1.0 INTRODUCTION

1.1 Funding and Authorization

Funding for this master plan effort has been provided by the Urban Drainage and Flood Control District (UDFCD), Boulder County, the City of Boulder, and the City of Longmont in addition to a Colorado Watershed Restoration Grant from the Colorado Water Conservation Board. ICON Engineering, Inc. (ICON) and their project team, including Ecological Resource Company (ERC) and DHM Design (DHM) were chosen by the funding partners complete this study through a competitive selection process. ICON's team includes engineers, GIS specialists, scientists, ecologists, planners, and landscape architects with diverse and extensive backgrounds. ICON's contract with the UDFCD was formalized in Agreement No. 14-09.07 on December 16, 2014 to begin work on this project.

1.2 Background

Between September 9 and September 15, 2013, a large rainfall event resulted in widespread flooding along the Colorado Front Range. Boulder Creek experienced peak flows during this event ranging from 4,956 cubic feet per second (cfs) within the City of Boulder at Broadway, to over 9,000 cfs downstream of US Highway 287 [Reference 1, CH2MHill]. This equated to around a 25-year and 50-year regulatory flood event peak discharge for Boulder Creek, at each location respectively. Within the City of Boulder, damages from the flood within the Boulder Creek drainage basin alone, were estimated to have exceeded $41 million [Reference 2, City of Boulder] and were largely attributed to high groundwater and sewer backups as compared to damages from surface water flooding. Significant damage was also prevalent within City of Boulder open space, unincorporated Boulder County, Weld County and the City of Longmont. Banks overtopped at adjacent open space ponds and former aggregate pit excavations. Roadway embankments, including 95th and 109th Streets, breached. In other locations, stream diversion systems were impaired. Structural damage was more evident in the vicinity of Kenosha Road and 115th Street, where several residential homes experienced flood damage. Finally, the flood left portions of Boulder Creek in a state of disrepair, highlighting the need for this master plan study.

It is important to recognize that the September 2013 flood was not the only significant flooding event on Boulder Creek. Since 1864, six other notable floods have occurred, including the flood of 1894 that had peak flow rates exceeding the September 2013 event. Peak flow rates from 1864 were estimated at 12,000 to 13,600 cfs near 4th Street in Boulder [Reference 3, Sherry Oaks].

1.3 Purpose, Scope, Limitations

The purpose of this master plan is to provide planning guidance to improve resiliency along Boulder Creek from the confluence with Fourmile Creek, in Boulder Canyon, to the confluence with the Saint Vrain Creek in the City of Longmont. This plan provides general guidance for stream and ecological restoration among other multiple objectives including:

- Identification of immediate project needs;
- Provide general guidance for stream restoration;
- Identify ecological needs and benefits;
- Identify floodplain management strategies;
- Identify transportation improvements at Boulder Creek stream crossings;
- Identify concurrent recreation and open space access planning;
- Identify an improvement prioritization plan;
- Develop cost estimates for financial planning.

It is important to note that this master plan provides general guidance for restoration efforts, but it does not re-evaluate the current 100-year floodplain limits regulated by FEMA. Although the implementation of some proposed projects presented in this master plan will also improve the regulatory floodplain, the focus of this master plan is to provide a planning tool for stream and ecological restoration.

Within the City of Boulder, Boulder Creek resembles an urban stream corridor. This master plan does not comprehensively evaluate Boulder Creek through the City limits. Instead, the plan addresses specific areas of concern identified by the city staff and other interested parties. General guidance for Boulder Creek is also presented by the City's Greenway's Master Plan [Reference 4, City of Boulder].

1.4 Planning Process

Planning for this report began in December 2014. The consultant team collected information related to stream characteristics and existing infrastructure, as well as observations related to 2013 flood event. Data was collected from multiple sources, including the Federal Emergency Management Agency (FEMA), the Colorado Water Conservation Board (CWCB), the Urban Drainage and Flood Control District (UDFCD), and the Colorado Department of Transportation (CDOT), and local counties and municipalities.

Once background information was collected, the consultant team identified focal areas, and prepared geomorphic and riparian field assessments. This information was presented to the project team and interested stakeholders at monthly progress meetings.

Public Awareness/ Public Outreach

Public awareness of the master planning effort was developed through a combination of direct mailings to adjacent property owners and the development of a project website. The project website included interactive features allowing individuals to subscribe to a mailing list or to leave site specific comments through an interactive comment map.

Two public meetings were held in early March 2015. These meetings were held prior to the development of improvement alternatives, allowing attendee s to offer specific feedback on problems and concerns that they had along the creek corridor. Feedback was gathered through a priority assessment survey, comment cards, and direct discussions with the planning team and key agencies involved in the project. Feedback was incorporated in the development of alternatives and in selecting priority projects.

- Public Meeting #1; March 10, 2015, City of Boulder
- Public Meeting #2; March 18, 2015, Weld County

On September 16, 2015 FEMA held an Open House meeting to present the proposed updated floodplain maps for Boulder Creek from Boulder Canyon to approximately 61st St. While this study does not update any floodplain

mapping, this meeting was attended by the project team to raise awareness about this study and gather public input.

A final public meeting was held on September 29, 2015 to get public input on the recommended plan. At this meeting renderings of the recommended plan were presented to help visualize key elements in the recommended plan.

1.5 Mapping & Survey

Topographic mapping was provided by FEMA for use on this project. Light Detection and Ranging (LiDAR) elevation points were collected in November of 2013. This mapping was completed on the NAVD88 vertical datum and NAD83 State Plane Colorado Central horizontal datum. Additional field measurements were collected by ICON Engineering in February and March of 2015 in order to determine existing bridge dimensions and flood depths. The field survey was conducted on all major roadway crossings within Boulder and Weld County. The results of the approximate survey can be found in Table 9-2: Bridge Information and Replacement Locations.

1.6 Data Collection

Multiple data sources were collected from groups including CDOT, the CWCB, UDFCD, Boulder County, City of Boulder, Weld County, City of Longmont, and Town of Erie. These studies include:

- U.S. Army Corps of Engineers, Floodplain Information Report, FIR, 1969.
- URS Company, Phase B Preliminary Design Master Plan, City of Boulder and Boulder County, 1979.
- Sherry Oaks, Floods in Boulder County, Colorado, Boulder County, 1982.
- Muller Engineering Company, Lower Boulder Creek Flood Hazard Area Delineation, Boulder County, 1983.
- Muller Engineering Company, Boulder Creek Flood Hazard Area Delineation, City of Boulder, 1983.
- Simons, Li & Associates, Inc., Major Drainageway Planning Study, Boulder Creek - South Boulder Creek Confluence Area, 1984.
- Phyllis Smith, History of Floods and Flood Control in Boulder, Colorado, City of Boulder, 1987.
- Boulder County Comprehensive Plan, 2nd Edition, Subsequent Updates, Boulder County 1996.
- Anderson & Company, Lower Boulder Creek and Coal Creek Open Space Master Plan, Boulder County, 1998
- Colorado Department of Transportation, Final Hydraulics Report SH 52 at Boulder Creek, Boulder County, 2008
- Anderson Consulting Engineers, Inc., Hydrology Verification Report for Boulder Creek, City of Boulder, 2009
- Boulder Valley Comprehensive Plan, City of Boulder, Boulder County, 2010.
- Boulder County Parks and Open Space, Walden Ponds Habitat Management Plan, Boulder County, 2010.
- Greenway's Master Plan, City of Boulder, 2011
- U.S. Army Corps of Engineers, Lower Boulder Creek Aquatic Ecosystem Restoration Project, Detailed Project Report and Environmental Assessment, Boulder County, 2011.
- Federal Emergency Management Agency, Flood Insurance Study and Flood Insurance Rate Maps, Boulder County and Incorporated Areas, 2012
- Anderson Consulting Engineers, Inc., Boulder Creek Floodplain Mapping Study, City of Boulder, 2013
- City of Boulder, The Plan for Boulder's Civic Area, City of Boulder, 2013
- Oz Architecture, North of Boulder Creek Master Site Development Plan, Concept Report, University of Colorado, Boulder, 2014
- Michael Baker International, St. Vrain Creek Watershed Master Plan, St. Vrain Creek Coalition, 2014.
- CH2MHill, Draft Report for Boulder Creek Hydrologic Analysis: Phase 2: Boulder Creek above St. Vrain Creek, Colorado Department of Transportation, 2015
- City of Boulder Open Space and Mountain Parks, Grassland Ecosystem Management Plan, 2009

1.7 Acknowledgements

This report was prepared with groups including the UDFCD, City of Boulder, Boulder County, Weld County, City of Longmont, Town of Erie, ICON Engineering, DHM Design, Ecological Resource Consultants, Inc., CWCB, the Colorado Department of Transportation (CDOT), and the Federal Emergency Management Agency (FEMA). Project participants are listed below.

Table 1-1: Project Participants

Name	Representing
Craig D. Jacobson	ICON Engineering, Inc., Project Manager
Brian LeDoux	ICON Engineering, Inc., Project Engineer
Jeremy Deischer	ICON Engineering, Inc., Project Engineer
Eben Dennis	ICON Engineering, Inc., GIS Specialist
Troy Thompson	Ecological Resource Consultants, Inc.
David Blauch	Ecological Resource Consultants, Inc.
Diane Krzysztof	Ecological Resource Consultants, Inc.
Mark Wilcox	DHM Design
Shea Thomas	Urban Drainage and Flood Control District
Julie McKay	Boulder County Creek Recovery & Restoration Program Manager
Diane Malone	Boulder County IT Project Manager
Kristine Obendorf	Boulder County Transporation Engineer
Varda Blum	Boulder County Floodplain Manager
Yige Gao	Boulder County Floodplain Permitting Specialist
Jesse Rounds	Boulder County Parks and Open Space Planner
Claire DeLeo	Boulder County Parks and Open Space Senior Resource Specialist
Katie Knapp	City of Boulder
Annie Noble	City of Boulder
Marianne Giolitto	City of Boulder Open Space and Mountain Parks
Dan Wolford	City of Longmont
Jonathan Akins	University of Colorado
Naren Tayal	FEMA
Dan Marcucci	Colorado Department of Transportation
Scott Holwick	Lyons Gaddis - Attorneys & Counselors
Diana Aungst	Weld County
Steve Stanish	Town of Frederick

2.0 PROJECT BACKGROUND

2.1 Project Area

The Boulder Creek watershed has a drainage area of approximately 440 square miles, and is located within Boulder and Weld Counties. The majority of the watershed is located within Boulder County. The watershed is bounded to the west by the continental divide, to the north by the Saint Vrain Creek watershed, and to the south by the Clear Creek watershed. This study focuses on the main stem of Boulder Creek from the confluence with Fourmile Creek, approximately 2 miles west of the City of Boulder, to the confluence with Saint Vrain Creek, located within the City of Longmont. The study encumbers over 24 miles of channel length along Boulder Creek.

Boulder Creek is a perennial stream which generally flows from west to northeast. The study area generally lies within the South Central Semi-Arid Prairie ecoregion of the Great Plains; while a small portion of the upstream project reach occurs within the Northwestern Forested Mountain ecoregion of the Southern Rockies. The topographic elevation ranges from approximately 5,700 feet above mean sea level (AMSL) at the confluence with Fourmile Creek to approximately 4,800 feet AMSL at the downstream end of the project area.

West of the City of Boulder, Boulder Creek is confined within the steep canyon terrain of Boulder Canyon. Boulder Canyon generally shares the stream corridor with State Highway 119. East of Boulder Canyon, Boulder Creek enters the City of Boulder, where the stream reflects more of an urban waterway and greenway than a natural stream system. Although, through this reach, Boulder Creek does incorporate some degree of natural landscapes, the encroachment from urban development has occurred over many years. The channel is more confined and numerous bridges, diversions, and stabilization structures exist along its path. East of the city, within Boulder and Weld Counties and the City of Longmont, Boulder Creek resembles a plains stream with a broad floodplain. Although this stretch has fewer bridges than within the urban areas of the City of Boulder, over time, the stream also has experienced significant channel modifications as a result of farming, diversions, sand and gravel ponds, and aggregate mining. As a result, in many areas sinuosity has decreased and the stream lacks natural meanders and bends.

The predominant land cover type within the study area is cultivated cropland, which includes grazing, alfalfa and other crop production. As noted above, aggregate mining of sand and gravel since the mid 1950's has visibly shaped the project area landscape as open water ponds are scattered within the floodplain. Natural vegetation cover exists within the riparian zone and a variety of wetland habitats also exist. However, riparian and wetland habitat only occupies a small percentage of the project area. Other land uses include high and low density development within the City of Boulder, roadways and transportation infrastructure.

The Boulder Creek corridor contains a variety of wildlife, threatened or endangered species, and aquatic habitat. Both the City of Boulder Open Space and Mountain Parks and Boulder County Parks and Open Space maintain land restrictions or seasonal closures throughout the project area.

Finally, the floodplain areas along Boulder Creek are regulated by local floodplain administrators and the Federal Emergency Management Agency (FEMA) over the entirety of the study reach. Regulatory floodplain areas include a variety of flood zones for riverine and shallow flooding locations. Base Flood Elevations (BFEs), and shaded Zone X designating the 0.2%-annual-chance, or 500-year floodplain area has been identified within Boulder County. A regulatory floodway has also been designated along a portion of Boulder Creek from Valmont Road through 61st Street. Boulder County regulates floodway along Boulder Creek although a floodway designation is not shown on the FIRM. Within Weld County the regulatory floodplain consists of an approximate study designation. It should be noted that the City of Boulder is undergoing a floodplain remapping effort for the reach of Boulder Creek and Boulder Slough through the city limits. Although the City is still awaiting the formal adoption of the study on the FEMA FIRM maps, concurrence from FEMA has been given to the technical data, and these changes have therefore been considered with this master plan where applicable.

2.2 Flood History

Reports of flooding along Boulder Creek extend back to the 1840's, however the first documented flood may have occurred as early as June 1864, following a fifty hour rainfall event [Reference 5, Phyllis Smith]. The flood of record is reported to have occurred in 1894, where nearly three days of rainfall resulted in unprecedented damage within the City of Boulder, Boulder County, and surrounding communities. During this flood, Boulder Creek's swell destroyed numerous homes, businesses, and bridges, including the 4th Street Railroad Bridge and bridges at 6th, 9th, 12th, and 17th Streets. For five days, Boulder was essentially cut off from the world. Total damages were later estimated by the U.S. Army Corps of Engineers to be around $725,000 [in 1894 dollars, Reference 5, Phyllis Smith]. Damage to surrounding transportation networks in the County also hindered trade networks with nearby mountain towns [Reference 3, Sherry Oaks]. Peak discharges from the 1894 flood were estimated to be between 12,000 and 13,600 cfs [Reference 6, Metcalf and Eddy]. Over time, the 1894 flood has been synonymous with a 1%-annual-chance recurrence, or 100-year flood. Since 1894, and prior to 2013 (discussed below), five other notable floods occurred along Boulder Creek, including floods in 1897, 1914, 1921, 1938, and 1969.

Planning for floods within the City of Boulder and Boulder County initiated in the early 1900's. Over time, high profile architects, professors, and engineers were contracted to study and provide recommendations related to managing or mitigation Boulder Creek. Harvard-trained landscape architect, Frederick Law Olmstead, Jr. was among the first to offer an opinion. In 1910, he published his findings and lectured about floods and flood control on Boulder Creek [Reference 5, Phyllis Smith]. In his findings, he lectured:

> "The principal waterway in Boulder is Boulder Creek, and its principal function, from which there is no escaping is to carry off the storm-water which runs into it from the territory which it drains. If, lulled by the security of a few seasons of small storms, the community permits the channel to be encroached upon, it will inevitably pay the price in destructive floods." [Reference 7, Olmsted, Jr.]

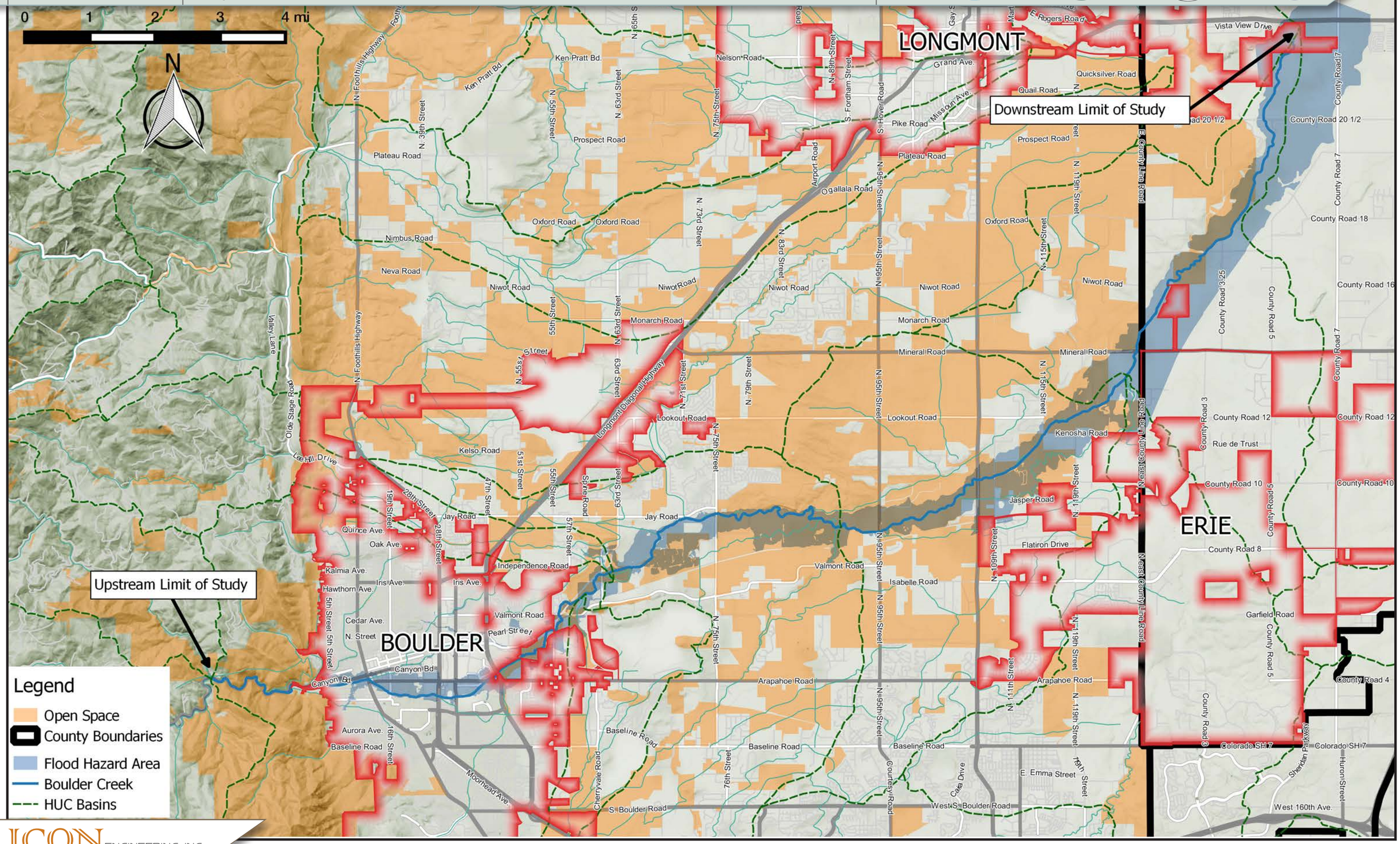
Since 1945 and 1973, the City of Boulder and Boulder County have commissioned over twenty flood studies. The studies recommend a varying degree of both structural and non-structural solutions for Boulder Creek in addition to recommendations related to surrounding land use and floodplain management. Prominent groups or individuals studying Boulder Creek have included the U.S. Army Corps of Engineers, Dr. Gilbert White (University of Colorado), and the Urban Drainage and Flood Control District, among others.

December 2015

Boulder Creek Master Plan

Figure 2-1

Project Overview



ICON ENGINEERING, INC.

2.3 September 2013 Flood Event

Between September 9 and September 15, 2013, a large rainfall event resulted in widespread flooding along the Colorado Front Range. Although damages along Boulder Creek were less severe than other locations along the Front Range, they were significant, none the less. Rainfall within the Boulder Creek watershed during the storm generally increased from west to east. Total rainfall between September 11th and 13th ranged from approximately 2.6 inches, west of the City of Boulder, to over 9.7 inches east of the City. Although the total volume of water greatly exceeded the 100-year regulatory design levels, the rainfall was spread out over the three days and did not translate to a 100-year degree of runoff. Peak discharges from the flood at various locations are shown in Table 2-1, as reported from Wright Water Engineers [Reference 8] and CH2MHill [Reference 1]. In general, the flood discharge was estimated to be on the order of a 25 year to 50 year flood event.

Table 2-1: 2013 Flood Discharge Observations

Location	Observed Discharge	Estimated Flood Frequency	Source
Boulder Creek at Broadway	Approx. 5,000 cfs	25-year	UCAR Estimate based on CDWR (Ref. 8)
Boulder Creek at 28th Street	Approx. 5,300 cfs	25-year	Colorado Water Conservation Board (Ref. 8)
Boulder Creek at 75th Street	Approx. 8,400 cfs	25-50 year	USGS Provisional Data (Ref. 8)
Boulder Creek at U.S. 287	Approx., 9,000 cfs	50-year	Estimated Peak Discharges - Phase 2 (URS per Ref. 1)

Damage from the September 2013 flood event along Boulder Creek was widespread. As noted previously, within the City of Boulder alone, damages were estimated to have exceeded $41 million [Reference 2, City of Boulder]; however, these damages were largely attributed to high groundwater and sewer backups. Within City of Boulder Open Space and Mountain Parks properties, unincorporated Boulder County, Weld County and the City of Longmont, stream banks overtopped and embankments along open space ponds and former aggregate pit sites failed. Roadway embankments breached, and stream diversion systems were damaged. Structural damage to homes also occurred in the vicinity of Kenosha Road and 115th Street. Within Boulder Canyon, avulsions and deposition changed the landscape of the riverine system. A partial list of flood related damages is described below, as well as discussed for each reach in Reach Descriptions.

City of Longmont (Confluence with the St. Vrain Creek):

- Areas of impact within the City of Longmont reflected avulsions of the St. Vrain Creek. During the flood, St. Vrain Creek diverted from its standard path, spilled through adjacent aggregate ponds, and defined a new confluence location with Boulder Creek, approximately 1,600 feet upstream of the historic confluence location. The newly defined confluence location will be kept going forward, shortening the overall channel length of Boulder Creek. Flood debris was prevalent through this reach, as was scour and deposition along the channel banks.

Weld County (20½ Road through County Line Road):

- Areas of impact with Weld County were identified along the County's roadway crossings with Boulder Creek, specifically at County Roads 20½ and 16½. At these locations, flooding resulted in scour around the bridge abutments and piers. The roadways were damaged where they overtopped, often a significant distance from the bridges.
- Boulder Creek through much of this reach is managed through irrigation diversions, sand and gravel ponds, and aggregate mining. Minor damage and breaches occurred at several ponds within Weld County. A significant bank cut developed adjacent to the Town of Erie's re-use pond downstream of County Line Road. This pond also experienced a deluge of flood waters from overtopping of adjacent ponds and roadways to the south. The bank cut is currently in process of repair by the Town of Erie.

Boulder County (County Line Road through 75th Street):

- A wide range of flood damages were experienced along Boulder Creek within Boulder County. Upstream of County Line Road, open space ponds breached and the stream bank failed along the Doniphan, Wittemeyer, and Bailey-Kenosha Pond open space properties. Similarly, the existing irrigation diversion and bridge connection, between the north and south properties at this location, were also damaged.
- Several residential properties and homes were damaged by flood water that overtopped Kenosha Road. Upstream of 109th Street, Boulder Creek diverted from its banks and washed out the 109th Street roadway approximately 600' north of the current bridge crossing. This roadway has since been repaired by Boulder County.
- Upstream of State Highway 287, within the Alexander Dawson Open Space, Boulder Creek diverted from its banks, short cutting recent channel and restoration features installed by Boulder County and the Urban Drainage and Flood Control District.
- Overtopping of 95th Street was significant and the roadway failed approximately 1,000 feet north of the current bridge location. Significant damage was also noted to downstream ponds and property. The overtopping of 95th Street was a result of channel avulsion upstream of the 95th Street bridge. This roadway has since been repaired by Boulder County.
- Within the Walden Pond Open Space, open space ponds breached at several locations. Boulder County is current in process of permanently breaching and making repairs to several of these ponds.

City of Boulder (75th Street to Boulder Canyon Mouth):

- Upstream of 61st Street, Boulder Creek's north bank breached in two locations, diverting floodwater and sediment into Pit D and the Cline Fish Ponds. The gravel pit south of the Fish Ponds, also breached to Boulder Creek. The City is currently in process of completing a design to restore this area.
- Downstream of 61st Street, Boulder Creek diverted its course and bypassed the Green Ditch diversion structure. The City is currently in the process of restoring the creek corridor in this area which will also re-establish the Green Ditch diversion point.
- Significant debris collected upstream of the Old Valmont Road Bridge. Flood debris also settled near the current Valmont Road location.

- Nearby, the Butte Mill Ditch breached at the crossing with South Boulder Creek, adjacent to where the flood washed out around the KOA Pond.
- Flooding was isolated in areas within the University of Colorado Campus (17th Street to Folsom) and was relatively minor. The 2013 flood destroyed an existing pedestrian bridge crossing near 19th Street.
- Damage to in-stream structures occurred along Boulder Creek within the Civic Center area. This damage has since been repaired by the City.

Boulder Canyon (City of Boulder to Fourmile Creek):

- Within Boulder Canyon, flood damage occurred to both Boulder Creek and State Highway 119. High velocities contributed to steam erosion, deposition and undermining of roadway infrastructure. Flows from inflow tributaries also overwhelmed infrastructure, resulting in damage to Highway 119, itself. Much of the immediate damage has since been repaired by the Colorado Department of Transportation (CDOT); however CDOT is currently planning for more permanent and flood resilient facilities in Boulder Canyon. Stream restoration needs are still prevalent within the master plan project reach, mostly along Boulder Creek Path upstream of Settler's Park trailhead.

2.4 Previous Studies

A comprehensive listing of past studies and information was previously described under Data Collection. Below are descriptions of key reports prepared concurrently with this master plan, which should be considered with the implementation of recommended improvements. Key studies are summarized below, organized by jurisdiction.

City of Longmont

- ***St. Vrain Creek Watershed Master Plan (Reference 9, 2014) –*** This plan was initiated following the 2013 flood event. The plan describes alternatives and restoration opportunities for the St. Vrain Creek and tributaries. Different restoration options were presented to restore the confluence location, between Boulder Creek and the St. Vrain River. The City of Longmont has since elected to maintain the confluence where the St. Vrain diverted from its bank, shortening the overall length of Boulder Creek by approximately 1,600 feet.

Boulder County

- ***Boulder Creek – South Boulder Creek Confluence Area (Reference 10, 1984) –*** This study provided preliminary design of drainageway improvements for the Boulder Creek / South Boulder Creek confluence area. The selected alternative from the plan includes: allowing the proposed Pearl Street roadway to be overtopped by 0.5 foot during the 100-year flood; removing the Union Pacific Railroad embankment; providing excavated floodway between 55th and Pearl Street; re-grading the Boulder Creek floodway north of the Union Pacific railroad crossing; removing the existing dike in the vicinity of 56th Street; examining if the existing Valmont bridge west of the Peal Street crossing should be removed; and investigating building a berm between 55th and Valmont. During the Phase B portion of the investigation it was determined that several changes to the selected alternative should be made including: elevating Pearl Street above the 100-year water surface elevation; remove the 61st Street roadway and bridge; provide a 100-year bridge for 55th Street. Several of the proposed improvements have been implemented from this study however; the proposed Pearl Street roadway was not constructed nor was 61st Street removed.

- ***Walden Ponds Management Plan (Reference 11, 2010) –*** This plan indicates that the Walden Pond area should continue to be managed as a high quality wildlife habitat with compatible and minimal-impact human uses.

- ***Lower Boulder Creek and Coal Creek Open Space Master Plan, Boulder County (Reference 12, 1998) –*** This plan developed a restoration master plan for the reach of Boulder Creek between the Alexander Dawson parcel, west of US 287, to the Boulder – Weld County line. This plan encumbered open space sites currently identified for repair following the 2013 flood, in addition to areas currently planned for restoration activities, including the U.S. Army Corps of Engineers, Lower Boulder Creek project described below. The confluence with Coal Creek was also evaluated. General project objectives included: re-establishing natural riverine function and self-sustaining ecosystems; restoring historic floodplain interaction; preserving, restoring, or creating diverse plant communities; enhancing pond and stream water quality; providing recreational opportunities; enhancing cultural and natural resources; and promoting sustainability along the project reach. This study evaluated a wide range of aspects related to Boulder and Coal Creeks, including: context; natural resources; channel morphology and stability; stream ecosystems; land planning; and implementation. Information from this report was reviewed to demonstrate compatibility with the planned improvements in this area.

- ***Lower Boulder Creek Aquatic Ecosystem Restoration Project, Detailed Project Report and Environmental Assessment, Boulder County (Reference 13, 2011)*** – This report was prepared by the U.S. Army Corps of Engineers (COE) and Boulder County to evaluate restoration opportunities and needs for Boulder Creek between 109th Street and Kenosha Road. This project is currently proceeding with a final design for the reach. Information from this report was reviewed to demonstrate compatibility with the planned (COE) improvements.

City of Boulder

- ***Civic Center Master Plan (Reference 14, 2013) –*** This draft plan includes redevelopment and improvements for the Civic Center area that extends from 13th Street on the east, 9th Street on the west, Arapahoe on the south, and Canyon Boulevard on the north. With regards to floodplain improvements, the proposed plan includes removal of several buildings and surface parking in an effort to increase floodplain capacity and reduce infrastructure in areas of high hazard designation. A potential underpass for the Boulder Creek Path below Arapahoe Road has been identified as a need; however improvement to the underpass also has potential for minor impacts to the floodplain in this area. With the Civic Center plan, Boulder Creek will continue to be a natural corridor with trees and creek-side vegetation. No specific proposed changes to the channel, ditch diversions, or to the existing crossing structures at 9th, Broadway, and Arapahoe Avenue were

identified. The master plan indicated that new or significantly altered buildings must be flood-proofed according to City of Boulder regulations.

- ***Civic Center Master Plan Flooding Evaluation (Reference 15, 2012)*** **–** This evaluation was completed by Anderson Consulting Engineers (ACE) in order to determine potential floodplain impacts for changes to the Civic Center area as a result of the Civic Center Master Plan (see above). This evaluation analyzed eleven flood mitigation scenarios using a hydraulic model. The scenarios included variations of the removal of the Park Central and New Britain buildings and increasing the opening of the Broadway and Arapahoe crossing structures. The evaluation determined that the base flood elevations upstream of Broadway could be reduced by removal of the buildings and increasing the opening area of the Broadway crossing, but the municipal building would remain within the 100-year floodplain. Additionally, it was noted that improvements have the potential to keep more water in the Boulder Creek channel area which would reduce discharges along the spill flow that follows Canyon Boulevard.

- ***Greenways Master Plan (Reference 4, 2011)*** **–** This master plan provides a planning tool for improvements along the Boulder Creek greenway and the 14 tributaries to Boulder Creek within the City. Along Boulder Creek the greenways plan calls for underpass improvements, over a mile of improved trail, and nearly 124 acres of habitat improvement and water quality improvements along Boulder Creek.

- **City of Boulder Open Space and Mountain Parks Grassland Ecosystem Management Plan (Reference 67, 2010) –** This grassland plan provides a framework for public policies, management actions, and land and water acquisition priorities to conserve the ecological values of Boulder's grasslands. The grassland plan focuses on 24,000 acres of OSMP lands where the Central High Plains meet the foothills of the Southern Rocky Mountains.

University of Colorado

- ***North of Boulder Creek Master Site Development Plan (Reference 16, 2014)*** **–** This plan identifies flood management strategies and infrastructure needs surrounding the North of Boulder Creek Campus, located between 17th Street and Folsom. Key goals and strategies include: maintaining flood water conveyance within open areas of athletic and recreation fields; maintaining existing roadway grades without further obstruction; elevating residential structures above flood elevations; and flood-proofing commercial infrastructure. Also noted as part of the North of Boulder Creek study was the need to improve existing bridge obstructions, and improve both pedestrian and emergency access to the stadium and campus south of Boulder Creek. A series of pedestrian bridge options have been considered to replace the existing access points over the creek.

3.0 HYDROLOGY AND HYDRAULICS

3.1 Hydrology

Baseline Hydrologic Information

Hydrologic information for the Boulder Creek Watershed has been documented from a variety of sources, initiating with the initial U.S. Army Corps of Engineers (COE) Floodplain Information Report in 1969 [Reference 17, U.S. Army Corps of Engineers], updates by the COE in 1977, more recent Flood Hazard Area Delineation (FHAD) reports [References 18 & 19, Muller Engineering Company] for the City of Boulder and Boulder County, and current FEMA Flood Insurance Studies (FIS) [Reference 20, FEMA]. In general, the current regulatory discharges are based on the 1977 COE findings.

In 2009, the City of Boulder initiated an update to the FEMA flood maps. As part of this study, an evaluation was completed to review and confirm previous hydrologic values [Reference 21, Anderson Consulting Engineers, Inc.]. This evaluation concluded that the regulatory discharges are reasonable.

For the purposes of this master plan, the current FEMA regulatory discharges were maintained for evaluating flood control aspects of each project alternative. These discharges are presented in Table 3-1, below. It should be noted that the regulatory discharges presented were confirmed within the referenced regulatory flood studies at each location.

Table 3-1: Summary of Boulder Creek Flood Discharges

Location	Drainage Area (sq. mi.)	10-Year (cfs)	25-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)
Fourmile Creek Mouth[2]	129	2,050	--[1]	7,960	11,660	21,180
Boulder Creek Canyon Mouth[2]	130	2,050	--[1]	7,960	11,660	21,180
6th Street[3]	130 [5]	2,200	5,830	8,100	12,150	22,100
55th Street[3]	155 [5]	3,600	7,070	9,300	13,050	22,056
75th Street[4]	305	3,350	--[1]	9,600	13,800	28,800
U.S. Highway 287[4]	331	2,800	--[1]	8,600	12,700	27,600
County Line Road[4]	431	2,850	--[1]	9,150	13,750	31,700
County Road 16.5[6]	443	--[1]	--[1]	--[1]	13,750	--[1]
County Road 20.5[7]	446	--[1]	--[1]	--[1]	12,250	--[1]

[1] Data Not Avaliable

[2] Floodplain Information Report, Upper Boulder Creek & Fourmile Creek, Gingery Associates, 1981

[3] Boulder Creek Floodplain Mapping Study, Anderson Consulting Engineers, Inc., 2013

[4] Flood Hazard Area Delineation, Lower Boulder Creek, Muller Engineering Company, Inc. 1983

[5] Flood Hazard Area Delineation, Boulder Creek, Muller Engineering Company, Inc. 1983

[6] Letter of Map Revision 12-08-0198P at 16.5 Road, Weld County

[6] Letter of Map Revision 12-08-1047P at 20.5 Road, Weld County

CDOT Peak Flow Estimates

In June of 2015, the Colorado Department of Transportation completed a report regarding peak discharges along Boulder Creek, including the reaches within the Boulder Creek Restoration Master Plan project limits [Reference 1, CH2MHill]. CDOT's study confirmed peak flow estimates from the September 2013 flood, as previously presented, as well as conducted an independent review of flood discharges and frequencies. Primary tasks for CDOT's evaluation included:

- Estimating peak discharges that were believed to have occurred at key locations during the 2013 flood;
- Preparing rainfall-runoff models for the watershed;
- Calibrating results from the hydrologic models;
- Preparing updated flood frequency analyses using gage data;
- Utilizing the rainfall-runoff models to estimate predictive peak discharges along Boulder Creek.

CDOT's study also incorporated the effects of flood control storage on both Barker Reservoir (Middle Boulder Creek) and Gross Reservoir (South Boulder Creek).

CDOT's study recommended changes to peak discharges along Boulder Creek. Significant reductions in the 1%-annual-chance (100-year) discharge, on the order of 40%, have been recommended between Fourmile Creek and the confluence with South Boulder Creek. Downstream of 75th Street, CDOT's recommended flows gradually increase compared to the current regulatory discharges. At the confluence between Boulder and St. Vrain Creeks, increases in the 1%-annual-chance discharges are on the order of a 55% increase. It should be noted that the changes in discharges have not been ratified by project sponsors, local regulatory officials, or FEMA. For this reason, these changes in peak flows have not been incorporated into this master planning study. However, in the future, we would encourage users of this document to confirm any changes in regulatory discharges with local officials prior to implementing improvements recommended within this report. A comparison profile from CDOT's study has been provided in APPENDIX C.

