFIP makes federal government-backed flood insurance available to homeowners, renters, and business owners whether they are in the floodplain or not. The NFIP also has a voluntary incentive program called the Community Rating System (CRS), which allows communities to obtain discounts on flood insurance premiums if the community floodplain management activities exceed minimum NFIP standards.

GOAL: Increase public awareness of flood risk and safety measures

Objective:	Provide bilingual public education events and materials through a variety of platforms to inform the public of flood risks and available community resources
Objective:	Seek to broaden outreach efforts as community needs and habits change

In 2021, the City Council adopted a Racial Equity Plan and hired a language access program manager who is responsible for developing the city's language access plan. Work is ongoing on these efforts to continue to reach as many community members as possible. These efforts were hindered by the COVID-19 pandemic, highlighting the need to provide continuity during times of disruption.

GOAL: Reduce associated flood risks and related insurance costs by participating in the NFIP CRS Program

Objective:	Engage in community floodplain management activities that exceed the minimum National Flood Insurance Program requirements to obtain discounted rates on flood insurance premiums for homeowners, renters, and business owners
Objective:	Maintain the lowest feasible CRS class

The city has an active floodplain management program and its progressive approach to managing flood risk is well recognized with a CRS Class 5 rating. Since the last CFS Master Plan update, the Utility has lowered its CRS rating from a Class 8 in 2004 (providing a 10% discount on community flood insurance policies) to a Class 5 (providing a 25% discount on certain flood insurance policies held by community members).

Stormwater Drainage Program Evaluation

As urbanization and impervious surfaces increase, less stormwater infiltrates into the ground, resulting in increased runoff. This increased stormwater runoff can produce localized and downstream flooding, as well as channel erosion and increased non-point source pollution. The Stormwater Drainage Program is responsible for the network of underground pipes, structures, and channels that convey stormwater or surface runoff to major drainageways within the city. Activities necessary to ensure the management of this infrastructure include master planning to guide upgrades and expansion of the system, inspections, maintenance, repairs, regulations, and stormwater collection and conveyance system capital improvements. At the time of this publishing, the breadth of this work is managed with two full-time equivalent (FTE) staff dedicated to both flood management and stormwater drainage engineering, and nine full-time staff in the Utilities Maintenance work group dedicated to stormwater infrastructure maintenance.

Stormwater Collection System

The city currently operates a stormwater collection and conveyance system to minimize impacts of localized and downstream flooding caused by stormwater runoff. Per the 2016 Stormwater Master Plan, this system consists of 713 detention ponds and approximately 160 miles of storm sewer, including associated structures and outfalls as part of the conveyance system. Additionally, the system is periodically assessed to identify areas within the system that lack sufficient capacity for existing and future needs.

GOAL: Provide an adequate stormwater collection and conveyance system for existing and future development within the city

> Objective: Size the storm sewer system to convey the runoff from 2-year storm events in residential areas, and from 5-year storm events for collector and arterial roadways and in commercial areas

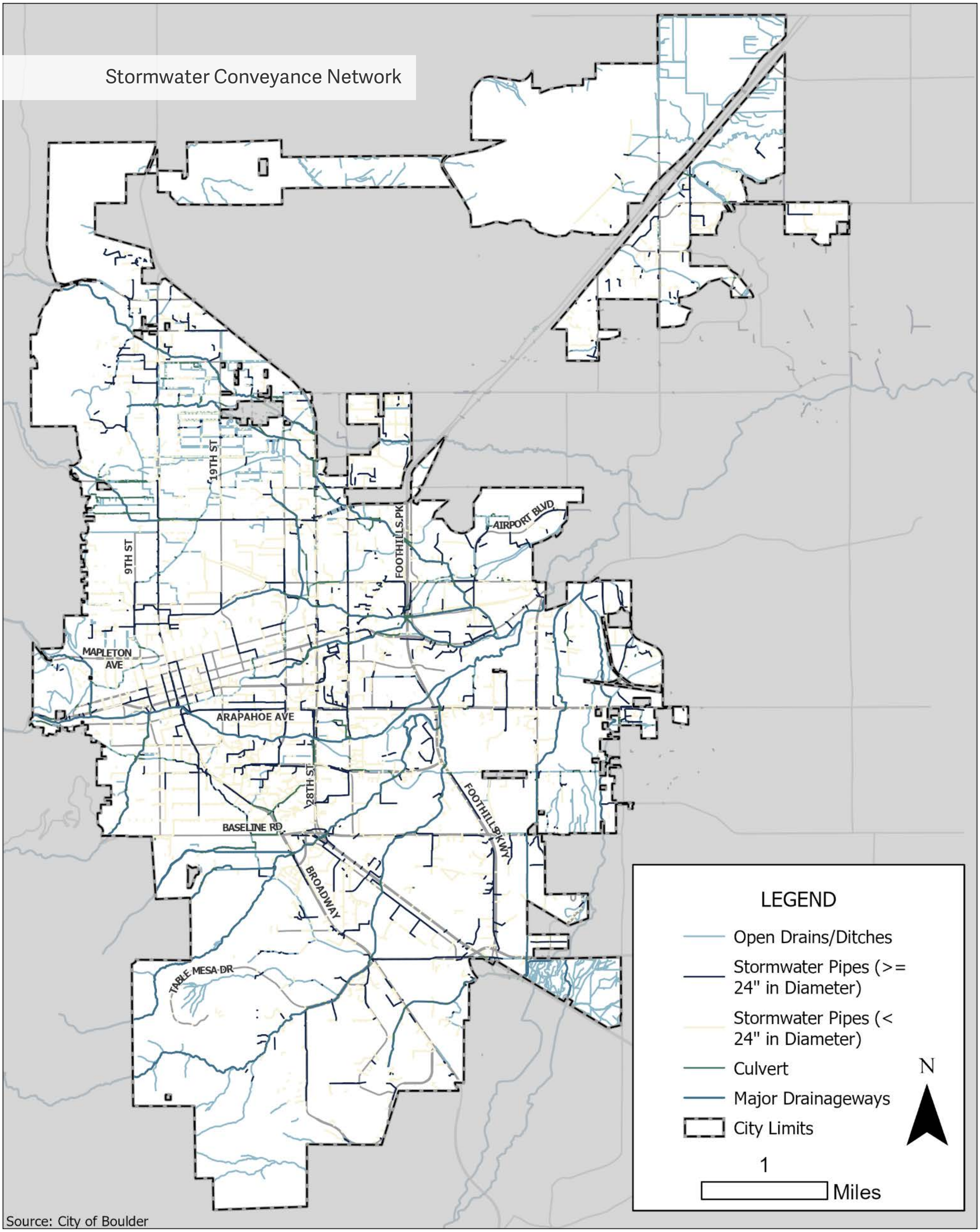
> Objective: Focus on problem areas created by smaller storms to address localized flooding

Per the city's Design and Construction Standards, the minimum pipe size for stormwater conveyance is 15 inches, and over 30% of the system consists of pipes smaller than this. There are significant areas within the city that do not have any stormwater conveyance pipelines. Other areas contain pipes that cannot adequately convey flows from the design storm, which results in localized flooding from these smaller storm events. The 2016 Stormwater Master Plan identified 35 areas within the local drainage system having insufficient service. Priority areas and recommended improvements were identified, but the number of people affected or area extent within these deficient service areas were not quantified.

GOAL: Minimize impacts of localized and downstream flooding, stream bank erosion, and channel erosion within the open channel stormwater drainage system by controlling the rate and volume of stormwater runoff from development and redevelopment projects

> Objective: Limit post-development peak flow conditions to match pre-development peak flow conditions

Detention is required on all development projects where peak flow rates are increased per the city's Design and Construction Standards; however, the current stormwater detention policy has gaps that should be addressed.


Stormwater Conveyance Network
19TH ST
9TH ST
FOOTHILLS PK
AIRPORT BLVD
MAPLETON AVE
ARAPAHOE AVE
28TH ST
FOOTHILLS PKWY
BASELINE RD
BROADWAY
TABLE MESA DR
LEGEND
Open Drains/Ditches
Stormwater Pipes (>= 24" in Diameter)
Stormwater Pipes (< 24" in Diameter)
Culvert
Major Drainageways
City Limits
N
1
Miles
Source: City of Boulder

GOAL: Provide a connected and continuous stormwater drainage system that does not discharge into irrigation ditches, where practical.

Objective:	Identify stormwater connections into irrigation ditches
Objective:	Identify irrigation ditches having insufficient capacity for stormwater conveyance

It is the policy of the Mile High Flood District and also recommended by the Colorado Water Conservation Board to disconnect all stormwater discharges from irrigation ditches. However, the situation in the City of Boulder is more nuanced, and disconnection of all stormwater discharges is not feasible. The Utility recognizes the limitations of using irrigation ditches for stormwater conveyance and has opted to identify whether irrigation ditches have capacity for stormwater conveyance prior to deciding whether to disconnect stormwater conveyance. As part of the 2016 Stormwater Master Plan update, stormwater connections to irrigation ditches were identified, but capacity of the receiving ditches has yet to be assessed.

Operations and Maintenance

The Utilities Maintenance work group is responsible for inspection and maintenance of about 160 miles of stormwater pipe, ranging from 10″ to 72″ in diameter, 2,771 manholes, 5,623 inlets, and 1,993 stormwater outfalls. Maintenance consists of cleaning, repairing, jetting, and inspecting stormwater infrastructure.

GOAL: Ensure the stormwater collection and conveyance system functions properly and yields expected capacity to protect public safety and the city's investment in the system

Objective:	Provide routine inspections and assessments of the entire system
Objective:	Provide routine maintenance of pipes, structures, natural and man-made channels including irrigation ditches, and public detention facilities
Objective:	Provide minor repairs to existing pipes and structures

In past years, the Utilities Maintenance work group activities were primarily reactive without having staff dedicated to stormwater maintenance. Because they provided emergency maintenance in the stormwater and floodway systems, along with irrigation ditch maintenance required by maintenance agreements, routine maintenance tasks required for the stormwater collection and conveyance system were often neglected due to more urgent maintenance needs. Recently, an asset management system was employed to track time and equipment for tasks. It was found that the inspection cycle for the stormwater conveyance system occurs on an estimated 11-year cycle and cleaning activities are completed on an estimated 31.5-year cycle. To proactively address the maintenance needs of the stormwater system, the Utilities Maintenance work group was split into two groups — a stormwater group and a flood and greenways group — and additional staff were added to reduce the time between routine maintenance of the entire stormwater conveyance system and increase the level of service.