3.2 Hydraulics

The focus of this study is stream restoration and ecological enhancement along Boulder Creek. The study does not re-evaluate the current 100-year floodplain limits as regulated by FEMA. For those reasons, a comprehensive floodplain model has not been generated for this study. However, hydraulic information was collected from a variety of sources. The hydraulic information utilized for this master plan is listed below:

- ***Boulder Canyon*** –From the confluence with Fourmile Creek to the western boundary of the City of Boulder, hydraulic information was obtained from the 1981 *Floodplain Information Report – Upper Boulder Creek and Fourmile Creek, prepared by Gingery Associates [Reference 23]*.
- ***City of Boulder*** – Within the City of Boulder and downstream to 61st Street, hydraulic information was obtained from the 2013 Boulder Creek Floodplain Mapping Study prepared by Anderson Consulting Engineers, Inc. [Reference 22].
- ***Boulder County*** – From 61st Street to the Boulder/Weld County line hydraulic information was obtained from the 1983 Lower Boulder Creek Flood Hazard Area Delineation (FHAD) report, prepared by Muller Engineering Company, Inc. [Reference 19].

- ***Weld County*** **–** Within Weld County hydraulic information was obtained from three separate FEMA Letter of Map Revisions (LOMRs) including:
  - **11-08-1090P** - Boulder / Weld County line to just downstream of the Town of Erie wastewater treatment facility;
  - **12-08-0198P** - from approximately 3,500 feet upstream of Weld County Road 16 ½, to approximately 6,500 feet downstream of Weld County Road 16 ½;
  - **12-08-1047P –** from approximately 3,900 feet upstream of Weld County Road 20 ½, to approximately 600 feet downstream of Weld County Road 20 ½;

  In addition, a floodplain modeling report for the bridge improvements at Mineral Road, at the Boulder-Weld County line was obtained through the Town of Erie. This report was prepared by CDOT in 2008 [Reference 24].

3.3 Climate Change and Uncertainty

Scientists are currently working to predict the future outlook with respect to climate change, uncertainty, and variability within watersheds across the United States. Boulder Creek is no exception and with its prolific flood history, would be considered susceptible to these changing elements. In a report titled *The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100* [Reference 66, AECOM], AECOM notes that 1%-annual-chance (100-year) floodplains in the Unites States are expected to increase by around 45%, with significant regional variations. Some areas within the U.S. would increase more. No significant decreases in floodplain depth or flood area were anticipated for any region. The report also noted that for primary areas of interest for the National Flood Insurance Program (NFIP), 30% of the increases in flood discharges, floodplain area, and depth would be attributed to population growth. The remaining 70% of the increases would be attributed to the influence of climate change. The impact of population growth was more apparent in population centers compared to more rural areas. It should be noted that the AECOM study is based on national averages and is not intended to be interpreted locally.

Urban Drainage and Flood Control District (UDFCD) and Wright Water Engineers, Inc. (WWE) prepared a technical paper titled *Planning for Variability & Uncertainty: Climate Change and the UDFCD Urban Drainage System* to review climate change projections specifically for Colorado and the Front Range. The paper finds there is insufficient data to reliably forecast changes in the intensity-duration-frequency estimates especially for less-frequent events. However, the variability of wetter-than-normal and drought years is likely to increase.

Variations in temperature can also impact the stream corridor by impacting the vegetation along the stream banks. These future deviations in temperature can affect the vegetation's ability to thrive which is vital to protecting the stream corridor from future erosion. Climate change experts project an increase in average temperature making it imperative to account for the resiliency of the vegetation's ability to handle a variation in both temperature and precipitation.

The Colorado Water Conservation Board (CWCB) also released a paper titled *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* The paper outlined statewide annual average temperatures have increased by 2.0^{o}F over the past 30 years and 2.5^{o}F over the past 50 years. All climate models project future warming statewide in Colorado. No long-term trends in average annual precipitation or heavy precipitation events have been detected. Climate models have a greater variability regarding future precipitation, not agreeing whether there will be an increase or decrease in future statewide annual precipitation. While total precipitation is not estimated to change significantly, the frequency of higher frequency storms is projected to increase.

WWE outlined the impact on Major Drainage Systems, quoted from their report below:

- Effects from increased temperatures would be expected to include stress on vegetation, greater potential evaporation and evapotranspiration, lower stream flow, and more frequent periods of precipitation as well as drought.
- Increased frequency in runoff from smaller storms would increase the potential for channel erosion and would increase the frequency of Stormwater flows in the major drainage system.
- Water quality may be affected by more frequent runoff and pollutant loading with increased runoff temperatures in summer.
- Current projections do not indicate a trend of increasing or decreasing flooding for large (e.g. 100-year and greater) events, and 100-yr floodplain limits would not be expected to change. In cases where floodplains that have been preserved and/or drainageways have been engineered with an adequate allowance for freeboard, the level of protection provided and flood risk would not be expected to change significantly based on projections from climate experts.
- Increased evapotranspiration would require additional water to maintain wetlands. If surface or groundwater levels decline, wetland vegetation will not be able to be sustained and wetlands may be displaced.
- Increases in precipitation may result in more frequent trail inundation, especially at crossings, resulting in a greater need for maintenance attention

Although recommendations presented in this master planning study are based on currently regulated discharges along Boulder Creek, users of this study are encouraged to consider future climate change estimates for any long term improvement that may be implemented.

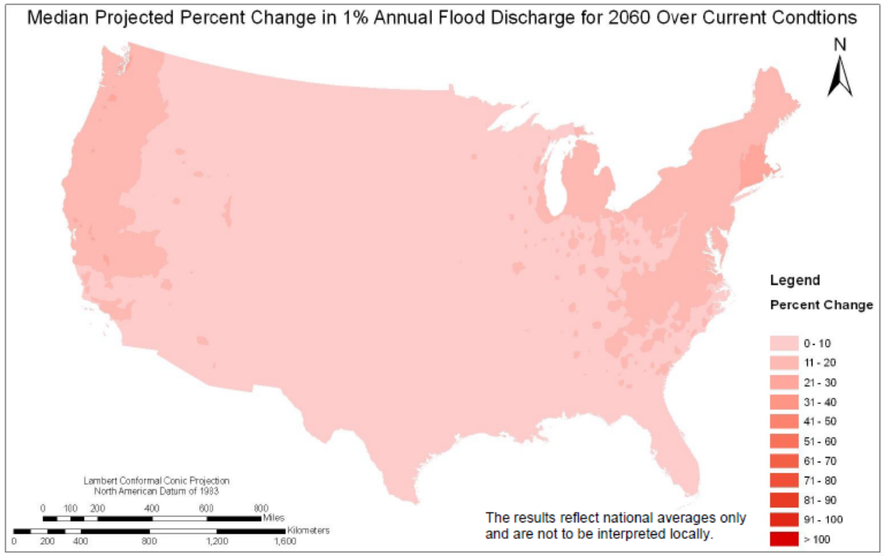


Figure 3-1: 1%-Annual Chance Projections for the United States, 2060 (AECOM, 2013)

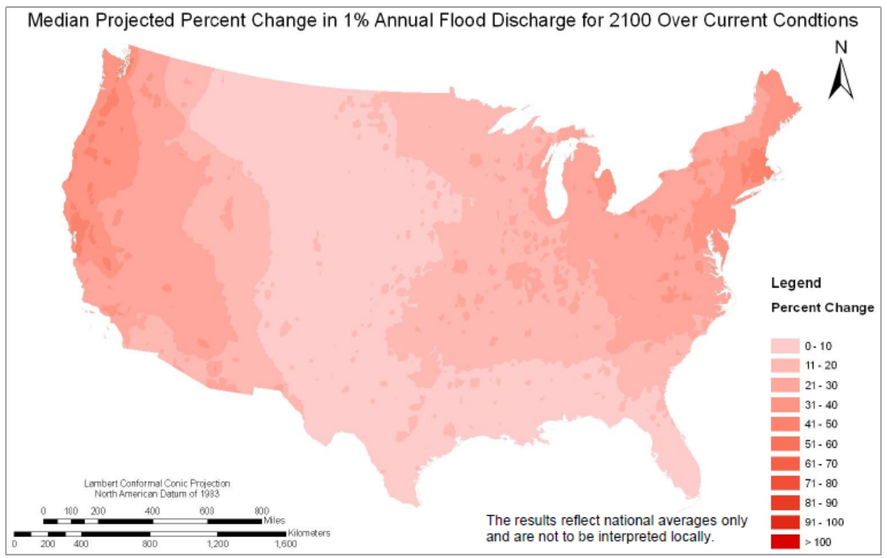


Figure 3-2: 1%-Annual-Chance Projections for the United States, 2100 (AECOM, 2013)

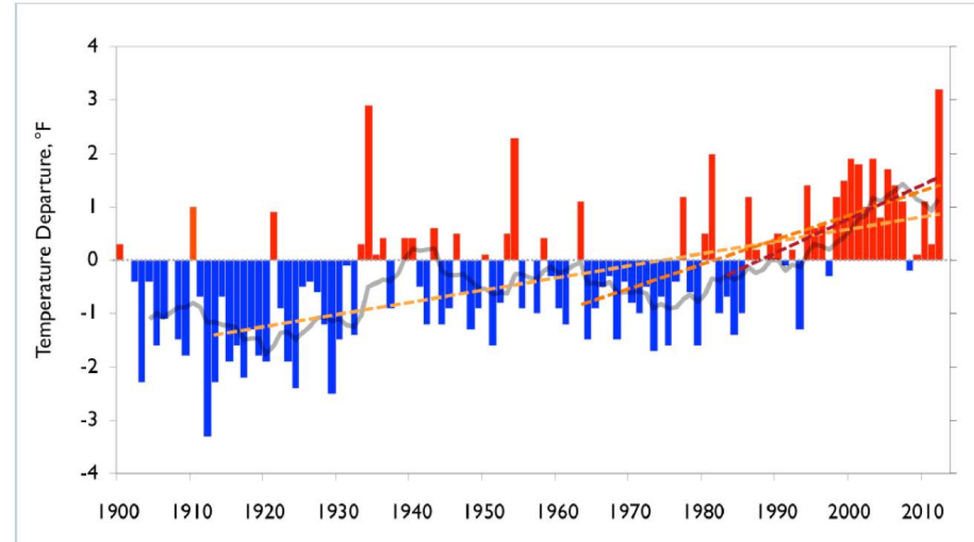


Figure 3-3: Colorado Statewide Annual Average Temperature, 1900-2012 (CWCB 2014)

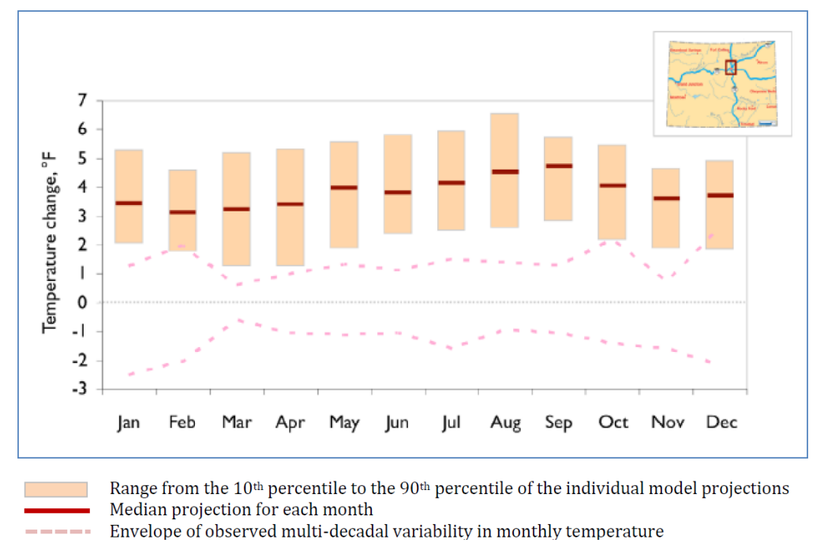


Figure 3-4: Projected Monthly Precipitation Change for Denver Metro Sub-region Low-moderate Emissions Scenario for 2035-2064 (Figure 5-9 CWCB 2014 from BCSD5 statistically downscaled CMIP5 projections, Reclamation 2013)

4.0 STREAM MORPHOLOGY AND EXISTING SITE CONDITIONS

4.1 Stream Classification

For the purposes of this master plan, Boulder Creek has been divided into ten separate reaches for description and planning purposes. Descriptions below discuss general observations along each stream reach, in addition to geomorphic classification based on Rosgen methodology. The Rosgen stream classification system is a widely used framework that defines stream types on the basis of geomorphic characteristics including channel slope, sinuosity, width/depth ratio, and entrenchment ratio. The classification system integrates geomorphic pattern with predominate bed material to identify different types of streams (Rosgen 1996). The Rosgen system defines eight Level I stream types on the basis of geomorphic characteristics including single thread or multiple channel condition, channel slope, sinuosity, width/depth ratio, and entrenchment ratio. Level I stream types are identified by letters, such as A, B, and C. The classification system integrates geomorphic pattern with predominate bed material to define 42 Level II stream types, identified by letters and numbers, such as B3, C3, C4, etc. (Rosgen and Silvey 1998). Numbers one through six are used to sequentially describe bedrock, boulders, cobble, gravel, sand, and silt and clay as the predominate bed material. A schematic showing the different Rosgen classification groupings based on observed and measured stream parameters is provided in Figure 4.1. Observation and stream types were determined based on aerial mapping, Google Earth (2013), and field assessments for the full length of Boulder Creek. In general, classification of Boulder Creek typically reflected a Type C stream. Rosgen Type C streams are typically characterized as being a "low gradient, meandering, point-bar, riffle/pool, alluvial channel with broad, well-defined floodplains" (Rosgen 1996). Type C streams have a sinuosity greater than 1.2, an average slope less than 0.02 feet per foot (ft/ft), and a meander width ratio (i.e., meander belt width divided by stream bankfull width) typically between 4 and 20 (Photo 1). These streams are slightly entrenched with well-defined meandering channels. In areas where Boulder Creek was more entrenched through encroachment, the stream was classified as a Type F stream. Finally, stream segments within the Boulder Canyon segment were classified as a Type B stream. Type B streams are defined as having "moderately entrenched, moderate gradient, riffle-dominated channels, with infrequently spaced pools". The plan, profile, and banks of Type B streams are all considered to be stable. The sinuosity of these stream types are greater than 1.2, with an average slope between 0.02 and 0.039 ft/ft, and a typical meander width ratio between 2 and 8. Type B streams are usually seen in narrower, steeper valleys than Type C streams, and contain colluvial deposition in the reach. Rapids and scour pools are characteristic of Type B streams. Photo 2 gives a representative example of a portion of a Type B channel that was observed in Boulder Canyon. Classifications assigned to individual stream segments are intended to describe their current physical characteristics; they are not intended to indicate information on the current stability of the channel or likely channel evolution.

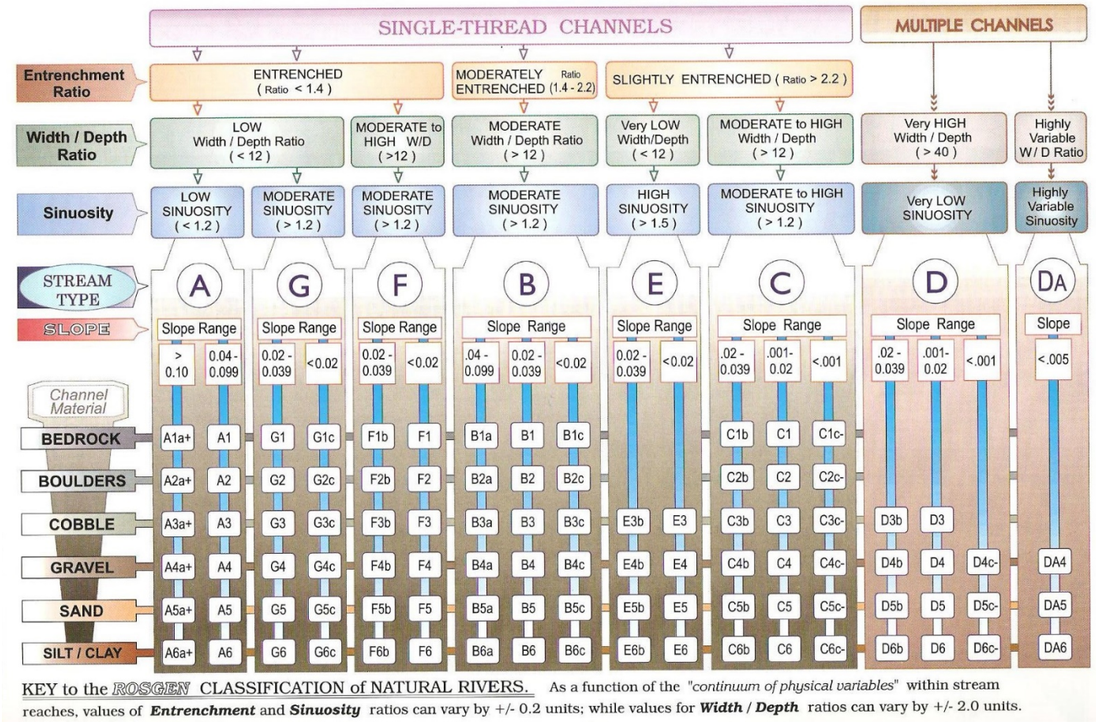


Figure 4-1: Rosgen Classification System System Schematic (from Rosgen 1996)

Photo 1: Typical riffle/pool sequence on Boulder Creek in Reach 1 (Type C classification)

Photo 2: Rapid and scour pools bedforms in Reach 10 (Type B classification)

4.2 Reach Descriptions

Ten stream reaches were defined for the purposed of this study. Reaches were separated based on a number of current stream characteristics including adjacent land uses, sinuosity, channel slope and geological transitions. As examples, the delineation point between the ends of Reach 1 and Reach 2 was selected based on stream sinuosity where Boulder Creek transitioned from a relatively laterally unconstrained system (Reach 1) to an area where gravel mining operations have channelized the stream (Reach 2). Reaches 6 and 7 were separated based on a physical feature (N. 75th Street) as well as an observed difference in stream characteristic while the limits of Reaches 9 and 10 were based on a change in valley type and slope. A combination of field investigations and review of mapping and channel slopes were utilized to assist in reach definition.

Reach 1 (Confluence with St. Vrain Creek to approximately 3,300 ft upstream of the City of Longmont)

Starting at the confluence with the Saint Vrain Creek, Reach 1 extends upstream along Boulder Creek for just over a mile of channel length. All of Reach 1 is contained within Weld County and the City of Longmont towards the downstream end. There are no channel crossings within this reach with the exception to a gravel pit conveyor crossing at the upstream end and several non-formalized low-water crossings for vehicles. This reach includes several gravel pits on either side of Boulder Creek that currently hold water. The riparian area within Reach 1 is approximately 700 feet wide near the confluence with Saint Vrain Creek and narrows to approximately 250 feet at the upstream end of Reach 1. Beyond the riparian area the floodplain overbanks generally consist of active and fallow farm lands. Sporadic residential and farm structures are also present within the overbanks along with several petroleum well pads.

From a channel morphology standpoint, the stream channel is in generally good condition and the riparian corridor is largely intact along the channel. Adjacent land development is limited throughout this reach. Channel sinuosity through Reach 1 is approximately 1.25 and average channel widths are on the order of 40 feet. The average slope through this reach is approximately 0.25%. Based on sinuosity, slope and observed bed material, Reach 1 classifies as a Type C4 stream using the Rosgen Stream Classification System. Some bank instability exists and there is evidence of past stabilization work.

Impacts within this corridor from the 2013 flood primarily reflect avulsions that developed from St. Vrain Creek. During the flood, St. Vrain Creek diverted from its standard path, flowed through adjacent aggregate ponds, and defined a new confluence location with Boulder Creek, approximately 1,600 feet upstream of the historic location. The new confluence location will be carried forward shortening the overall length of Boulder Creek. Although the Boulder Creek generally remained intact, flood debris in this reach still remains.

Photo 3: Flood debris along Boulder Creek (Reach 1)

Photo 4: New confluence between St. Vrain and Boulder Creeks (Reach 1)

Reach 2 (From approximately 3,300 ft upstream of the City of Longmont to CR 16½)

Reach 2 is approximately three miles long and includes bridge crossings at Weld County Roads 20½ and 16½. Although Reach 2 is located in Weld County, upstream locations are co-managed through Boulder County Conservation Easements. Two major diversion structures to Rural Ditch and Idaho Creek are located within this reach. The floodplain overbanks throughout Reach 2 generally consist of sand and gravel ponds, and aggregate mining operations. Disturbances from historic land use practices and other channel alterations are generally widespread. The channel within Reach 2 is relatively straight as a result of encroachment on both banks.

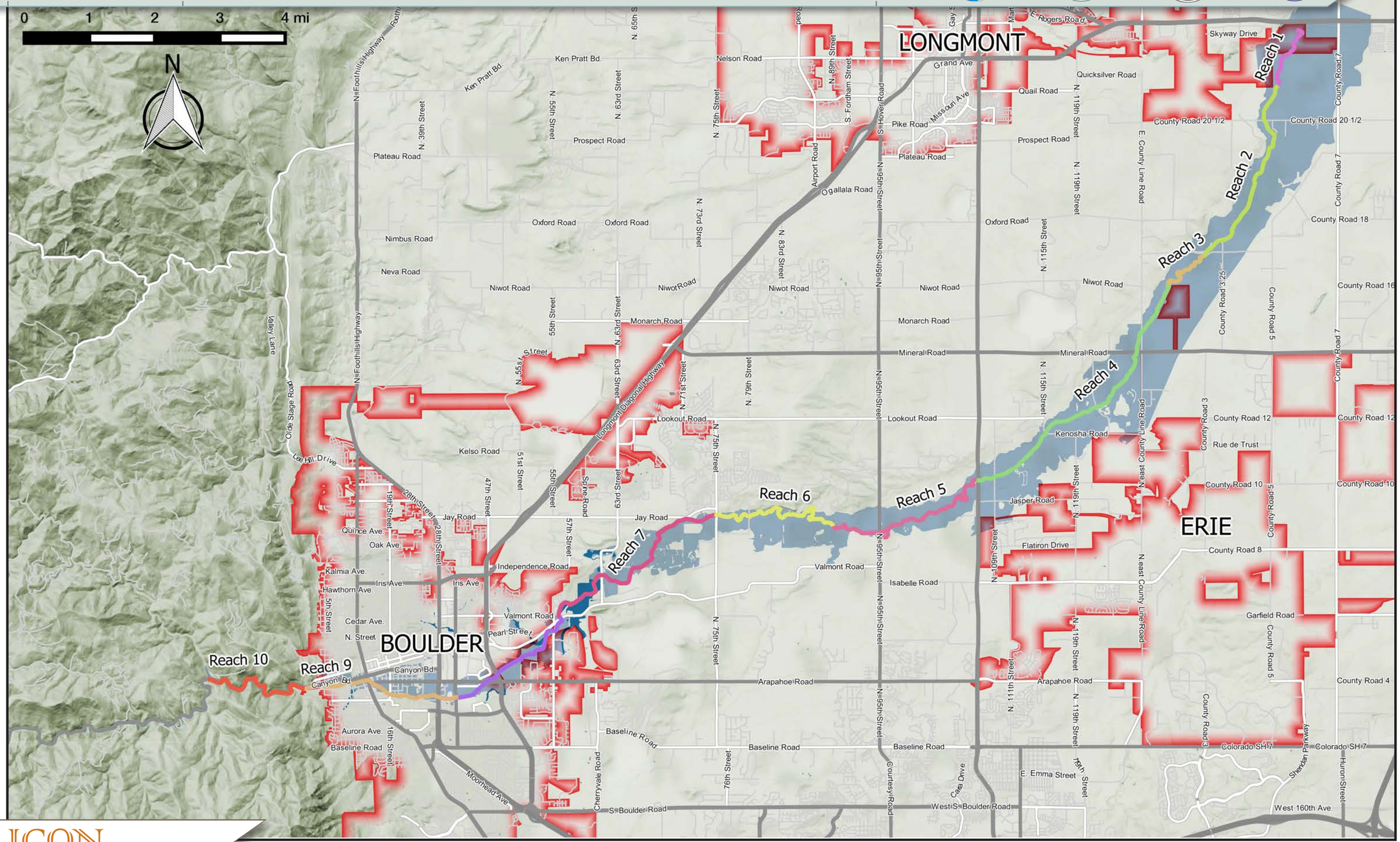
From a channel morphology standpoint, the significant past aggregate mining and other land use practices result in Reach 2 being very channelized. A narrow riparian fringe remains along the banks at some portions along Reach 2 while other sections of this reach have effectively no riparian vegetation. Sinuosity in Reach 2 is 1.04, which is the lowest of any stretch of Boulder Creek downstream from the City of Boulder. The average slope through this reach is approximately 0.28%. Based on sinuosity, slope, observed bed material and estimated entrenchment, Reach 2 is most similar to a Type F4 stream using the Rosgen Stream Classification System, although its sinuosity is lower and the natural stream type is very likely a C4. Encroachment and channelization have resulted in the unnatural F4 stream type. Bank instability and signs of past stabilization work exist at many locations along Reach 2. Through this reach the stream has an average width of approximately 30-40 feet.

December 2015

Boulder Creek Master Plan

Figure 4-2

Reach Overview



ICON ENGINEERING, INC.

Impacts within this corridor from the 2013 flood primary reflect damage along the County's roadway crossings with Boulder Creek, specifically at County Roads 20½ and 16½. At these locations, flooding resulted in scour around the bridge abutments and piers. The roadways were damaged where they overtopped.

Photo 5: Flood debris at 20½ Road (Reach 2)

Photo 6: Pier scour at 16½ Road (Reach 2)

Reach 3 (From CR 16½ to approximately 5,800 ft upstream)

Reach 3 lies completely within Weld County, although the majority of the property is managed through Boulder County Open Space Conservation Easement. This is a short reach with a stream length of 5,800 ft. but only spans a distance of 3,900 ft. The most significant, and ongoing, problem within Reach 3 occurs upstream of Weld County Road 16.5, where a breach in the Bryant Pond diverts flow from Boulder Creek east into the Williams Reservoir No. 1. This has led to overtopping of 16.5 Road well east of the bridge and has led to the continued cut through the south bank of Idaho Creek downstream of the Idaho Creek diversion structure thus bypassing the controlled diversion element at the confluence of Boulder Creek and Idaho Creek.

From a channel morphology standpoint, the remainder of Reach 3 appears to have not been significantly impacted by adjacent land use. Sinuosity through this reach was measured to be 1.49 and evidence of past stream meanders observed on aerial photos suggest that the current stream alignment has a sinuosity that is consistent with past channel alignments. These aerial photos can be found in APPENDIX D

The average slope through this reach is approximately 0.31%. Based on sinuosity, slope and observed bed material, Reach 3 classifies as a Type C4 stream using the Rosgen Stream Classification System. A riparian corridor exists adjacent to the channel throughout a majority of Reach 3, although there are locations along the channel where minimal vegetation remains. The channel takes on a meandering pattern with point bars and bend pools throughout this segment. Average stream widths are on the order of 30-40 feet. Bank instability exists but beyond the 16.5 Road corridor, are not a concern as there is an adequate riparian zone.

Reach 4 (From approximately 5,800 ft. upstream of CR 16½ to U.S. 287)

Reach 4 is the longest reach with a stream length of 4.5 miles. The downstream section is in Weld County and flanked by past aggregate mining activities, the Town of Erie's sanitary and re-use facility, and areas under active gravel operations. The overbanks include active and fallow farm lands and minimal residential development (including a small trailer park). Reach 4 is located in both Weld County and Boulder County with portions of the land owned or managed by Boulder County Parks and Open Space. There are six stream crossings that span Boulder Creek through Reach 4, some of which have the capacity exceeding the 100-year event. Others are more limited in capacity, dilapidated, or un-usable. Several diversion systems also exist within Reach 4. Finally, downstream of 109th Street, Boulder County is pursuing a stream restoration project with the U.S. Army Corps of Engineers. This project extends from 109th Street to Kenosha Road.

From a channel morphology standpoint, Reach 4 has been significantly impacted by adjacent land use as it is channelized along the full length of reach. Sinuosity through this reach was measured to be 1.05, which is essentially the same as Reach 2 and illustrates that the stream has been straightened. A narrow riparian fringe remains along the banks at some portions along Reach 4 while other sections of this reach have effectively no riparian vegetation. The average slope through this reach is approximately 0.34%. Based on sinuosity, slope, observed bed material and estimated entrenchment, Reach 4 classifies most closely to a Type F4 stream using the Rosgen Stream Classification System, although the natural stream type is very likely a C4. Encroachment and channelization have resulted in the unnatural F4 stream type. Bank instability and signs of past stabilization work exist at many locations along this reach. Through this reach the stream has an average width of approximately 30-40 feet.

During the September 2013 minor damage and breaches occurred of the adjacent ponds. A significant bank cut developed adjacent to the Town of Erie's re-use pond, downstream of County Line Road. This pond also experienced a deluge of flood waters from overtopping of adjacent ponds and roadways to the south. Following the flood, the south bank of Boulder Creek was reinforced with concrete rubble as a temporary stabilization measure. This bank should be repaired permanently. Upstream of County Line Road, open space ponds breached and the stream bank failed within the Doniphan, Wittemeyer, and Bailey-Kenosha Pond open space properties. Similarly, the bridge connection between the north and south properties in the open space, and existing irrigation diversion was damaged and in need of removal or repair. Damage to stream banks, sedimentation, and flooding of homes also occurred within the Wheeler Ranch property, located between Boulder County Open Space areas and County Line Road.

Further upstream. Residential properties were significantly damaged by flood water which overtopped Kenosha Road. Upstream of 109th Street, Boulder Creek diverted from its banks and washed out the 109th Street roadway approximately 600 ft. north of the current bridge crossing. This roadway has since been repaired by Boulder County.

Photo 7: Bank erosion at the Town of Erie Reuse Pond (Reach 4)

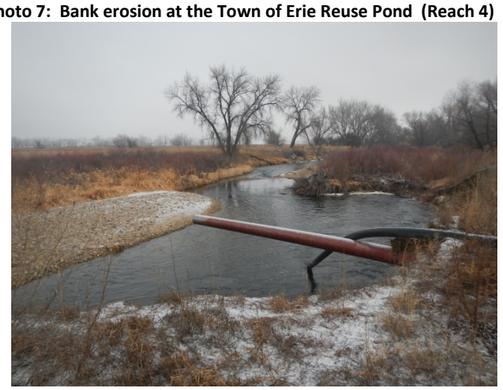


Photo 8: Failed bridge at Bailey-Kenosha Open Space (Reach 4)

Photo 9: Bank erosion near the Bailey-Kenosha Pond (Reach 4)

Photo 10: Flood damaged home near Kenosha Road (Reach 4)

Photo 11: Downstream County Line Road (Reach 4)

Photo 12: Downstream from U.S. 287 (Reach 4)

Reach 5 (From U.S. 287 to approximately 4,200 ft. upstream of 95th Street)

This reach is completely within Boulder County and has a stream length of approximately 3 miles. Within Reach 5, Boulder Creek crosses 95th Street, which washed out during the September 2013 flood event. Two diversion structures feed the Boulder and Weld County Ditch and the Lower Boulder Ditch. The overbanks generally consist of inactive gravel pit areas and both active and fallow farm fields. A vast majority of this reach is within property owned by Boulder County Parks and Open Space, including the Alexander Dawson Open Space, or conservation easements. Past stabilization efforts have been implemented in this reach, although damage was extensive following the flood.

From a channel morphology standpoint, Reach 5 appears to have been impacted somewhat by adjacent land use but still retains some of the characteristics of a natural stream. Sinuosity through this reach was measured to be 1.15, which is lower than would be expected from a natural stream in this setting. Aerial photos show that past alignments took on a more sinuous configuration. The average slope through this reach is approximately 0.34%. Based on sinuosity, slope, observed bed material and assumed entrenchment, Reach 5 classifies most closely as either a Type C4 or Type F4 stream using the Rosgen Stream Classification System. The natural stream type is very likely C4. A marginal riparian corridor exists adjacent to the channel throughout much of Reach 5, but the riparian zone has been largely impacted. The channel takes on a minimal meandering pattern with limited point bars and bend pools throughout this segment. Average stream widths are on the order of 30-40 feet. Bank instability exists in many locations in Reach 5.

During the September 2013 flood, Boulder Creek diverted from its banks upstream of US 287 and within the Alexander Dawson Open Space property. The diversion short-cut the preexisting channel and recent restoration features installed by Boulder County and the Urban Drainage and Flood Control District. Overtopping of 95th Street caused by creek avulsion upstream of 95th Street was also significant, and the roadway failed approximately 1,000 feet north of the current bridge location. Significant damage was also noted to downstream ponds and property. This roadway has since been repaired by Boulder County.

Photo 13: Braided flooding within the Alexander Dawson Open Space (Reach 5)

Photo 14: 95th Street flooding (Reach 5)
photo courtesy of David Mallory, UDFCD

Photo 15: Lower Boulder Ditch Diversion (Reach 5)

Photo 16: Upstream 95th Street (Reach 5)

Reach 6 (From approximately 4,200 ft. upstream of 95th Street to 75th Street)

Reach 6 is approximately 4.5 miles long and is completely contained within Boulder County. The stream corridor itself is contained within land managed by the City of Boulder's OSMP. This reach appears to be in a fairly natural state with little encroachments on either overbank. However, gravel mining operations on the south side of the creek have left several small gravel pits in the floodplain. Hydraulic drop structures exist both upstream and downstream of 75th Street and the diversion structure for the Leggett Ditch is centrally located.

From a channel morphology standpoint, Reach 6 appears to have not been significantly impacted by adjacent land use as the stream is only confined by one pond along its right (south) bank at its downstream end and by natural topography along much of its left bank. Sinuosity through this reach was measured to be 1.43 and evidence of past stream meanders observed on aerial photos suggests that the current stream alignment has a sinuosity that is slightly less yet generally consistent with past channel alignments. The average slope through this reach is approximately 0.40%. Based on sinuosity, slope and observed bed material, Reach 6 classifies as a Type C4 stream using the Rosgen Stream Classification System. A riparian corridor exists adjacent to the channel throughout a majority of Reach 6, although there are locations along the channel where minimal vegetation remains. The channel takes on a meandering pattern with point bars and bend pools throughout this segment. Average stream widths are on the order of 30-40 feet. Bank instability exists but is not a concern in areas with an adequate riparian zone.

Problems related to the September 2013 flood were minor relative to other reaches.

Photo 17: 75th Street Bridge (Reach 6)

Photo 18: Upstream 75th Street bridge (Reach 6)

Reach 7 (From 75th Street to Valmont Road)

This reach is approximately 3.5 miles in length and covers areas of both City of Boulder Open Space and Mountain Parks and Boulder County Parks and Open Space properties. Through this reach, the channel is nearly completely flanked by sand and gravel ponds, and mining operations. Most of these operations are no longer active and the excavated ponds remain full of water. A single large active gravel pit is located on the south bank of the creek approximately ½ mile downstream of 61st Street. The City of Boulder wastewater treatment plant is located just south of the creek, upstream of 75th Avenue. This wastewater treatment plant is protected from flooding by a ring levee. Private stream crossings, minor arterial (61st Street), bike path, and a major arterial (Valmont Road), are all located within Reach 7. The confluence of South Boulder Creek and Boulder Creek is located within Reach 7.

From a channel morphology standpoint, Reach 7 is impacted by adjacent land use but is the first segment downstream of high intensity development that starts to take on some of the characteristics of a natural stream. Sinuosity through this reach was measured to be 1.11, which is lower than would be expected from a natural stream in this setting and similar to Reach 5. The average slope through this reach is approximately 0.43%. Based on sinuosity, slope, observed bed material and assumed entrenchment, Reach 7 classifies most closely as a Type F4 stream using the Rosgen Stream Classification System. The natural stream type is very likely C4. The riparian corridor ranges from good to marginal at different locations within Reach 7, but it has been heavily impacted throughout by past land uses. There is a limited channel meander pattern. Average stream widths are on the order of 30-40 feet. Bank instability exists in many locations in Reach 7.

During the September 2013 flood, ponds within the Walden Pond Open Space breached in several locations. Boulder County is currently in the process of permanently breaching and repairing several of these ponds. The majority of flood damages within the City of Boulder occurred within open space locations. Upstream of 61st Street, Boulder Creek's north bank breached in two locations, diverting floodwater and sediment into Pit D, and the Cline Fish Ponds. The gravel pit south of Pit D also breached to Boulder Creek. Downstream of 61st Street, Boulder Creek breached its north bank, carving a new course through a former gravel pit and bypassing the existing Green Ditch diversion point. The City is currently developing design plans in preparation for future restoration of these areas, in addition to the reach immediately east of 61st Street. Within the confluence area of Boulder Creek and South Boulder Creek, the nearby Butte Mill Ditch breached at the crossing with South Boulder Creek and floodwater washed around the KOA Pond, also on South Boulder Creek. Finally, significant sedimentation and debris collected upstream of the Old Valmont Road Bridge. Flood debris also settled near the current Valmont Road location.

Photo 19: Downstream 61st Street (Reach 7)

Photo 20: Upstream 61st Street (Reach 7)

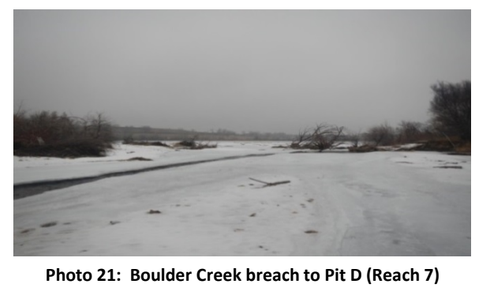


Photo 21: Boulder Creek breach to Pit D (Reach 7)

Photo 22: Old Valmont trail bridge (Reach 7)

Reach 8 (From Valmont Road to 30th Street)

This reach is approximately 2.3 miles in length and primarily within the City of Boulder. The channel characteristics generally include a combination of riparian habitat and roadway, or trail crossings. Wonderland and Goose Creeks enter Boulder Creek within Reach 7, and several small ponds are adjacent to the stream. For Boulder Creek, Reach 8 reflects the transition to an urban flood channel and for the most part, Boulder Creek has been locked in place through urbanization. The Burlington Northern and Santa Fe (BNSF) railroad embankment presents a significant obstacle for Boulder Creek and its connectivity with upstream and downstream floodplain areas. The BNSF crossing also has significantly less conveyance capacity than the larger span bridges within Boulder.

From a channel morphology standpoint, Reach 8 is heavily impacted by adjacent land use. Sinuosity through this reach was measured to be 1.07, which is extremely low and illustrates the channelization that has occurred. The average slope through this reach is approximately 0.68%. Based on sinuosity, slope, observed bed material and assumed entrenchment, Reach 8 classifies most closely as either a Type C4 or Type F4 stream using the Rosgen Stream Classification System, although the bed of the stream contains a fair amount of cobble. The natural stream type is very likely C4. There are small segments within Reach 8 where a healthy riparian corridor exists, however much of the riparian zone has been lost due to urbanization. Significant bank armoring exists within this reach. Average stream widths are on the order of 30-40 feet. Bank instability exists in many locations in Reach 8.

Problems within this reach during the 2013 flood event were not as significant as other locations. Principal problems related more to South Boulder Creek than Boulder Creek.

Photo 23: Upstream of Valmont Road (Reach 8)

Photo 24: Upstream of 55th Street (Reach 8)

Photo 25: BNSF Railroad Embankment (Reach 8)

Photo 26: BNSF Railroad Bridge (Reach 8)

Reach 9 (From 30th Street to City of Boulder Limits)

Reach 9 extends through downtown Boulder from 30th St. to upstream of the Arapahoe Avenue crossing. The reach includes the University of Colorado (CU) Campus, between 17th Street and Folsom. Many roadway crossings exist through this reach as well as Boulder Creek trail bridges. The Boulder Creek trail runs along the creek for the entire reach. Many buildings are located within the Boulder Creek floodplain. Both FEMA and the City of Boulder have designated additional regulatory zones to manage development and redevelopment. Strategic plans, including CU's North of Boulder Creek study review management strategies to reduce flood risk with future development. The City of Boulder is currently in process of planning for redevelopment surrounding the Civic Center area and are evaluating this plan with respect to flood management.

From a channel morphology standpoint, Reach 9 is heavily impacted by adjacent land use. Sinuosity through this reach was measured to be 1.02, which is extremely low and illustrates the channelization that has occurred. The average slope through this reach is approximately 1.11%, which is notably steeper than downstream segments and typical of a transitional segment between the mountains and the plains. Based on sinuosity, slope, observed bed material and assumed entrenchment, Reach 9 classifies most closely as either a Type C3 or a Type F3 stream using the Rosgen Stream Classification System. Near the upper ends of Reach 9 where slopes and median substrate material size increase the classification approaches B2 to B3 Type. A narrow riparian zone exists along the length of Reach 9, but in most cases it is surrounded by dense development. Significant bank and bed armoring exists within this reach. Average stream widths are on the order of 30-40 feet. Bank instability exists in many locations in Reach 9.

Problems within this reach during the 2013 flood event were not as significant as other locations. Flooding occurred within isolated areas of the University of Colorado Campus. The flooding was relatively minor and contained to landscape locations, although an existing pedestrian bridge crossing near 19th Street was washed out. Damage to in-stream structures also occurred along Boulder Creek within the Civic Center area. This damage has since been repaired by the City. The City of Boulder estimated that damages from Boulder Creek exceeded $41 million; however, these damages were largely attributed to high groundwater and sewer backups.

Photo 27: 19th Street Pedestrian Bridge (Reach 9)

Photo 28: Downstream 28th Street (Reach 9)

Photo 29: Downstream Broadway Bridge (Reach 9)

Photo 30: Boulder Creek at Civic Center Park (Reach 9)

Reach 10 (Boulder Canyon – City of Boulder to confluence with Fourmile Creek)

Reach 10 reflects the reach of Boulder Canyon between the City of Boulder and the confluence with Fourmile Creek. This reach has much steeper overbank slopes and narrower cross section than the reaches to the east. The reach length is approximately 2 miles and the riparian zone is narrow at less than 100 feet wide. Through the canyon, State Highway 119 parallels the creek, crossing it twice. The Boulder Creek trail also parallels Boulder Creek along the opposite bank of the highway. In general, the stream banks are steep and stable but armored with cobble, rock, and riprap. Boulder County is currently in process of repairing sections of the Boulder Creek trail and extending the path up to Fourmile Creek.

From a channel morphology standpoint, Reach 10 is heavily impacted by Highway 119. The highway abuts against the stream in many locations. While the stream alignment is largely defined by the geology of the canyon, the highway further constrains the stream. Sinuosity through this reach was measured to be 1.18, which is typical for this type of a canyon setting. The average slope through this reach is approximately 2.81%, which is notably steeper than downstream segments and controlled by the canyon. The channel substrate consists predominantly of cobbles, boulders and some bedrock. Based on sinuosity, slope and observed bed material, Reach 10 classifies as B1 to B3, depending on the specific substrate at a given location along the reach. The riparian zone is largely impacted by the highway. In areas where the stream and highway are immediately adjacent to one another, streamside vegetation is often completely absent. In a few locations where the highway and stream are separate, a narrow riparian corridor typical for this stream type was observed. Very significant bank and bed armoring exists within this reach. Average stream widths are on the order of 25-35 feet. Much of the armoring is associated with the highway but in other locations armoring appears to have occurred to protect other infrastructure. Bank instability exists in many locations in Reach 10.

Within Boulder Canyon, flood damage occurred to both Boulder Creek and State Highway 119. High velocities contributed to steam erosion, deposition and undermining of roadway infrastructure. Flows from inflow tributaries also overwhelmed infrastructure, resulting in damage to Highway 119. Much of the immediate damage has since been repaired by CDOT; however CDOT is currently planning for more permanent and flood resilient facilities in Boulder Canyon. Stream restoration needs are still prevalent, particularly along the Boulder Creek Path upstream of Settler's Park Trailhead.

Photo 31: Bank armoring in Boulder Canyon (Reach 10)

Photo 32: Depositional island in Boulder Canyon (Reach 10)

Photo 33: Deposition in Boulder Canyon (Reach 10)

Photo 34: Stable stream section near Fourmile Creek confluence (Reach 10)

Table 4-1: Existing Reach Properties

Reach	Length (ft)	Slope (%)	Sinuosity
1	5,970	0.25%	1.25
2	16,615	0.28%	1.04
3	5,815	0.31%	1.49
4	24,300	0.34%	1.05
5	15,210	0.34%	1.15
6	13,660	0.40%	1.43
7	18,450	0.43%	1.11
8	12,330	0.68%	1.07
9	13,100	1.11%	1.02
10	10,840	2.81%	1.18

4.3 Recreation and Public Access

Recreation and Public Access are an integral part of Boulder Creek. Extensive studies have been prepared that have reviewed recreation and its impact to the natural systems along Boulder Creek. These studies have been well vetted with the public over the years and have been founded on scientific and ecological principles. As part of this current study we have reviewed these previous studies and have incorporated their findings within the overall master plan. Previous studies include the Boulder County Comprehensive Plan, published May 27, 1999; the Lower Boulder Creek and Coal Creek Open Space Master Plan, published by Boulder County Parks and Open Space Department, 1997; the Boulder County Trail Plan published in 2003; the Weld County Trails Inventory Map 2010, and the City of Boulder Open Space and Mountain Parks Grassland Ecosystem Management Plan.

Boulder County Comprehensive Plan – Trails Guiding Principles

- ***OS 6.01*** Trails and trailheads shall be planned, designed, and constructed to avoid or minimize the degradation of natural and cultural resources, especially riparian areas and associated wildlife habitats. Riparian areas proposed for preservation but for which trail development is inappropriate include: 1) Boulder Creek between 55th Street and U.S. Highway 287, 2) St. Vrain Creek west of Airport Road, 3) Left Hand Creek west of State Highway 119, and 4) Rock Creek west of McCaslin Boulevard.
- ***OS 6.02*** Adverse effects on private lands shall be minimized insofar as possible by trail and trailhead placement, posting of rules and signs against trespassing, installation of containing fences where critical, and any other appropriate measures.
- ***OS 6.03*** The County shall acquire trail rights-of-way through purchase, lease, donation or dedication from any public or private entity. When appropriate and beneficial, existing roads and rights-of-way will be used.
- ***OS 6.04*** Trails shall provide for pedestrian, equestrian, bicycle, and/or other non-motorized uses, where each is warranted. Incompatible uses shall be appropriately separated.
- ***OS 6.05*** Special consideration shall be given to pedestrian, equestrian, bicycle, and/or other uses of road rights-of-way during the design and construction of road improvements.
- ***OS 6.06*** The County shall work through the Consortium of Cities to assure linkage of municipal and county trails and connections between communities.
- ***OS 6.07*** Where appropriate, trails should be incorporated into and provided by new development and linked to established trails, if possible.
- ***OS 6.08*** Trails constructed by the County Parks and Open Space Department shall be soft-surface except where necessary to prevent erosion and/or other resource damage.

Lower Boulder Creek and Coal Creek Open Space Master Plan:

Objectives

The foundation of this planning effort was the identification of specific project objectives to guide development of the Lower Boulder Creek and Coal Creek Open Space Master Plan.

- Re-establish successional river processes and restore self-sustaining riparian ecosystems
- Restore historic floodplain and associated features
- Preserve, restore, and create diverse, functional wetland communities
- Preserve, restore, and create a diversity of native plant communities and wildlife habitats throughout the stream corridor
- Enhance pond and stream water quality through natural processes
- Enhance aquatic habitat in surface waters
- Restore upland habitat
- Preserve and enhance viewsheds and open space in perpetuity
- Provide for a diversity of post-gravel mining land uses that complement the rural character of the region and promote a healthy stream corridor ecosystem
- Provide for recreational opportunities while preserving the integrity of the ecosystem
- Preserve and enhance cultural and agricultural resources
- Demonstrate the legacy of and Promote a sustainable future for the Boulder and Coal Creek systems

To sustain the function and value of native ecosystems in a landscape so affected by human activity both in and beyond the project boundaries requires that a delicate balance be maintained: a balance which is just beginning to be understood. The visible effects of past human activity on this property are, in fact, extensive.

Restoration is emphasized as a primary objective of this Master Plan; however restoration does not infer that the landscape is restored to a pristine state, or that human activity be precluded.

It is the conscious, careful synthesis of people and environment which creates sustainable community. This Master Plan addresses ecosystem function in the regional context. It also emphasizes restoring healthy, natural systems and preserving and enhancing biodiversity while accommodating compatible land uses such as agriculture, linear extraction, interpretation, and recreation within the project area. The principle goal of this planning effort is to preserve, restore, and enhance both ecosystem functions and cultural values.

Trails, Recreation, and Interpretation

Recreational features such as a regional trail, internal trails, fishing opportunities, and interpretive facilities are also recommended. These are located to minimize adverse environmental impacts and maximize the diversity, education, and enjoyment of the park user.

While preservation, ecological enhancement, and restoration are emphasized for much of the project area, the Master Plan recognizes that providing appropriate public access and recreation opportunities in open lands is essential to instilling a conservation ethic. It is recommended that a trailhead, and passive recreational/interpretive area be developed at the Kenosha parcel, herein referred to as Kenosha Ponds Park, situated near the Erie town limits. Numerous features of interest exist and are proposed for this site. Also, the Lower Boulder Creek and Coal Creek Master Plan is aimed at demonstrating ecosystem restoration and beneficial land management practices. Kenosha Ponds Park has the potential to be an invaluable educational center at the eastern gateway to Boulder County: one which demonstrates the County's philosophy and commitment to its environmental and cultural heritage.

General Planning and Management Recommendations

Maximizing species diversity and breeding bird population density on the property while protecting habitat for species of special concern is emphasized. The following recommendations are provided:

- Preserve mature riparian trees
- Encourage shrub growth along riparian corridors
- Preserve cattail marshes and exclude cattle from marsh (wetland #5) north of Boulder Creek
- Retain all standing dead trees along Boulder Creek and Coal Creek for cavity-nesting birds such as wood ducks
- Divert trails away from red-tailed hawk nest sites
- Divert trails away from Boulder Creek and some wetlands between the western study area boundary and Kenosha Road
- Generally locate future trails west of Kenosha Road a minimum of 10 meters from the creek and provide visual buffer from the creek bed for the protection of herons and cormorants

Trails

The Boulder County Comprehensive Plan (BCCP) designates a conceptual regional trail corridor along Boulder Creek from west of N. 95th St. to the Boulder County line. Although an exact alignment has not been determined for the linkage from this site west, a recommended trail alignment through the project area is proposed in this plan.

While access to streams and ditches provides an interesting park user experience, these waterways also provide the most diverse and valuable habitat zones onsite, and provide the critical function of wildlife movement corridors. It was determined, therefore, that the proposed trail should not follow the length of any waterway, but accesses them only intermittently. Other historic or natural points of interest are linked by trail to direct public use away from environmentally sensitive areas, including those scheduled for restoration.

A regional trail spur is proposed to access the Wise Museum, near 119th Street and Jasper Road, south of Boulder Creek. The lands east of 119th Street and south of Kenosha Road also have recently been annexed to the Town of Erie, and residential development has begun in this area.

In addition, an Erie neighborhood park is slated for construction here, accessed by an internal trail. Linkage to this privately developed trail system will provide valuable opportunities for the residents to access the open space lands, and will allow a regional trail connection to the eastern portion of the open space lands known as Kenosha without traversing the Boulder Creek corridor, An internal loop trail system and passive recreation I interpretive area is proposed at Kenosha Ponds Park.

Several equestrian facilities occur in the vicinity of the lower Boulder Creek/Coal Creek open space. It is recommended that the County consider allowing equestrian use on the regional trail, and provide hitching posts at trailheads. The internal trails proposed are best suited to pedestrian use only.

Kenosha Pond Park

The Kenosha parcel adjoins the town of Erie. Residential development has begun to occur in the area. Providing a passive recreational area in this vicinity to serve the citizens of Erie was an important consideration of the previous Master Plan efforts. Because the potential for stream restoration is limited in this reach, and a variety of interesting amenities exists, west Kenosha, herein referred to as Kenosha Ponds Park is a prime location for passive recreation, interpretation, and trailhead facilities at the eastern limit of the Boulder Creek regional trail corridor. Passive recreational activities recommended include hiking, fishing, wildlife viewing and picnicking. Programmed educational activities would also be appropriate. Phasing of park development in this area does not rely on sequential stream restoration phasing and can occur at any time according to Boulder County's priorities and budget.

Boulder County Regional Trail Program – Union Pacific Rail Trail

Boulder County has plans to pursue a resource inventory of the Union Pacific (UP) Rail Trail corridor. An inventory would identify environmental resources, trail opportunities, and alignment constraints along the UP rail line from the City of Boulder to the Town of Erie. This resource inventory would need to examine alternative trail alignments to protect wildlife resources.

The Union Pacific (UP) Trail (Figure 4-4) will run from the eastern boundary of the City of Boulder traversing nine miles to the Town of Erie along the Regional Transportation District (RTD) rail line when possible. Boulder County plans to pursue a technical report for the trail corridor that will identify trail alignment options, environmental resources, property ownership and any constraints. The trail could qualify as Rails-to-Trails project that may also accommodate a long-term Rails-with-Trail option.

The Weld County Trails Inventory Map 2010

The Weld County Trails Inventory Map highlights planned trail priorities based on a 2020 vision. The plan highlights the St Vrain Legacy Trail as a top priority.

City of Boulder Open Space and Mountain Parks Grassland Ecosystem Management Plan

The grasslands of the City of Boulder's Open Space and Mountain Parks (OSMP) land system are located where the Central High Plains meet the foothills of the Southern Rocky Mountains. These lands and waters have been acquired as part of a system designed to protect the agricultural, ecological, recreational, and scenic values of one of the most rapidly developing regions in North America.

The Grassland Ecosystem Management Plan (Grassland Plan) proposes specific on-the-ground management actions, public policies and lands & water acquisition priorities to conserve the ecological values of Open Space & Mountain Park's grasslands and ensure on-going agricultural production.

OSMP currently manages about 24,000 acres in the Grassland Ecosystem Management Plan project area. These areas conserve the species and natural communities that characterize the grasslands of the Boulder Valley. OSMP grasslands have been recognized by local, state and national agencies for their ecological values. They also support traditional agricultural uses such as livestock, hay and small grain production. Boulder's grasslands are popular destinations for outdoor recreation and see millions of visits annually.

Research and monitoring conducted on OSMP grasslands over time has revealed and emphasized the value of Boulder's native prairies as habitat for numerous rare and sensitive birds, mammals, insects, plants and other components of local prairie ecosystems. The ecological significance of Boulder's grasslands becomes increasingly important as urbanization spreads along the Front Range. Municipal open space is also important for the preservation of agriculture in Boulder County. Much of the land in agricultural use in the Boulder Valley is protected by ownership or partnership agreements by OSMP.

The Grassland Planning Area (GPA) is known to support more than 800 species of vascular plants, over 400 species of vertebrates and many more species in other, lesser-known groups (e.g., insects, mosses, algae). Rather than attempt to address each part of the grassland system individually, OSMP staff worked with partner agencies, biologists, ecologists, naturalists and other community members to identify the aspects of biological diversity that would best serve as the basis for setting objectives, taking action and measuring success.

These "conservation targets" include the Mixedgrass Prairie Mosaic and the Xeric Tallgrass Prairie—the two dominant cover types in the GPA.

The Agricultural Operations target addresses the long-term sustainability of agriculture on OSMP lands and the conservation of native species dependent upon agricultural operations.

The ecological system centered on the black-tailed prairie dog was also identified as a separate conservation target due to the distinctive ecological conditions and community of animals associated with prairie dogs. This target, Black-tailed Prairie Dogs and Associates, was also called out because of the unique challenges of managing a prairie dog-based system in a highly fragmented landscape.

OSMP also identified three targets dependent upon ground or surface water: Wetlands—including ponds, Riparian Areas—including creeks, and the Mesic Bluestem Prairie.

The White Rocks cliffs were identified as a target because they support a large number of rare species—well out of proportion to the small size of the area.

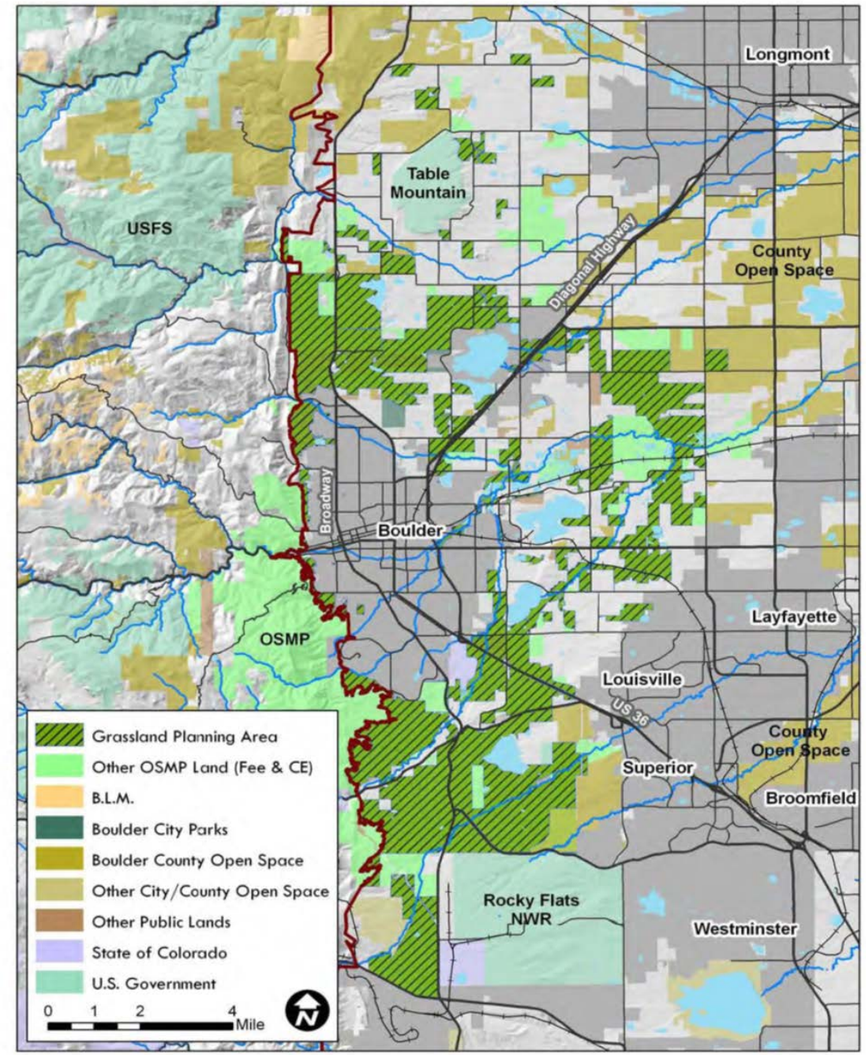


Figure 4-3: Grassland Planning Area

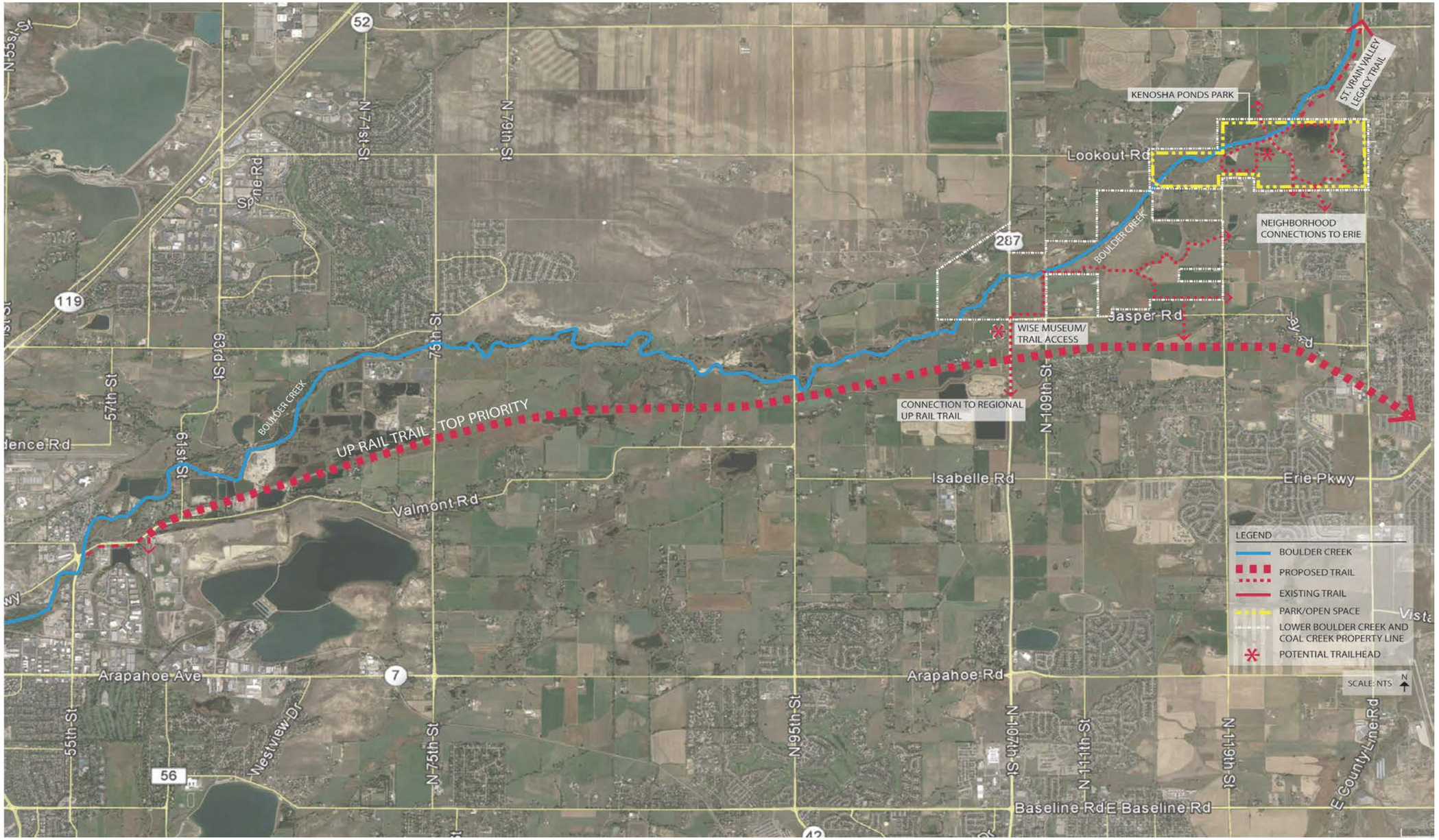


Figure 4-4: UP Rail Trail

5.0 HISTORIC STREAM EVALUATION

5.1 Background

As a way to understand alteration to the natural stream resulting from human impacts, historic mapping was used to evaluate historical stream alignments and how this data compares with current condition; confirm the gradual channelization of the stream which has led to a straighter alignments which lack natural meanders and bends; and to compare any noticeable changes in stream bank conditions.

To accomplish this, Boulder County supplied ERC with historic photographs showing a portion of Boulder Creek for years 1937, 1949, 1955, 1963, and 1969. In each of these years, aerial photos were only available for a relatively small portion of Boulder Creek. These historic photographs were inserted into the current Boulder Creek ACAD base map drawing and scaled by correlating known points from year to year. The entire study area includes Reach 1 through Reach 10, which accounts for approximately 25 miles (132,000 feet) of the current stream length. Historic aerial photographs overlays were available only for the southwest portion of Reach 4 and the northeast corner of Reach 5, with the specific extents of the photos varying by year. For each historic year, the creek alignment was traced in ACAD and changes were noted. The historic mapping for each year did not cover the same area from data year to data year; consequently the traced stream length for each data year varied in length. The minimum length covered of the existing stream was 18,120 feet (3.4 miles) and the maximum coverage was 32,610 feet (6.2 miles) based on 2015 stream conditions. For each data year, the length of traced stream was measured and the corresponding current (2015) length was recorded. The historic maps with the historic aerial overlays are included as attachments. The results of this evaluation are described in the following sections.

5.2 Channel Straightening

The results of the overlay and tracing exercise indicate that the creek has become straighter over time as is apparent when comparing the current stream length to the historic stream lengths for each data year. Every data year shows a decrease in length in comparison to the current stream length. The table and graph shown in Figure 5-1 show the historic length, the comparable 2015 length and the loss comparison, as a percentage, from the data year to the current year. Note that the extent of mapping for each of the different historic aerial imagery is different. As such, the historic stream lengths shown in the second column in Figure 5-1 represent the length of stream shown on the historic aerial. The 2015 length of stream presented in the third column indicates the current stream length for the individual historic aerial photographs. In order to compare data in Figure 5-1 across the different aerial images of 1937 to 1969, the right hand column showing percent change was added. This column indicates that the present decrease in stream length is greatest when comparing current conditions to 1937 and has decreased over time. This illustrates the continued trend of channel straightening over time.

Year	Historic Length (ft)	2015 Length (ft)	Length Change (ft)	Percent Change
1937	29,555	21,070	8,485	29%
1949	23,620	18,120	5,500	23%
1955	32,115	26,070	6,045	19%
1963	35,570	30,155	5,415	15%
1969	36,560	32,610	3,950	11%

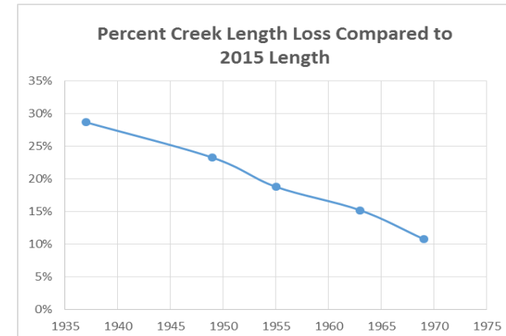


Figure 5-1: Loss of Stream Length over Time as a Percentage

An additional comparison was completed by taking the year with the least stream coverage (1949) and truncating the other historic year lengths to match the 1949 segment ends as a way of normalizing this segment. These values were recorded to see the reduction in the length over the same stream corridor section. As evident in the table below, this segment of channel has experienced channel straightening continually throughout the years. The table and graph below show the length loss when normalizing each year's length to the 1949 stream length. With the data years available, it appears the largest stream straightening occurred between 1949 and 1955.

Year	Historic Length (ft)	Length Change from Previous Data Year (ft)	Length Change Extrapolated on a per Year Basis (ft)
1937	25,250		
1949	23,620	1,630	136
1955	21,630	1,990	332
1963	20,735	895	112
1969	20,360	375	63
2015	18,120	2,240	49

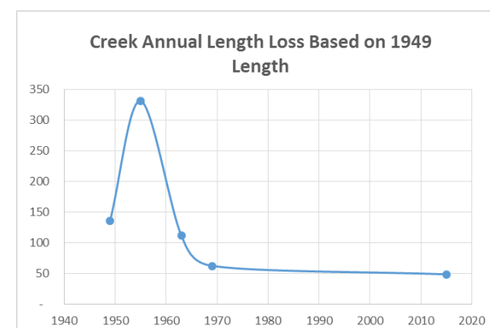
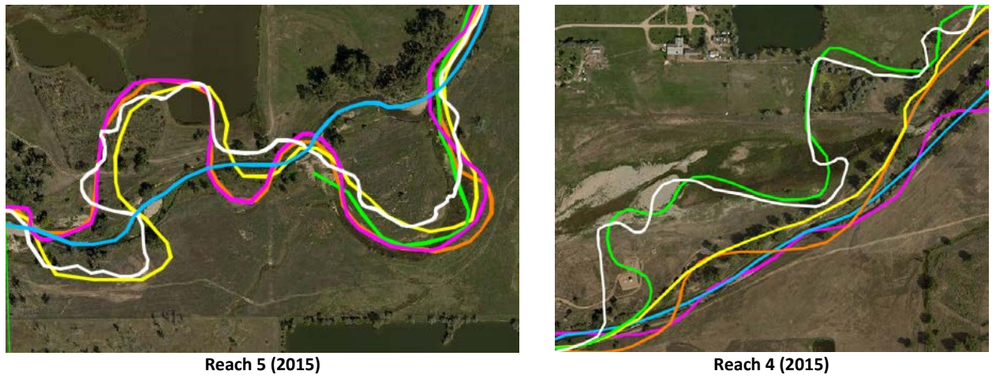


Figure 5-2: Loss of Stream Length

5.3 Sinuosity Changes

It is apparent from the stream length shortening that there is a corresponding change in the course of the river with the reduction of stream meanders. Below are two figures that show the historic creek pathways in comparison to the existing creek. The figure on the left, Reach 5, shows channel realignment occurring after 1969 and the figure on the right, Reach 4, shows channel realignment occurring between 1949 and 1955. The stream color coding is the following: 1937-White, 1949-Green, 1955-Yellow, 1963-Orange, 1969-Magenta, and 2015-Blue. In all cases the stream has straightened over time.



Reach 5 (2015) Reach 4 (2015)

Figure 5-3: Depiction of Modification to Channel Meanders

Channelization can be quantified by evaluating stream sinuosity. Sinuosity is the ratio of the length of a stream channel to the length of the valley. A sinuosity value of 1.0 indicates a straight channel whereas a sinuosity of 1.5 indicates that the length of the stream is 50% longer than the straight length of the valley. The higher the sinuosity of a channel, the more it meanders along its length. The figure below provides a graphic representation of a stream. Sinuosity is calculated as channel length (C_L) divided by Valley Length (V_L).

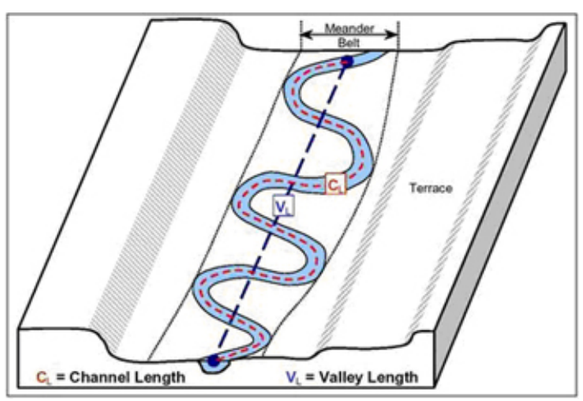


Figure 5-4: Stream Sinuosity

In order to quantify impacts of channelization on Boulder Creek, sinuosity was determined from historic mapping. These calculations were undertaken by measuring a valley length within the normalized section and comparing this value to the data year lengths. The results are shown below.

Year	Historic Length (ft)	Valley Length (ft)	Sinuosity
1937	25,250	17,060	1.480
1949	23,620	17,060	1.385
1955	21,630	17,060	1.268
1963	20,735	17,060	1.215
1969	20,360	17,060	1.193
2015	18,156	17,060	1.064

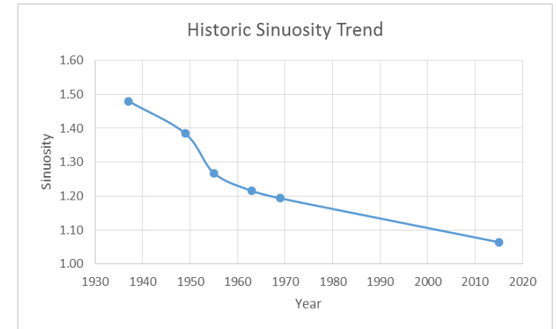


Figure 5-5: Change in Stream Sinuosity

5.4 Prior Stream Realignment

There is evidence of stream realignment occurring prior to 1949 when observing the 1949 photo overlay in Reach 5. There are distinct places where it is apparent that the creek followed a different alignment as is indicative of the curves and bends apparent in the 1949 natural ground surface photos below. Also it is apparent that stream straightening is more pronounced at road crossings as shown in the picture to the right below.

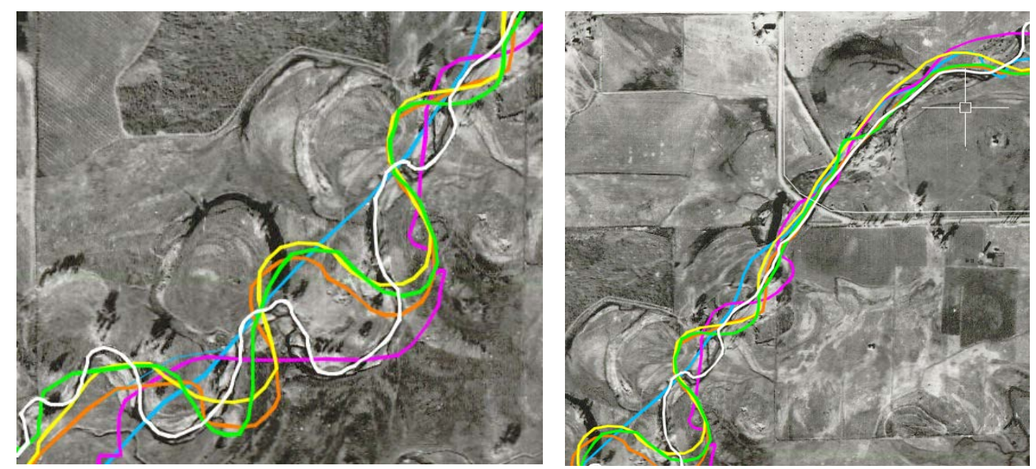


Figure 5-6: Straightening Trends in Reach 5

5.5 Conclusions

Historic aerial photographs dating from 1937 were available for a portion of reaches 4 and 5. Based on overlays of the available historic streams and comparison to the current stream alignment the following conclusions can be made:

- There has been an on-going trend of channelization.
- Land use practices have likely contributed heavily to the observed channelization.
- The channel has been straightened significantly by removing the natural sinuosity of the stream. This has led to steeper stream slopes and faster moving stream flows which negatively impact the entire biodiversity and health of the stream. Most likely the stream straightening has also resulted in a more uniform, shallow stream bed.
- Bank erosion is typically more prevalent in streams that have been straightened. Much of the bed and bank armoring that has been completed on Boulder Creek has likely occurred in response to channelization.

6.0 NATURAL RESTORATION OBJECTIVES

6.1 Background

Evaluation of current stream conditions identified impacts that past and current land use practices have on the condition of the stream. One of the objectives of the master plan is to define what a naturally occurring, unimpacted Boulder Creek would look like so that future restoration work can incorporate these types of stream characteristics. As part of the assessment, natural stream conditions that would likely exist for an unimpacted channel were defined. Potential alignments for a restored - unimpacted stream system, restored – confined stream system, or hybrid of the unimpacted and more confined stream system can be found in the appendix. It should be noted that there is not a singular correct solution in defining a restored stream alignment for Boulder Creek. The figures in the appendix are intended to provide an example for what a more natural system may look like. Final alignments would depend on many factors and should be further refined with individual project goals.