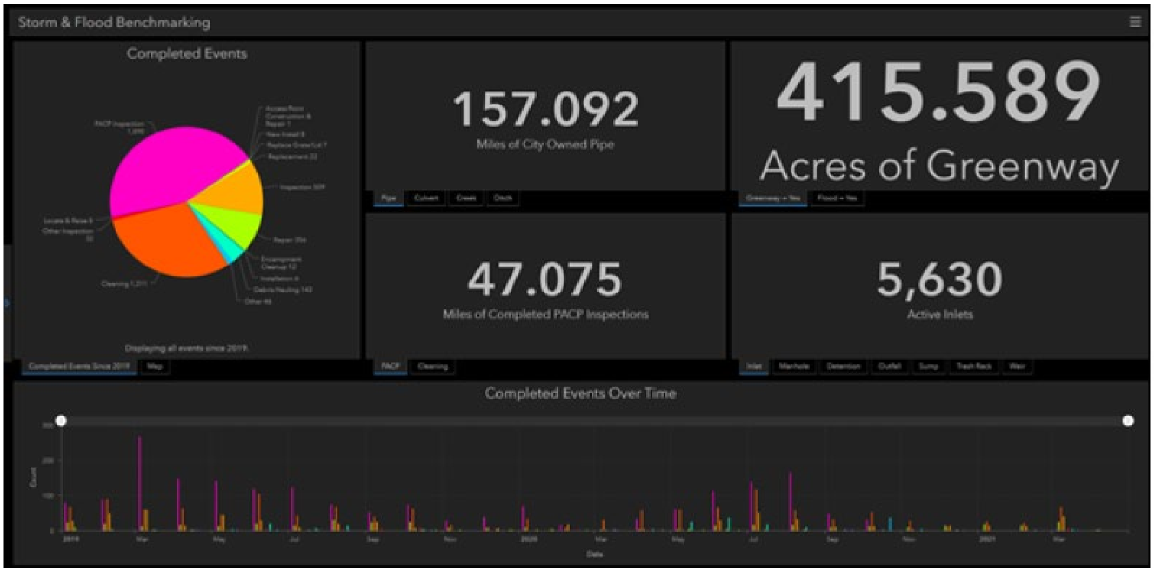


Figure 13 – Beehive Asset Management System Benchmarking and Data Collection

GOAL: Provide maintenance accessibility to the entire stormwater collection and conveyance system

Objective: Identify reaches of the stormwater conveyance system lacking adequate maintenance access

Objective: Provide permanent access to reaches of the stormwater conveyance system, detention facilities, and other drainage facilities for routine and major maintenance activities

Information and data input into the Utility's asset management system is an ongoing process that will take time to complete. Identification of insufficient maintenance accessibility will be included as part of this process.

GOAL: Provide irrigation ditch maintenance per existing maintenance agreements with irrigation ditch companies

Objective: Identify tasks for irrigation ditch maintenance in current asset management system to develop a predictive maintenance plan

Maintenance responsibilities associated with irrigation ditches can vary significantly between individual maintenance agreements. As with other operations and maintenance tasks, these responsibilities are being entered into the Utility's asset management system and are not expected to be fully complete until at least 2022. Once this process is completed, the Utilities Maintenance work group will have greater capacity to predict and plan for maintenance needs to increase efficiency.

GOAL: Ensure resources are available to provide emergency maintenance on the stormwater conveyance system

Objective: Identify resources required to provide emergency maintenance during and after storm events

Currently, on-call construction contracts are in place to handle emergency maintenance beyond what the current operations and maintenance work group staff and equipment can provide. This system was put in place following the 2013 flood, and while its efficacy has not been tested in large storm events, it has shown to work well in smaller storm events. Additionally, Mile High Flood District is also available as a resource for this work.

Groundwater

Groundwater and sump systems can create nuisance drainage in the public rights-of-way and across adjacent private properties. Also, groundwater dewatering systems can affect local water wells and wetlands by lowering the groundwater table. Requirements for groundwater extraction and release are loosely defined in current city regulations.

GOAL: Mitigate impacts of dewatering on groundwater or surface water quantity and quality, groundwater recharge, local water wells, wetlands, and ecosystems

Objective:	Identify areas within the city where groundwater issues may arise including naturally high groundwater locations, seasonally high groundwater locations, and groundwater pollutants
Objective:	Require the identification of mitigation and remediation measures prior to dewatering
Objective:	Minimize subsurface construction that requires ongoing dewatering

Policy recommendations to evaluate a proactive approach to dealing with the discharge of groundwater as overland flow and into surface waters was included in the previous CFS Master Plan and also in the BVCP. To date, groundwater issues have not been addressed by the Utility. The City of Boulder stopped issuing groundwater permits in 2019, as it was largely duplicative of the State's general permit for discharges from subterranean dewatering activities, which focus on discharged volume and water quality.

GOAL: Prevent nuisances to other properties created by dewatering activities

Objective:	Require dewatering mitigation for residential basements and other ongoing dewatering

Groundwater dewatering mitigation is not currently required for residential basements or for ongoing dewatering. The determination of whether to require mitigation measures has not yet been addressed.

Stormwater Quality Program Evaluation

The built urban environment has negative impacts on the water quality in Boulder's streams and drainageways in the forms of polluted runoff, spills, and excess sediment. The city's Stormwater Quality Program is responsible for managing local activities to preserve, protect, and enhance water quality affecting Boulder's surface waters. The program not only seeks to comply with state water quality regulations, but to educate the public and improve water quality through better understanding of issues and enhanced stewardship. Currently, this work is being performed by four full-time staff in the Stormwater Quality Program with assistance from other Utilities Department staff, Planning and Development Services staff, and partnerships with regional organizations for outreach, education, and water quality data reporting.

Stormwater Regulatory Compliance

The city holds a permit for discharge from its storm sewer system to waters of the state. This stormwater permit has requirements related to a number of city activities, including operations and maintenance, development, and education and outreach. Other water quality regulations include Total Maximum Daily Load (TMDL) requirements for *E. coli* in Boulder Creek.

GOAL: Maintain compliance with current MS4 permit requirements

Objective:	Provide effective and engaging education and outreach on the importance of water quality and its protection
Objective:	Provide appropriate response, cleanup, and documentation for spills and other illicit discharges in the city
Objective:	Conduct construction stormwater program oversight with appropriate inspections and follow-up enforcement
Objective:	Require the installation and proper maintenance of permit required post-construction stormwater control measures
Objective:	Conduct municipal operations in a manner that promotes pollution prevention and good housekeeping

The city is currently in compliance with their MS4 permit. As part of the Program's efforts to comply with permit requirements and meet the needs of the broader community, there are specific areas where the activities of the Utility go well above and beyond minimum permit requirements. For example, the MS4 permit requires that a combination of four different types of education and outreach activities be completed annually, whereas the Utility reports that they conduct at least fifteen activities annually. The Utility is also in the process of expanding their construction and post-construction stormwater quality programs to meet community needs.

GOAL: Reduce sources of *E. coli* in Boulder Creek to meet TMDL requirements

Objective:	Work to identify potential *E. coli* sources and determine controllability
Objective:	Identify and implement strategies to reduce controllable sources of *E. coli* in stormwater runoff entering Boulder Creek

It is well known in the stormwater quality community that identification and control of *E. coli* sources is notoriously difficult. The City of Boulder has been extensively involved in evaluating and researching *E. coli* sources that extend well beyond regulatory requirements. The city also voluntarily completed an update to the TMDL Implementation Plan in 2019 that highlights a tiered and methodical approach to identifying and addressing *E. coli* sources.

GOAL: Develop compliance strategies in anticipation of future MS4 regulatory requirements

Objective:	Closely track the MS4 permit renewal process and provide appropriate input and feedback as a partner with CDPHE

The city brings a unique perspective to many areas of permit implementation. Presenting this perspective to the State has proven valuable to ensure reasonable and achievable regulatory requirements for the city. It is the intent of the Utility to continue participation and fostering these relationships in the future.

Enhancement of Urban Stream Health

In addition to meeting permit requirements, the Stormwater Quality Program is dedicated to addressing broader stormwater quality concerns and critical aquatic habitats in ways that protect and enhance urban stream health. This approach requires the implementation of projects and programs above and beyond stormwater quality permit requirements.

GOAL: Protect and enhance water quality and urban stream health through strategic collaboration, data collection, programmatic planning, and implementation of stormwater quality projects

Objective:	Implement the Boulder Urban Stream Health (BUSH) program through internal city collaboration and the funding of water quality related projects
Objective:	Implement data collection and assessment projects that further understanding of local watershed conditions
Objective:	Develop and implement municipal policies related to urban runoff or stream health
Objective:	Design and construct stormwater quality projects to improve urban stream conditions or mitigate the effects of urban runoff

In conjunction with current MS4 Permit requirements, the Stormwater Quality Program has increased efforts related to the control of stormwater pollutants through the use of stormwater control measures on construction sites and for post-construction stormwater management. Post-construction stormwater control measures are not required on development sites less than an acre in size or on residential properties.

Recently, the Boulder Urban Stream Health (BUSH) program was initiated to create a project implementation framework to address water quality concerns. Additionally, the Stormwater Quality Program has taken a more focused approach to water quality data collection based on specific concerns and plans to track stream health function ratings in 2022 to support these efforts.

Bioswale Installation in Parking Lot

GOAL: Support the preservation, restoration, and maintenance of greenways, creek corridors, and wetlands for the protection and improvement of water quality

Objective: Manage the greenways program to provide appropriate understanding, oversight, maintenance, planning, and projects for the preservation and enhancement of the riparian corridor

Objective: Strive for no net loss of wetlands

In recent years, the Stormwater Quality Program has shifted from mostly focusing on MS4 Permit compliance to building larger programs to enhance water quality and stream health which incorporate permit compliance measures. Additionally, the Greenways Program was historically under the purview of the Flood Management Program until it recently became a part of the Stormwater Quality Program. Because of these factors, greater support for preservation and restoration of natural water systems and their ecosystems beyond what is required for permit compliance has not been a focus of this Program. However, efforts are already underway to incorporate this moving forward.

Water Quality Regulation and Monitoring

The city's Stormwater Quality Program conducts various water quality monitoring and special studies along the creek including implementing studies related to the *E. coli* TMDL Implementation Plan.

GOAL: Support compliance related to surface water permitting and regulations

Objective: Continue the ongoing water quality monitoring program in support of surface water permits and regulations

The Stormwater Quality Program monitors for temperature variations, nutrients, metals, sediments, *E. coli*, periphyton/chlorophyll-a, and benthic macroinvertebrates in multiple locations to meet routine monitoring and sampling requirements for State permits and regulations.