6.2 Characteristics of a Natural Channel

Observation of historic mapping indicates that the alignment and shape of the stream corridor has evolved in recent history in response to land use practices. Encroachment into the natural riparian corridor has caused channelization as is observed by the straightening of significant portions of the stream.

Some of the physical properties of natural channel conditions in Boulder Creek can be estimated based on flow, slope, geologic setting and an understanding of natural stream types. As part of this assessment, channel characteristics including stream bankfull width, stream depth, shape of the overbank and ideal sinuosity were estimated for the 10 individual stream reaches. In many instances it is not practical to implement these parameters due to land constraints and development, but these characteristics are intended to provide a template of what should be considered in areas where natural restoration is contemplated and sufficient land exists.

6.3 Typical Channel Geometries

Information on channel classification along with estimated flows were used to approximate natural channel geometries for the 10 individual stream reaches. One of the physical geomorphologic parameters of streams is bankfull flow. Bankfull flow is generally observed to be the flow rate at which the water exceeds the capacity of its active channel at starts to access its floodplain. Studies of typical stream geometry indicates that flood flows with a recurrence interval of approximately 1.5 to 2 years are the flows that exceed the bankfull level. Bankfull flows, which were approximated for this study using the 1.75-year flood flow, were used to help estimate the geometry of the active channel. Typical values of width to depth ratios (width of the stream at bankfull conditions divided by the bankfull stream depth) and entrenchment ratios (width of the stream channel for a depth that is twice the bankfull depth divided by the bankfull stream width) were used to help approximate natural channel geometry.

For each of these 10 reaches, the bankfull flows were used in combination with assumed natural channel types to define typical channel geometries. This information is provided in Table 6-1. Target bankfull channel widths, width/depth ratios, sinuosity and entrenchment ratios used to establish standard channel geometries are provided in Table 6-2. Target sinuosity values for reaches 1-8 were determined based on values from natural Type C streams, measured values in less disturbed areas and observation of historic meander patterns. Bankfull flows were calculated from gage records at the downstream end of Boulder Creek (Reach 1), at 75th Street (Reaches 6 and 7), in the City of Boulder (Reach 9) and in the canyon (Reach 10). Approximate bankfull flows in other reaches were interpolated. Bankfull widths were estimated based on observed areas where the current channel was found to be in good condition and was verified using bankfull flows and typical geomorphologic relationships between bankfull flow and width (Andrews 1984). Target entrenchment ratios were estimated based on stream type and typical values for the subgrade materials.

Table 6-1: Bankfull Flows and Stream Classifications at Locations with Estimated Flows

Reach	Bankfull Flow (cfs)	Target Bankfull Channel Width (ft)	Assumed Natural Stream Classification	Target Sinuosity
1	620	40	C4	>1.4
2	630	40	C4	>1.4
3	640	40	C4	>1.4
4	650	40	C4	>1.4
5	660	40	C4	>1.4
6	670	40	C4	>1.4
7	670	40	C4	>1.4
8	635	40	C4	>1.4
9	600	40	C3	>1.2
10	460	30	B3	>1.2

Table 6-2: Target Width/Depth Ratios, and Entrenchment Ratios for Each Stream Classification

Stream Classification	Width/Depth Ratio	Approximate Entrenchment Ratio
C4	>12	3.5
C3	>12	3.5
B3	>12	1.8

Approximate sizing for the bankfull channel and floodprone area adjacent to the active channel were defined. For this application the floodprone area describes the approximate width of the channel for a flow that is twice the bankfull channel depth. This is different than the floodplain and is intended to provide an indication of how quickly land adjacent to the channel slopes away from the channel. Given that changing the sinuosity of a reach would change its average slope, an approximate slope based on the desired sinuosity was assumed for these calculations.

A summary of recommended geometries for each reach is given in Table 6-3. This table can be used to define the approximate channel geometries throughout the basin. All channel sections are assumed to be generally trapezoidal with a bankfull width that is defined in the table.

These tabulated values provide average channel geometry information, but it is not the intent nor is it desired that the channel take on a uniform, defined cross section. Variability is inherent in any natural system and is desired for improvements along Boulder Creek.

Table 6-3: Geometries for Primary Stream Types at Each Flow Location

Reach	Assumed Sinuosity	Slope (%)	Bankfull Width (ft)	Bankfull Depth (ft)	Width at 2x Bankfull Depth (ft)
1	1.6	0.20%	40	3	140
2	1.6	0.19%	40	3	140
3	1.6	0.29%	40	3	140
4	1.6	0.22%	40	3	140
5	1.6	0.24%	40	3	140
6	1.6	0.36%	40	3	140
7	1.6	0.30%	40	3	140
8	1.6	0.46%	40	3	140
9	1.4	0.81%	40	2.5	140
10	1.3	2.60%	30	2	54

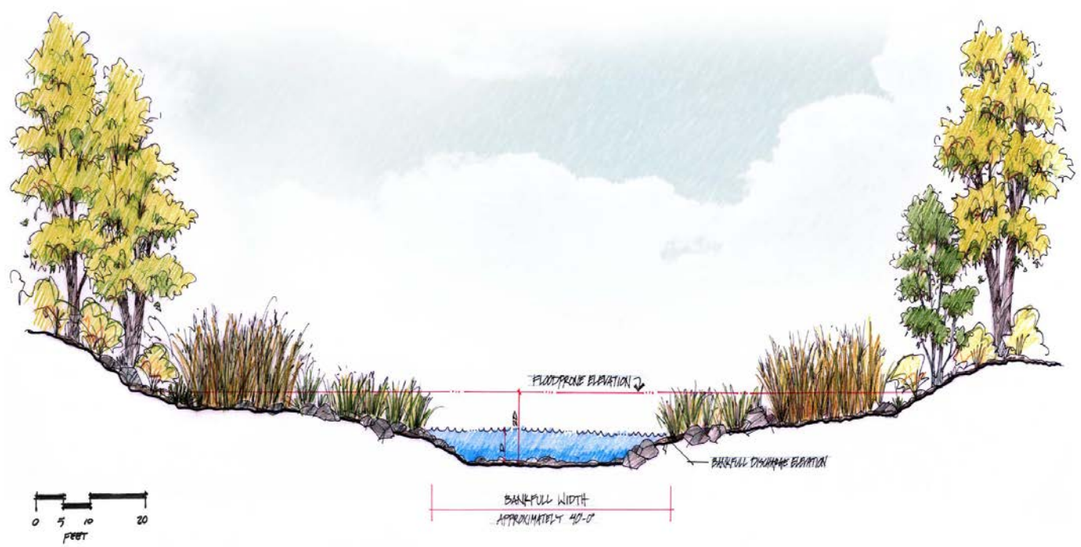


Figure 6-1: Typical Geomorphic Cross-section

In addition to variability in cross section, variability in channel slopes is a characteristic of natural channels. Features such as step pools, scour pools, rapids and riffles/pool sequences occur naturally and provide variety from both a habitat and aesthetic standpoint. Step pools, rapids and scour pools are bedform types that are typical of Type B stream that would be found in Reach 10. Riffle/pool sequences are alternating stretches of shallow, fast-moving sections (riffles) and deeper, slower pools, with glides or runs in between the end of a pool and beginning of the next riffle to allow for gradual bedform transformation. Riffle/pool sequences are typical bedforms seen in meandering, Type C streams such as Reaches 1-9. A schematic of a riffle/pool sequence, along with glides and runs is shown in Figure 6-2 (obtained from the Public Works Research Institute's Aquatic Restoration Research Center, 2004).

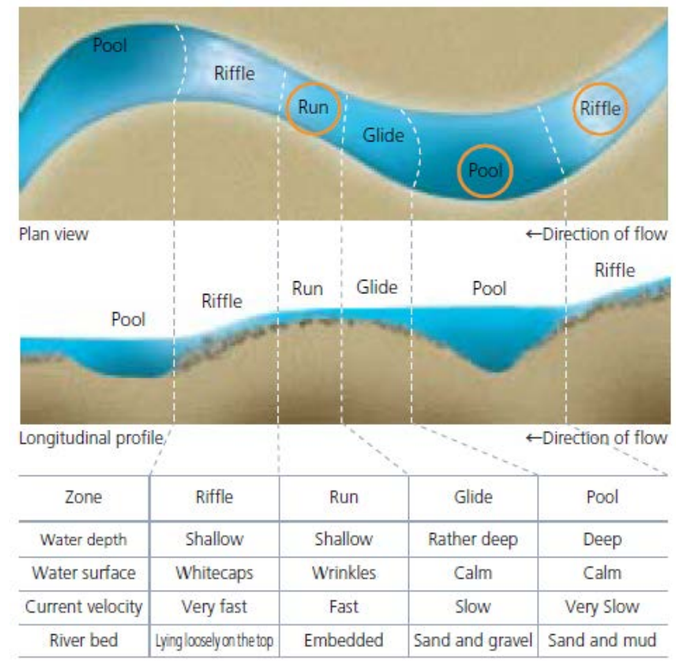


Figure 6-2: Typical Riffle/Pool Schematic

7.0 BOULDER CREEK RIPARIAN ZONE

7.1 Background

During the September 2013 flood event, Boulder Creek experienced high peak flows for an extended duration which resulted in not only damages to infrastructure, but also widespread damages to the stream corridor. This section addresses the general condition of the existing riparian communities within the Boulder Creek corridor after the flooding and provides recommendations for re-establishment (or restoration) of the riparian zone within the project area.

During the initial flood recovery efforts, emergency stabilization measures focused more on hardened methods such as riprap, grout, boulders and infrastructure repair. As the focus shifts towards long-term recovery, measures must also consider restoration of critical natural riparian and aquatic ecosystem function.

The importance of a well-developed riparian corridor is well documented. Well vegetated riparian corridors provide important terrestrial wildlife habitat, provide instream aquatic habitat benefits, stabilize soils and reduce problems from erosion, flooding and excessive nutrients. A properly functioning riparian corridor protects the physical integrity of the aquatic environment.

A cursory baseline assessment of the existing post-flood riparian corridor was completed within the project area. The general condition of the existing riparian corridor was assessed including dominant vegetation community types remaining, species composition and primary vegetation strata that remain or that may have been damaged or lost. In addition, the assessment defined a typical "reference condition" riparian community or in other words the ideal natural riparian vegetation community that existed prior to the flood event and in an undisturbed state that should be the focus for riparian restoration during long-term recovery efforts.

The riparian corridor of the Boulder Creek project area also provides critical habitat that should be considered during flood recovery efforts. A cursory screening of potential federal and state threatened and endangered species that may occur on or immediately surrounding the project area was also completed. Included in this section is a summary of additional data reviewed for the project area including migratory birds, aquatic and macroinvertebrate data, wildlife closures and other important habitat management areas.

7.2 Importance of the Riparian Zone

A riparian corridor or "riparian zone" is defined as the transitional area or interface between upland terrestrial and aquatic habitats. A riparian zone is generally considered that portion of the landscape from the ordinary high water mark towards the adjoining uplands that affect or are affected by the presence of water (Figure 7-1). The riparian zone is often unique within a watershed containing notably different vegetation communities from the surrounding upland habitat. Properly functioning riparian zones of high ecological integrity contain an unfragmented, structurally diverse vegetation community, typically composed of three strata that includes trees, shrubs and grasses that are native to the region and that are adapted to the climatic, soil, and hydrologic conditions. The riparian zone has a variety of functions important to the stream or aquatic environment. Well vegetated riparian zones provide important terrestrial wildlife habitat, provide aquatic habitat benefits (shading, decreased water temperatures, biomass and instream cover), soil stabilization, and reduced problems from erosion, sedimentation and nutrients. Riparian vegetation also contributes to bank stability by dissipating the energy of moving water and reducing velocity, which is imperative during typical flood events. In an ideal situation, natural stream flows are able to access a broad floodplain. A properly functioning riparian zone protects not only water quality but also the physical integrity of the aquatic environment.

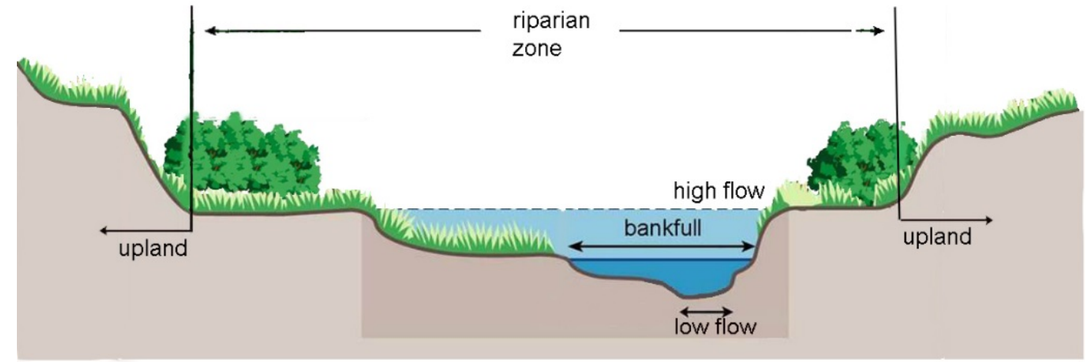


Figure 7-1: Components of a properly functioning riparian zone (Image modified from FISRWG 1998.)

In general, the riparian zone width necessary to provide a particular level of function depends on the functions of the stream, the characteristics of the riparian zone, topography, intensity of adjacent land use, and overall watershed characteristics. The riparian zone is also often considered as a protective buffer to the aquatic system.

7.3 Land use and Vegetation Cover Types

Existing land use and vegetation cover types were evaluated within the project area using mapping from the US Geological Survey (USGS) Southwest Regional Gap Analysis Project (SWReGAP) (2001). The predominant land cover type of the project area is cultivated cropland (42% of land) which includes grazing, alfalfa and other crop production. Aggregate mining of sand and gravel since the mid 1950's has visibly shaped the project area landscape as open water ponds scatter the floodplain, occupying approximately 16% of project area. Natural vegetation cover types within the riparian zone occupy only 27% of the project area and are mainly classified as Western Great Plains Riparian Woodland and Shrubland and to a lesser degree Western Great Plains Floodplain. Other land mapped within the project includes high and low density developed areas (12%) such as land within the City of Boulder, larger paved roads and other miscellaneous developments.

7.4 Riparian Zone Vegetation Community and Reference Standard

Of the vegetation cover types identified within the project area (SWReGAP 2001), the primary natural riparian zone vegetation community type that occurs within the project area is the Western Great Plains Riparian Woodland and Shrubland. This vegetation community type is most characteristic of habitats within the project area thus would be considered the reference standard or ideal natural community.

The Western Great Plains Riparian Woodland and Shrubland community type is found widely in the Great Plains of Colorado and occurs in wide river corridors that have low-gradient and primarily sandy/gravelly beds (becoming cobbly with increasing gradients). The type is most often found proximal to perennial rivers on low sidebars and streambanks near stream bankfull levels (NatureServe 2004). Because of its low position, the type is flooded frequently (average recurrence interval is 5 years). Dominant communities within this streamside system range from floodplain forests to wet meadows where properly functioning systems are linked by underlying soils and the flooding regime (FGDC 2008).

Within the project area, this reference standard community would occur on low terraces and along the immediate streambanks of Boulder Creek through the riparian zone. The unconfined, active stream channel would frequently inundate vegetation through the riparian zone and active floodplain forming a complexity of habitats which support a variety of plant communities. Figure 7-3 depicts the components of a properly functioning and structurally diverse riparian community for Boulder Creek.

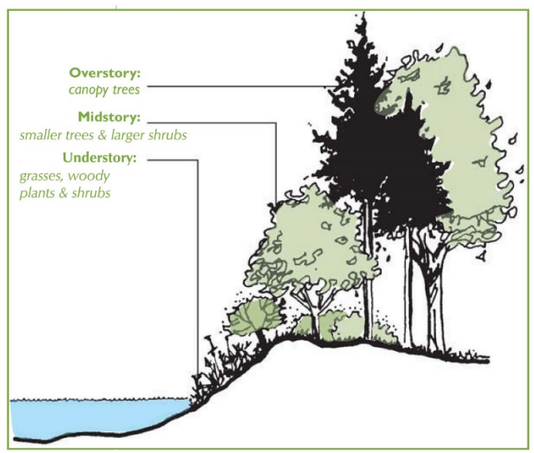


Figure 7-2: Components of a Riparian Community (modified from: Montgomery county planning commission 2006).

Within the project area, the existing riparian vegetation community is also generally characteristic of the Western Great Plains Riparian Woodland and Shrubland community; however, the community is largely modified in vegetation structure, diversity and hydrologic regime from the ideal or reference standard community. The specific plant associations within the project area's riparian vegetation community can include drier species typically associated with upland forests and cultivated fields/pastures to mesic species associated with scrub-shrub fringe wetlands, wet meadows or emergent marshes. Some locations within the project area can also differ from the reference standard in the number of vegetation strata present, the amount of non-native species and overall percent cover.

Figure 7-3: Boulder Creek: Example Riparian Reference Standard (dominated by cottonwood overstory with willow midstory and grass understory)

7.5 Riparian Zone Post Flood

The existing condition of the riparian zone both pre- and post- flood varies across the project area and is largely influenced by historic and current land use practices. In general, the overall extent and condition of riparian habitat and value has been impacted more from historic land use practices than direct impacts from the flood. Land use including riparian vegetation removal, urban development, grazing, mining, stream channelization and establishment of non-native invasive vegetation have significantly shaped the character and function of the riparian corridor. In addition, land leveling, stream channelization, water diversions and levees reduce the extent and frequency of floodplain inundation, which further diminishes the quality and quantity of riparian vegetation [Reference 29, Anderson & Company]. In these historically degraded areas, the riparian zone is narrow (<50 feet wide), fragmented and often dominated by non-native or weedy species.

Higher quality riparian areas typically occur within the project in areas less impacted by human land use. In these areas, Boulder Creek's riparian zone is wide, stable and densely vegetated extending well over 500 feet across the floodplain (Figure 7-4). The narrow riparian zone (left) is limited by land use and bisected by a railroad; the more naturalized downstream section (right) is wide and less confined.

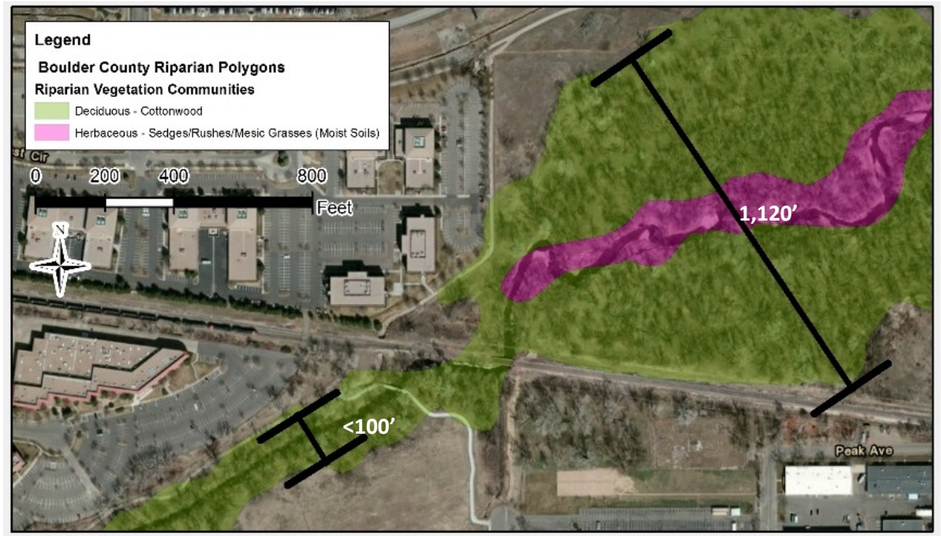


Figure 7-4: Example of varying riparian zone widths through the project area
The narrow riparian zone (left) is limited by land use and bisected by a railroad; the more naturalized downstream section (right) is wide and less confined. (Note: Example is provided for riparian width characteristics only - site specific vegetation communities and species may not represent an appropriate restoration target.)

The overall development and extent of the riparian zone through the project area is closely correlated with existing landforms, land use practices and geomorphic processes. Therefore the structure of the riparian zone (shape/width) within the project area varies across topographic gradients from the steep canyon slopes to the level landscape across the plains.

The existing (post-flood) riparian zone was evaluated within the project area reaches to determine the general overall effects from the September 2013 regional flood event. Overall, direct damage and loss to the riparian zone appears to be much less devastating than in other drainages affected by the flood event. For the most part, the riparian corridor of Boulder Creek remains intact and generally functioning with only relatively minor to moderate disturbance to the riparian zone.

Observed disturbance to the riparian zone varied throughout the project area reaches from minor or no impact within the more urban reaches which are designed to withstand higher peak flood flows; to more significant, moderate disturbances within downstream reaches which received higher volume of floodwater and debris flow from the upstream watershed. The effects included debris flows from the steep canyon reaches upstream that caused both bank erosion and sediment deposition in downstream riparian areas, along with conveyance and deposition of significant debris including boulders, trees, and household materials throughout the stream corridor. Within Boulder's city limits, significant maintenance was conducted post-flood to stabilize critically failing stream banks and to remove debris/sediment upstream and downstream of crossings; therefore these impacts appeared to be less severe through the project area.

The most significant impacts to the riparian zone observed in the project reaches are those areas where flood flows caused the stream to breach into nearby gravel ponds, completely abandoning the existing channel. This occurrence has altered the stream's connection to the original floodplain and riparian zone which will likely, over time, effect species diversity, abundance, structure, and functional characteristics of the riparian community. A summary of riparian zone post-flood conditions within the project area is presented as follows. More detail regarding each reach is provided in the appendix to this report.

Table 7-1: Post-flood Riparian Zone conditions

REACH	2013 REGIONAL FLOOD DAMAGE – RIPARIAN ZONE
Boulder Canyon	Low Disturbance • Stable armored stream banks. • Minor tree/shrub damage/loss. • Minor localized bank erosion and steep slope failure. • Debris accumulation. • Channel remains in original alignment and connected to riparian zone. • Limited existing riparian zone remains relatively intact.
City of Boulder	Low Disturbance • Stable armored stream banks. • Minor tree damage/loss. • Minor localized bank erosion. • Debris and sediment deposition removed by City of Boulder, CDOT, and UDFCD. • Channel remains in original alignment and connected to riparian zone. • Limited existing riparian zone remains relatively intact.
Foothills to N 107th Street	Low to Moderate Disturbance • Significant sediment deposition/vegetation burial. • Localized bank erosion. • Significant accumulation of debris from dead/downed trees. • Stream breach into gravel ponds – alteration of hydrology (channel and riparian zone abandoned). • Stream breach areas subject to potential long-term impacts to riparian species diversity, abundance, structure, and functional characteristics from alteration of hydrology.
N 107th Street to St. Vrain Creek	Low to Moderate Disturbance • Significant sediment deposition/vegetation burial. • Localized bank erosion. • Significant accumulation of debris from dead/downed trees. • Stream breach into gravel ponds – alteration of hydrology (channel and riparian zone abandon). • Stream breach area subject to potential long-term impacts to riparian species diversity, abundance, structure, and functional characteristics from alteration of hydrology.

Photo 35. Confluence with St. Vrain Creek. Example of reference standard riparian habitat which includes dense vegetation community with three strata, stable stream banks, a wide floodplain and little human disturbance. Flood flows resulted in minimal damage to the riparian corridor.

Photo 36. N 107th Street to St. Vrain Creek reach. Here flood flows resulted in abandonment of the pre-flood channel and riparian corridor. Herbaceous vegetation has begun to establish in the previous active channel bottom, indicative of an altered hydrologic regime.

Photo 37. Boulder Creek east from 61rd Street. Example of wide, well vegetated riparian zone with only moderate post-flood disturbance to the riparian zone. At this location, flood flows deposited significant amounts of cobble material within the existing overly wide stream channel which resulted in altered stream flow. The riparian zone is now disconnected from stream flow which can result in long-term habitat community shifts or complete loss of riparian species.

Photo 38. Boulder Creek near Valmont Road. Example of moderate post-flood disturbance to the riparian zone including: significant sediment deposition/vegetation burial, tree damage/loss and significant accumulation of debris from dead/downed trees. While moderate disturbance has occurred in this reach, a majority of the riparian vegetation remains intact and will continue to function.

Photo 39. Highly urbanized area within City of Boulder reach characterized by overstory trees and armored stream banks. Through this reach, Boulder Creek overtopped its banks and inundated the existing riparian zone. After the flood event, the riparian zone remains relatively intact.

Photo 40. City of Boulder reach example of low-disturbance: debris accumulation and riparian zone tree damage (trunk damage and bark removal) as a result of the flood. For the most part, while damaged, a majority of the riparian vegetation community will persist and continue to function.

Photo 41. Boulder Canyon reach. The existing riparian zone is characterized by one vegetation strata including either trees or shrubs with no mid- or understory present. Flood damages to the riparian zone are low. Much of the riparian zone remains intact with little change the pre-flood condition.

Photo 42. Boulder Canyon reach example of low post-flood disturbances which includes only minor bank erosion and shrub damage.

7.6 Wetlands

A variety of wetland habitats do exist within the riparian zone of Boulder Creek. Wetlands and other waters of the US are regulated under Section 404 of the Clean Water Act (CWA). Future restoration and recovery efforts which result in disturbances to regulated areas may be subject to permitting and approval by the US Army Corps of Engineers (USACE), the US Environmental Protection Agency, and/or the US Fish and Wildlife Service (USFWS). A formal wetland delineation, by a qualified wetland consultant, and coordination with the USACE Denver Regulatory Office is recommended prior to implementation of any future restoration and recovery efforts to ensure CWA compliance. In addition, any future restoration and recovery efforts must comply with local wetland, stream and wildlife regulations.

7.7 Riparian Zone Restoration Guidelines

The framework for any successful riparian zone restoration effort is understanding the local (reference standard) community that is either present or known to have existed in the local area, in order to restore the functional integrity and biodiversity of the riparian zone. As stated in previous sections, the reference community or primary habitat type recommended for restoration within this project area which is locally native and appropriate for the environmental setting is the Western Great Plains Riparian Woodland and Shrubland. Replicating the natural characteristics of the local Western Great Plains Riparian Woodland and Shrubland habitat type including re-establishment of cottonwood tree overstory and a willow shrub mid-story with a mixed grassland understory that properly interacted with the channel flow should be the primary objective for natural restoration efforts. Successful riparian zone restoration is dependent on a thorough understanding of numerous environmental factors and site-specific conditions. Stream flow, soil moisture, groundwater table, soil chemistry and sun-orientation are all critical elements to consider. Any restoration efforts should carefully consider such factors which should generally be defined by an expert to ensure greater success. A number of references and guidance documents are available for restoration activities in Colorado and Boulder County. Further guidance is provided in the appendix of this report.

Riparian Zone Restoration shall generally follow the following guidelines:

- Natural riparian zone vegetation community type within the project area is characteristic of the *Western Great Plains Riparian Woodland and Shrubland;*
- A properly functioning riparian zone should have routine interaction with stream flows;
- In a more undisturbed condition, vegetation would be continuous along the entire corridor and occupy three strata (i.e., overstory, midstory and understory);
- Relatively dense native vegetation extending from the water's edge (bankfull) outward;
- Buffers that are wider, longer and more densely vegetated with herbaceous, shrub and tree layers provide more benefits. A minimum width should be at least 50 feet and extend upwards of 200 feet from the stream edge.

Overstory – Forest Canopy Establishment

Restoration or planting efforts should focus on re-establishing the overstory or forest canopy that has been lost. The plains cottonwood tree is one of the primary species of the forest canopy regionally as well as the largest tree reaching heights of up to 60 feet with trunk diameters of 2.5 feet. Cottonwoods are now primarily found along drainages and streams of the region. Cottonwood stands provide habitat for 82% of all bird species breeding in northeastern Colorado (Simonin 2001). This species establishes quickly under ideal conditions and is tolerant of frequent and prolonged flooding as well as seasonal low water conditions. Reproduction by seed is a primary means of cottonwood establishment (Hines 1999). The best conditions for establishment include moist, unvegetated mineral soils where the seedlings are not subject to significant erosion/deposition or prolonged flooding during the first growing season (Friedman et al., 1992) (Borman and Larson 2002) (Scott et al. 1997).

Many of the large mature cottonwoods of the project area appear to be relatively stable after the September 2013 flooding, however many have been damaged and populations may start to decline over time. The planting of second generation stands of cottonwood and other species during recovery efforts will ensure the continued existence of this valuable habitat type. Special care should be taken during restoration to protect cottonwood seedlings that are newly established on flood exposed flats or deposits.

Midstory - Shrubs Establishment

Shrubs are considered one of the most valuable strata in a natural riparian zone. Shrubs generally form dense thickets with extensive root systems immediately along the water's edge and can tolerate fluctuating flows.

Willows are a widely-distributed shrub species throughout lower montane habitats in the region. Species can range from 6.5 to 20 feet tall forming large colonies with up to 95% cover. Roots of willows are wide and spreading, forming an extensive root system, especially with the development of large clones. Willow can be both drought resistant and very tolerant of flooding. The ability to generate new roots on the original root or submerged stem is important to riparian restoration. Narrowleaf willow, particularly, colonizes rocky, gravelly, and sandy stream edges, moist, well-drained alluvial terraces, and recently deposited sand and gravel bars that are below the high-water mark, where it is subject to annual flooding, and associated scouring and deposition (Anderson 2006). Where cottonwoods are not present, other willows may become the climax vegetation as narrowleaf willow communities promote bank building and soil development, preparing hospitable sites for other species (Anderson 2006). Midstory shrub species not only provide bank stability but also increased biomass, structural habitat and complexity for wildlife.

Understory - Native HERBACEOUS

An established understory community provides numerous environmental benefits including soil stabilization, overland runoff filtration as well as forage and cover for wildlife. During restoration efforts native seeding should focus on quickly establishing a groundcover to stabilize soil, minimize establishment of invasive species and promote long-term successional development. In restoration areas, the ground surface should be seeded with specialized riparian seed mix that promotes species diversity, contains locally native species that germinate rapidly and provides complete groundcover over a wide variety of hydrologic conditions.

Table 7-2: Representative Native Riparian Zone Tree Species

Tree Species	
Scientific Name	Common Name
Acer glabrum	Rocky Mountain maple
Acer negundo	box elder
Alnus incana	thinleaf alder
Populus deltoides	plains cottonwood
Salix amygdaloides	peachleaf willow

Table 7-3: Representative Native Riparian Zone Shrub Species

Shrub Species	
Scientific Name	Common Name
Alnus incana	thinleaf alder
Amelanchier alnifolia	western serviceberry
Symphoricarpos occidentalis	western snowberry
Prunus americana	wild plum
Rosa woodsii	Woods' rose
Ribes aureum	golden currant
Salix exigua	narrowleaf willow

Table 7-4: Representative Native Riparian Zone Herbaceous Species

Seed Mix		
Scientific Name	Common Name	Comments
Achnatherum hymenoides	Indian ricegrass	Sandy, p/f, (FACU)
Sporobolus airoides	alkali sacaton	Damp, alkaline, p/f, (FAC)
Elymus canadensis	Canada wildrye	Disturbed sites, p/f, (FACU)
Panicum virgatum	switchgrass	Marshes, prairies, foothills, p/f, (FAC)
Pascopyrum smithii	western wheatgrass	Adaptable to variety of habitats, p,f, (FACU)

Notes:
Life Zones: p = Plains 4,000-6,000 feet; f = Foothills 6,000-8,000 feet;
USACE Wetland Indicator Status: (FAC) = Facultative; (FACU) = Facultative Upland

8.0 THREATENED AND ENDANGERED SPECIES, AND AQUATIC HABITAT ASSESSMENT

8.1 Background

A preliminary screening for federal and state threatened and endangered species was conducted within the project area. It will be important during long-term recovery and restoration efforts that protected species and habitats are considered. Close coordination with the agencies mentioned below is recommended.

Federal or state listed threatened and endangered species and/or habitat protected under the Endangered Species Act (ESA) or by the Colorado Parks and Wildlife (CPW) under Colorado Statute Title 33 are summarized below. Raptor nest sites are further protected by the US Fish and Wildlife Service (UFWS)/CPW under the Migratory Bird Treaty Act (MBTA) therefore the applicable regulatory requirements are also summarized subsequently.

Additionally, aquatic habitat data for the project area was also reviewed from the CPW and macroinvertebrate data from the City of Boulder: Boulder Habitat Assessment Report (CDM Smith 2014) City of Boulder. This information is also briefly summarized below.

Finally, the City of Boulder Open Space and Mountain Parks (OSMP) maintains land restrictions and seasonal wildlife closures throughout the project area pursuant to City Municipal Code, B.R.C. 1981. Additionally, Boulder County has identified important environmental resources and habitat areas that should be considered in land use decisions and preserved through management practices as summarized in the Boulder County Comprehensive Plan (BCCP) (Second Addition 1996, As Amended). These ecologically-significant areas are utilized by reference in the Boulder County Land Use Code are protected through administration of the Code and in conformance with applicable federal and state law.

8.2 Species Protected Under the Endangered Species Act of 1973

The ESA of 1973 was enacted by the United States to conserve endangered and threatened species and the ecosystems that they depend on. Under the ESA, species may be listed as either “endangered” or “threatened”; both designations are protected by law. The ESA is administered by the USFWS. The USFWS has developed project specific species lists, available online by request, identifying threatened, endangered, and proposed species, designated critical habitat, and candidate species protected under the ESA that may occur within the boundary of the proposed project and/or may be affected by the proposed project (USFWS 2014). Eleven species are identified to occur or historically occur within range of the project area in Boulder County (USFWS 2014). No USFWS critical habitat is present within or near the potential project areas. Further evaluation of the eleven species’ distribution and habitat requirements indicates that three species potentially occur within range of the project area (Table 8-1). During restoration and recovery efforts coordination with the USFWS is recommended.

Table 8-1: Federal Threatened or Endangered Species

	Common Name	Scientific Name	*Status	Suitable habitat not present.
1	Canada-lynx	Lynx Canadensis	FT	Suitable habitat not present
2	Greenback cutthroat trout	Oncorhynchus clarki stomias	FT	Suitable habitat not present.
3	Mexican spotted owl	Strix occidentalis lucida	FT	Suitable habitat not present.
4	Interior Least tern	Sternula antillarium	FE	Water depletion species.
5	Pallid sturgeon	Scaphirhycchus albus	FE	Water depletion species.
6	Piping Plover	Charadrius melodus	FT	Water depletion species.
7	Western prairie fringed orchid	Platanthera praeclara	FT	Water depletion species.
8	Whooping crane	Grus americana	FE	Water depletion species.
9	Preble’s Meadow Jumping Mouse	Zapus hudsonius preblei	FT	Suitable habitat may be present.
10	Ute Ladies’-tresses	Spiranthes diluvialis	FT	Suitable habitat may be present.
11	Colorado Butterfly Plant	Guara neomexicana spp.	FT	Suitable habitat may be present.

*Status:
FT - Federally Listed Threatened
FE - Federally Listed Endangered

Species identified as state threatened or endangered are protected by the CPW under Colorado Statute Title 33. State regulations prohibit “*any person to take, possess, transport, export, process, sell or offer for sale, or ship and for any common or contract carrier to knowingly transport or receive for shipment*” any species or subspecies listed as state endangered or threatened. State listed threatened and endangered species were screened as potential inhabitants of the project area based on general habitat requirements and CPW information (CPW 2014), *Colorado Listing of Endangered, Threatened, and Wildlife Species of Special Concern*. Seventeen species are identified to occur or historically occur within the project area [Reference 35, CPW 2014]. Further evaluation of the seventeen species’ distribution and habitat requirements indicates that five species (PMJM, Ute ladies’-tresses, Colorado butterfly plant, burrowing owl and river otter) potentially occur within range of the project area.

8.3 Migratory Bird Treaty Act

Migratory birds are protected under the Migratory Bird Treaty Act (MBTA) (16 U.S.C. 730-712). The MBTA makes it illegal for anyone to take, possess, import, export, transport, sell, purchase barter, or offer for sale, purchase, or barter any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. In Colorado, all birds except for the European starling (*Sturna vulgaris*), house sparrow (*Passer domesticus*), rock dove (*Columba livia*) and common grouse/pheasant species (*Order Galliformes*) are protected under the MBTA. A total of 523 migratory bird species are known to occur in the Mountain-Prairie Region (USFWS Region 6, Montana, Wyoming, Utah, North Dakota, South Dakota, Nebraska, Kansas and Colorado); 320 of the 523 migratory bird species are known to breed in USFWS Region 6.

Based upon literature review and an onsite assessment of the project area, it was determined that some migratory birds likely utilize the project area. These birds are protected under the MBTA, and killing or possession of these birds is prohibited. Future recovery and restoration efforts which remove vegetation should first ensure that active

nests are not disturbed. Generally, the active nesting season for most migratory birds in this region of Colorado occurs between April 1 and August 31.

Disturbance to raptor nest sites is further protected by the CPW. Within the project area, available CPW Species Activity Mapping (SAM) depicts known mapped buffer zones within the project area for bald eagle (*Haliaeetus leucocephalus*) and osprey (*Pandion haliaetus*) (NDIS 2013). Future recovery and restoration efforts should also be aware of any new raptor nest sites and consult with the CPW.

CPW SAM mapping also depicts great blue heron (*Ardea herodias*) nesting areas throughout the project area. The great blue heron is considered a Colorado species of special concern, protected under the MBTA. The rookery (nesting) areas are considered important habitat features for conservation within the project area.

8.4 Aquatic Life

Boulder Creek throughout the project area is classified as Water Supply Recreation 1A Agriculture Aquatic Life Warm 1 by CDPHE. Aquatic Life Warm 1 classification indicates the waters are currently capable of sustaining a wide variety of warm water biota, including sensitive species. Waters shall be considered capable of sustaining such biota where physical habitat and, water flows or levels and water quality conditions result in no substantial impairment of the abundance and diversity of species.

Informal discussions with local Colorado Parks and Wildlife (CPW) staff indicates that the project reach of Boulder Creek is a transitional zone between a cold water fishery (extending upstream of Boulder Canyon) dominated by trout to a warm water fishery (downstream of Boulder Canyon) dominated by native minnow species. Brown trout are present through the Canyon and City reaches, however east of 75th Street small bodied native fish become more dominate. CPW also indicated that future restoration efforts in the project reach and in particular east of 75th Street should focus on native small bodied native fish species and not typical trout habitat. CPW's most recent fish population survey (2014), identified the following dominant species: brown trout, common carp, creek chub, fathead minnows, green sunfish, largemouth bass, longnose dace, longnose sucker and white sucker. Of the 17 species collected, 9 species were non-native and 8 species were native to South Platte River basin.

CDM Smith completed a City of Boulder - Boulder Creek Habitat Data Review (Draft 2014) in anticipation of: a) the inclusion of habitat and biological data in future assessments and potential impairment determinations, and b) the importance of understanding habitat quality as part of the biological assessment process. The primary objective of the study was to organize the city's habitat data in a manner that supports meaningful evaluation of macroinvertebrate data that may be used to support aquatic life use attainment determinations in the Boulder Creek watershed. This study was also used to develop recommendations for streamlining future habitat characterization efforts so that in the future, monitoring resources are expended on the collection of the most useful habitat data. The Review study area begins in the canyon at the west end of the urban core and extends to the confluence of Boulder Creek and Coal Creek near the Boulder/Weld County line. The Review concluded that datasets show lower habitat quality through the City as seen in the habitat scores below the canyon through 28th Street. Associated biological indices also follow the general pattern of lower scores at 28th Street. Urban density begins to decrease east of Foothills Parkway and habitat scores and biological metrics generally improve as the area becomes more rural. Habitat subcategory scores show that the overall habitat results are driven by habitat scores related to riparian quality. Of particular note is habitat parameter 10, which scores vegetative riparian zone width. Scores are lower through the urban corridor where the riparian zone is most confined.

8.5 City of Boulder's Open Space & Mountain Parks (OSMP) Closures

The City of Boulder's Open Space & Mountain Parks land has been set aside for preservation and the protection of the natural environment. Within the project area, the Open Space and Mountain Parks (OSMP) division maintains the following closures:

- Bald Eagle Closures Nov. 1 - July 31. One area on OSMP within the project area is closed from Nov. 1 to July 31 every year to protect bald eagle nesting and roosting activity.
- New Zealand Mudsnail Closures Year Round. Portions of Boulder Creek downstream of Valmont Road are closed year round because of the non-native, invasive New Zealand Mudsnail.

9.0 PROJECT FOCAL AREAS / RESTORATION PROJECTS

9.1 Project Focus

As noted previously, the purpose of this master plan is to provide planning guidance to improve flooding resiliency along Boulder Creek. The focus is on general guidance for stream and ecological restoration; however consideration has also been given to other multi-purpose objectives along the corridor. Descriptions of different alternative categories are presented below.

The study reviews Boulder Creek, as a whole and the geomorphic and ecological principles described can be applied uniformly over the entire project reach. Restoration would most likely occur as property and funding become available. There is not a singular, correct solution in defining restored stream alignments for Boulder Creek. Alignments should be refined further through individual project goals, but keeping in mind compatibility with neighboring stream reaches.

Alternatives presented apply the stream restoration principles at locations with immediate restoration needs and a higher likelihood of implementation in the future. Larger restoration projects are generally focused in areas where property has already been acquired, such as public lands or locations where changes to private infrastructure could be more easily implemented.

It is important to note that although this master plan provides general guidance for restoration efforts, it does not re-evaluate the current 100-year floodplain limits regulated by FEMA. Although the implementation of some proposed projects presented in this master plan may also reduce the regulatory floodplain limits; the focus of this master plan is to provide a planning tool for stream and ecological restoration.

General guidance within the City of Boulder addresses specific areas of concern identified by city staff, and other public or interested stakeholders to the project. The master plan does not comprehensively evaluate and recommended changes to Boulder Creek through the City limits. Users are encouraged to reference standards presented in the City's Greenway's Master Plan for additional information along Boulder Creek.

Several projects within this reach of Boulder Creek are currently in process of design and/or construction. This includes the U.S. Army Corps of Engineers stream restoration project, east of 109th Street; restoration projects within the City of Boulder between 63rd Street and Valmont, improvements within Eben G. Fine Park, and bank stabilization at the Town of Erie's re-use facility. Improvements in these areas have been recognized by this master plan as in-progress. New alternatives and project costs estimates were not developed for the in-progress projeccts. Similarly, within the City of Boulder, this master plan completed a review of ongoing planning efforts for the Civic Center area and North of Boulder Creek. These studies were reviewed for compatibility with planning solutions and effectiveness on flood management. New alternatives were not developed or carried forward into this master plan.

9.2 Criteria and Constraints

Prior to construction, or commencing other work on private property or within the drainageways, it is recommended that individuals consult with the appropriate jurisdictions regarding the proposed changes and construction requirements, such as obtaining engineered plans, permitting requirements, erosion and sediment control, water quality and natural resource protection, easements or other items that may be required. If working within 100 feet of a ditch diversion, notify the ditch company early in the design. The following websites address specific requirements set forth by local jurisdictions:

1. City of Boulder: Flood Recovery Website: https://bouldercolorado.gov/flood
2. Boulder County: Flood Recovery Website: http://www.bouldercounty.org/flood/pages/default.aspx
3. Weld County: Flood Recovery Website: http://flood2013.weldgov.com/
4. City of Longmont: Flood Recovery Website: http://longmontcolorado.gov/departments/departments-n-z/public-information/flood-information
5. CDOT: Private Access Reconstruction Guide: http://jeffco.us/Disaster-Recovery/Documents/CDOT-Private-Access-Reconstruction-Guide-for-Residents/

Section 404 of the Clean Water Act (CWA) established a program to regulate the discharge of dredged or fill material into waters of the United States and wetland areas. Activities in waters of the United States regulated under this program include fill for development, water resource projects, infrastructure, and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States. Proposed activities are regulated through a permit review process. An individual permit is required for potentially significant impacts. Individual permits are reviewed by the U.S. Army Corps of Engineers, which evaluates applications under a public interest review, as well as the environmental criteria set forth in the CWA Section 404(b)(1) Guidelines, regulations promulgated by EPA. General permits may also be suitable. General permits are issued on a nationwide, regional, or State basis for particular categories of activities. Local agencies, including the COE should be consulted and required permits should be obtained prior to filling or dredging material in streams or drainageways, on a both a permanent and temporary basis.

Rebuilding and new construction activities within the watershed should consider best practices to reduce the loss of human life and property from flood and storm damage, as managed through local floodplain administration. General guidance has also been provided to flood impacted communities by the Colorado Association of Stormwater and Floodplain Managers (CASFM), through a white paper distributed on October 4, 2013. This white paper is available at http://www.casfm.org/2013_Flood/CASFM_media_summary_statement_2013-10-04.pdf.

Boulder Creek is a regulated floodplain by FEMA, the City of Boulder, and Boulder and Weld Counties. Proper floodplain permitting through local jurisdictions will be required prior to commencing construction activities.

Future improvements along Boulder Creek shall give full consideration to policies presented in community planning documents, including the Boulder Valley Comprehensive Plan, City of Boulder's Greenways Master Plan and the Grassland Ecosystem Management Plan. These documents present multi-objective goals achievable with drainageway and open space improvements. Between Foothills Parkway and 95th Street, the Greenways' Master Plan and Grassland Ecosystem Management Plan present ancillary project goals which should be considered with any stream restoration project in this area.

Improvements to existing roadway crossings in Boulder and Weld Counties follow criteria set forth by each jurisdiction. As a minimum standard, both counties allow overtopping of the roadways during large flood events. However, county criteria require that the actual bridge structures, including the low chord, be elevated above the 100-year flood levels. This criterion was used as a minimum standard in evaluating transportation infrastructure.

For three other locations including: East County Line Road, 75th Street, and 61st Streets, Boulder County also requested that 100-year capacity bridge alternatives be evaluated.

9.3 Improvement Alternative Categories

Sediment Maintenance

Sediment buildup occurs at many locations along the Boulder Creek Path in the City of Boulder. Although restoration activities recommended with this master plan will alleviate several of these routine problem areas over time, ongoing maintenance, particularly with existing trail underpasses is still needed. Maintenance activities generally include removal of sediment on an annual basis.

Natural Stream / Channel Restoration

In order to allow Boulder Creek to return to a more natural state, channel restoration projects have been proposed along Boulder Creek. These projects consist of providing an appropriate channel width, bank full depth, stream sinuosity, overbank floodplain connection, and ecological / habitat enhancements. Alternatives presented apply the stream restoration principles at locations with immediate restoration needs and a higher likelihood of implementation in the future. These projects are generally focused in areas where property has already been acquired, such as public lands, or locations where changes to private infrastructure could be more easily implemented. However, the geomorphic and ecological principles presented can be applied uniformly for Boulder Creek, as property and funding become available.

Roadway Crossing Improvements

It is typical for roadway crossings of Boulder Creek, particularly east of the City of Boulder, to experience overtopping while the bridge structure, itself, remains perched over the main channel. As discussed above, per Boulder and Weld County criteria, new bridges are required to be elevated above the 100-year flood level. Overtopping is allowed elsewhere, often hundreds of feet from the bridge location. Per discussions with Boulder County transportation staff, it was determined that all bridges over Boulder Creek would need to meet this criteria, at a minimum. Boulder County also requested that additional alternatives be evaluated for 61st Street, 75th Street, 95th Street, and East County Line Road, which would convey the 100-year event without overtopping in order to provide emergency services during flooding. A summary of major roadway crossings along Boulder Creek is presented in Table 9-2: Bridge Information and Replacement Locations. This table compares the existing bridge elevations and estimated bridge deck thicknesses with FEMA's regulatory 100-year water surface elevations along Boulder Creek to determine if a bridge currently meets criteria. Bridges outside of criteria were selected to be replaced by this master plan.

In addition to comparing bridge elevations with current criteria, consideration was given to minimizing bridge obstructions on geomorphic channel boundaries. For this master plan, the project team recommended that standard bridges, within the plains stream region be sized: to convey a minimum of 60% of the 100-year discharge; to accommodate the stream and floodplain at twice the bank flow depth (as presented in Section 6.0); and to maintain less than a 6 ft./sec velocity through the bridge section at a maximum of depth of 10-feet. A 180-foot bridge opening width was used for this criterion, bridges with a smaller opening were recommended to be replaced.

For 100-year bridges alternatives at 61st Street, 75th Street, and County Line Road, a 220-foot bridge opening width was selected to closely match existing 100-year crossings at Mineral Road and Highway 287.

Bridge replacement recommendations focused on bridges outside of the City of Boulder, although general capacity observations in Table 9-2: Bridge Information and Replacement Locations included city roadways for informational purposes. Evaluating bridge changes within the City of Boulder was beyond the scope of this study due to the complexity of floodplain impacts; however the City's infrastructure was generally higher in capacity and more accommodating of both flood flows and geomorphic stream conditions. Improvement recommendations were made, however, at the Burlington, Northern, and Santa Fe Railroad Bridge, which has less flood capacity and a poor orientation with respect to the stream conditions.

Stream Stabilization and Ditch Diversions

Numerous water diversion points exist in Boulder Creek. Currently very few of the existing diversions structures also accommodate fish passage or macro-invertebrates common to the region. Improvements are recommended to retro-fit or rebuild diversions to satisfy this multi-objective need. Specifically these systems are proposed to be replaced with sloped drop faces and fish passage measures. Projects would need to ensure that private water rights are not negatively impacted by channel modifications and/or improvements. These conversions will allow the adjacent channel to exist in a more natural state while also providing the long term ability to divert water at the diversion point.

Plans to modify any diversion structure should be coordinated with the representative of the ditch company. The following diversion structures are proposed to be modified to allow for aquatic and habitat passage while maintaining the efficiency to divert water to the water rights holder.

Table 9-1: Alternative Ditch Diversion Structures

Ditch Name	Reach	Project ID
Rural Ditch	2	2C
Idaho Creek Diversion*	2	2D
Gooding A. and D. Plumb Ditch	4	4A
Howell Ditch	4	4G
Boulder Weld Ditch	5	5B
Lower Boulder Ditch	5	5E
Leggett Ditch	6	6A
Unknown Ditch	7	7C
Green Ditch	7	7D
Butte Mill Ditch	7	7G
Boulder Ditches	9	9E
Farmers' Ditch	10	10A

*Representative of 5 ditches in addition to the natural drainageway
(Delehant Ditch, Houck No. 2 Ditch, Carr & Tyler Ditch, Smith & Emmons Ditch, and Godding Ditch)

Drop structures, and other existing stabilization measures, which present obstruction to fish passage or macro-invertebrate habitat, have also been proposed to be replaced in a similar manner.

Photo 9.1 - Example of diversion structure and fish passage channel (ERC, East River)

Mining / Gravel Pond Spillways

Several aggregate mining or gravel pit ponds, located adjacent to Boulder Creek, experienced bank failures during the 2013 flooding event. These failures can cause surges in flood flows, imbalance in the stream's sediment transport, and diversion of stream flow, until repairs or restoration can be completed. Natural stream and floodplain restoration projects described previously are one means to address the challenges associated with floodplain mining or gravel pit ponds. However, this often leads to the elimination of the pond which is not always desired. Where eliminating the pond is not desired, retro fitting the mining or gravel pit ponds with spillways that will reduce the potential for bank failure is proposed. At a minimum, these spillways shall meet the guidelines set forth in the *Technical Review Guidelines for Gravel Mining and Water Storage Activities Within or Adjacent to 100-year Floodplains,* produced for the UDFCD [Reference 60, Wright Water Engineers, Inc.]. Per the UDFCD guidelines, ponds with a riverside berm length less than 1,300 feet long are proposed to be retro-fitted with a single spillway, while gravel pits with a riverside berm length greater than 1,300 feet are proposed to be retrofitted with two spillways. UDFCD also recommended that a minimum 100-feet of spillway width be provided. Most existing spillways within the watershed fall below this threshold and would also require a retro-fit.

Debris and Vegetation Removal

Debris along Boulder Creek is significant in some areas. In order to provide improved floodplain conveyance and to reduce the potential for debris related issues (such as debris clogging bridge openings or damaging diversion structures), removal of debris and/or vegetation has been proposed in some reaches of the project reach. This does not apply to areas in which vegetative flood debris (i.e. large woody debris not trash) provides important habitat and function in the creek and riparian systems. It is recommended that bridges be inspected and maintained clear of debris up to 200-feet upstream of each bridge crossing, at a minimum.

Bank Stabilization

Typical bank stabilization efforts have been proposed for areas of bank that have experienced damage due to flooding events. Bank stabilization is typically located in areas that would not otherwise be addressed through channel restoration or stream crossing improvements. This includes work near the City of Boulder sewage treatment interceptor, where stream stabilization and bank revetment has been proposed to address routine maintenance areas. When implementing bank stabilization, bio-engineered methods should be used when possible instead of traditional rip rap, grouted rock, etc. All bank stabilization projects should help restore the ecological function of the creek while repairing the integrity of the bank.

Other Project Alternatives

Other potential alternatives were evaluated and reviewed with project sponsors on a site specific level. In some cases, these additional alternatives demonstrated limited feasibility and were not carried forward further. Site specific alternatives are discussed below:

Property Acquisition: A review of flood prone properties was completed in select areas. Specifically, several properties along Kenosha Road in Boulder County, Cordry Court in the City of Boulder, and buildings that are part of the Millennium Harvest House property (south of the creek) were reviewed to determine if acquisition would be an effective flood management tool. For these locations, FEMA's Benefit-Cost-Analysis software [Reference 61, FEMA] was used to compare properties on an individual basis. No properties demonstrated a strong potential for acquisition. Staff from Boulder County also indicated that post-flood acquisition activities have been performed on a voluntary basis with property owners initiating discussions. Based on these conditions, property acquisition was not pursued further within this master plan.

Boulder Community Foothills Hospital Access: Access to the Boulder Community Foothills Hospital during flooding up to the 500-year event is required to meet the City's critical facilities ordinance. Currently, the intersection of 48th Street and Riverbend Road would be required to be elevated approximately 2 feet to provide access at the hospital's main entrance during the 500-year event. As an option, this master plan proposes to add a secondary paved emergency access location to the hospital's parking lot from 48th Street, north of the Arapahoe Avenue intersection. This would provide access to the hospital during the 500-year event and would be less costly than raising the intersection and entrance roadway.

Butte Mill Ditch (South Boulder Creek): The Butte Mill Ditch is originally diverted from Boulder Creek just upstream of Valmont Road, and then after approximately 400 feet, travels east to South Boulder Creek. In 2013 flooding in this area was exacerbated by the Butte Mill Ditch diversion on South Boulder Creek. Given that all the Butte Mill decreed flows originate from Boulder Creek, there are several needs for the ditch. At Boulder Creek, the ditch diversion is proposed to be retro-fitted to accommodate aquatic and habitat passage. At South Boulder Creek, the ditch is proposed to be improved to maintain separation from flows within the creek. This project includes an inverted siphon for the Butte Mill Ditch as it crosses South Boulder Creek, removal of the associated South Boulder Creek diversion structure, and channel restoration in the vicinity of the crossing along South Boulder Creek. Any modifications impacting the Butte Mill Ditch require written ditch company approval.

Old Valmont Trail Crossing: Significant amounts of debris collected between the Old Valmont trail crossing on Boulder Creek and Valmont Road. This trail crossing is proposed to be replaced with a bridge structure more accommodating of flood flow, geomorphic channel dimensions, and restoration needs.

***University of Colorado North of Boulder Creek*:** The University of Colorado planning study for North of Boulder Creek was completed in 2014. This plan identifies flood management strategies and infrastructure needs surrounding the North of Boulder Creek Campus, located between 17th Street and Folsom. Key goals and strategies

include: maintaining flood water conveyance within open areas of athletic and recreation fields; maintaining existing roadway grades without further obstruction; elevating residential structures above flood elevations; and flood-proofing commercial infrastructure. Also noted as part of the North of Boulder Creek study was the need to improve existing bridge obstructions, and improve both pedestrian and emergency access to the stadium and campus south of Boulder Creek. A series of pedestrian bridge options have been proposed with the Boulder Creek Master Plan alternatives to replace the existing access points over the creek.

High Hazard Mitigation at Cordry Court and Millennium Harvest House; Floodplain Reduction at Senior Housing Facility (Carillion): The City of Boulder regulates a high hazard zone along Boulder Creek in the vicinity of 28th Street. This high hazard zone encumbers property and structures adjacent to Cordry Court and the Millennium Harvest House. Hydraulic modeling was performed to verify if high hazard could be reduced, or removed on the Millennium Harvest House or Cordry Court properties through excavation within the Boulder Creek overbanks. For properties along Cordry Court, it was determined that channel bank grading between the existing residences and Boulder Creek would alleviate the High Hazard determination north of the homes. Bank grading and redevelopment concepts were explored for the property between the Millennium Harvest House and Carillion Senior Housing. It was determined that through overbank excavation (south bank between sections 24386 and 25267 and north bank around sections 25182), high hazard could be removed from abutting the Millennium Harvest House building, north of Boulder Creek, and the floodplain would be lowered by as much as 2-feet near the Carillion Senior Housing facility. However, accomplishing this would require many of the following projects:

- Modification or removal of the 7 court tennis complex, west of 28th Street;
- Removal of the three ancillary Harvest House buildings located South of Boulder Creek;
- Modification or removal of the western-half parking area north of the senior center;
- Modification or removal of the Millennium Harvest House basketball court, north of Boulder Creek;
- Excavation and expansion of the Boulder Creek channel and floodplain between 28th Street and Folsom;
- Adjustments to the Boulder Creek Trail.

With these changes, the split flow along Taft Drive that circumvents the Carillion Senior Housing development would also be eliminated, bringing the facility into compliance with the Boulder Critical Facilities Ordinance.

Cost estimates for projects along Cordry Court, the Millennium Harvest House, and Carillion Senior Housing facility have been provided; however it is anticipated that these improvements would occur with redevelopment. At this time, a more thorough evaluation of floodplain management aspects should be compared with land uses and site needs. As an alternative, non-residential buildings could be flood proofed as a mitigation option.

During evaluation of this alternative, it was noted, using FEMA's BCA software, that removal of the three 1,700 sf Harvest House buildings, south of Boulder Creek, alone, would yield over $570,000 in direct benefits. However, due to the nature of home and property values, the benefit versus cost ratio was only estimated at 0.6. This estimate was based on comparisons with nearby homes in the Cordry Court area, using a $100/sf estimate for building values, $26/sf estimate for property values (0.3 ac), and $40,000 estimate for demolition and disposal of each building.

Boulder Slough Mitigation: The slough currently originates as a diversion from Boulder Creek at the structure east of the Broadway Bridge, commonly known as the 12th Street diversion structure. Five ditches divert their respective water rights from this structure and waters co-mingle in Boulder Slough as it traverses the City. The five ditches are the Boulder & White Rock Ditch, Boulder & Left Hand Ditch, McCarty Ditch, Smith and Goss Ditch, and North Boulder Farmer's Ditch. Boulder Slough extends from Boulder Creek at Broadway downstream to Goose Creek, east of Foothills Parkway. In addition to carrying private irrigation ditch flows, Boulder Slough has the potential to also collect stormwater runoff derived from the area west of the slough and north of Boulder Creek. During the September 2013 flood, flows that entered the Boulder Slough spilled from its banks upstream and downstream of 15th Street and flooded residences within the Goss Grove neighborhood. An alternative has been proposed at 14th street to intercept flows beyond the ditch capacity and convey the overflow to Boulder Creek via a storm sewer. For the purposes of the analysis, the overflows were assumed to be approximately 110-cfs during the 100-year event, approximately half of the 100-year discharge at 18th Street, as referenced by the floodplain mapping study prepared by Anderson Consulting Engineers, Inc. (ACE) in 2014 [Reference 62]. A 48 inch RCP was assumed for the outfall. Any modifications impacting irrigation ditches require written ditch company approval.

Photo 9.2 – Boulder Slough Diversion at Broadway

City of Boulder Civic Center Area Plan: The City of Boulder is currently reviewing redevelopment and improvements options for the Civic Center between 13th Street and 9th Street. With regards to floodplain improvements, the proposed plan includes removal of several buildings and surface parking in an effort to increase floodplain capacity and reduce infrastructure in areas of high hazard designation. With the Civic Center plan, Boulder Creek will continue to be a natural corridor with trees and creek-side vegetation. No specific proposed changes to the channel, ditch diversions, or to the existing crossing structures at 9th, Broadway, and Arapahoe Avenue were identified. An evaluation of potential mitigation improvements was completed by ACE in 2012 [Reference 63]. This evaluation analyzed eleven flood mitigation scenarios using a hydraulic model. The scenarios included variations of the removal of the Park Central and New Britain buildings and increasing the opening of the Broadway and Arapahoe crossing structures. The evaluation determined that the base flood elevations upstream of Broadway could be reduced by removal of the buildings and increasing the opening area of the Broadway crossing, however the municipal building would remain within the 100-year floodplain. Additionally, it was noted that improvements have

the potential to keep more water in the Boulder Creek channel and reduce discharges along the spill flow that follows Canyon Boulevard. Future improvements should consider these potential affects.

No new alternatives have been presented for the Civic Center area in this master plan study; however changes to Boulder Creek at this location should consider the following scenarios presented by the City in a draft planning summary [Reference 64, City of Boulder]:

- *Removing the Park Central and New Britain buildings:* 100-year flood levels upstream of Broadway could be reduced slightly (less than 0.2 feet) by removing the Park Central and New Britain buildings though this action would eliminate two critical facilities from the 100-year floodplain, conveyance zone, and high hazard zone.
- *Adding conveyance capacity at the Broadway Bridge:* 100-year flood levels upstream of Broadway could be reduced by up to 0.70 feet by adding conveyance capacity at the Broadway Bridge. The bridge has been constructed in a manner that would facilitate conveyance capacity improvements. Based on the available topography, it appears that the 0.70-foot drop in flood level associated with increasing the bridges flow capacity would not remove the Municipal Building from the 100-year floodplain or conveyance zone, nor the Park Central and New Britain building from the conveyance and high hazard zones. This alternative would increase flows along Boulder Creek, while reducing flows on Canyon Boulevard.

Higher flows along the creek would persist downstream to west of 30th Street and cause higher 100-year flood levels that would need to be mitigated. However, increases in flood levels downstream of Arapahoe would be relatively small (less than 0.1 feet) and could likely be mitigated with one or more of the following: select grading of overbank areas, reducing the potential for debris obstruction at bridges, and/or increasing conveyance under road crossings.

Reduced flows on Canyon Boulevard (due to increased flows along the creek at Broadway) would likely not result in significant reductions in flood levels, or significant reductions in the footprint of either the conveyance zone or the high hazard zone, along Canyon Boulevard or the street system east of Broadway.

Reduced flows on Canyon Boulevard between Broadway and 13th Street could result in a slightly narrower footprint for the conveyance zone through the band shell area in the northern portion of Central Park. However, it would be unlikely that the conveyance zone could be confined to the street corridor in this area. Therefore, it appears the northern portion of Central Park would be available for building development assuming a significant building setback from Canyon Boulevard that avoids the conveyance zone.

- *Adding conveyance capacity at the Arapahoe Bridge:* Increasing the conveyance at Arapahoe would not significantly influence flood levels upstream of Arapahoe and does not make sense as a standalone project. Increasing the conveyance at Arapahoe would be required to mitigate increases in flood levels between Broadway and Arapahoe if conveyance capacity is added at Broadway.
- *Overbank grading of Boulder Creek between the Library and Broadway:* It is possible that lowering the grade adjacent to Boulder Creek between the Library and Broadway would reduce the footprint of the existing high hazard and conveyance zones on the north side of Arapahoe. This would possibly allow building construction along the north side of Arapahoe in a limited area. The grading would result in the removal of significant existing vegetation and parking.

Additional guidance for Flood Regulatory Considerations, Flood Policy Consideration, and Site Opportunities and Flood Constraints were provided for the Civic Area in June 2015. A summary of the guidance is provided below:

Flood Regulatory Consideration: Existing flood standards will be met or exceed, including avoiding placing new structures and parking in the HHZ. Existing regulations also include:

- No new buildings intended for human occupancy can be built within the HHZ.
- A building that is touched by the HHZ is regulated as if the entire structure is in the HHZ.
- An existing building in the HHZ cannot have additional space intended for occupancy built nor can the footprint be increased.
- An existing building cannot be improved by more than 50% of the value of the building.
- Any improvements that are within the conveyance zone require evaluation and certification of no impact.

Flood Policy Consideration: Consideration must be taken for public safety, but that does not prohibit all use of floodplain areas or HHZ. Uses that are outdoors and provide a safe and convenient evacuation route from the HHZ promotes a higher level of public safety compared to occupied buildings. Buildings occupied on a daily basis by the same people provide an opportunity for the occupants to be trained and aware of their risks when equated to assembly areas where occupants are not routinely in the building.

Site Opportunities and Flood Constraints: The west and east area of the Civic Area present different risks in flooding potential. The HHZ has a greater influence on the structures on the west end of the Civic Area. Although the HHZ designations are more confined on the east end, the structures are still inundated by the 100-year floodplain. Below grade parking structures should be avoided in the Civic Area due to the flood risk and groundwater challenges that below grade structures provide.

Figure 9-1: City of Boulder Civic Area Plan [Reference 65]

Table 9-2: Bridge Information and Replacement Locations

BRIDGE DATA							CRITERIA CONFIRMATION		GEOMORPHIC CONFIRMATION		REPLACEMENT	
Stream Reach	Bridge Location	Jurisdiction	Classification	Estimated Bridge Capacity	Estimated Roadway Elevation	Estimated 100-Year WSEL	Estimated Bridge Deck Thickness	Is Bridge Above 100-Year WSEL?	Existing Bridge Width	Does Bridge Meet Geomorphic Width Recommendations?	Does Bridge Require Replacement?	100-Year Emergency Access Considerations?
				(cfs, approx. freq)	(NAVD 1988)	(NAVD 1988)	(in)	(Yes/No)	(ft)	(Yes/No)	(Yes/No)	(Yes/No)
Reach 2	WC Road 20 1/2	Weld County	Collector	< 100-year	4884	4882	41	NO	132	NO	**YES**	NO
Reach 2	WC Road 16 1/2	Weld County	Local	1,000 cfs	4927	4920	51	YES	126	NO	**YES**	NO
Reach 4	East County Line Road	Boulder / Weld Counties	Collector	1,200 cfs	4957	4951	53	YES	124	NO	**YES**	**YES**
Reach 4	Mineral Road (SH 52)	CDOT	State Highway	> 100-year	4961	4958	26	YES	218	YES	NO	**YES**
Reach 4	Kenosha Road	Boulder County	Local	600 cfs	4996	4994	43	NO	92	NO	**YES**	NO
Reach 4	109th Street	Boulder County	Local	5,400 cfs	5016	5015	25	NO	77	NO	**YES**	NO
Reach 4	State Highway 287	CDOT	State Highway	> 100-year	5027	5021	66	YES	218	YES	NO	**YES**
Reach 5	95th Street	Boulder County	Arterial	3,300 cfs	5065	5059	56	YES	121	NO	**YES**	NO
Reach 6	75th Street	Boulder County	Arterial	6,200 cfs	5121	5117	46	YES	108	NO	**YES**	**YES**
Reach 7	61st Street	Boulder County	Arterial	8,300 cfs	5170	5171	30	NO	90	NO	**YES**	**YES**
Reach 7	Valmont Road	Boulder County	Arterial	> 100-yr	5199	5198	42	Yes	--	--	--	--
Reach 8	BNSF Railroad	BNSF Railroad	Railroad	1,000 cfs	5231	5228	30	YES	52	NO	**YES**	NO
Reach 8	55th Street	City of Boulder	Minor Arterial	> 100-yr	5214	5205	--	Yes	--	--	--	--
Reach 8	Foothills Parkway	City of Boulder	Principal Arterial	> 100-yr	5255	5244	--	Yes	--	--	--	--
Reach 8	Arapahoe Avenue	City of Boulder	Principal Arterial	> 100-yr	5254	5251	--	Yes	--	--	--	--
Reach 8	30th Street	City of Boulder	Minor Arterial	< 100-yr	5276	5275	--	Yes	--	--	--	--
Reach 9	28th Street	City of Boulder	Principal Arterial	< 100-yr	5291	5291	--	No	--	--	--	--
Reach 9	Folsom Street	City of Boulder	Minor Arterial	5,764 cfs	5304	5304	--	No	--	--	--	--
Reach 9	17th Street	City of Boulder	Collector	< 100-yr	5332	5329	--	Yes	--	--	--	--
Reach 9	Arapahoe Avenue	City of Boulder	Minor Arterial	6,800 cfs	5344	5345	--	No	--	--	--	--
Reach 9	Broadway Street	City of Boulder	Principal Arterial	5,272 cfs	5348	5350	--	No	--	--	--	--
Reach 9	9th Street	City of Boulder	Minor Arterial	> 100-yr	5366	5359	--	Yes	--	--	--	--
Reach 9	6th Street	City of Boulder	Local Street	11,078 cfs	5378	5380	--	No	--	--	--	--

9.4 Summary of Project Alternatives

A summary of project alternatives are presented in Table 9-3, below.

Table 9-3: Summary of Project Alternatives

Reach	ID	Description	Jurisdiction
1	A	Stream Restoration & Debris Removal City of Longmont Open Space	City of Longmont / Weld County
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge	Weld County
	B	Replace Existing Grade Control for Aquatic and Habitat Passage	Weld County
	C	Modify Rural Ditch for Aquatic and Habitat Passage	Town of Frederick / Weld County
	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage	Weld County
	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County
	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County
	G	Stream Restoration Downstream of CO Rd. 16.5	Weld County
3	A	Stream Restoration Upstream of CO Rd. 16.5	Weld County
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Weld County
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage	Weld County
	B	East County Line Rd. - Replace Bridge with 180 ft. Span Bridge, Restore Channel Banks Option: Install 100-yr Crossing (220 ft. Span Bridge)	Weld County / Boulder County
	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County
	D	Stabilize Bank at Bailey-Kenosha Pond Outlet	Boulder County
	E	DS of Kenosha Rd. - Remove Washed Out Bridge	
	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space	
	G	Stabilize Diversion System, Modify Diversion for Aquatic and Habitat Passage	
	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge	
	I	Replace Grade Control for Aquatic and Habitat Passage	
	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel	
	K	Stream Restoration Through Wheeler Ranch	
5	A	Stream Restoration at Alexander Dawson Open Space	Boulder County
	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage	
	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typical.	
	D	Modify Grade Control Structures for Aquatic and Habitat Passage	
	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage	
	F	Stream Restoration Downstream of 95th St.	
	G	95th St. - Replace Bridge with 180 ft. Span Bridge Option: Install 100-yr Crossing (220 ft. Span Bridge)	
	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail	
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage	Boulder County
	B	75th St. - Replace Bridge with 180 ft. Span Bridge; Option: Install 100-yr Crossing (220 ft. Span Bridge)	
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County
	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical	
	C	Modify Diversion for Aquatic and Habitat Passage	
	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage	
	E	61st St. - Replace Bridge with 180 ft. Span Bridge Option: Install 100-yr Crossing (220 ft. Span Bridge)	
	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge	
	G	Modify Butte Mill Ditch Crossing on South Boulder Creek	
	H	Protect Sanitary Interceptor Sewer	
	I	Stream Restoration from Valmont Rd to 61st St.	
8	A	Stream Restoration from 55th St. to Valmont Drive	City of Boulder
	B	Stream Restoration from BNSF RR to 55th St.	
	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge	
	D	Stream Restoration from Foothills Pkwy to BNSF RR	
	E	Hospital Access Improvements for 500-yr Event	
	F	Sediment Maintenance along Boulder Creek Path	
9	A	Cordry Ct. - High Hazard & Flood Mitigation	City of Boulder
	B	Millenium Harvest House and Senior Housing - High Hazard Flood Mitigation	
	C	North of Boulder Creek Access Improvements	
	D	Boulder Slough Mitigation	
	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage	
	F	Sediment Maintenance along Boulder Creek Path	
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage	Boulder County
	B	Boulder Canyon Stream Restoration	

9.5 Alternative Cost Estimates

Cost estimates for alternatives were developed using UDFCD's master planning cost estimating spreadsheet UD-MP COST, version 2.2. 2012 unit costs values were adjusted to present value using the current Colorado Construction Cost Index report. An inflation rate of 1.2166 was used to adjust unit costs to 2014 4th quarter costs. Effective interest rate was estimated to be 1.50%. This assumption was made based upon current discount rates from the Federal Reserve Discount Window and inflation rates published by the US government. Operation and Maintenance was also included within the UD-MP Cost worksheet. Bridge maintenance, channel maintenance and hydraulic structure maintenance were assumed to be performed once every five years. Sediment Maintenance removal costs were included for areas identified by the City of Boulder as frequent problem areas. Each sediment maintenance alternative was assumed to remove 200 cubic yards of sediment a year.

Regarding stream restoration and ecological enhancement costs, costs of recent stream and riparian restoration projects were used as the basis for costs in this master plan. Unit costs from these projects were generated and applied to the restoration quantities assumed for each of the Boulder Creek alternatives where restoration is recommended. Given the range of improvements, unit costs were developed for the following items:

1. Restoration of a stream where the work includes constructing a new channel alignment ($700,000 per mile)
2. Restoration of a stream where the work includes habitat enhancement and related improvements that are to occur within the existing channel ($400,000 per mile)
3. Restoration of the adjacent riparian corridor ($35,000 per acre)

When estimating restoration costs for alternative projects along Boulder Creek, unit restoration costs were combined with the quantity and type of work estimated to be required at each site. For all stream work downstream of the canyon, stream restoration was assumed to include realignment of the channel. Stream restoration within the canyon was assumed to occur within the existing channel with no realignment. The extents of stream restoration were selected to coincide with the alternatives presented in the plan.

Areas of riparian restoration were also estimated for each section. When generating costs for riparian restoration, a target riparian width of 25 feet on either side of the stream was used for the canyon section. The target riparian width was set at 200 feet on either side of the channel for all other segments. The actual amount of riparian restoration needed at each of the alternative sites accounted for the amount of room currently available and the condition of existing vegetation when estimating how much riparian work would be required at each location.