Routine Stream Monitoring

GOAL: Seek to better understand surface water quality, dynamics, and impacts related to stream health and regulations

Objective: Implement projects and studies to inform regulatory decisions related to city surface water permits

Special studies are conducted on an as-needed basis to support focused project implementation and regulatory decisions. Since 2015, four special studies were conducted to: evaluate watershed conditions; monitor for neonicotinoids; evaluate temperature thresholds; and identify connections between nutrient concentrations and macroinvertebrates.

Flow Monitoring

Findings and Gap Analysis

This section summarizes the main findings from the policy and program evaluations to underscore areas where the Utility is performing well and supporting the intent of the BVCP policies. Additionally, the evaluation also found opportunities where the Utility might improve processes or policy to address current and future community needs.

This information will be further analyzed and form the basis for policy and procedure recommendations contained in the Master Plan.

Policy Evaluation

Because the Boulder Valley Comprehensive Plan provides overarching guidance for the entire city, it is not surprising that many of the policies contained therein provide overlapping direction as they relate to the functions of the Utility. Their overarching nature often does not provide tangible objectives that are typically defined at the utility master plan level. Therefore, qualitative and semi-quantitative discussions, versus strict qualitative analyses are presented below on the major program themes. Utilities will participate in the upcoming 2025 BVCP update process and suggest ways to streamline language though that process.

Flood Management Program Themes

Within the Flood Management Program, themes related to floodplain preservation and restoration are supported by ten policies in the BVCP, however floodplain preservation efforts tend to be underrepresented in flood mitigation projects that seek to remove people and property from floodplains by reducing floodplain size. This conflicts with restoration efforts intended to support critical ecological processes associated with the flooding of riparian areas and wider floodplains. Improved definition and/or description of non-structural drainageway improvements or protection of riparian areas may support future implementation of these concepts.

The city has delineated floodplains for the entire city that have been accepted by FEMA and has developed regulations to control or prohibit development in these areas. Thereby protecting people and property as identified in BVCP policies. These floodplain regulations may benefit from further evaluation to determine whether they have unintended consequences, such as continued encroachment into the floodplain, which could eventually result in negative cumulative effects of flood damage. Additional recommended policy actions such as addressing risk and damage associated with larger flooding events and how to best incorporate climate change may also be considered.

A city-wide Multi-Hazard Mitigation Plan[1] is in place that is routinely updated to implement projects and programs that mitigate risk from defined hazards such as floods. The Utility may want to enhance its internal emergency preparedness and response processes aside from those in the MHMP. This will help to conform to the structure and processes specific to the Utility and avoid overreliance on ODM for response and recovery efforts. Further specifics regarding what should be addressed by the Utility related to emergency response and recovery will require further definition.

[1] At the time of this writing, the MHMP is a city-wide plan. This plan is moving into a jurisdiction (county) wide plan in the next couple of years.

Stormwater Quality Program Themes

Between the functions of the Greenways Program, OSMP, and MS4 Permit requirements, the Stormwater Quality Program is meeting or exceeding the intent of the stormwater quality policy themes. While groundwater dewatering can affect surface water quality, this can most likely be addressed from a program standpoint with the Stormwater Drainage Program. BVCP policy guidance supports consideration of, but does not require, policies and regulations related to groundwater dewatering.

Five separate policies in the BVCP address wetland preservation and restoration. Efforts to preserve wetlands are addressed by other departments and programs within the city; however, it is not currently a priority of the Stormwater Quality Program. Given that wetlands perform many services that are directly related to the enhancement of water quality, it has been noted that preservation and restoration of wetlands should be a bigger focus for the Program going forward.

Overarching Utility Themes

The Utility actively engages in integrated planning efforts with external regional and State entities to address multi-jurisdictional concerns. Within the city, Utilities partners with other departments in the design and construction of projects to achieve multiple objectives. Improving upon these internal coordination efforts by developing a streamlined approach may help avoid missed opportunities. The Utility has recently created a project management office (PMO) to share resources in an organized way and further develop project management knowledge and skill. Implementation of this PMO will likely enhance project execution and planning efforts across the Utility.

The Utility has begun to, but has not yet fully integrated planning for the effects of climate change, resiliency, ecosystem frameworks, and racial equity into planning and policy decisions.

Guiding Principles

The guiding principles found in the previous CFS Master Plan lack supporting definitions (**Table 3**), which makes it difficult to determine whether the activities of the Utility support their intent. These guiding principles should be evaluated for current relevancy and revised as necessary.

Table 3 – Current Guiding Principles

Floodplain Management	Stormwater Quality	Stormwater Drainage
1. Preserve floodplains **2. Preparation for floods** **3. Help people protect themselves from flood hazards** **4. Prevent unwise uses and adverse impacts in the floodplain** **5. Seek to accommodate floods, not control them**	1. Preserve our streams 2. Prevent adverse impacts from stormwater 3. Protect and enhance stream corridors	4. Maintain and preserve existing and natural drainage systems 5. Reduce and manage developed runoff 6. Eliminate drainage problems and nuisances

Program Evaluation

A qualitative assessment was conducted to identify minimum preconditions for Program functions. This information was used to support the subsequent program evaluation. Three primary activities were undertaken:

- Description of the program model with particular attention to, and consensus around, the program goals and objectives
- Assessment of how well defined and evaluable the model is
- Identification of public, community working group, and staff interest in the evaluation and a determination of how the results are to be used

Logic models were developed to understand the sequence of steps and Utility staff activities, going from program services to outcomes. Further, efforts were made to codify what visible, measurable, or tangible results are or might be present as evidence that the objective has been met.

Policies in the BVCP did not provide complete coverage of the necessary functions required by the Utility. Existing information was gathered through data collection and review, information provided by city staff, GIS data, and staff interviews to evaluate the program efficacy.

Limitations of the evaluation included: quantitative data could not be obtained in many instances for the evaluation; and the stated goals lacked specific and measurable objectives. It is recommended that the goals and objectives be refined to better reflect the needs of Utility moving forward and defined metrics be developed to track whether activities produce desired outcomes. This will allow for a more streamlined approach to Utility evaluation in future master plan updates.

Finally, all programs are constrained by the available resources — funding, personnel, and tacit community and organizational support.

- **Funding.** The 2021 budget for the Stormwater and Flood Management Utility is $17M, of which $9M is reserved for CIP/debt service and $6M is the annual operating budget. At the funding rate, when compared with the backlog of project and maintenance needs, it will take several decades to implement the identified needs.
- **Staff.** Within the Stormwater and Flood Management Utility, five FTEs are assigned to stormwater quality and only two FTEs are in place to manage the mapping, engineering and construction components for both flood management and stormwater drainage. Additional staff within the Utilities Department also provide support with maintenance, communications, finance, outreach, and management. However, these staff are dedicated across the City of Boulder Utilities Department, and as such, also support work plans for the Water and Wastewater Utilities.
- **Support.** As documented in the 2019 city-commissioned Tipton report, Boulder Utilities staff expressed concern regarding the ability to implement program work plans with a perceived lack of support from senior officials and the City Council. Numerous personnel and structural changes have been made since that time; however, some staff continue to express concern regarding public perceptions and overall support for the Stormwater and Flood Management Utility.

Flood Management Program

The Utility follows floodplain mapping procedures approved by FEMA, but consideration should be given to mapping additional floodplain hazards (i.e., fluvial hazard zones) and to evaluate mapping approaches, such as when a map should be scheduled for remapping and what technology should be employed (e.g., 1D vs 2D models). Flood mitigation studies lack consistency between procedures used for hydraulic and hydrologic analyses along with alternatives prioritization and flood protection levels that should be addressed.

The Utility has an active flood education and outreach program that produces collateral and outreach materials and conducts engagement and education events on an annual basis. In discussions with the CWG, however, there was a perception that the city does not provide adequate education and outreach. To bridge this gap, methods for evaluating the success of education and outreach efforts, along with an annual communications plan to address changing outreach needs and bilingual communications, should be further developed.

There is a clear need to strike a balance between floodplain management that focuses on the preservation and restoration of floodplains — due to the many environmental and social benefits floodplains can provide — with individual property rights and flood mitigation that seeks to reduce floodplain extents to protect people and property from floods.

Stormwater Drainage Program

The 2016 Stormwater Master Plan update provided a hydraulic analysis of the local drainage network to identify deficiencies in stormwater conveyance capacity. Development of metrics would assist with CIP prioritization, and should include racial equity and climate change considerations.

There were some inconsistencies noted between existing regulations, design standards, and recommendations made by the MHFD Urban Storm Drainage Criteria Manual related to hydrologic calculations, storm sewer sizing, and detention pond design that should be further addressed.

The Utilities Maintenance work group has recently undergone a restructuring process to better address both flood and stormwater drainage maintenance needs, along with irrigation ditch maintenance required through contractual obligations. This process should be monitored, with the incorporation of recommendations to enhance routine maintenance on existing infrastructure. Additionally, irrigation ditches should be evaluated for capacity and recommendations for stormwater disconnection identified where applicable.

Stormwater Quality Program

Meeting MS4 Permit requirements is a significant task for any municipality to undertake. The City of Boulder's Stormwater Quality Program has completed a substantial amount of work to both comply with, and exceed, minimum permit requirements in many cases. This includes a robust water quality outreach program with help from regional partners and extensive *E. coli* source identification and elimination efforts. Because of this, the Stormwater Quality Program has been undertaking water quality initiatives that reach beyond state required actions. Many of these initiatives are still in their infancy and will require continued evaluation and adaptive management.