Other costs were calculated as a percent of Capital Improvement Costs, such as Engineering, Legal/Administrative, Contract Administration/Construction Management, and Contingency. No alterations to the default values provided by the UD-MP Cost spreadsheet were made to these items. Traffic Control and Utility Coordination/Relocation were assumed to be 2.5% of the Total Capital Improvements unless site conditions warranted otherwise. All projects assumed 1% of Total Capital Improvements for Dewatering.

Costs estimates assumed: bridge, culvert and storm sewer, channel maintenance for restoration reaches, and maintenance for hydraulic structures or other in-stream features would each occur once every five years.

Table 9-4: Minimum Improvement Alternative Costs (Reach 1 – 6)

Reach	ID	Description	Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
1	A	Stream Restoration & Debris Removal City of Longmont Open Space	City of Longmont / Weld County	$ 476,965	$ 143,090	$ 119,241	$ 739,296	$ 19,600
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 4,270
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 420
	B	Replace Existing Grade Control for Aquatic and Habitat Passage	Weld County	$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	C	Modify Rural Ditch for Aquatic and Habitat Passage	Town of Frederick / Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage	Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 420
	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County	$ 5,481,000	$ 1,644,300	$ 1,370,250	$ 8,495,550	$ 89,389
	G	Stream Restoration Downstream of CO Rd. 16.5	Weld County	$ 1,054,200	$ 316,260	$ 263,550	$ 1,634,010	$ 28,000
3	A	Stream Restoration Upstream of CO Rd. 16.5	Weld County	$ 1,058,840	$ 317,652	$ 264,710	$ 1,641,202	$ 28,000
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Weld County	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 4,270
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage	Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	East County Line Rd. - Replace Bridge with 180 ft. Span Bridge Restore Channel Banks	Weld County / Boulder County	$ 2,384,281	$ 715,284	$ 596,070	$ 3,695,635	$ 560
	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County	$ 3,915,000	$ 1,174,500	$ 978,750	$ 6,068,250	$ 63,840
	D	Stabilize Bank at Bailey-Kenosha Pond Outlet	Boulder County	$ 17,088	$ 5,126	$ 4,272	$ 26,486	$ 3,220
	E	DS of Kenosha Rd. - Remove Washed Out Bridge		$ 69,600	$ 20,880	$ 17,400	$ 107,880	$ -
	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space		$ 4,477,600	$ 1,343,280	$ 1,119,400	$ 6,940,280	$ 118,999
	G	Stabilize Howell Ditch Diversion System, Modify Diversion for Aquatic and Habitat Passage		$ 399,308	$ 119,792	$ 99,827	$ 618,927	$ 7,490
	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge		$ 2,296,800	$ 689,040	$ 574,200	$ 3,560,040	$ 560
	I	Replace Grade Control for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel		$ 2,834,752	$ 850,426	$ 708,688	$ 4,393,866	$ 420
	K	Stream Restoration Through Wheeler Ranch		$ 2,424,657	$ 727,398	$ 606,164	$ 3,758,219	$ 64,399
5	A	Stream Restoration at Alexander Dawson Open Space	Boulder County	$ 2,378,000	$ 713,400	$ 594,500	$ 3,685,900	$ 62,999
	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typ.		$ 1,305,000	$ 391,500	$ 326,250	$ 2,022,750	$ 21,280
	D	Modify Grade Control Structures for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	F	Stream Restoration Downstream of 95th St.		$ 1,054,200	$ 316,260	$ 263,550	$ 1,634,010	$ 28,000
	G	95th St. - Replace Bridge with 180 ft. Span Bridge		$ 2,366,400	$ 709,920	$ 591,600	$ 3,667,920	$ 560
	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail		$ 2,371,947	$ 711,584	$ 592,987	$ 3,676,518	$ 62,999
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage	Boulder County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	75th St. - Replace Bridge with 180 ft. Span Bridge		$ 2,343,200	$ 702,960	$ 585,800	$ 3,631,960	$ 560

Table 9-5: Minimum Improvements Alternative Costs (Reach 7 - 10)

Reach	ID	Description	Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County	$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 29,785
	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical		$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 29,785
	C	Modify Diversion for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	61st Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		$ 2,843,416	$ 853,025	$ 710,854	$ 4,407,295	$ 420
	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge		$ 1,117,813	$ 335,344	$ 279,453	$ 1,732,610	$ 210
	G	Modify Butte Mill Ditch Crossing on South Boulder Creek		$ 235,160	$ 70,548	$ 58,790	$ 364,498	$ 4,200
	H	Protect Sanitary Interceptor Sewer		$ 511,009	$ 153,302	$ 127,752	$ 792,063	$ 8,505
	I	Stream Restoration from Valmont Rd to 61st Street		$ 1,546,781	$ 464,034	$ 386,695	$ 2,397,510	$ 87,499
8	A	Stream Restoration from 55th St. to Valmont Drive	City of Boulder	$ 429,200	$ 128,760	$ 107,300	$ 665,260	$ 23,800
	B	Stream Restoration from BNSF RR to 55th St.		$ 1,194,800	$ 358,440	$ 298,700	$ 1,851,940	$ 67,199
	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge		$ 2,697,000	$ 809,100	$ 674,250	$ 4,180,350	$ 280
	D	Stream Restoration from Foothills Pkwy to BNSF RR		$ 638,000	$ 191,400	$ 159,500	$ 988,900	$ 36,400
	E	Hospital Access Improvements for 500-yr Event		$ 46,932	$ 14,080	$ 11,733	$ 72,745	$ -
	F	Sediment Maintenance along Boulder Creek Path		$ -	$ -	$ -	$ -	$ 839,993
9	C	North of Boulder Creek Access Improvements	City of Boulder	$ 3,496,000	$ 1,048,800	$ 874,000	$ 5,418,800	$ -
	D	Boulder Slough Mitigation		$ 485,529	$ 145,658	$ 121,382	$ 752,569	$ 10,815
	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage		$ 406,000	$ 121,800	$ 101,500	$ 629,300	$ 4,270
	F	Sediment Maintenance along Boulder Creek Path		$ -	$ -	$ -	$ -	$ 1,259,989
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage	Boulder County	$ 300,000	$ 90,000	$ 75,000	$ 465,000	$ 4,270
	B	Boulder Canyon Stream Restoration		$ 696,000	$ 208,800	$ 174,000	$ 1,078,800	$ 67,199
			Total Costs	$ 69,531,293	$ 20,859,388	$ 17,382,822	$ 107,773,503	$ 3,131,844

Table 9-6: 100-yr Crossing Improvements

Reach	ID	Description	Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
4	B	County Line Road - Install 100-yr Crossing Replace Bridge with 220 ft. Span Bridge	Boulder County	$ 3,655,196	$ 1,096,559	$ 913,799	$ 5,665,554	$ 560
5	F	95th Street - Install 100-yr Crossing Replace Bridge with 220 ft. Span Bridge	Boulder County	$ 3,778,680	$ 1,133,604	$ 944,670	$ 5,856,954	$ 560
6	B	75th Street - Install 100-yr Crossing Replace Bridge with 220 ft. Span Bridge	Boulder County	$ 3,097,220	$ 929,166	$ 774,305	$ 4,800,691	$ 560
7	E	61st Street - Install 100-yr Crossing Replace Bridge with 220 ft. Span Bridge	Boulder County	$ 2,843,416	$ 853,025	$ 710,854	$ 4,407,295	$ 420

9.6 Qualitative Evaluation Process

As discussed previously, the focus is on general guidance for stream and ecological restoration and does not re-evaluate the current 100-year floodplain limits regulated by FEMA. Alternatives generally apply the stream restoration principles at locations with immediate restoration needs and a higher likelihood of implementation, and in most cases, where property has already been acquired. As discussed, there is a wide range of options related to the implementation of the master plan and no singular, correct solution in defining restored stream alignments. Alignments should be refined further through individual project goals, but keeping in mind compatibility with neighboring stream reaches.

For these reasons, formal evaluations on direct project benefits, such as flood reduction, were not quantified with this study. Benefits from the alternatives presented would be ancillary, reflecting:

- Geomorphic resiliency for Boulder Creek for minor and major flood events;
- Improved ecological needs and function within the stream, riparian, and floodplain areas;
- Improved conveyance for roadway and public infrastructure (in some cases meeting 100-year levels);
- Improved safety and function of existing aggregate and natural resource ponds;
- Bank and stream stability;
- Promotion of fish passage and continuous habitat for in-stream organisms;
- Planning around trail and other multi-use functions.
- Emergency access to location susceptible to flooding;
- Reduction of High Hazard areas.

With exception to comparing bridge capacity at 61st Street, 75th Street, and County Line Road, alternatives presented were not comparable in nature. Ultimate alternative for inclusion in the conceptual design will be made through further discussions and rankings with project sponsors and other interested parties.

9.7 Water Quality Impacts

No formal regional water quality plan is proposed with these improvements. Eroding channel banks and stream instability leads to degradation in water quality throughout a watershed and challenges to habitat and aquatic species. Stream restoration, as recommended, will help improve water quality aspects through stabilizing channel slopes and banks, and improving adjacent riparian habitat. Any new development within the watershed is encouraged to handle water quality on a site specific basis.

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Figure 9-2

Boulder Creek Restoration Master Plan

Project Alternatives

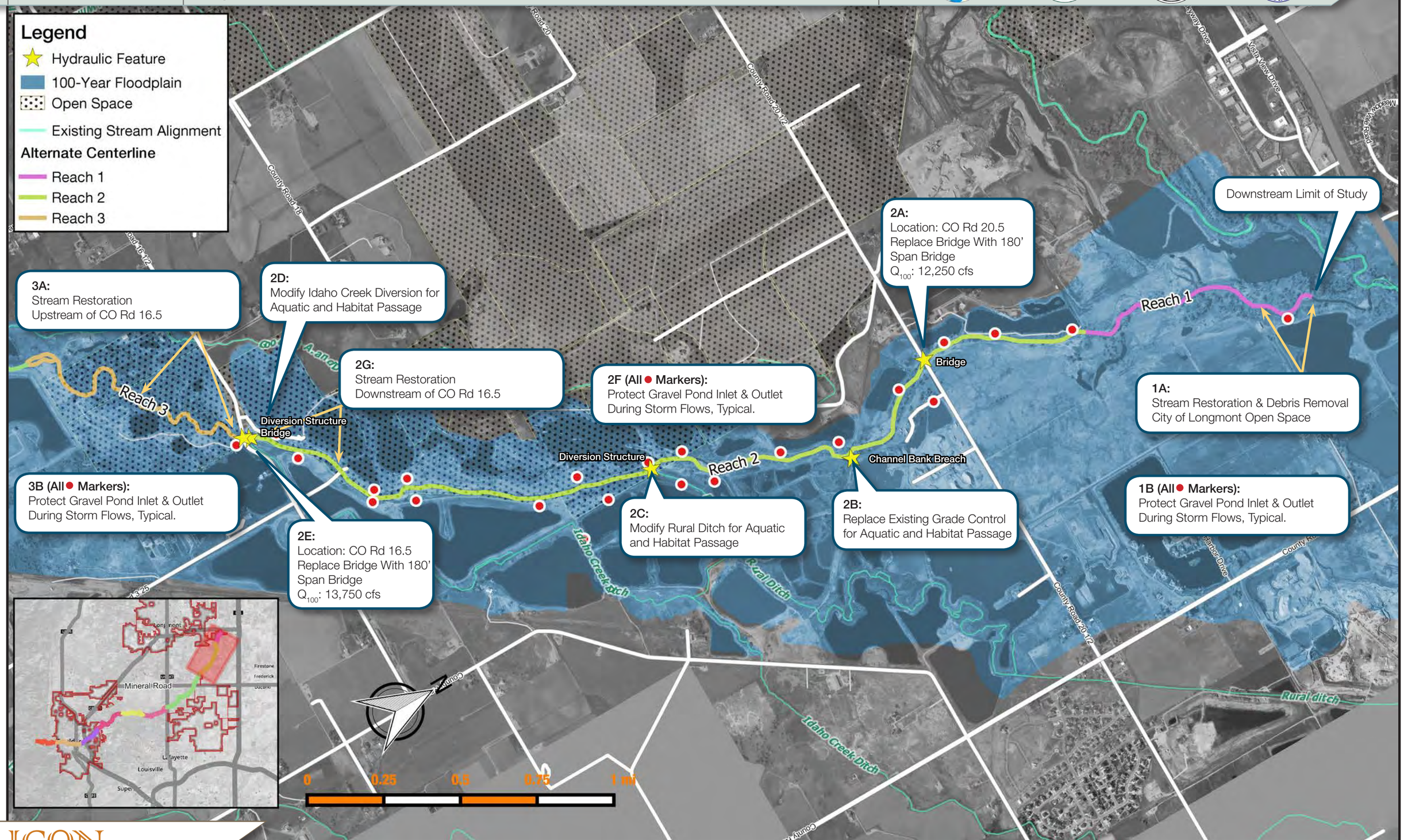

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Figure 9-3

Boulder Creek Restoration Master Plan

Project Alternatives

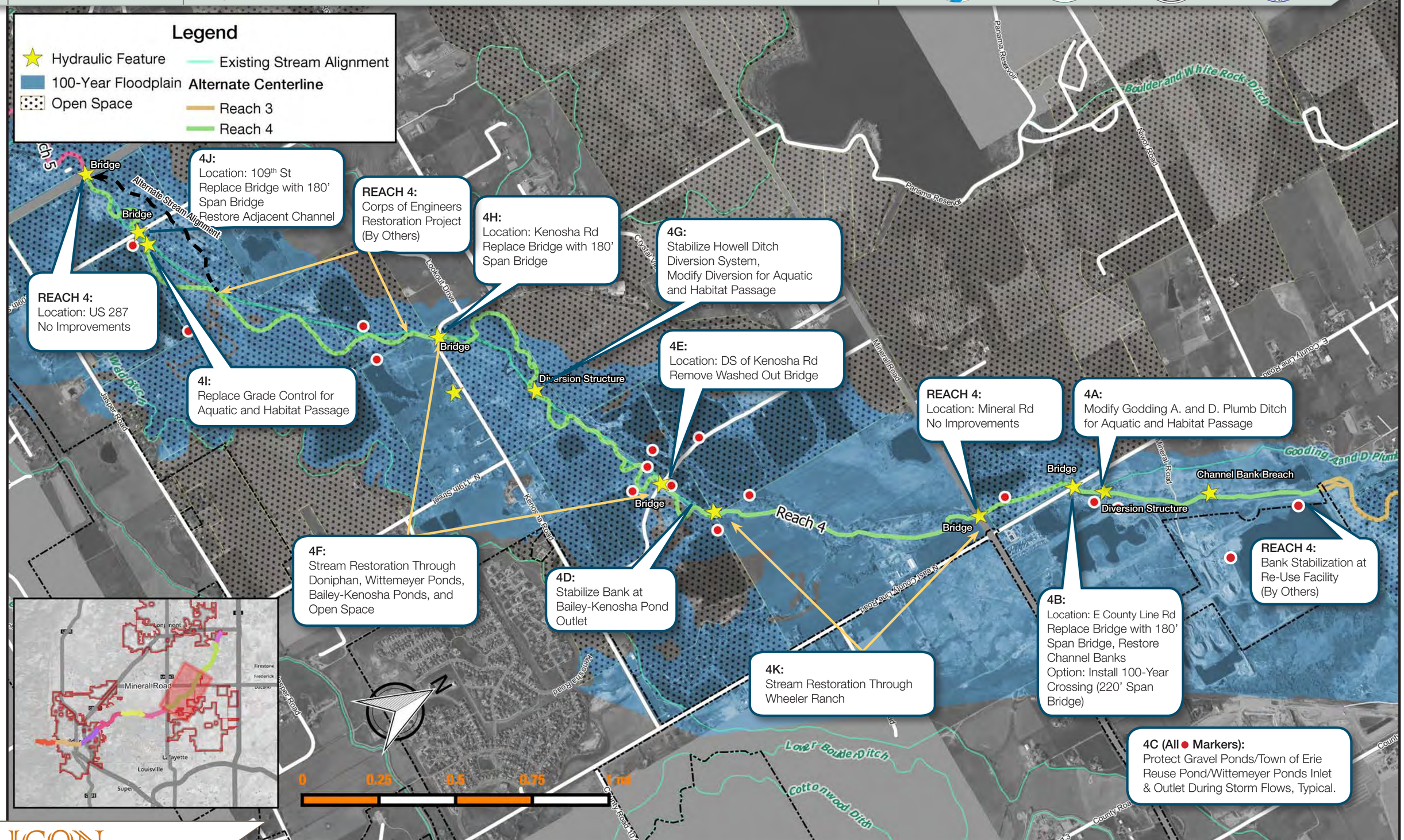

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Figure 9-4

Boulder Creek Restoration Master Plan

Project Alternatives

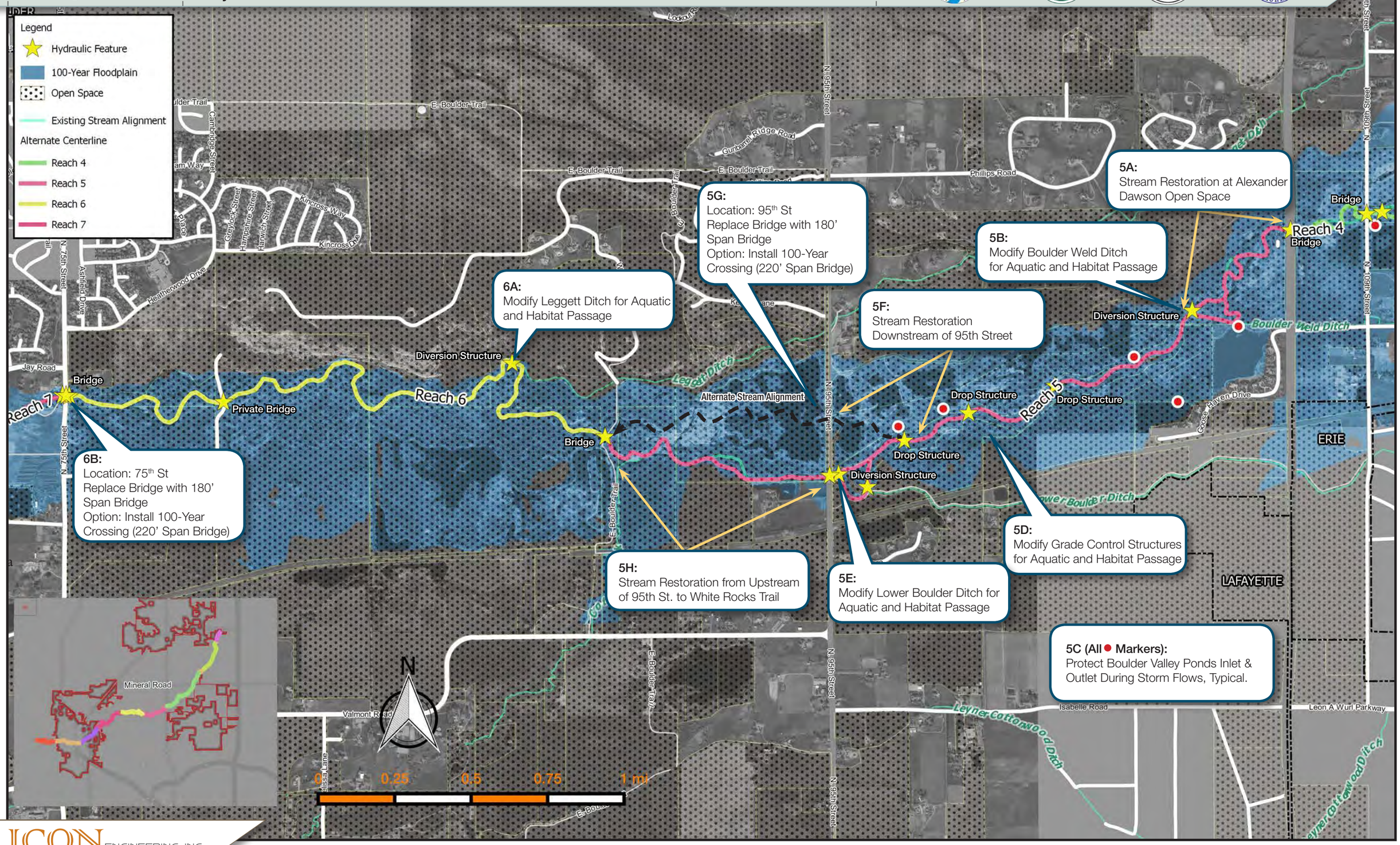

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Figure 9-5

Boulder Creek Restoration Master Plan

Project Alternatives

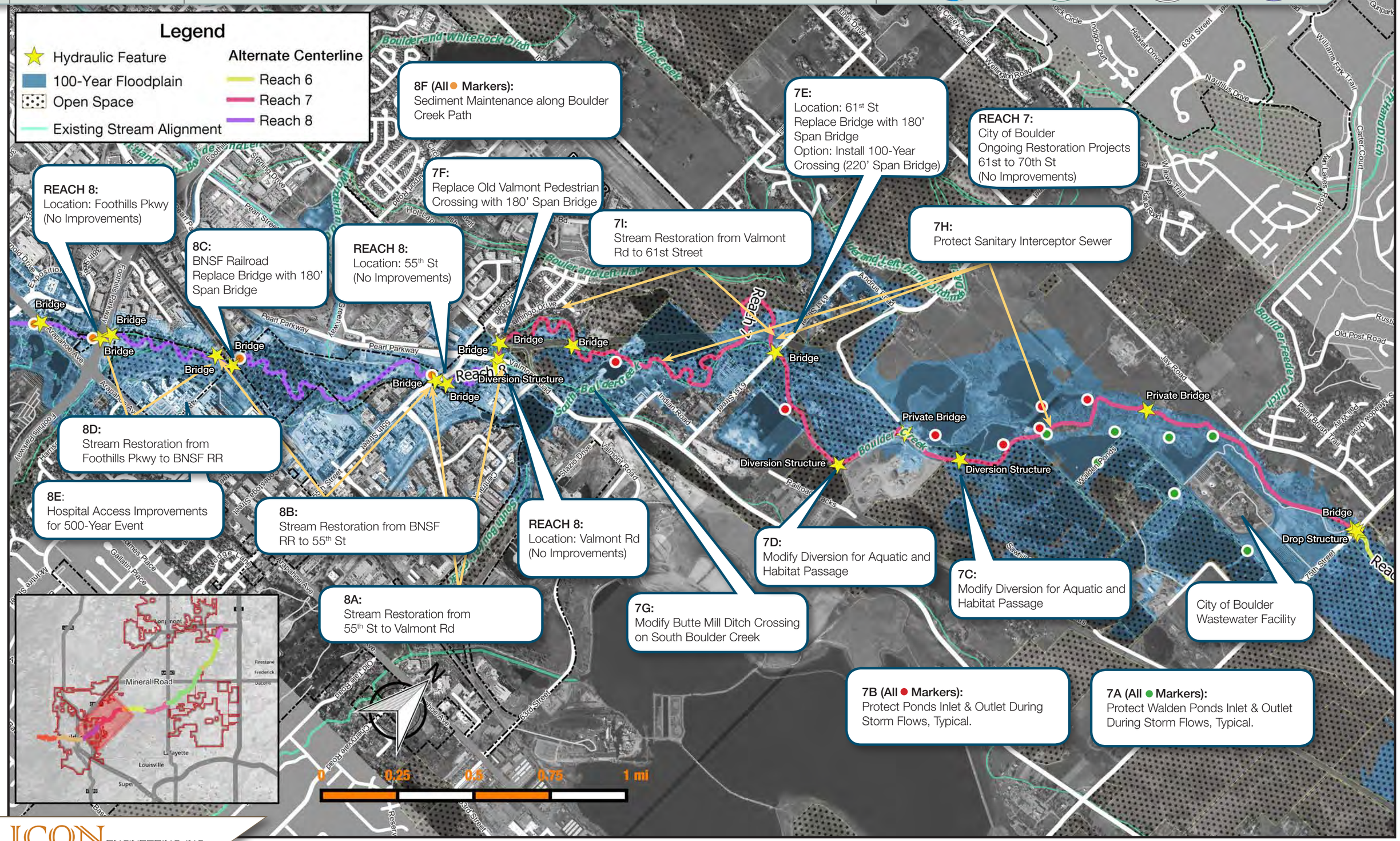

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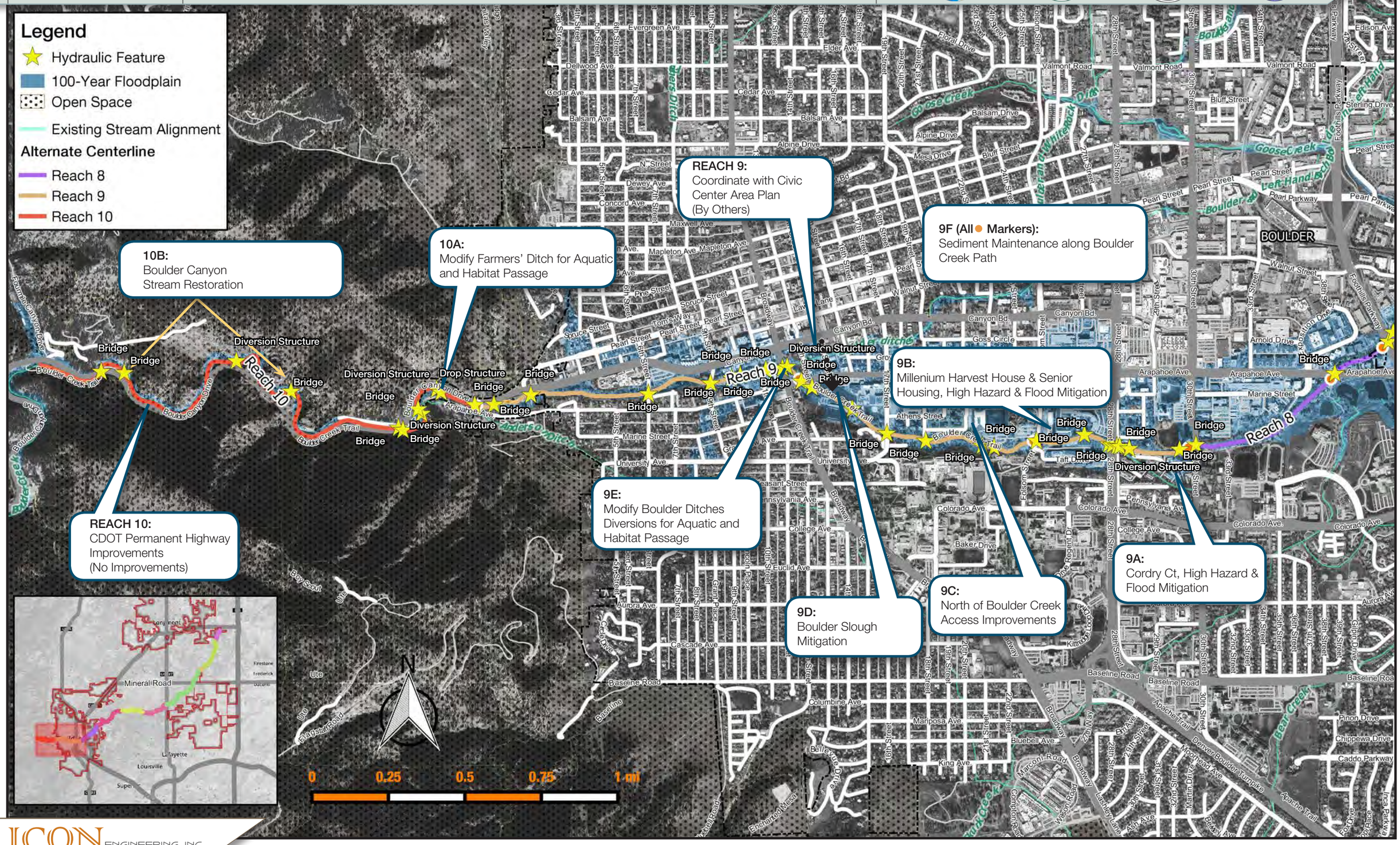
Figure 9-6

Boulder Creek Restoration Master Plan

Project Alternatives



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10.0 RECOMMENDED PLAN

The recommended plan is shown in Figure 10-1-10-5: Recommended Plan Maps. Project descriptions and summary of costs are provided in Table 10-1. In general, the recommended plan incorporates project alternatives discussed under Section 9.0, with exception to the following items:

1. 100-year stream crossings were recommended at 61st Street, 75th Street, 95th Street and County Line Road to maintain emergency access during flood events in the future.
2. High Hazard and floodplain mitigation for the Millennium Harvest House Property and Carillion Senior Housing Facility were not recommended in the master plan, as improvements in these areas would occur through future private redevelopment and planning.

Table 10-1 : Summary of Recommended Plan Project Alternatives (Reach 1-6)

Reach	ID	Description	Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
1	A	Stream Restoration & Debris Removal City of Longmont Open Space	City of Longmont / Weld County	$ 476,965	$ 143,090	$ 119,241	$ 739,296	$ 19,600
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 4,270
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 420
	B	Replace Existing Grade Control for Aquatic and Habitat Passage	Weld County	$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	C	Modify Rural Ditch for Aquatic and Habitat Passage	Town of Frederick / Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage	Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 420
	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County	$ 5,481,000	$ 1,644,300	$ 1,370,250	$ 8,495,550	$ 89,389
	G	Stream Restoration Downstream of CO Rd. 16.5	Weld County	$ 1,054,200	$ 316,260	$ 263,550	$ 1,634,010	$ 28,000
3	A	Stream Restoration Upstream of CO Rd. 16.5	Weld County	$ 1,058,840	$ 317,652	$ 264,710	$ 1,641,202	$ 28,000
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Weld County	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 4,270
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage	Weld County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	East County Line Road - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	$ 3,655,196	$ 1,096,559	$ 913,799	$ 5,665,554	$ 560
	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County	$ 3,915,000	$ 1,174,500	$ 978,750	$ 6,068,250	$ 63,840
	D	Stabilize Bank at Bailey-Kenosha Pond Outlet	Boulder County	$ 17,088	$ 5,126	$ 4,272	$ 26,486	$ 3,220
	E	DS of Kenosha Rd. - Remove Washed Out Bridge		$ 69,600	$ 20,880	$ 17,400	$ 107,880	$ -
	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space		$ 4,477,600	$ 1,343,280	$ 1,119,400	$ 6,940,280	$ 118,999
	G	Stabilize Howell Ditch Diversion System, Modify Diversion for Aquatic and Habitat Passage		$ 399,308	$ 119,792	$ 99,827	$ 618,927	$ 7,490
	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge		$ 2,296,800	$ 689,040	$ 574,200	$ 3,560,040	$ 560
	I	Replace Grade Control for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel		$ 2,834,752	$ 850,426	$ 708,688	$ 4,393,866	$ 420
	K	Stream Restoration Through Wheeler Ranch		$ 2,424,657	$ 727,398	$ 606,164	$ 3,758,219	$ 64,399
5	A	Stream Restoration at Alexander Dawson Open Space	Boulder County	$ 2,378,000	$ 713,400	$ 594,500	$ 3,685,900	$ 62,999
	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typical.		$ 1,305,000	$ 391,500	$ 326,250	$ 2,022,750	$ 21,280
	D	Modify Grade Control Structures for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage		$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	F	Stream Restoration Downstream of 95th Street		$ 1,054,200	$ 316,260	$ 263,550	$ 1,634,010	$ 28,000
	G	95th St. - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		$ 3,778,680	$ 1,133,604	$ 944,670	$ 5,856,954	$ 560
	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail	City of Boulder	$ 2,371,947	$ 711,584	$ 592,987	$ 3,676,518	$ 62,999
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage	Boulder County	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	75th Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		$ 3,097,220	$ 929,166	$ 774,305	$ 4,800,691	$ 560

Table 10-2: Summary of Recommended Plan Project Alternatives (Reach 7 - 10)

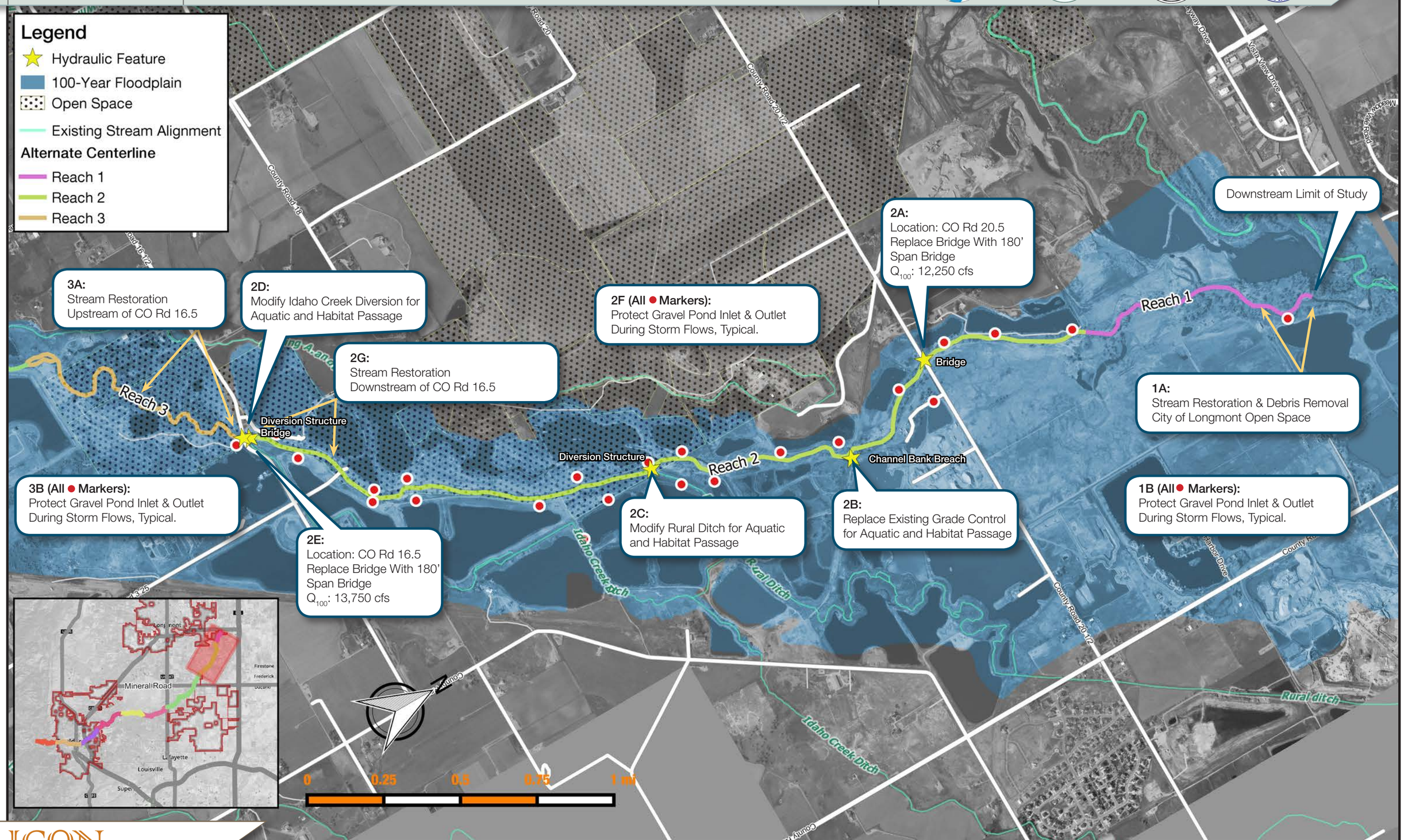
Reach	ID	Description	Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County	$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 29,785
	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical		$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 29,785
	C	Modify Diversion for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage		$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	61st Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		$ 2,843,416	$ 853,025	$ 710,854	$ 4,407,295	$ 420
	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge		$ 1,117,813	$ 335,344	$ 279,453	$ 1,732,610	$ 210
	G	Modify Butte Mill Ditch Crossing on South Boulder Creek		$ 235,160	$ 70,548	$ 58,790	$ 364,498	$ 4,200
	H	Protect Sanitary Interceptor Sewer		$ 511,009	$ 153,302	$ 127,752	$ 792,063	$ 8,505
	I	Stream Restoration from Valmont Rd to 61st Street		$ 1,546,781	$ 464,034	$ 386,695	$ 2,397,510	$ 87,499
8	A	Stream Restoration from 55th St. to Valmont Drive	City of Boulder	$ 429,200	$ 128,760	$ 107,300	$ 665,260	$ 23,800
	B	Stream Restoration from BNSF RR to 55th St.		$ 1,194,800	$ 358,440	$ 298,700	$ 1,851,940	$ 67,199
	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge		$ 2,697,000	$ 809,100	$ 674,250	$ 4,180,350	$ 280
	D	Stream Restoration from Foothills Pkwy to BNSF RR		$ 638,000	$ 191,400	$ 159,500	$ 988,900	$ 36,400
	E	Hospital Access Improvements for 500-yr Event		$ 46,932	$ 14,080	$ 11,733	$ 72,745	$ -
	F	Sediment Maintenance along Boulder Creek Path		$ -	$ -	$ -	$ -	$ 839,993
9	C	North of Boulder Creek Access Improvements	City of Boulder	$ 3,496,000	$ 1,048,800	$ 874,000	$ 5,418,800	$ -
	D	Boulder Slough Mitigation		$ 485,529	$ 145,658	$ 121,382	$ 752,569	$ 10,815
	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage		$ 406,000	$ 121,800	$ 101,500	$ 629,300	$ 4,270
	F	Sediment Maintenance along Boulder Creek Path		$ -	$ -	$ -	$ -	$ 1,259,989
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage	Boulder County	$ 300,000	$ 90,000	$ 75,000	$ 465,000	$ 4,270
	B	Boulder Canyon Stream Restoration		$ 696,000	$ 208,800	$ 174,000	$ 1,078,800	$ 67,199
			Total Costs	$ 69,531,293	$ 20,859,388	$ 17,382,822	$ 107,773,503	$ 3,131,844

December 2015

Figure 10-1

Boulder Creek Restoration Master Plan

Recommended Plan



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December 2015 | **Boulder Creek Restoration Master Plan**

Figure 10-2 | Recommended Plan

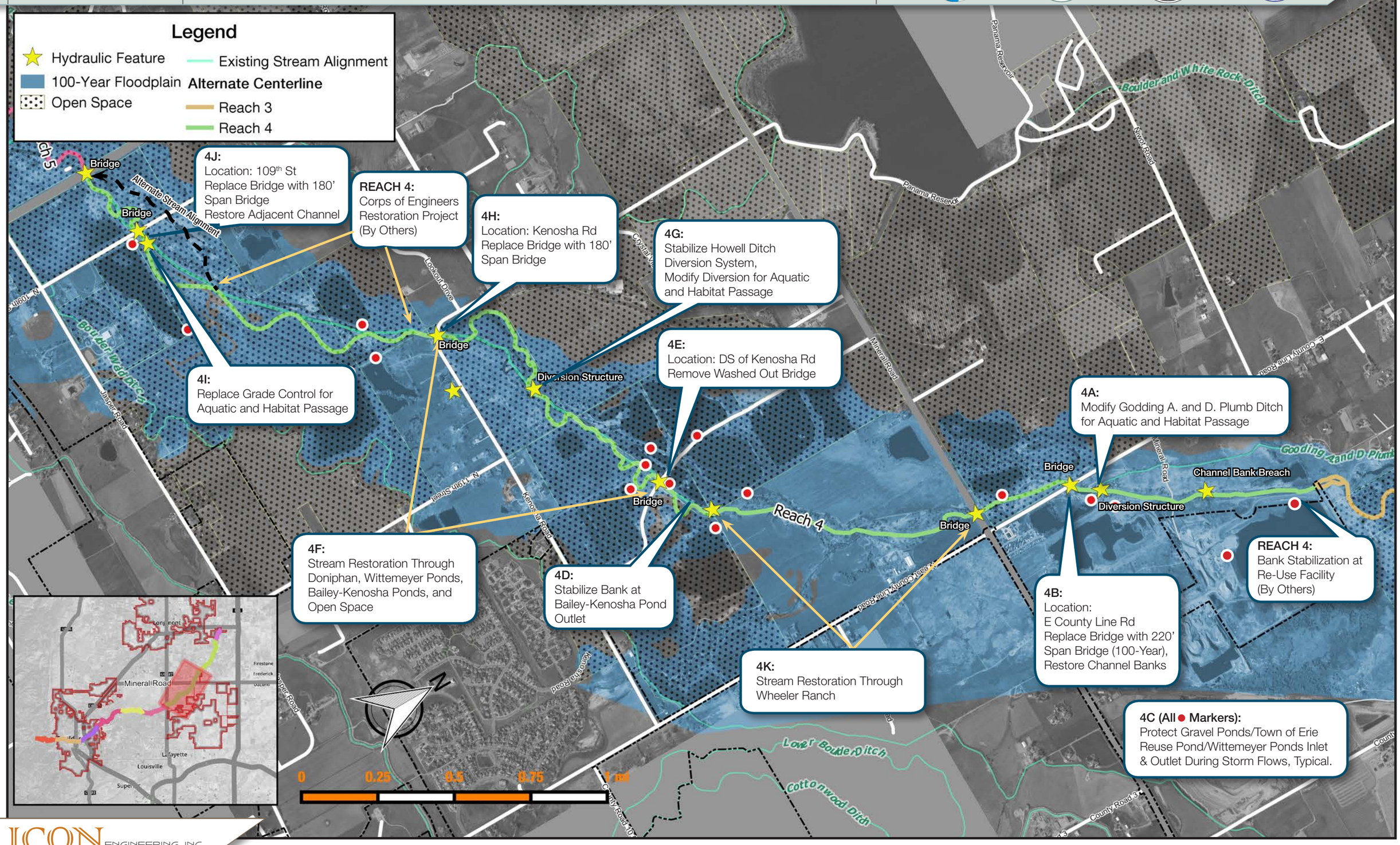

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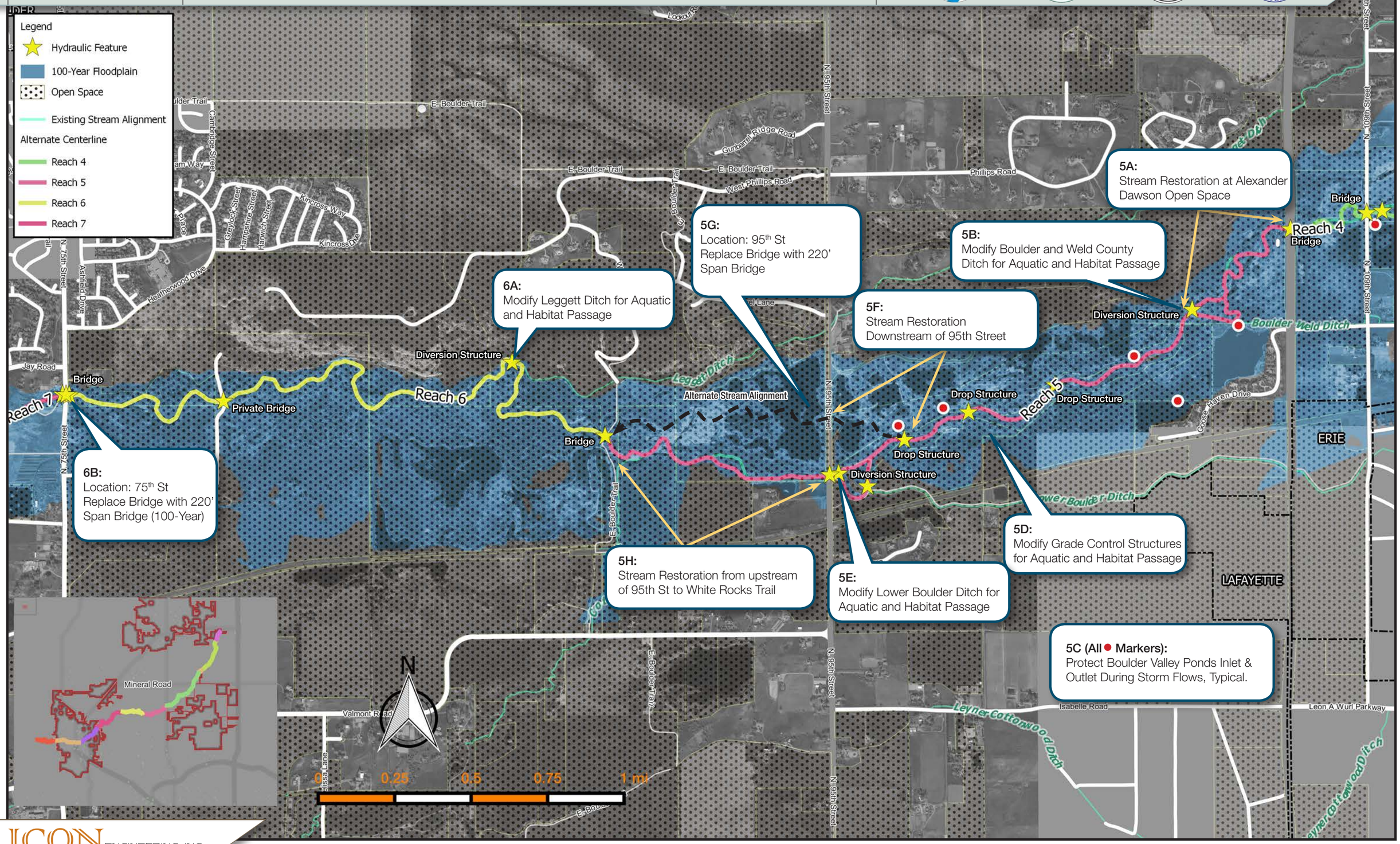
Figure 10-3

Boulder Creek Restoration Master Plan

Recommended Plan



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Boulder Creek Restoration Master Plan

Figure 10-4

Recommended Plan

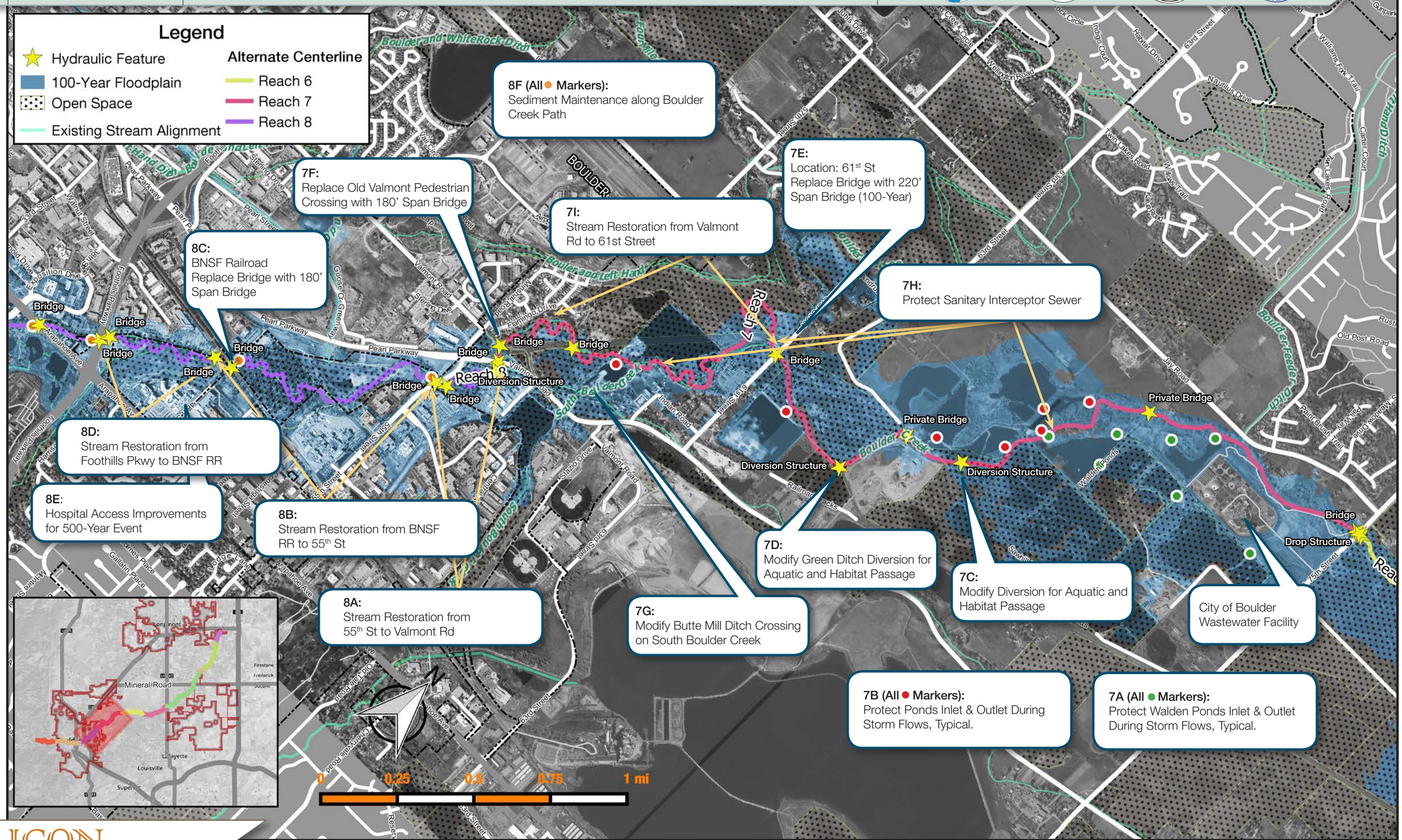

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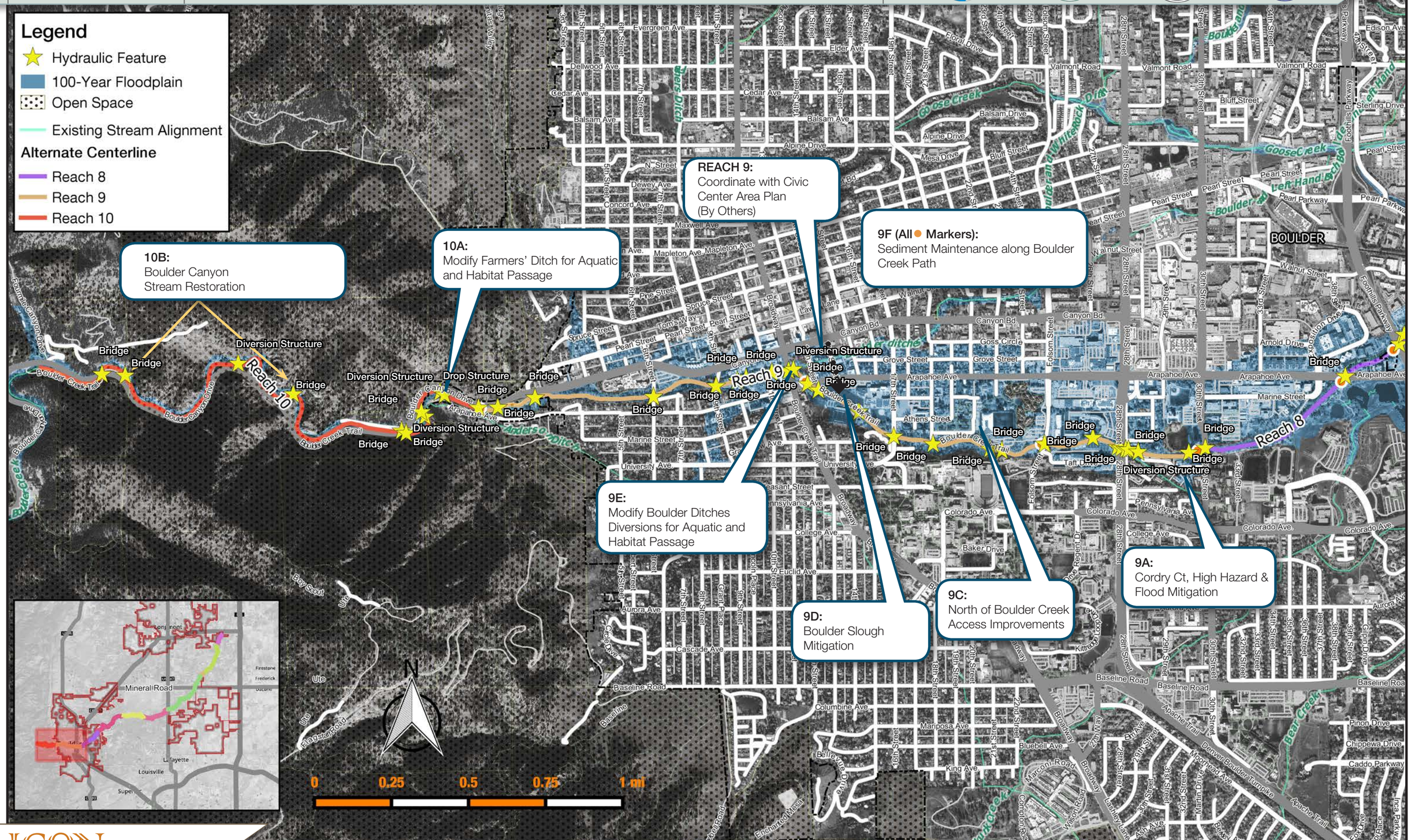
Figure 10-5

Boulder Creek Restoration Master Plan

Recommended Plan



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11.0 CONCEPTUAL DESIGN

11.1 Plan Development Overview

The Selected Plan letter was received from project sponsors on September 14, 2015 and can be found in APPENDIX B. The Conceptual Design follows the alternatives proposed in the recommended plan with the exception of three areas.

At the confluence with the St. Vrain River, Boulder Creek has breached along the north bank at a different location since the Alternative Analysis submittal. The project plan would reflect maintaining the current stream alignment with the Boulder Creek / St. Vrain Creek confluence remaining at its existing location. Given the stream segment and breach occurs on City of Longmont Open Space, improvements in this area will be more related to maintenance of the existing configuration and ecological enhancements.

Flooding events have become more common at 95th Street. At the request of Boulder County, an interim improvement was developed to help prevent overtopping of the roadway during these more frequent storms, while still maintaining the current bridge configurations and relation to downstream private property. This interim plan proposes changes to the roadway and integrates with stream restoration needs upstream of 95th Street on City of Boulder Open Space property. The interim condition is presented by the project rendering; however the master plan improvements and cost estimate will ultimately reflect a more long term solution.

At Cordry Court, improvements to the Boulder Creek Trail and grading between the trail and the Cordry Court residences have been added as a recommended improvement to eliminate the high hazard on the residences in the area. In accordance with City greenway's objectives, property acquisition in this area should be considered as a means to eliminate high flood hazard and improve overall public safety.

11.2 General Recommendations

Land-use changes to contributing watersheds affect the flood hazard nature (i.e., runoff rates, volumes and depths), the transport of sediment, and the water quality of the receiving natural waterways. To encourage the implementation of this master plan, it is recommended:

a. That the controlling jurisdictions take steps to stabilize all major waterways when their watershed urbanizes, rehabilitate existing degraded reaches of the waterways and their tributaries, and aggressively control erosion and sediment transport during construction activities.
b. That Sponsors and any other jurisdiction having land use control powers in this watershed require new land development and significant redevelopment and publicly funded projects to provide to the maximum extent practicable runoff volume control practices (i.e., minimize directly connected impervious areas and employ infiltrating permanent BMPs) whenever site conditions permit.
c. That the controlling jurisdictions take steps to require that all BMPs for all new development, redevelopment, and publicly funded projects provide to the maximum extent practicable a Water Quality Capture Volume (WQCV) as recommended in the Urban Storm Drainage Criteria Manual – Volume 3, after accounting for volume reductions achieved using volume control practices as recommended under item b above.
d. That all jurisdiction having land use control powers in this watershed continue to implement their floodplain management regulations, including regulation of the 100-year floodway and floodplain.
e. If not already done so, all jurisdictions should adopt a policy of preserving the defined floodplains as open spaces to the maximum extent possible and that at least 1-foot freeboard be provided for the lowest floor above the 100-year flood elevation shown on the latest flood hazard area delineation of FIRM maps for all human occupied structures built adjacent to, or within, the defined 100-year floodplains. NOTE: Freeboard requirements in Boulder County Land Use Code apply for structures that have some portion within the designated 100-year floodplain (no reference to adjacent).
f. That all jurisdiction having land use control powers in this watershed continue to participate in FEMA's flood insurance Community Rating System and public education programs.

Prior to construction, or commencing other work on private property or within the drainageways, it is recommended that individuals consult with the appropriate jurisdictions regarding the proposed changes and construction requirements, such as obtaining engineered plans, permitting requirements, erosion and sediment control, water quality and natural resource protection, easements or other items that may be required. The following websites address specific requirements set forth by local jurisdictions:

1. City of Boulder: Flood Recovery Website: https://bouldercolorado.gov/flood
2. Boulder County: Flood Recovery Website: http://www.bouldercounty.org/flood/pages/default.aspx
3. Weld County: Flood Recovery Website: http://flood2013.weldgov.com/
4. City of Longmont: Flood Recovery Website: http://longmontcolorado.gov/departments/departments-n-z/public-information/flood-information

Section 404 of the Clean Water Act (CWA) established a program to regulate the discharge of dredged or fill material into waters of the United States and wetland areas. Activities in waters of the United States regulated under this program include fill for development, water resource projects, infrastructure, and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States. Proposed activities are regulated through a permit review process. An individual permit is required for potentially significant impacts. Individual permits are reviewed by the U.S. Army Corps of Engineers, which evaluates applications under a public interest review, as well as the environmental criteria set forth in the CWA Section 404(b)(1) Guidelines, regulations promulgated by EPA. General permits may also be suitable. General permits are issued on a nationwide, regional, or State basis for particular categories of activities. Local agencies, including the COE should be consulted and required permits should be obtained prior to filling or dredging material in streams or drainageways, on a both a permanent and temporary basis.

A variety of wetland habitats do exist within the riparian zone of Boulder Creek. Wetlands and other waters of the US are regulated under Section 404 of the Clean Water Act (CWA). Future restoration and recovery efforts which result in disturbances to regulated areas may be subject to permitting and approval by the US Army Corps of Engineers (USACE), the US Environmental Protection Agency, and/or the US Fish and Wildlife Service (USFWS). A formal wetland delineation, by a qualified wetland consultant, and coordination with the USACE Denver Regulatory Office is recommended prior to implementation of any future restoration and recovery efforts to ensure CWA

compliance. In addition, any future restoration and recovery efforts must comply with local wetland, stream and wildlife regulations.

Rebuilding and new construction activities within the watershed should consider best practices to reduce the loss of human life and property from flood and storm damage, as managed through local floodplain administration. General guidance has also been provided to flood impacted communities by the Colorado Association of Stormwater and Floodplain Managers (CASFM), through a white paper distributed on October 4, 2013. This white paper is available at http://www.casfm.org/2013_Flood/CASFM_media_summary_statement_2013-10-04.pdf.

Boulder Creek is a regulated floodplain by FEMA, the City of Boulder, Boulder and Weld Counties. Proper floodplain permitting through local jurisdictions will be required prior to commencing construction activities.

Future improvements along Boulder Creek shall give full consideration to policies presented in community planning documents, including the Boulder Valley Comprehensive Plan, City of Boulder's Greenways Master Plan and the Grassland Ecosystem Management Plan. These documents present multi-objective goals achievable with drainageway and open space improvements. Between Foothills Parkway and 95th Street, the Greenways' Master Plan and Grassland Ecosystem Management Plan present ancillary project goals which should be considered with any stream restoration project in this area.

Improvements to existing roadway crossings in Boulder and Weld Counties follow criteria set forth by each jurisdiction. As a minimum standard, both counties allow overtopping of the roadways during large flood events. However, both Weld and Boulder County criteria require that the actual bridge structures, including the low chord, be elevated above the 100-year flood levels. This criterion shall be used as a minimum standard in evaluating transportation infrastructure; however; for East County Line Road, 75th Street, 61st Street, and 95th Street, 100-year capacity should also be considered for emergency access.

11.3 Conceptual Design Cost Estimates

Cost estimates for alternatives were developed using UDFCD's master planning cost estimating spreadsheet UD-MP COST, version 2.2. 2012 unit costs values were adjusted to present value using the current Colorado Construction Cost Index report. An inflation rate of 1.2193 was used to adjust unit costs to 2015 2nd quarter costs. Effective interest rate was estimated to be 1.50%. This assumption was made based upon current discount rates from the Federal Reserve Discount Window and inflation rates published by the US government. Operation and Maintenance was also included within the UD-MP Cost worksheet. Channel maintenance and hydraulic structure maintenance were assumed to be performed once every five years. Maintenance to gravel pit spillways were assumed to occur once every 20 years, with bridge maintenance occurring once a year with a user defined cost of $800/year. Sediment Maintenance removal costs were included for areas identified by the City of Boulder as frequent problem areas. Each sediment maintenance alternative was assumed to remove 200 cubic yards of sediment a year.

Regarding stream restoration and ecological enhancement costs, costs of recent stream and riparian restoration projects were used as the basis for costs in this master plan. Unit costs from these projects were generated and applied to the restoration quantities assumed for each of the Boulder Creek alternatives where restoration is recommended. Given the range of improvements, unit costs were developed for the following items:

- Restoration of a stream where the work includes constructing a new channel alignment ($700,000 per mile)
- Restoration of a stream where the work includes habitat enhancement and related improvements that are to occur within the existing channel ($400,000 per mile)
- Restoration of the adjacent riparian corridor ($35,000 per acre)

When estimating restoration costs for alternative projects along Boulder Creek, unit restoration costs were combined with the quantity and type of work estimated to be required at each site. For all stream work downstream of the canyon, stream restoration was assumed to include realignment of the channel. Stream restoration within the canyon was assumed to occur within the existing channel with no realignment. The extents of stream restoration were selected to coincide with the alternatives presented in the plan.

Areas of riparian restoration were also estimated for each section. When generating costs for riparian restoration, a target riparian width of 25 feet on either side of the stream was used for the canyon section. The target riparian width was set at 200 feet on either side of the channel for all other segments. The actual amount of riparian restoration needed at each of the alternative sites accounted for the amount of room currently available and the condition of existing vegetation when estimating how much riparian work would be required at each location.

Other costs were calculated as a percent of Capital Improvement Costs, such as Engineering, Legal/Administrative, Contract Administration/Construction Management, and Contingency. No alterations to the default values provided by the UD-MP Cost spreadsheet were made to these items. Traffic Control and Utility Coordination/Relocation were assumed to be 2.5% of the Total Capital Improvements unless site conditions warranted otherwise. All projects assumed 1% of Total Capital Improvements for Dewatering.

11.4 Master Plan Description

The Conceptual Design for this master plan generally follows the alternatives proposed in the recommended plan with exception of three areas noted by sponsors in the Selected Plan Letter. Cost Estimates for the Selected Plan can be found in Table 11-5 and Table 11-6.

At the confluence with the St. Vrain Creek, Boulder Creek has breached along the north bank at a different location since the Alternative Analysis was submittal. The project plan would reflect maintaining the current stream alignment with the Boulder Creek / St. Vrain Creek confluence remaining at its existing location. Given the stream segment and breach occurs on City of Longmont Open Space, improvements in this area will be more related to maintenance of the existing stream configuration and ecological enhancements.

Flooding events have become more common at 95th Street. At the request of Boulder County, an interim improvement was developed to help prevent overtopping of the roadway during these more frequent storms, while still maintain the current bridge configurations and relation to downstream private property. This interim plan proposes changes to the roadway and integrates with stream restoration needs upstream of 95th Street on City of Boulder Open Space property. Although the interim condition is presented with the conceptual design, the master plan improvements and cost estimate reflect a more long term solution.

At Cordry Court, improvements to the Boulder Creek Trail and grading between the trail and the Cordry Court residences have been added as a recommended improvement to eliminate the high hazard on the residences. In accordance with City greenway's objectives, property acquisition in this area could be considered as a means to eliminate high flood hazard and improve overall public safety.

11.4.1 Reach 1 – Confluence with St. Vrain Creek to approximately 3,300 ft. upstream of the City of Longmont

Beginning at the confluence with the Saint Vrain Creek, Reach 1 extends upstream along Boulder Creek for just over a mile of channel length. All of Reach 1 is contained within Weld County and within City of Longmont Open Space towards the downstream end. There are no channel crossings within this reach with the exception to a gravel pit conveyor crossing and several non-formalized low-water crossings for vehicles. This reach includes gravel pit ponds on either side of Boulder Creek that currently hold water. The riparian area within Reach 1 is approximately 700 feet wide near the confluence with Saint Vrain Creek and narrows to approximately 250 feet at the upstream end. Beyond the riparian area the floodplain overbanks generally consist of active and fallow farm lands. Sporadic residential and farm structures are also present within the overbanks along with several petroleum well pads.

During the 2013 flood, the Saint Vrain Creek breached its banks, avulsing through nearby gravel pit ponds. A further breach of the pond bank between the Saint Vrain Creek and Boulder Creek redefined the confluence location of the two streams, moving it approximately 1,300 feet upstream of the original location. In 2015, following spring runoff, Boulder Creek also breached the same pond bank further west. This again modified the confluence. The streams continue to change over time. Given the changes are occurring on City of Longmont Open Space property, there is less risk to private property or infrastructure; therefore, the master plan recommendations reflect maintaining the creek in-place and providing additional ecological enhancements along the original stream alignment which can be seen in Figure 11-9. Gravel pond spillways have also been recommended for ponds adjacent to Boulder Creek.

11.4.2 Reach 2 – From approximately 3,300 ft. upstream of the City of Longmont to CR 16 ½

Reach 2 is approximately three miles long and includes bridge crossings at Weld County Roads 20½ and 16½. Although Reach 2 is located in Weld County, upstream locations are also co-managed through Boulder County Conservation Easements. Two major diversion structures to Rural Ditch and Idaho Creek are located within this reach. Disturbances from historic land use practices and channel alterations are widespread. Similarly, floodplain overbanks throughout Reach 2 generally consist of sand and gravel ponds, and aggregate mining operations. The channel within Reach 2 is relatively straight as a result of encroachment on both banks.

Master plan improvements through this reach include: replacement of the bridge crossing at Weld County Roads 20½ and 16½ with 180 foot span bridges compatible with baseline geomorphic conditions; retro-fit of the two ditch diversion structures to accommodate aquatic and habitat passage; modification of a grade control structure for aquatic and habitat passage; and the installation of gravel pond spillways to reduce the chance of failure during flood events. Downstream of CO Rd. 16 ½, general stream restoration is also recommended to repair bank erosion and revitalize Boulder Creek and the surrounding environment as seen in Figure 11-10. Through this reach Boulder Creek is more confined by adjacent land uses; therefore a more confined approach to stream restoration would be anticipated.

11.4.3 Reach 3 – From CR 16 ½ to approximately 5,800 ft. upstream

Reach 3 is located completely within Weld County with the majority of the property managed through Boulder County Open Space Conservation Easements. This is a short reach with a stream length of only 5,800 ft., spanning a distance of approximately 3,900 ft. The most significant, and ongoing, problem within Reach 3 occurs upstream of Weld County Road 16.5, where a breach in the Bryant Pond diverts flow from Boulder Creek east into the Williams Reservoir No. 1. This has led to overtopping of 16.5 Road well east of the bridge and has led to the continued cut through the south bank of Idaho Creek downstream of the Idaho Creek diversion structure thus bypassing the controlled diversion element at the confluence of Boulder Creek and Idaho Creek.

Master plan improvements in this reach focus on stream restoration and protection of the gravel pit pond from further failure. Stream restoration improvements propose a new alignment of Boulder Creek further west than its current location, reestablishing more historic stream alignment and providing additional buffer between the creek and reservoir as seen in Figure 11-10. Installation of gravel pond spillways will reduce the opportunity for failure of the reservoir embankment.

11.4.4 Reach 4 – From approximately 5,800 ft. upstream of CR 16 ½ to U.S. 287

Reach 4 is the longest reach with a stream length of 4.5 miles. Reach 4 is located in both Weld County and Boulder County with portions of the land owned or managed by Boulder County Parks and Open Space. The downstream most section is flanked by past aggregate mining activities; the Town of Erie's sanitary and Re-use facility; and areas under active gravel operations. The remaining overbanks include active and fallow farm lands and minimal residential development. There are six stream crossings that span Boulder Creek through Reach 4, some of which have capacity exceeding the 100-year event. Others are more limited in size, dilapidated, or un-usable. Several irrigation diversions also exist within Reach 4. Finally, downstream of 109th Street, Boulder County is pursuing a stream restoration project with the U.S. Army Corps of Engineers. This project extends from 109th Street to Kenosha Road.

Several different improvements are recommended through Reach 4 including: modifications to ditch diversions; improvements at roadway crossings; and stream restoration. At the downstream limits, an existing project is underway to stabilize channel banks adjacent to the Town of Erie's Re-use facility. Downstream of East County Line Road the conceptual design proposes to modify the Godding A. and D. Plumb Ditch to accommodate aquatic and habitat passage, in addition to installing gravel pond spillways at adjacent reservoirs. The East County Line Road Bridge is proposed to be improved to a 220 ft. span bridge, improving the crossing to a 100-year conveyance level consistent with the upstream Mineral Road Bridge. Bridge improvements at East County Line Road should also address stream restoration needs immediately downstream where concrete rubble has been used to stabilize stream banks. No improvements are proposed for the Mineral Road crossing as the existing crossing already meets the 100-year conveyance criteria.

Upstream of Mineral Road, stream restoration is proposed throughout the Wheeler Ranch property. Although a more unimpacted approach restoration can be performed in this area, the final restoration plan should consider constraints defined by the land owner and needs for the confluence with Coal Creek as seen in Figure 11-11. Upstream of the Wheeler Ranch property, channel banks have eroded and exposed the pipe outlet from the Bailey-Kenosha Pond. Stabilization is proposed along the east bank of Boulder Creek in this area. Upstream of the Bailey-Kenosha Pond, additional stream restoration is recommended downstream of the proposed U.S. Army Corps of Engineers project limits located upstream of Kenosha Road. The existing Howell Ditch Diversion, as well as local grade control, are also proposed to be modified for aquatic and habitat passage. Several gravel pond spillways have been proposed to reduce the chance of failure during flood events. At Kenosha Road and 109th Street, 180 ft. span bridges are proposed to increase the conveyance capacity and accommodate geomorphic channel conditions. The

Kenosha Road bridge should be evaluated to determine whether the structure could be removed in the future based on the transportation needs in the area before improving the roadway crossing.

Alternate stream alignments for restoration between U.S. 287 and 109th Street should be considered during final design to best balance the historic stream alignment, with current land uses and transition to the downstream U.S. Army Corps of Engineers project.

11.4.5 Reach 5 – From U.S. 287 to approximately 4,200 ft. upstream of 95th St.

This reach is located completely within Boulder County and has a stream length of approximately 3 miles. Within Reach 5, Boulder Creek crosses 95th Street, which washed out during the September 2013 flood event and nearly again in 2015. Diversion structures feed the Boulder and Weld County Ditch and the Lower Boulder Ditch. The overbanks generally consist of inactive gravel pit ponds and both active and fallow farm fields. A vast majority of this reach follows Boulder County Parks and Open Space, including the Alexander Dawson Open Space, or conservation easements. Past stabilization efforts have been implemented in this reach, although damage was extensive following recent floods.

Master plan improvements for Reach 5 consist of stream restoration, modifications to ditch diversions, and improving the roadway crossing at 95th Street. No improvements are proposed to the roadway crossing at U.S. 287 as the bridge crossing already exceeds the 100-year conveyance capacity.

Upstream of U.S. 287, stream restoration is proposed through Alexander Dawson Open Space, with aquatic and habitat passage improvements at the Boulder and Weld County Ditch diversion and upstream grade control. A more unimpacted approach to restoration is recommended through this area given the open space designation.

Upstream and downstream of 95th Street, stream restoration has been proposed to reestablish geomorphic channel geometry and improve riparian habitat. Similar to between U.S. 287 and 109th Street, several options for restoration may exist, including changes to both public and private property. Costs for the master plan improvements at this location generally reflect the restoration of Boulder Creek to the north of the current alignment, including: reestablishment of Boulder Creek through the 95th Street Pond (City of Boulder Open Space), new 100-year crossing of 95th Street at the roadway low point; construction of a new channel and easements across the Boulder Valley Farms property; and diversion to the current Lower Boulder Ditch at its current location. The master plan improvements represent a long term solution for the area.

Given the many entities involved and challenges of implementation for the long term solution, Boulder County requested that an interim solution be developed to address more frequent flooding problems at 95th Street. The interim solution will maintain the existing bridge, raise the roadway elevation to prevent frequent overtopping, and provide conveyance from the pond to the bridge through a vegetated spillway. This interim solution is depicted in Figure 11-13.

- Restoration of Boulder Creek: Stream restoration of Boulder Creek is proposed both upstream and downstream of 95th Street along the existing diversion and stream alignments. Stream restoration through this area will help reestablish baseline geomorphic conditions, increase channel sinuosity, and improve overall riparian vegetation and habitat.
- Reduce overtopping frequency for 95th Street: 95th Street is proposed to be raised at the low point by approximately two feet to help reduce overtopping frequency. Overflows to the 95th Street Pond are proposed to be redirected back to Boulder Creek upstream of the existing bridge crossing through a vegetated spillway section. Given the roadway will still overtop during significant storms, geo-fabric is proposed along the downstream embankment to prevent erosion.
- Maintain existing bridge: Given the 95th Street bridge is relatively new; the interim improvements accommodate the current location and size of the bridge.
- Aquatic and Habitat Passage: Changes to the Lower Boulder Ditch diversion have been proposed to accommodate fish and habitat passage.

Table 11-1: 95th Street Interim Conditions Improvements

Reach	ID	Description	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
5	G	95th Street - Interim Conditions	$ 3,592,232	$ 1,077,670	$ 898,058	$ 5,577,645	$ 87,674

It should be noted that raising the elevation of 95th Street will potentially increase 100-year water surface elevations regulated by FEMA and Boulder County. The final design should give consideration to eliminating, or minimizing, floodplain impacts to public and private property, or adjacent insurable structures.