Evaluation of Racial Equity and Social Vulnerability

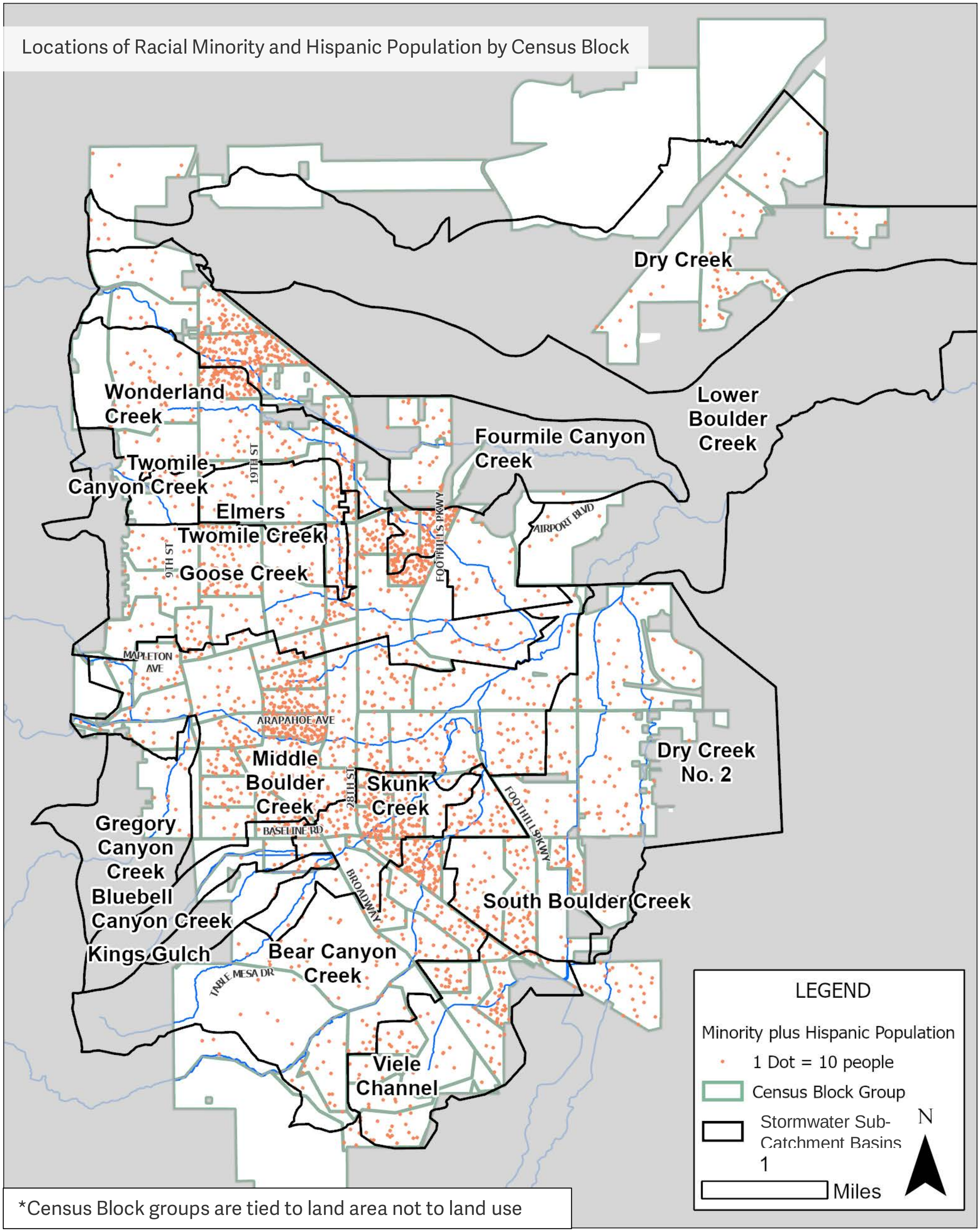
As part of the city's master planning process, the city employs Community Connectors to engage underrepresented communities, bridge cultural and language barriers, help develop effective engagement opportunities, and support activities related to master planning efforts with city staff and partners. Additionally, education and outreach related to flood preparedness, response, and recovery have not uniformly been published or presented in both English and Spanish. To address this, the city hired a language access program manager who is responsible for developing the city's language access plan.

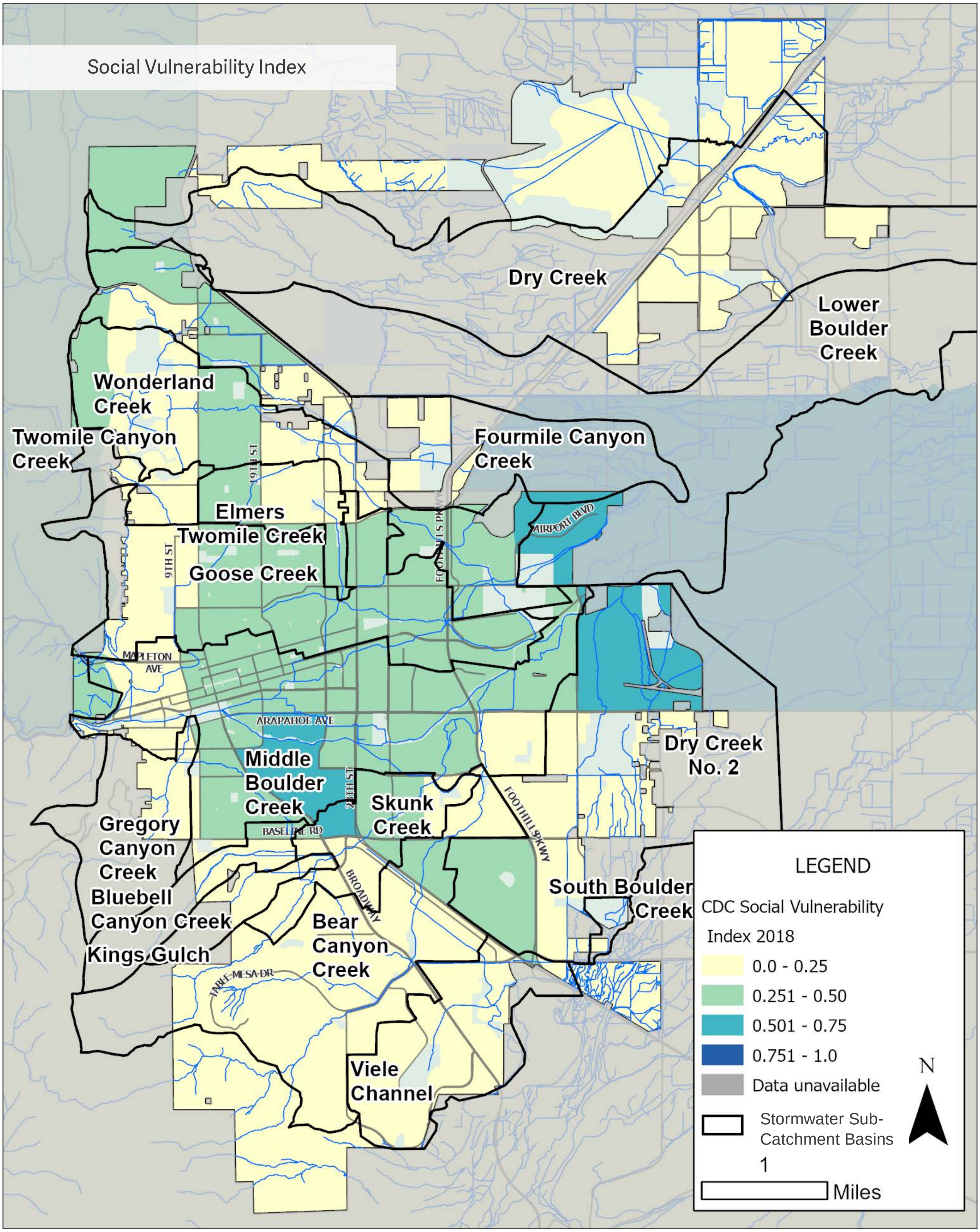
The Utility strives to incorporate racial equity into its operations by first evaluating whether undue burdens may have inadvertently been created by existing regulations, policies, or procedures and then to identify corrections that can be made moving forward. In a review of current floodplain regulations, properties located in the High Hazard Zone that sustain flood damage equal to or greater than 50% of their pre-flood market value are not allowed to be rebuilt. This regulation places undue burden on low-income communities where property values are lower. For example, a $200,000 home that sustains $110,000 in damage cannot be rebuilt; whereas a $2,000,000 home that sustains up to $1,000,000 in damage can be reconstructed.

Racial equity has not previously been a factor in project prioritization for the Utility's programs or for CIP projects. Additionally, some flood mitigation projects are currently being proposed to provide flood mitigation solutions that provide less than 100-year flood conveyance to protect the redevelopment potential of the site, where other projects located in the same watershed have relocated mobile home residents from a site so that 100-year flood mitigation could be provided. In addition to looking at racial equity, social vulnerability is another well-accepted index developed by the Centers for Disease Control and Prevention (CDC) to predict a community's ability to respond to, and recover from, natural disasters based on a number of social and economic factors. The Social Vulnerability Index ranges from 0 to 1 with lower indices indicating lower social vulnerability. By integrating social vulnerability into flood mitigation planning and emergency response and recovery plans, the most vulnerable populations can be prioritized for resource allocation during and after emergencies or prioritized for removal from the floodplain all together.

Potential Racial Equity Metrics

- Value of structures removed from floodplains or rebuilt in floodplains
- Location of floodplain permits rejected or accepted as it relates to neighborhood demographics
- Median value of structures removed from the floodplain due to mitigation projects
- Percent of minority residents removed from floodplains due to mitigation projects


Locations of Racial Minority and Hispanic Population by Census Block
Dry Creek
Lower Boulder Creek
Wonderland Creek
Fourmile Canyon Creek
Twomile Canyon Creek
Elmers Twomile Creek
Goose Creek
19TH ST
9TH ST
FOOTHILLS PKWY
AIRPORT BLVD
MAPLETON AVE
ARAPAHOE AVE
Middle Boulder Creek
Skunk Creek
28TH ST
BASELINE RD
Dry Creek No. 2
Gregory Canyon Creek
Bluebell Canyon Creek
Kings Gulch
BROADWAY
South Boulder Creek
Bear Canyon Creek
TABLE MESA DR
Viele Channel
LEGEND
Minority plus Hispanic Population
1 Dot = 10 people
Census Block Group
Stormwater Sub-Catchment Basins
1
Miles
N
*Census Block groups are tied to land area not to land use


Social Vulnerability Index
Dry Creek
Lower Boulder Creek
Wonderland Creek
Twomile Canyon Creek
Fourmile Canyon Creek
Elmers Twomile Creek
Goose Creek
Middle Boulder Creek
Skunk Creek
Dry Creek No. 2
Gregory Canyon Creek
Bluebell Canyon Creek
Kings Gulch
Bear Canyon Creek
South Boulder Creek
Viele Channel
19TH ST
9TH ST
FOOTHILLS PKWY
AIRPORT BLVD
MAPLETON AVE
ARAPAHOE AVE
28TH ST
BASELINE RD
BROADWAY
TABLE MESA DR
LEGEND
CDC Social Vulnerability Index 2018
0.0 - 0.25
0.251 - 0.50
0.501 - 0.75
0.751 - 1.0
Data unavailable
Stormwater Sub-Catchment Basins
1
Miles
N

Evaluation Summary

Table 4 represents a summary of actions that have been identified for improvement as part of the policy and program evaluation efforts. Improvement actions are further addressed in subsequent chapters as part of the master planning analysis process.

Table 4 – Identified Improvement Actions

Program	Identified Policy Improvement Actions	Identified Program Improvement Actions
Overarching Utility	▪ Incorporate multiple objectives in the planning, design, and operation of the Utility ▪ Approach planning and policy decisions through an ecosystem framework ▪ Address specific guidance related to climate change and resilience ▪ Evaluate impacts of policies, planning, and decision making to ensure geographic and socioeconomic equality	▪ Identify metrics needed for tracking progress and future evaluation ▪ Review existing Guiding Principles and define terms like unwise uses in the floodplain and non-structural practices ▪ Develop prioritization criteria for CIP projects and establish a framework for prioritization ▪ Address coordination between Programs within the Utility and with other city departments like Transportation ▪ Develop standards and requirements for annual work plans ▪ Address racial equity in regulations, planning, and project prioritization

Program	Identified Policy Improvement Actions	Identified Program Improvement Actions
Flood Management Program	▪ Proactively preserve and restore floodplains ▪ Define and map riparian areas ▪ Define and prioritize use of non-structural drainageway improvements ▪ Monitor effects of climate change on floodplain delineation and management ▪ Prepare flood response and recovery plans ▪ Restrict development on undeveloped high hazard zone properties ▪ Address risks and damages associated with floods larger than the 100-year flood event	▪ Review floodplain mapping standards to include increased risk and evaluate mapping approaches ▪ Identify how to evaluate success with flood education and outreach efforts ▪ Provide resources to socially underrepresented populations for preparedness and response ▪ Update emergency response plan for Utility ▪ Develop standardized guidance for flood mitigation plans and address flood protection levels based on drainageway ▪ Address future floodway maintenance needs ▪ Review existing floodplain regulations to determine what the balance should be between environmental, social, and individual property rights ▪ Explore effort required to further reduce CRS rating
Stormwater Drainage Program		▪ Evaluate current level of service being provided ▪ Evaluate current detention pond design standards ▪ Identify irrigation ditches with insufficient capacity to receive stormwater runoff ▪ Address routine maintenance needs ▪ Discuss whether groundwater should be addressed by the Utility
Stormwater Quality Program	▪ Consider regulating groundwater dewatering activities to mitigate impacts ▪ Minimize subsurface construction requiring ongoing dewatering ▪ Proactively preserve and restore wetlands	▪ Incorporate BUSH program implementation into master plan ▪ Track stream health function ratings ▪ Evaluate success of green infrastructure plan ▪ Address management of greenways program ▪ Incorporate wetlands into water quality planning efforts

APPENDIX B:
Further Discussion of 1-D versus 2-D Modeling Approaches

Further discussion of 1-D versus 2-D modeling approaches

Most existing SFHAs that are based on 1-D models typically provide results only on a cross-sectionally averaged basis for a series of cross sections (that are defined by the modeler). The 2-D computations are performed at numerous discrete computational points spread over the model domain; thus, 2-D models provide information on a spatially-distributed basis, typically at a much higher resolution than 1-D models. Additionally, flows splits must be defined in 1-D models based on the modeler's professional expertise and related assumptions about their specific locations and characteristics versus actual observation or experience. These same splits are typically explicitly quantified by the 2-D model algorithms without these assumptions. On the other hand, many of the 2-D models on FEMA's approved hydraulic model list lack the capability to directly simulate the effects of bridges, culverts and other structures, while most 1-D models have robust algorithms for simulation of these features. Additional considerations are noted in FEMA's December 2020 Hydraulics Two-Dimensional Analysis Guidance[2], which includes a section on the decision factors for appropriate use of two-dimensional modeling. Agreement for the use of 2-D models with other stakeholders may also need to be considered. The MHFD Hazard Area Guidelines[3] indicate approval is required for hydraulic analysis that is not based on the standard step-backwater method with the most recent HEC-RAS version.

Current FEMA guidelines for establishing the regulatory floodway (referred to as the "conveyance zone" in Boulder's floodplain regulations) were developed based on 1-D modeling. While the higher resolution from 2-D model output can improve quantification of flood hazards in specific areas, it presents significant challenges in establishing the floodway within the current regulatory framework. The December 2020 FEMA guidelines address some of the challenges concerning 2-D floodways by allowing equitable consideration of overbanks and incorporating the use of evaluation lines that provide a method for comparing 2-D floodway results to the 1-D floodway results. The recommended method for determining equitable floodways was initially based on maximum velocity times the maximum depth, a method currently used by the city to determine the High Hazard Zone. However, the 2-D floodway models are generally more time-intensive, as the automated methods for 1-D floodways are not available in HEC-RAS. The document also outlines methods for considering flood elevation increases across the floodplain, but these may need to be adjusted to comply with Colorado's 0.5' rise floodway.

The higher-resolution results provided by 2-D hydraulic models provide valuable information, but also often require additional review and consideration by the Utility for the purpose of regulatory mapping when compared to 1-D. Small islands and isolated inundation areas often occur in flood-inundation maps developed from 2-D model results in urban areas, which may complicate regulation. Each 2-D scenario may present different mapping issues and solutions, such as identification of shallow floodplain areas. FEMA guidelines provide for smoothing some of these floodplain areas, but also require compliance with floodplain boundary standards. As 2-D regulatory floodplains and floodways become more standard, additional solutions will be explored. Nevertheless, current standards of practice and forthcoming solutions are complicated by numerous factors and can further complicate review and regulation.

[2] *Hydraulics Two-Dimensional Analysis Guidance (fema.gov)*
[3] *NONSTRUCTURAL BEST MANAGEMENT PRACTICES (mhfd.org)*

2-D models require significant additional effort and potential complications for regulatory maps. Yet, they provide benefits for analysis, as a design tool, and for hazard communication. 2-D models add value in terms of non-regulatory products when the method is appropriately based on the stream flow.

FEMA has indicated the growing use of 2-D analyses may warrant additional changes in the regulatory floodway approach (FEMA, 2019). It is anticipated that additional 2-D analyses guidelines will be developed and there is potential for a shift in the floodway concept over time. FEMA currently provides announcements for flood risk analysis and mapping activities and a master index of standards and guidelines on their website. It is recommended that the city stay abreast of developments in this area and provide input, as appropriate, to ensure that challenges specific to conditions in the city are reflected in forthcoming standards and guidance.

Per the NFIP and the city's floodplain regulations, development within the regulatory floodway (conveyance zone) is prohibited unless it can be confirmed that flood depths will not increase. This regulation may require additional capability and effort if 2-D hydraulic models become the basis for portions of the regulatory floodways. The city should ensure there is a plan to address the evaluation of floodway development with 2-D models. Incorporation of a list of city-approved hydraulic models, also meeting appropriate MHFD and FEMA requirements, would facilitate the city's use and review of 2-D models.

APPENDIX C:
Community Working Group Findings Report

City of Boulder
Comprehensive Flood and Stormwater Master Plan
CWG Findings Report

We are pleased to present the Findings Report for the Community Working Group on the 2022 revision to the City of Boulder's Comprehensive Flood and Stormwater Utility Master Plan (CFS), last updated in 2004. The purpose of the plan is to improve the management of stormwater to help protect people, places, property and ecosystems in the City in a way that builds resilience and is consistent with community values.

The Community Working Group was comprised of 19 people, representing a diverse range of participants, to reflect the diversity in the Boulder community and encourage engagement from typically underrepresented populations. The CWG was tasked to provide feedback to staff on master plan information, including community values, policies, technical information, engagement process, and evaluation criteria, at various stages of the master plan update.

We met 12 times over more than 16 months, formed subcommittees, conducted community interviews, reviewed feedback from the Be Heard Boulder website, and attended site tours, neighborhood meetings, and pop-up events. We attended community feedback sessions, reviewed Volume I of the draft Master Plan and commented on the Technical Memoranda that ultimately comprised Volume 2.

We, the CWG, agree that the substantive **outcomes** of the Master plan are as listed below. The CWG identified two items - project prioritization and funding – as the top two key outcomes but was not in agreement about which should be listed first in order of importance; therefore, the key outcomes below are listed in no particular order:

- **Development of a Project Prioritization Framework.** We support a comprehensive project prioritization framework that allows the city to compare objectively different community interests in choosing which of the many backlogged Flood Mitigation Projects to advance. The unified framework uses metrics for both quantitative and qualitative community values for project prioritization.

- **Funding Considerations.** The CWG agreed it was important for an effective update to the CFS to consider the methods of funding and the levels of funding in addition to focusing on the uses. A subset of the CWG, feel strongly that the City of Boulder shall pursue the Vision funding scenario as described in Volume I of the Master Plan. Other members of the CWG felt it was more important for the community to understand the trade-offs implicit in various funding levels.

- **Social Equity.** We concluded it was important to incorporate the impact of flood risk on disadvantaged communities, including minorities, the poor, the homeless, children and the elderly. We advocated for giving Social Equity appropriate weight in the Project Prioritization Framework.

- **Elevation of Climate Change.** Global warming is changing the hydrologic risks faced by the city, including the frequency and intensity of flooding events. We sought to emphasize climate change in the plan to ensure that the city considers this increasing uncertainty and risk in its flood and stormwater infrastructure planning.

The CWG feels it is urgent to implement flood mitigation. **Priorities for future action** therefore include:

- **Compile a list of major flood mitigation projects**. We recommend that staff apply the Project Prioritization Framework immediately upon approval of the Master Plan to generate a clear list of projects and share with the community. We also recommend that staff compile a list of all projects and their associated costs throughout the City which are necessary to provide all Boulder residents with an adequate level of flood protection, so that residents and City staff have a realistic view of the scope and cost of work necessary.

- **Prioritize maintenance as well as repairing and upgrading the sewer and stormwater systems.** We believe nothing can influence situational flooding more than regular stormwater and floodway system maintenance by the city, and addressing sump pumps, neighborhood drainage, and other micro-level issues. This requires city and community engagement. Expediting sewer pipe and stormwater system improvements will also help protect our community from flood events.

- **Invest in flood preparedness.** Because of the potentially long timeframe before all Boulder residents will have adequate flood protection, we recommend that the city advance other flood protection initiatives. Ideas include: a flood proofing handbook distributed to all residents and businesses in mapped floodplains, re-establishment and maintenance of borrow ditches in areas in floodplains without storm drains/curb/gutter, and a subsidized flood insurance for residents of low-income housing/mobile home parks. We recommend the city develop an early warning system for potential flood closures with full coverage, street analysis re closures, etc., plus using best practices regarding how this information will be communicated.

- **Modify Rate Revision Analysis.** In its annual review and revision of utility rates, and in the overall approach to financing, we recommend the city consider rate and/or debt increases for the Storm and Floodwater Utility and compare them to the cost of delaying or not implementing major flood mitigation plans, including the possible costs of a flood during the delay. At the same time, the city needs to be sensitive to the burden of increases in fees on the community.

- **Enhance engagement**. We recommend the city increase its current engagement with all residents to increase awareness of and preparedness for floods and to ensure better water quality in Boulder's creeks. We believe the city should continue to look for new opportunities to engage the community to reach those who are typically underrepresented in engagement efforts, including improving methods of reaching non-English speakers in an emergency.

- **Continue leading on climate change.** We believe that Boulder should continue to be a leader in addressing climate change and the city should act now to make infrastructure resilient and prepare for extreme events. The city should place substantive emphasis on nature-based solutions, resilient infrastructure and management of habitats along stream corridors.

- **Pursue Flood Protection Outside Utilities.** The CFS master plan was guided in part by the Boulder Valley Comprehensive Plan. There are policies in the BVCP that support flood risk mitigation that are outside the jurisdiction of the Utility, particularly development and land use policies. The city should amplify the benefits realized by this CFS plan by implementing many of the BVCP development and land use policies.

Finally, the CWG reviewed the planning process and engagement activities. Since the engagement was done during the time when the city was largely shut down due to the pandemic, much of the outreach had to be done virtually.

Recognizing the constraints and opportunities of virtual engagement, CWG members felt the following activities worked well during the planning process:

- CWG Interviews – learning community views through person-to-person communication
- Creation of "one-pager" highlighting the challenges and opportunities for flood mitigation in Boulder
- Walking tour- Seeing the impacts to a floodway is very helpful.
- Dotstorming exercise to aid project prioritization tool
- Regional meetings were helpful, but they were poorly attended. Without the ability to meet in-person, some detail and connection get lost.
- Interpreters need to be familiar with the subject matter to be effective in communicating technical information.

CWG recommendations for virtual and in person engagement in the future are as follows:

Working Group Facilitation

- Consider adopting a more intuitive platform for information sharing rather than Be Heard Boulder

- Structure the process with more collaboration from CWG members
- Provide more review time for and consideration of feedback delivered regarding the technical memos
- Distribute a contact list of the CWG members at the beginning of the process

Public Engagement

- Look for ways to improve community engagement to ensure we have a data set of responses that are representative of the community
- Create a "sparkly" video for these types of projects to attract community engagement.
- Provide more specific information to the community to answer the question: when will the drainageway in my neighborhood be addressed? Ask clear questions.
- Clarify the role of Community Connectors and provide adequate resources to enable personal outreach. Going into the communities where Spanish speakers live/work/play is vital to obtaining more participation. Printed or personal communications are more effective with the Spanish speaking community than online engagement.

We believe the revised CFS presented here for adoption has incorporated some of our suggestions and feedback. As a group, we achieved consensus on the outcomes, future priorities and process comments listed above. We did not achieve consensus on every point or emphasis in the Master Plan, but we do agree that the plan as presented to Council, incorporates many community priorities, and can form the foundation for sound flood mitigation policies and investments in the years and decades to come.

ATTACHMENTS

Attachment A: Individual comments and Ideas for Pet Projects

ATTACHMENT A: Individual Comments and Ideas for Pet Projects

From:	Elizabeth Black
To:	CFSInfo
Subject:	Comments for "Pet Ideas"
Date:	Thursday, May 26, 2022 3:42:13 PM
Attachments:	image001.png

External Sender

Here are my comments for the "Pet Ideas" section of the CWG report. Thanks, Elizabeth

- **Close Linden Avenue during major storm events in the Two-Mile drainage.** 4 people have died in floods on Two Mile Canyon Creek. This creek's geomorphology makes it particularly dangerous in flood events. Every public safety agency must be made aware and stay aware of the danger to motorists which flooding on Two Mile Canyon Creek presents. Linden Avenue must be closed when flooding is imminent on Two Mile Canyon Creek. Emergency alerts must be sent to all phones in the Two Mile drainage area directing them to shelter in place or climb to safety, and to avoid driving at all costs.
- **Include Flood Fatalities on Maps:** On every floodplain map that the City produces, include an icon that represents each person that died in a flood, and put the icon in the location where each person died. For instance, 4 little fatality icons would be on Two Mile Canyon Creek on every floodplain map that the City produced.
- **Flood-proofing Handbook:** Provide residents and businesses in mapped floodplains with a flood-proofing handbook, to assist with their own protection and preparedness efforts.
- **E. coli in Boulder Creek:** Develop an on-site public warning system to inform water-users of high e. coli levels for at-risk reaches of Boulder Creek.
- **Public Education about Flooding:** On bike and pedestrian underpasses and concrete walls of paths along all creeks, stencil a graphic delineating the water level in that location during the 2013 flood. **Water Level 2013 Flood** Add additional water level stencils for future floods.
- **Neighborhood Meetings are Necessary:** Citizens want city staff to come to neighborhood meetings and answer their questions. They want to learn when and what improvements will happen in their neighborhood, and learn how to deal with flood-hazards in the meantime. Combine informational meetings with a sign-up for a Home Preparedness and Flood Proofing assessment to incentivize attendance. Attendees can figure out how much of a risk they face and decide whether they want to get individualized advice about how to stay safer and flood-proof their residence.
- **Allocate Funds Equally:** Limited flood mitigation funding must be allocated fairly and equally across all drainages. We must first provide adequate hamburger-level flood protection for all drainages before providing chateaubriand-500-year flood protection for a single drainage.
- **Timelines for future flood protection:** Inform citizens of their flood risks and timelines for flood protection, due to current funding levels. Provide residents in mapped floodplains with an estimate of when future flood mitigation projects will protect their property from flood damage.

- **Ditch Companies are Valuable Partners:** In partnership with irrigation companies, assess stormwater carriage opportunities and improvements to irrigation ditches to mitigate flooding. Irrigation ditches already carry storm water in flood events, and ditch companies are valuable and necessary partners that the City needs to work closely with to solve flooding issues.
- **Basements "Not Recommended" in some areas:** Notify property owners in areas of high groundwater that basements and other improvements requiring dewatering are not advised in their area. Create an overlay map that combines complaints, floodplain maps, creeks, wetlands, irrigation ditches and laterals with building lots, to flag lots where basements are "NOT RECOMMENDED due to high water table".
- **Hazards of 3 Upstream Dams:** Develop early warning systems and evacuation plans for the event of a dam failure. Educate all City residents on the hazard that Boulder's 3 upstream dams (Barker, Gross & Pinebrook Hills) pose. Analyze retention and spills from the 3 upstream dams during the 2013 floods to better understand the effects of dam management on potential flooding during flood events.
- **Borrow Ditches Protect Properties:** Reestablish borrow ditches (drainage ditches) in neighborhoods without storm drains, giving priority to areas in mapped floodplains. Develop sizing recommendations for borrow ditches and culverts in neighborhoods without curb, gutter and storm drains. Train Planning and Building & Inspection staff to include the installation and adequate sizing of culverts and drainage ditches when redevelopment permits are applied for in areas of Boulder without curb, gutter and storm drains.
- **Incorporate Mapping Assumptions:** Floodplain mapping is an inexact science and uses certain assumptions (for instance that there will be no debris in flood waters) to create flood maps. Include the assumptions used to make the map on all floodplain maps, both printed and on-line.
- **Our Creeks are not "Natural":** Change language in City documents to emphasize that creeks and drainage-ways within City limits are man-made constructed landscapes rather than "natural or native" landscapes. Our city is built on multiple alluvial fans, where creeks would naturally fill their channels with debris and create new channels. But we cannot allow them to do this natural thing anymore because our city is built on top of the alluvial fans. We must instead maintain and clear our creeks so they will stay in the same place, and so the next flood will have a clear channel through town and do the least damage to our city. Use different language to describe our creeks, referring to them instead as what they are: "maintained creek corridors", "constructed man-made landscapes" and "managed habitats". It will help smooth future controversies about the necessary maintenance of our floodways.

Elizabeth Black

APPENDIX D:
July 18, 2022, WRAB Presentation
Clarification of Project Prioritization Framework Example

CITY OF BOULDER
WATER RESOURCES ADVISORY BOARD
AGENDA ITEM

MEETING DATE: July 18, 2022

AGENDA TITLE: Public Hearing – Consideration of a Recommendation to approve the updated Comprehensive Flood and Stormwater Master Plan

PRESENTERS:
Joe Taddeucci, Utilities Director
Joanna Bloom, Utilities Deputy Director of Policy and Planning
Chris Douglass, Utilities Engineering Manager

EXECUTIVE SUMMARY

The city is continuing the process of updating the Comprehensive Flood and Stormwater Master Plan (CFS, or plan) that is the guiding policy document for Boulder's Stormwater and Flood Utility. The purpose of the plan is to improve the management of stormwater and drainageways to help protect people, places, property, and ecosystems in a way that builds resilience and is consistent with community values. Staff received feedback from the Water Resources Advisory Board (WRAB) at the June 27, 2022, meeting requesting clarification of how the project prioritization framework will be applied and to which projects, among other comment themes. The purpose of this memo is to address WRAB and public feedback on the plan and to request a recommendation from the WRAB to City Council on approval of the plan.

STAFF RECOMMENDATION

Staff recommends that the WRAB make the following motion regarding the CFS update:

> The Water Resources Advisory Board recommends that City Council approve the 2022 Comprehensive Flood and Stormwater Master Plan update, including the recommendation to adopt the vision level of funding as recommended by the plan to expedite the pace of major flood project implementation.

FISCAL IMPACT – The CFS recommends moving from the current Action level of funding to the Vision level of funding (as described on pages 38 and 29 of Volume I) to expedite the pace of major flood project completion. Actual funding levels will be considered by the WRAB as part of the annual Capital Improvement Program (CIP) process.

BOARD FEEDBACK - WRAB members asked questions and provided verbal comments on the draft plan during the June 2022 meeting. Major themes of WRAB and public comments and staff's responses are below. CFS updates will be made where indicated and responses to WRAB feedback will be further discussed at the July 18 WRAB meeting.

PUBLIC FEEDBACK - The draft plan was posted on the project site in English and Spanish, and public feedback was requested through Be Heard Boulder from late June through July 15. Comments received echo themes heard from the Community Working Group (CWG), including confirmation that the plan aligns with community values and also reflects a high degree of interest in drainageway specific action. A public hearing for this item is scheduled during the July 18, 2022, WRAB meeting.

BACKGROUND

This 2022 CFS Master Plan is an update to the previous Comprehensive Flood and Stormwater Utility Master Plan developed in 2004 and provides a framework for implementing programs and projects in the Stormwater and Flood Management Utility. The project team worked closely with a CWG throughout the process to support the development of the update, which consists of two volumes and details six key findings and outcomes in the areas of project prioritization; racial equity; climate change and resilience; flood preparedness; outreach and education; support for maintenance; and recommends a Capital Improvement Program level of funding moving forward. These topic areas align with areas of community and CWG interest and reflect community values. At the June 2022 meeting, the WRAB heard report-outs from staff and CWG representatives and provided feedback on the plan.

ANALYSIS

Local Drainageway Interest - The WRAB, the CWG and the public voiced that the CFS update generally aligns with community values. This feedback was accompanied by questions about how the CFS relates to neighborhood- and drainageway-specific improvements, when such improvements will be made, and whether this plan replaces existing plans. The CFS does not replace, but rather compliments and provides guidance for other planning efforts, including drainageway-specific plans that include the engineering analysis that determines which projects are needed where. *When* these projects are ultimately built is largely determined through the annual CIP process where funding is secured for project design and construction. The relationship between plans is illustrated on page 17 of CFS Volume I[1].

Prioritization Framework – The WRAB and community also voiced general support for the project prioritization framework but had remaining questions about how it will be used, including how project prioritization metrics will be applied to specific projects. In response, staff will walk through an example of how the criteria and metrics are applied at the July WRAB meeting.

The prioritization framework allows for relative comparison of project benefits; as such, an individual project score serves as a comparative value in relation to other projects, and their respective scoring. The criteria weighting that informs these project scores was assigned based

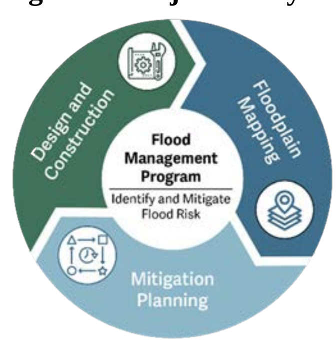
[1] A printer-friendly version of Volume 1 is now available online on the project website

on direct feedback from the community and the WRAB, lending to tool results that reflect how well a particular project aligns with community values. Staff does not anticipate that the weighting (as described on pages 130 and 131 of Volume II) will be modified after plan approval. However, staff would return to the WRAB and council should something arise as the tool is put into use. From initial model testing, the tool clearly communicates priorities and differences between projects as displayed in **Figure 1** below.

Figure 1: Example prioritization tool outcomes showing criteria contribution by project

Project Prioritization List - Staff received questions about which projects will be prioritized using the new framework. Projects that are not yet in the design and construction phase of the project lifecycle (shown in green in **Figure 2)** will be prioritized using the new framework. Projects already in the design and construction phase are not under consideration for reprioritization as they have been in process for some time and are nearing the end of the project cycle. For completeness, the table of projects to be prioritized[2] will be updated to include

Figure 2: Project Lifecycle



[2] Included on pages 36-37 of Volume I and included as Table 10-1 on pages 114-115 in Volume II

drainageways that do not yet have mitigation plans, including Boulder Creek, Boulder Slough, and Sunshine Canyon Creek.

NEXT STEPS

The project team will present the updated plan to Planning Board on August 2; the concepts discussed in the plan will be touched on at the August 11 City Council Study Session, and staff will ask for City Council approval on September 1, 2022.

ATTACHMENTS

A: CFS Master Plan Volume I: Summary Plan
B: CFS Master Plan Volume II: Technical Plan

Comprehensive Flood and Stormwater Master Plan

Water Resources Advisory Board

July 18, 2022

Thanks Joe. I'm Joanna Bloom, Utilities Deputy Director for Policy and Planning. Thank you WRAB for the opportunity to provide responses to some of the questions and comments we've received in the last few weeks since we provided an overview of the master plan at the June WRAB meeting.

Project Prioritization Details

- Provide an example of how the metrics are applied
- Which projects will be prioritized with the new framework?

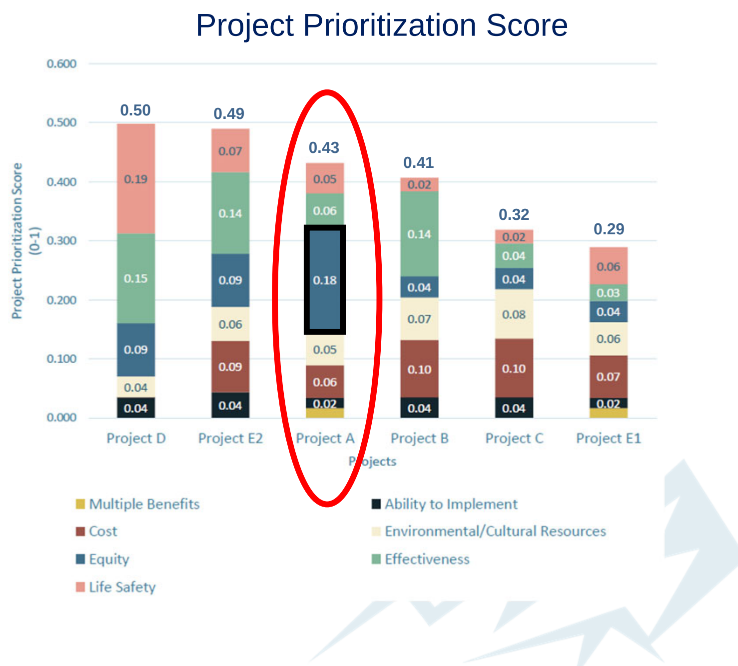
The largest category of feedback received was related to the Project Prioritization tool. We generally heard that it is credible and aligns with community values, but questions remain about how it will be used. The WRAB specifically said it would be useful to walk through an anonymous example to better understand how the tool works. So to do that, we'll be taking a look at **project A** from the master plan and its associated equity score.

Ranking – Prioritization Framework versus Benefit/Cost ratio

Project	Priority Using Benefit/Cost Ratio	Priority Using Prioritization Framework
Project D	2	1
Project E2	3	2
Project A	6	3
Project B	1	4
Project C	4	5
Project E1	5	6

As a reminder, when we met last month we saw that Project A moved from last to third in terms of priority when using the Project Prioritization Framework versus solely using a Benefit / Cost ratio analysis.

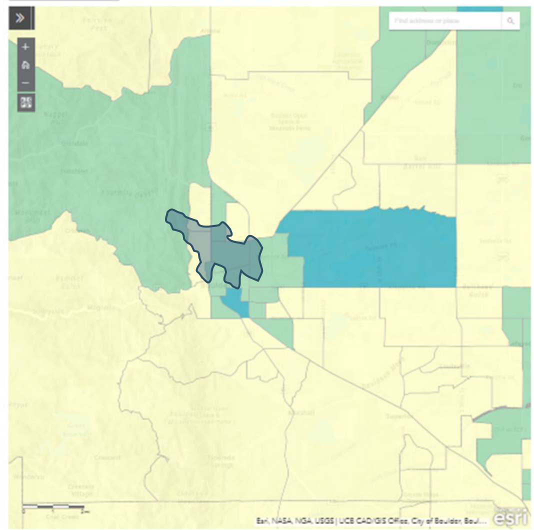
How are the metrics applied?



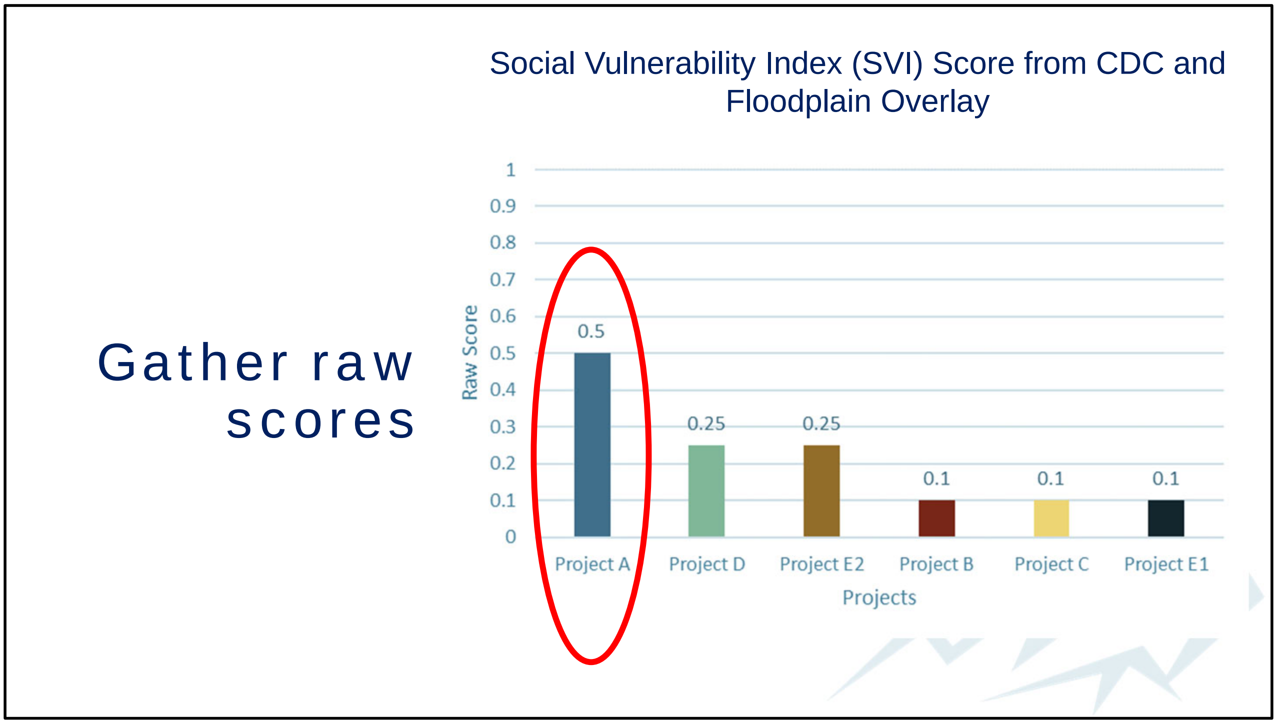
Here is Project A again among the other projects with the values for each criterion displayed as a part of the total score on the graph. We're going to walk through an example of how one of these numbers was calculated. For this exercise, we'll focus on the blue bar with the heavy black outline, which represents the equity score. An important thing to remember as we walk though the process is that these are **comparative scores versus actual scores**. This approach works to magnify the difference between projects and more clearly display how each factor contributes to the final ranked order of projects.

Gather raw scores

Social Vulnerability Index Score from CDC and Floodplain Overlay

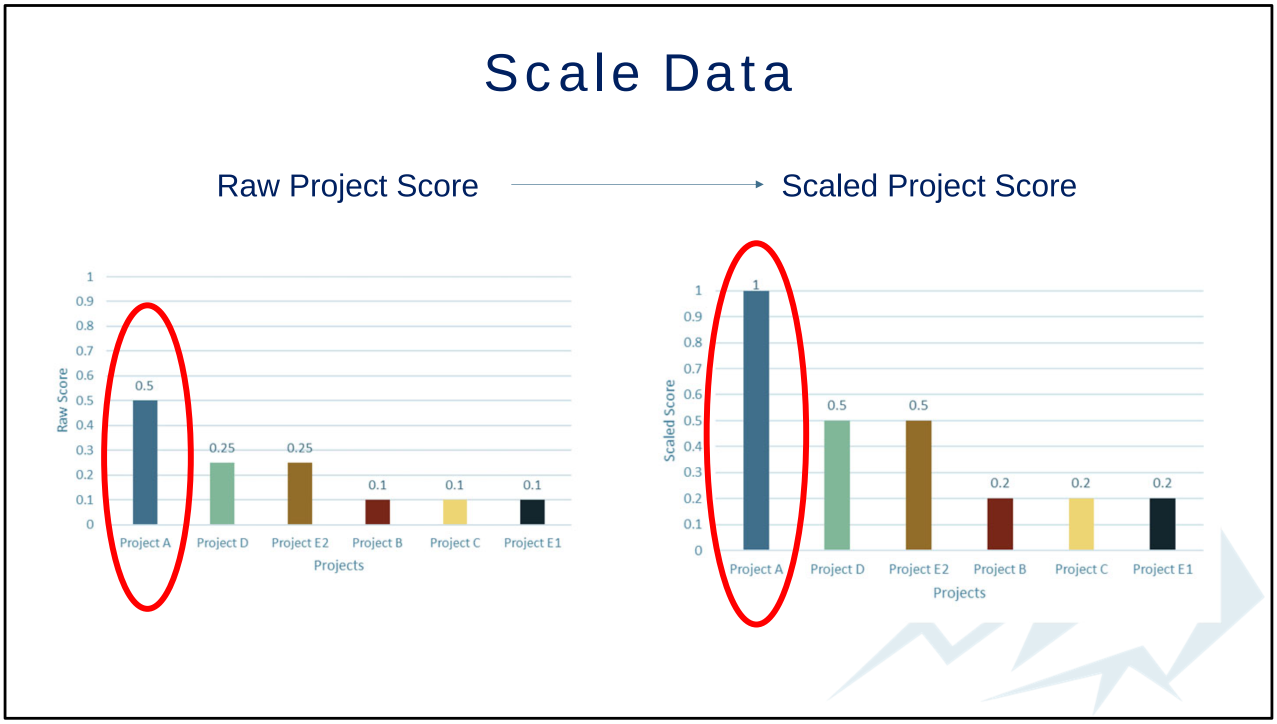


So, how do we get the equity score? First, we gather raw data associated with the identified metric for each criterion. The equity score uses the Social Vulnerability Index score, which is calculated by the Center for Disease Control and Prevention using Census data. We then overlay the floodplain delineation and calculate an area weighted average for each project.

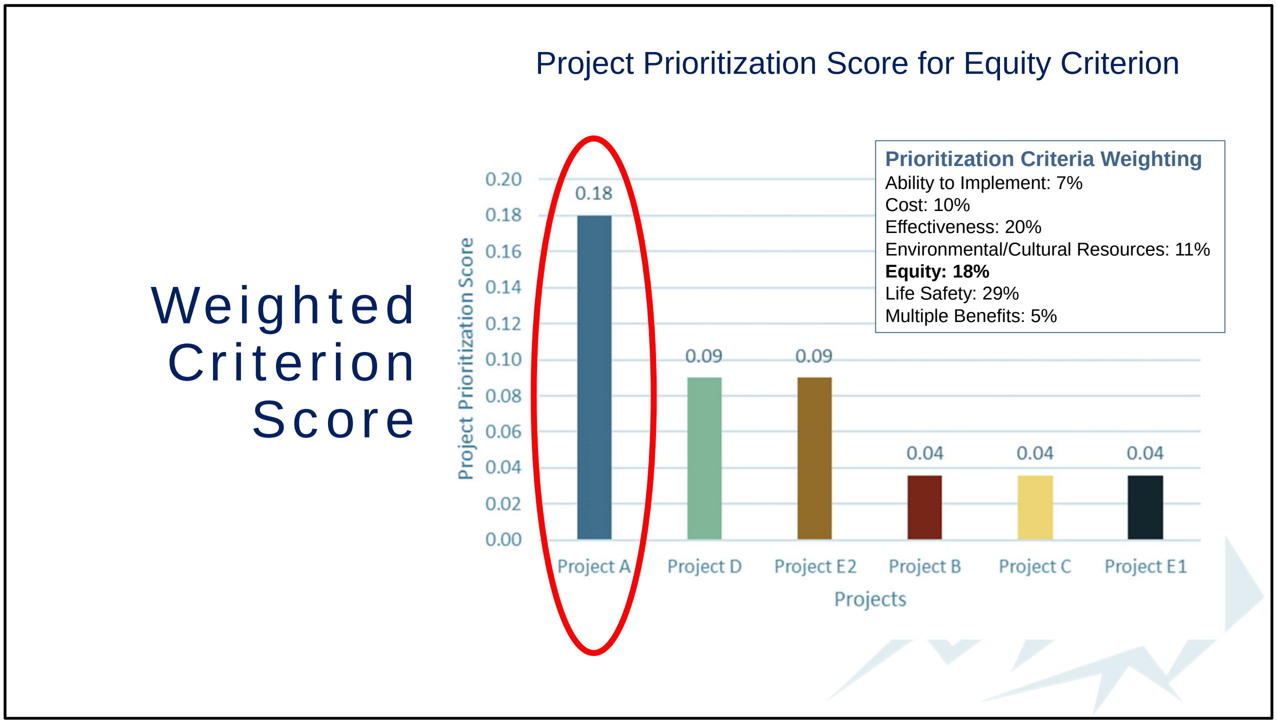


Here you see a raw SVI score for each project using that CDC and floodplain data we just saw. For reference, SVI scores range 0 to 1 - 1 being the most vulnerable. Project A received the highest SVI score of 0.5.

Note: these are estimated values. Weighted area averages will be calculated as part of project prioritization tool implementation.

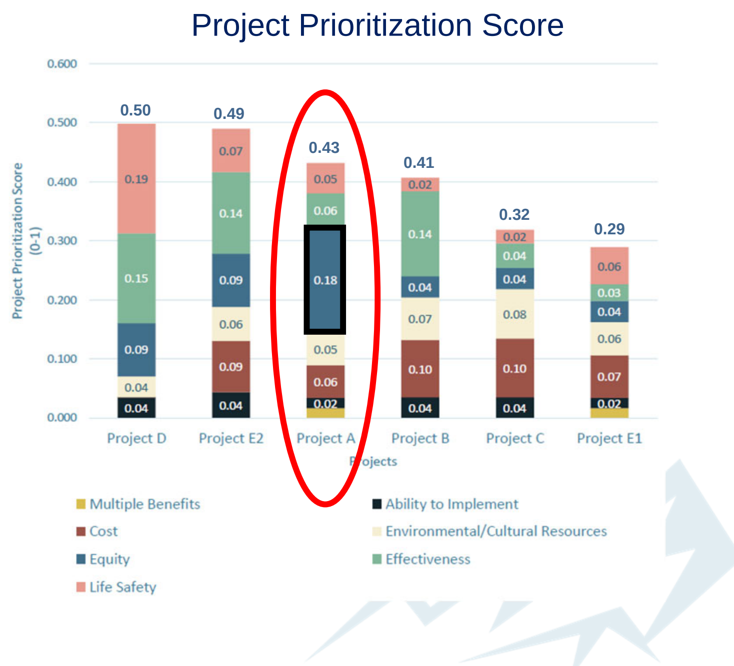


We then scale the raw data so that the highest raw data value equals 1 and apply that same multiplier to the other projects to get scaled scores so we can compare them to one another. Again, this approach works because we want comparative values versus actual values so we can better see the differences between projects. And you cannot, for example, compare number of houses removed from the floodplain to project cost unless you get those metrics on the same scale.



Finally, the scaled score is multiplied by the weighted value for that criterion that was informed by the dotstorming exercise we did late last fall to determine the final project prioritization score. In the case of equity, the scaled score of 1 is multiplied by the 18% allotted to the equity criterion.

Final Project Prioritization Score



Here is that **Project A** equity score again as a component of the final project score and you can see the full 18% in the blue bar. The process I just described is repeated for each of the criterion and their associated metrics, which are described in detail in Chapter 10 of Volume II, and include things such as road level of service or number of structures removed from the 100 year floodplain, and so on.

Project A Scoring

Weight	Criteria	Weight	Subcriteria	Weight	Sub-Subcriteria	Raw Score	Scaled Score	Weighted Score	Criteria Score
7%	Ability to Implement	50%	Constraints			Difficult	0.00	0.000	0.018
		50%	Community Support			3	0.50	0.018	
10%	Cost	60%	Capital Cost			$ 18,200,000	0.55	0.033	0.055
		40%	O&M Cost			$ 2,480,850	0.55	0.022	
20%	Effectiveness	80%	Protect Property	60%	Reduce Physical Damage	82	0.19	0.019	0.057
				40%	Reduce Economic Loss	22.30	0.00	0.000	
		20%	Level of Service			95%	0.95	0.038	
11%	Environmental/Cultural Resources	70%	Protection/ Restoration of Environmental Resources	75%	Protect Existing Natural Features	-0.50	0.90	0.052	0.055
				25%	Restore or Reclaim Natural Features	0.60	0.13	0.003	
		30%	Protect Cultural Resources			0	0.00	0.000	
18%	Equity	100%	Social Vulnerability			0.50	1.00	0.180	0.180
29%	Life Safety	40%	Protect Critical Facilities	60%	Critical Facilities Removed from HHZ	0	0.00	0.000	0.051
				40%	Critical Facilities Removed from 500-Yr floodplain	2	0.50	0.023	
		40%	Remove Residential Structures from HHZ			0	0.00	0.000	
		20%	Road Level of Service			20,384	0.48	0.028	
5%	Multiple Benefits	100%	Multiple Benefits			2	0.33	0.017	0.017
								Total Score:	0.432

I know this is a busy slide, but wanted to show what the detailed version looks like with specific **Project A** metrics applied to the overall framework. Again, you'll see the total equity score of 18% associated with this project highlighted in red. If we were to walk through each of the criteria on this slide, this would be a 45 minute or more presentation so we've highlighted one criterion for the sake of efficiency. However, the approach, including the weighting and the sub-weighting are held constant from project to project.

I just have a few more slides and then I am happy to answer questions about any of this.

CITY OF BOULDER

2022 Comprehensive Flood and Stormwater Master Plan

bouldercolorado.gov