11.4.6 Reach 6 – From approximately 4,200 ft. upstream of 95th St. to 75th St.

Reach 6 is approximately 4.5 miles long and is completely contained within Boulder County. The stream corridor itself is located on land managed by the City of Boulder's Open Space and Mountain Parks Division. This reach appears to remain in a natural state with little encroachments on either overbank. Gravel mining operations on the south side of the creek have left several small gravel ponds in the floodplain. Hydraulic drop structures exist both upstream and downstream of 75th Street and the diversion structure for the Leggett Ditch is centrally located.

Master plan improvements for this reach include modifying Leggett Ditch for aquatic and habitat passage and improving the 75th Street crossing to a 220 ft. span bridge. Similar to the Kenosha Road bridge, the roadway crossing at 75th Street should be evaluated at a future time to determine whether the structure can be removed based on the transportation needs in the area.

11.4.7 Reach 7 – From 75th St. to Valmont Rd.

This reach is approximately 3.5 miles in length and covers areas of both City of Boulder Open Space and Mountain Parks and Boulder County Parks and Open Space properties. Through this reach, the channel is nearly completely flanked by sand and gravel ponds, and mining operations. Most of these operations are no longer active and the excavated ponds remain full of water. The City of Boulder wastewater treatment plant is located just south of the creek, upstream of 75th Street. The wastewater treatment plant is protected from flooding by a ring levee. Private stream crossings, minor arterial (61st Street), bike path, and a major arterial (Valmont Road) crossings, are all located within Reach 7. The confluence of South Boulder Creek and Boulder Creek is located within Reach 7.

Projects within Reach 7 include the installation of gravel pond spillways, protection of the City of Boulder's sanitary sewer trunk line, improved roadway crossings, stream restoration, and modification of existing diversion structures. Seven gravel pit spillways are proposed to protect Walden Ponds near the downstream limit of Reach 7. Several gravel pond spillways are proposed within the Walden Ponds Wildlife Habitat area and along private ponds within

Reach 7. Stream stabilization and bank protection is proposed to provide additional protection from erosion and degradation in the vicinity of the City of Boulder's central sanitary interceptor. These locations will be protected using grade control structures and bank stabilization.

The master plan improvements do not include stream restoration downstream of 61st Street, as this reach is currently being addressed by ongoing City of Boulder Open Space and Mountain Parks improvements; however general restoration guidance for this area is provided. Master plan improvement through this reach do, however, include modifying the two irrigation ditch diversion structures to accommodate aquatic and habitat passage.

The existing 61st Street bridge is proposed to be replaced with a 220 ft. span bridge to accommodate the 100-year event. Upstream of 61st Street to Valmont Road, stream restoration has been proposed to reestablish baseline geomorphic conditions, increase channel sinuosity, and improve overall riparian vegetation and habitat. This reach is also currently being evaluated by City of Boulder Open Space and Mountain Parks.

The existing trail crossing of Boulder Creek at Old Valmont Road is currently undersized. During the 2013 flood, the crossing was an obstruction to flow and a significant amount of blockage developed from debris and other items. This bridge is proposed to be replaced with a 180 ft. span pedestrian bridge to better convey flood flow, debris, and accommodate geomorphic channel conditions and habitat.

Finally, improvements through Reach 7 include improving the Butte Mill Ditch Crossing across South Boulder Creek. For this ditch, which originates from Boulder Creek, modifications include siphoning the canal flows underneath South Boulder Creek in a 54" RCP.

11.4.8 Reach 8 – From Valmont Rd. to 30th St.

This reach is approximately 2.3 miles in length and primarily located within the City of Boulder. The channel characteristics generally include a combination of riparian habitat, roadway, and trail crossings. Wonderland and Goose Creeks enter Boulder Creek within Reach 8, and several small ponds are located adjacent to the stream. For Boulder Creek, Reach 8 reflects the transition to an urban flood channel and for the most part, Boulder Creek has been locked in place through urbanization. The Burlington Northern and Santa Fe (BNSF) railroad embankment presents a significant obstacle for Boulder Creek and its connectivity with upstream and downstream floodplain areas. The BNSF crossing also has significantly less conveyance capacity than the larger span bridges within Boulder.

Master plan improvements within Reach 8 are comprised of stream restoration, improving the railroad crossing conveyance capacity, access to the Boulder Community Health Hospital, and management of accumulated sediment. Stream restoration is proposed from the downstream limit of Reach 8 at Valmont Road through Foothills Parkway. As described above, the BNSF railroad is a significant obstacle for Boulder Creek. The crossing is proposed to be increased to a 180 ft. span bridge to better convey flood flows and accommodate geomorphic channel conditions.

To ensure safe access to the hospital during major floods, up to the 500-year event, an alternate access point from 48th Street has been recommended. This access point would only serve emergency vehicles and would not provide routine access as seen in Figure 11-14.

Frequent sediment deposition has been observed throughout Reach 8 along Boulder Creek and pedestrian trail crossings. This sediment is believed to be conveyed downstream from into the City from Boulder Canyon where the manmade obstructions cause the sediment to collect around infrastructure. Maintenance level sediment removal projects (up to 200 cubic yards per year) have been incorporated into the master plan at various crossing locations.

11.4.9 Reach 9 – From 30th St. to City of Boulder Limits

Reach 9 extends through the City of Boulder from 30th St. to upstream of Arapahoe Avenue. This reach also includes the University of Colorado (CU) Campus, between 17th Street and Folsom. Many roadway crossings exist through this reach as well as Boulder Creek trail bridges. The Boulder Creek trail also follows the creek for the entire reach. Many buildings are located within the Boulder Creek floodplain. The City of Boulder has designated additional regulatory zones to manage existing development and redevelopment. Strategic plans, including CU's North of Boulder Creek study have also been developed to identify management strategies to reduce overall flood risk. Similarly, the City of Boulder is currently in the process of planning for redevelopment surrounding the Civic Center area, and is evaluating this plan with respect to flood management.

Master plan improvements within Reach 9 include mitigating flood hazards, improving access near Boulder Creek, modifying diversions, and sediment maintenance. Downstream of 28th Street, along Cordry Court, realignment of the Boulder Creek Trail is proposed to increase conveyance and mitigate the high hazard conditions near residences. In accordance with City greenway's objectives, property acquisition in this area should be considered as a means to eliminate high hazard designation and improve overall public safety. Near the CU campus, two new pedestrian bridges are proposed to improve access to the North of Boulder Creek campus. These bridges, or walkways, will provide emergency access to areas otherwise susceptible to isolation during flood events.

To mitigate flood hazards along the Boulder Slough, an overflow diversion structure is proposed at 14th Street. This diversion system will divert flows in excess of the conveyance capacity of the ditch back into Boulder Creek, reducing flood risk to adjacent properties and can be seen in Figure 11-14. A 48" RCP pipe underneath 14th Street is proposed to convey the flows from the diversion structure south to Boulder Creek.

Changes to the diversion structure at Broadway are also proposed to accommodate aquatic and habitat passage. The conceptual rendering of a typical diversion structure can be seen in Figure 11-17.

Similar to other locations, six areas have been identified for annual sediment removal (up to 200 cubic yards per year) in Reach 9.

No new alternatives have been developed for the Civic Center area in this master plan study; however changes to Boulder Creek at this location should consider implementing recommendations discussed in 9.3 Improvement Alternative Categories, including:

- Removing the Park Central and New Britain building from the 100-year floodplain, conveyance zone, and high hazard zone;
- Adding conveyance capacity at the Broadway Bridge;
- Overbank grading of Boulder Creek between the Library and Broadway to reduce high hazard and conveyance zones on the north side of Arapahoe.
- Consideration with respect to Flood Regulatory, Flood Policy, and Site Opportunities and Flood Constraints in accordance with the Civic Area Guiding Principles

It should be noted that with these changes, higher flows along the creek would persist downstream to west of 30th Street and cause higher 100-year flood levels that would need to be mitigated. Given that these increases in flood levels would be relatively small, they could likely be mitigated through: select grading of overbank areas, reducing the potential for debris obstruction at bridges, and/or increasing conveyance under road crossings.

11.4.10 Reach 10 – From City of Boulder Limits to Fourmile Creek

Reach 10 reflects the reach of Boulder Canyon between the City of Boulder and the confluence with Fourmile Creek. This reach has much steeper overbank slopes and narrower cross section than the reaches to the east. The reach length is approximately 2 miles and the riparian zone is narrow at less than 100 feet wide. Through the canyon, State Highway 119 parallels the creek, crossing it twice. The Boulder Creek trail also parallels Boulder Creek along the opposite bank of the highway. In general, the stream banks are steep and stable, and have been armored with cobble, rock, and riprap. Boulder County is currently in process of repairing sections of the Boulder Creek trail and extending the path up to Fourmile Creek.

Reach 10 improvements consist of modifying the Farmers' Ditch diversion for aquatic and habitat passage. Restoration of Boulder Creek has also been proposed in areas of disrepair following the 2013 flood event. Restoration locations have been depicted by the project conceptual design renderings seen in Figure 11-15.

11.5 Stream Restoration Recommendations

In 6.0 Natural Restoration Objectives, approximate sizing for the bankfull channel and floodprone areas adjacent to the active channel were defined. A summary of recommended geometries for each reach is given in Table 11-2. Cross-sections of typical restoration channels can be found in Figure 11-7.

In addition to variability in cross section, variability in channel slopes is a characteristic of natural channels. Features such as step pools, scour pools, rapids and riffles/pool sequences occur naturally and provide variety from both a habitat and aesthetic standpoint. Step pools, rapids and scour pools are bedform types that are typical of Type B stream that would be found in Reach 10. Riffle/pool sequences are alternating stretches of shallow, fast-moving sections (riffles) and deeper, slower pools, with glides or runs in between the end of a pool and beginning of the next riffle to allow for gradual bedform transformation. Riffle/pool sequences are typical bedforms seen in meandering, Type C streams such as Reaches 1-9.

This table can be used to define the approximate channel geometries throughout the basin. All channel sections are assumed to be generally trapezoidal with a bankfull width that is defined in the table. These tabulated values provide average channel geometry information, but it is not the intent nor is it desired that the channel take on a uniform, defined cross section. Variability is inherent in any natural system and is desired for improvements along Boulder Creek.

Table 11-2: Recommended Geometries for Primary Stream Types

Reach	Assumed Sinuosity	Slope (%)	Bankfull Width (ft)	Bankfull Depth (ft)	Width at 2x Bankfull Depth (ft)
1	1.6	0.20%	40	3	140
2	1.6	0.19%	40	3	140
3	1.6	0.29%	40	3	140
4	1.6	0.22%	40	3	140
5	1.6	0.24%	40	3	140
6	1.6	0.36%	40	3	140
7	1.6	0.30%	40	3	140
8	1.6	0.46%	40	3	140
9	1.4	0.81%	40	2.5	140
10	1.3	2.60%	30	2	54

11.6 Ecological Recommendations

A riparian corridor or "riparian zone" is defined as the transitional area or interface between upland terrestrial and aquatic habitats. A riparian zone is generally considered that portion of the landscape from the ordinary high water mark towards the adjoining uplands that affect or are affected by the presence of water. The riparian zone is often unique within a watershed containing notably different vegetation communities from the surrounding upland habitat.

The framework for any successful riparian zone restoration effort is understanding the local (reference standard) community that is either present or known to have existed in the local area, in order to restore the functional integrity and biodiversity of the riparian zone. As stated in previous sections, the reference community or primary habitat type recommended for restoration within this project area, which is locally native and appropriate for the environmental setting, is the Western Great Plains Riparian Woodland and Shrubland. Replicating the natural characteristics of the local Western Great Plains Riparian Woodland and Shrubland habitat type including re-establishment of cottonwood tree overstory and a willow shrub mid-story with a mixed grassland understory that properly interacted with the channel flow should be the primary objective for natural restoration efforts.

Successful riparian zone restoration is dependent on a thorough understanding of numerous environmental factors and site-specific conditions. Stream flow, soil moisture, groundwater table, soil chemistry and sun-orientation are all critical elements to consider. Any restoration efforts should carefully consider such factors which should generally be defined by an expert to ensure greater success. Further guidance is provided in the appendix of this report.

Riparian Zone Restoration shall generally follow the following guidelines:

- Natural riparian zone vegetation community type within the project area is characteristic of the *Western Great Plains Riparian Woodland and Shrubland;*
- A properly functioning riparian zone should have routine interaction with stream flows;

- In a more undisturbed condition, vegetation would be continuous along the entire corridor and occupy three strata (i.e., overstory, midstory and understory);
- Relatively dense native vegetation extending from the water's edge (bankfull) outward;
- Buffers that are wider, longer and more densely vegetated with herbaceous, shrub and tree layers provide more benefits. A minimum width should be at least 50 feet and extend upwards of 200 feet from the stream edge.

11.7 Recommended Bridge Improvements

A summary of existing major roadway crossings along Boulder Creek is presented in Table 9-2: Bridge Information and Replacement Locations. This table compares the existing bridge geometry with FEMA's regulatory 100-year water surface elevations along Boulder Creek to determine if a bridge currently meets criteria. Bridges outside of criteria were selected to be replaced by this master plan. The project team recommended that standard bridges, within the plains stream region be sized: to convey a minimum of 60% of the 100-year discharge; to accommodate the stream and floodplain at twice the bank flow depth; and to maintain less than a 6 ft./sec velocity through the bridge section at a maximum of depth of 10-feet. A 180-foot bridge opening width was used for this criterion, bridges with a smaller opening were recommended to be replaced. Renderings of typical bridge cross sections can be found in Figure 11-8.

Boulder County requested that additional alternatives be evaluated for 61st Street, 75th Street, 95th Street, and East County Line Road, which would convey the 100-year event without overtopping in order to provide emergency services during flooding. For 100-year bridges alternatives, a 220-foot bridge opening width was selected to closely match existing 100-year crossings at Mineral Road and Highway 287.

Table 11-3: Recommended Bridge Replacement

Stream Reach	Bridge Location	Jurisdiction	Estimated Existing Bridge Capacity (cfs, approx. freq)	Proposed Bridge Span (ft)
Reach 2	WC Road 20 1/2	Weld County	< 100-year	180
Reach 2	WC Road 16 1/2	Weld County	1,000 cfs	180
Reach 4	East County Line Road	Boulder / Weld Counties	1,200 cfs	220
Reach 4	Kenosha Road	Boulder County	600 cfs	180
Reach 4	109th Street	Boulder County	5,400 cfs	180
Reach 5	95th Street	Boulder County	3,300 cfs	220
Reach 6	75th Street	Boulder County	6,200 cfs	220
Reach 7	61st Street	Boulder County	8,300 cfs	220
Reach 8	BNSF Railroad	BNSF Railroad	1,000 cfs	180

11.8 Recreation

Recreation and Public Access are an integral part of Boulder Creek. Extensive studies have been prepared that have reviewed recreation and its impact to the natural systems along Boulder Creek. These studies have been well vetted with the public over the years and have been founded on scientific and ecological principles. Previous studies include: the Boulder County Comprehensive Plan, published May 27, 1999; the Lower Boulder Creek and Coal Creek Open Space Master Plan, published by Boulder County Parks and Open Space Department, 1997; the Boulder County Trail Plan published in 2003; the City of Boulder Open Space and Mountain Parks Grassland Ecosystem Management Plan, and the Weld County Trails Inventory Map 2010.

Section 4.3 discussed guiding principles from each plan and relationship to Boulder Creek and surrounding properties.

Table 11-4: Conceptual Design Cost Summary by Jurisdiction

Jurisdiction	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
City of Longmont	$300,146	$90,044	$75,037	$465,227	$10,885
Weld County	$13,069,240	$3,920,772	$3,267,310	$20,257,322	$169,575
Boulder County	$43,973,780	$13,192,137	$10,993,445	$68,172,847	$1,563,718
City of Boulder	$12,054,634	$3,616,390	$3,013,658	$18,849,682	$1,578,171

Table 11-5: Conceptual Design Cost Estimate by Reach (1-6)

Reach	ID	Description	Jurisdiction	Reach Length (mi)	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
1	A	Stream Maintenance and Ecological Enhancements City of Longmont Open Space	City of Longmont / Weld County	0.13	$ 39,146	$ 11,744	$ 9,787	$ 60,677	$ 9,800
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County	--	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 1,085
		Reach 1 Total		**0.83**	**$ 300,146**	**$ 90,044**	**$ 75,037**	**$ 465,227**	**$ 10,885**
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	--	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 35,420
	B	Replace Existing Grade Control for Aquatic and Habitat Passage	Weld County	--	$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	C	Modify Rural Ditch for Aquatic and Habitat Passage	Town of Frederick / Weld County	--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage	Weld County	--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	--	$ 1,792,200	$ 537,660	$ 448,050	$ 2,777,910	$ 35,420
	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County	--	$ 5,481,000	$ 1,644,300	$ 1,370,250	$ 8,495,550	$ 22,435
	G	Stream Restoration Downstream of CO Rd. 16.5	Weld County	0.38	$ 1,054,200	$ 316,260	$ 263,550	$ 1,634,010	$ 28,000
		Reach 2 Total		**3.14**	**$ 10,937,400**	**$ 3,281,220**	**$ 2,734,350**	**$ 16,952,970**	**$ 134,085**
3	A	Stream Restoration Upstream of CO Rd. 16.5	Weld County	0.38	$ 1,058,840	$ 317,652	$ 264,710	$ 1,641,202	$ 28,000
	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Weld County	--	$ 261,000	$ 78,300	$ 65,250	$ 404,550	$ 1,085
		Reach 3 Total		**1.03**	**$ 1,319,840**	**$ 395,952**	**$ 329,960**	**$ 2,045,752**	**$ 29,085**
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage	Weld County	--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	East County Line Road - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	--	$ 3,655,197	$ 1,096,560	$ 913,799	$ 5,665,556	$ 28,560
	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County	--	$ 3,915,000	$ 1,174,500	$ 978,750	$ 6,068,250	$ 16,030
	D	Stabilize Bank at Bailey-Kenosha Pond Outlet	Boulder County		$ 17,089	$ 5,126	$ 4,272	$ 26,487	$ 3,220
	E	DS of Kenosha Rd. - Remove Washed Out Bridge		--	$ 69,600	$ 20,880	$ 17,400	$ 107,880	$ -
	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space			$ 4,477,600	$ 1,343,280	$ 1,119,400	$ 6,940,280	$ 118,999
	G	Stabilize Howell Ditch Diversion System, Modify Diversion for Aquatic and Habitat Passage		--	$ 399,308	$ 119,792	$ 99,827	$ 618,927	$ 7,490
	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge		--	$ 2,296,800	$ 689,040	$ 574,200	$ 3,560,040	$ 28,560
	I	Replace Grade Control for Aquatic and Habitat Passage		--	$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel		--	$ 2,834,752	$ 850,426	$ 708,688	$ 4,393,866	$ 28,420
	K	Stream Restoration Through Wheeler Ranch		0.87	$ 2,424,657	$ 727,398	$ 606,164	$ 3,758,219	$ 64,399
		Reach 4 Total		**4.59**	**$ 20,617,803**	**$ 6,185,342**	**$ 5,154,450**	**$ 31,957,595**	**$ 304,218**
5	A	Stream Restoration at Alexander Dawson Open Space	Boulder County	0.85	$ 2,378,000	$ 713,400	$ 594,500	$ 3,685,900	$ 62,999
	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage		--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typical.		--	$ 1,305,000	$ 391,500	$ 326,250	$ 2,022,750	$ 5,355
	D	Modify Grade Control Structures for Aquatic and Habitat Passage		--	$ 237,800	$ 71,340	$ 59,450	$ 368,590	$ 4,270
	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage		--	$ 475,600	$ 142,680	$ 118,900	$ 737,180	$ 8,540
	F	Stream Restoration Downstream of 95th Street		0.38	$ 1,054,200	$ 316,260	$ 263,550	$ 1,647,495	$ 28,000
	G	95th St. - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		--	$ 3,778,680	$ 1,133,604	$ 944,670	$ 5,856,954	$ 28,560
	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail	City of Boulder	0.85	$ 2,371,947	$ 711,584	$ 592,987	$ 3,676,518	$ 62,999
		Reach 5 Total		**2.83**	**$ 11,891,227**	**$ 3,567,368**	**$ 2,972,807**	**$ 18,444,887**	**$ 204,993**
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage	Boulder County	--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	B	75th Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		--	$ 3,097,220	$ 929,166	$ 774,305	$ 4,800,691	$ 28,560
		Reach 6 Total		**2.53**	**$ 3,387,220**	**$ 1,016,166**	**$ 846,805**	**$ 5,250,191**	**$ 32,830**

Table 11-6: Conceptual Design Cost Estimate by Reach (7-10)

Reach	ID	Description	Jurisdiction	Reach Length (mi)	Capital	Eng / Admin / Legal	Contingency	Total Capital Cost	50-yr O&M Cost
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County	--	$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 7,490
	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical		--	$ 1,827,000	$ 548,100	$ 456,750	$ 2,831,850	$ 7,490
	C	Modify Diversion for Aquatic and Habitat Passage		--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage		--	$ 290,000	$ 87,000	$ 72,500	$ 449,500	$ 4,270
	E	61st Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		--	$ 2,843,416	$ 853,025	$ 710,854	$ 4,407,295	$ 28,420
	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge		--	$ 1,117,813	$ 335,344	$ 279,453	$ 1,732,610	$ 28,210
	G	Modify Butte Mill Ditch Crossing on South Boulder Creek		--	$ 235,238	$ 70,572	$ 58,810	$ 364,620	$ 4,200
	H	Protect Sanitary Interceptor Sewer		--	$ 511,010	$ 153,304	$ 127,753	$ 792,067	$ 8,540
	I	Stream Restoration from Valmont Rd to 61st Street	City of Boulder	1.18	$ 1,546,781	$ 464,034	$ 386,695	$ 2,397,510	$ 87,499
		Reach 7 Total		**3.51**	**$ 10,488,258**	**$ 3,146,479**	**$ 2,622,065**	**$ 16,256,802**	**$ 180,389**
8	A	Stream Restoration from 55th St. to Valmont Drive	City of Boulder	0.32	$ 429,200	$ 128,760	$ 107,300	$ 665,260	$ 23,800
	B	Stream Restoration from BNSF RR to 55th St.		0.91	$ 1,194,800	$ 358,440	$ 298,700	$ 1,851,940	$ 67,199
	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge		--	$ 2,697,000	$ 809,100	$ 674,250	$ 4,180,350	$ 28,280
	D	Stream Restoration from Foothills Pkwy to BNSF RR		0.49	$ 638,000	$ 191,400	$ 159,500	$ 988,900	$ 36,400
	E	Hospital Access Improvements for 500-yr Event		--	$ 46,932	$ 14,080	$ 11,733	$ 72,745	$ -
	F	Sediment Maintenance along Boulder Creek Path		--	$ -	$ -	$ -	$ -	$ 839,993
		Reach 8 Total		**2.3**	**$ 5,005,932**	**$ 1,501,780**	**$ 1,251,483**	**$ 7,759,195**	**$ 995,672**
9	A	Cordry Ct, High Hazard & Flood Mitigation	City of Boulder	0.06	$ 65,589	$ 19,676	$ 16,397	$ 266,662	$ 13,650
	C	North of Boulder Creek Access Improvements		--	$ 3,496,000	$ 1,048,800	$ 874,000	$ 5,418,800	$ 69,999
	D	Boulder Slough Mitigation		--	$ 486,385	$ 145,916	$ 121,596	$ 753,897	$ 10,815
	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage		--	$ 406,000	$ 121,800	$ 101,500	$ 629,300	$ 4,270
	F	Sediment Maintenance along Boulder Creek Path		--	$ -	$ -	$ -	$ -	$ 1,259,989
		Reach 9 Total		**2.87**	**$ 4,453,974**	**$ 1,336,192**	**$ 1,113,493**	**$ 7,068,659**	**$ 1,358,723**
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage	Boulder County	--	$ 300,000	$ 90,000	$ 75,000	$ 465,000	$ 4,270
	B	Boulder Canyon Stream Restoration		0.91	$ 696,000	$ 208,800	$ 174,000	$ 1,078,800	$ 67,199
		Reach 10 Total		**1.64**	**$ 996,000**	**$ 298,800**	**$ 249,000**	**$ 1,543,800**	**$ 71,469**
			Total Costs	**25.27**	**$ 69,397,800**	**$ 20,819,343**	**$ 17,349,450**	**$ 107,745,078**	**$ 3,322,349**

Boulder Creek Master Plan
Conceptual Design Interactive Map

Open detailed sheets in new window:

Conceptual Design Alternatives	Reach 1 - 3
Stream Restoration Alternatives	Reach 4
Bridge Replacement Alternatives	Reach 5 - 6
Public Safety Alternatives	Reach 7 - 8
Maintenance Alternatives	Reach 9 - 10

City Boundaries - ON or OFF

100-yr Floodplain - ON or OFF

Open Space - ON or OFF

This drawing is for master planning purposes and represents preliminary and conceptual engineering. Alternatives will be considered by local agencies and the Urban Drainage and Flood Control District provided the alternative offers an equivalent intent of the plan, including hydraulic capacity, water quality, stream stability, and natural waterway features. The alternative must comply with all requirements of the local jurisdiction and the Urban Drainage and Flood Control District. In addition, there may be State and Federal requirements that will need to be considered and met. This drawing does not provide a final design and shall not be used for construction purposes.

Many activities that occur in or affect ditches, drainages, creeks, ponds or wetlands require a Section 404 Permit Authorization from the US Army Corps of Engineers. During preliminary design, and prior to final design or starting work, contact the Corps' Denver Regulatory Office at 303-979-4120 for appropriate permit authority to avoid compromising and delaying the completion of the project.

N

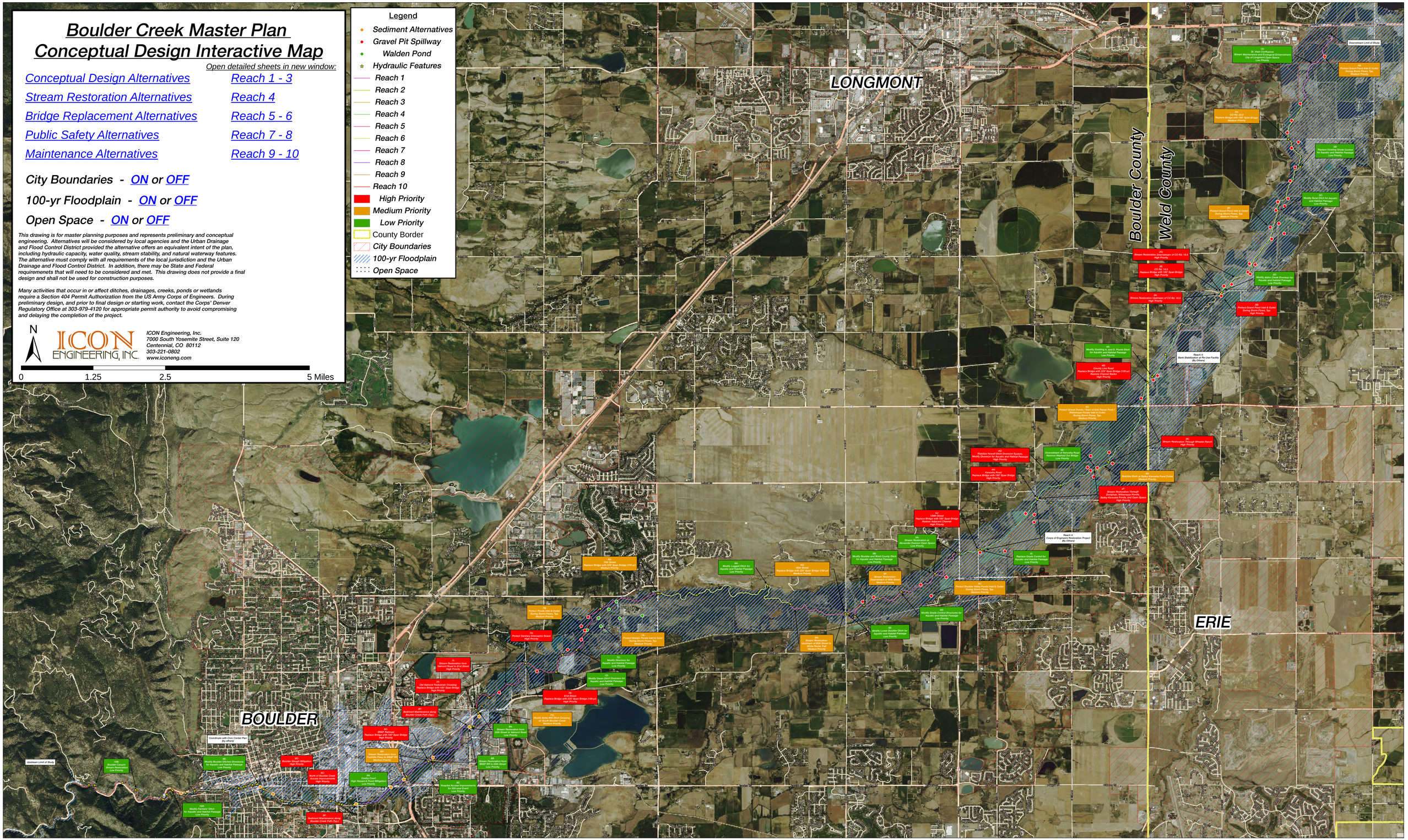
ICON ENGINEERING, INC.

ICON Engineering, Inc.
7000 South Yosemite Street, Suite 120
Centennial, CO 80112
303-221-0802
www.iconeng.com

0 1.25 2.5 5 Miles

Legend

- Sediment Alternatives
- Gravel Pit Spillway
- Walden Pond
- Hydraulic Features
- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6
- Reach 7
- Reach 8
- Reach 9
- Reach 10
- High Priority
- Medium Priority
- Low Priority
- County Border
- City Boundaries
- 100-yr Floodplain
- Open Space

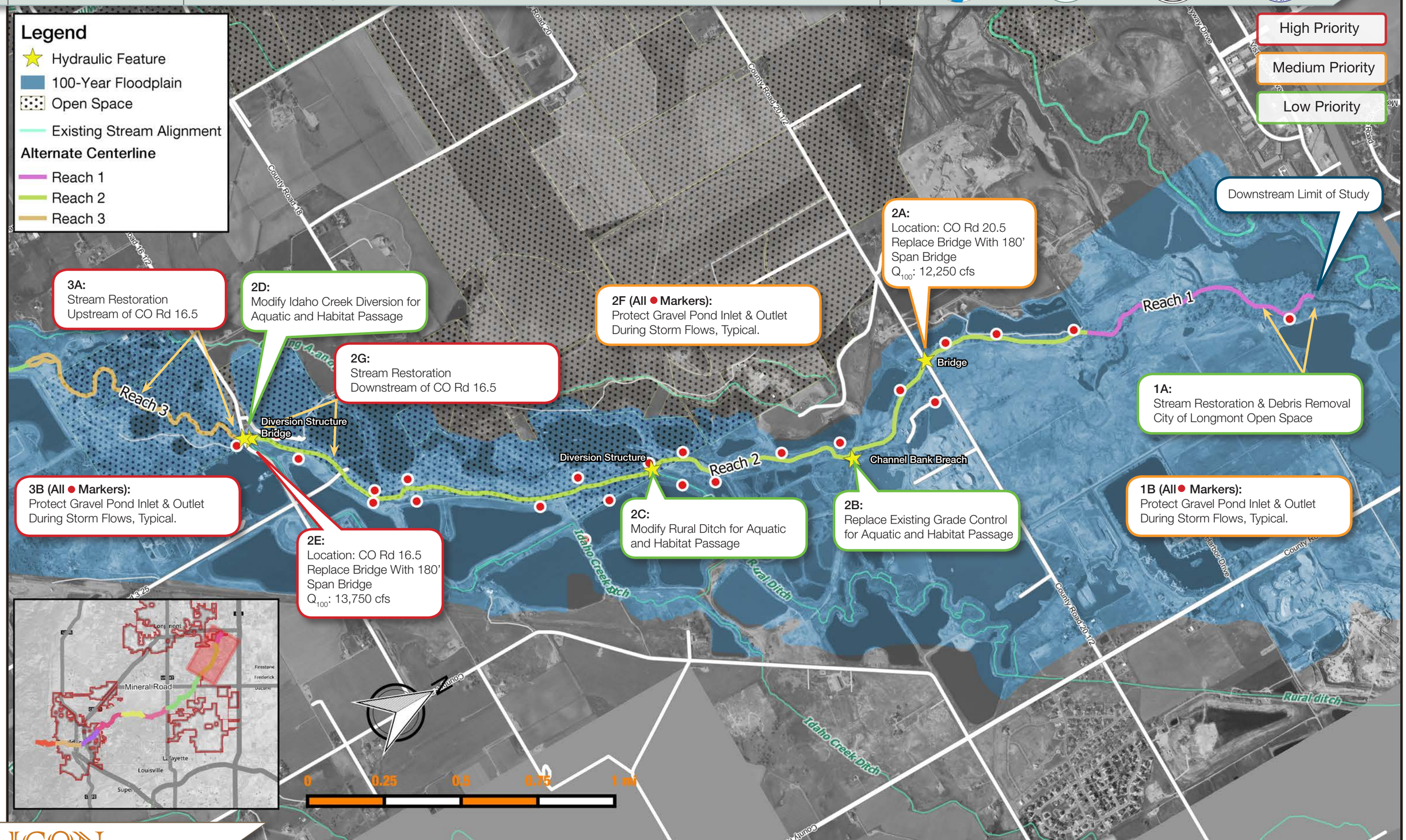


December 2015

Figure 11-2

Boulder Creek Restoration Master Plan

Conceptual Design



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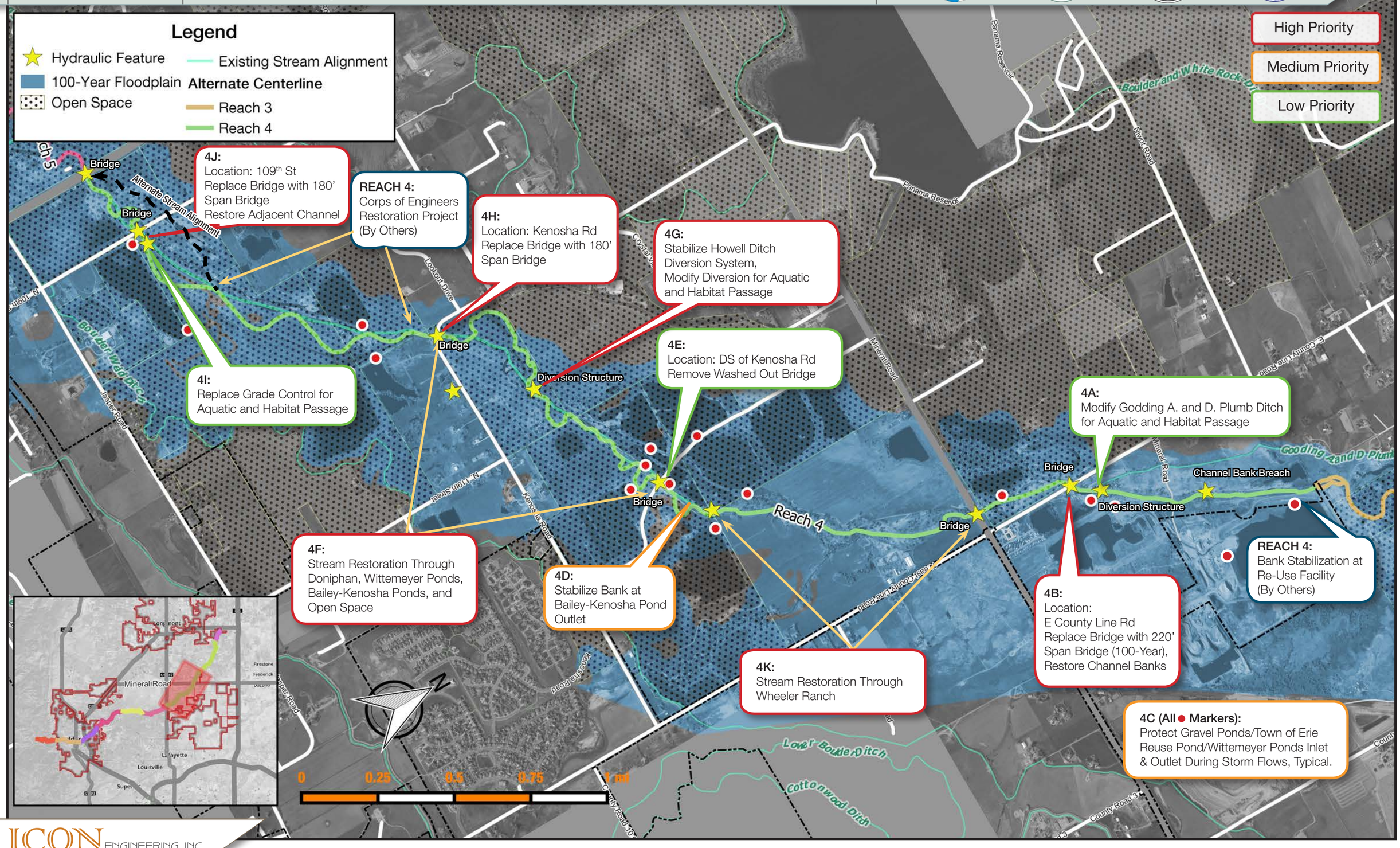

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Figure 11-4

Boulder Creek Restoration Master Plan

Conceptual Design

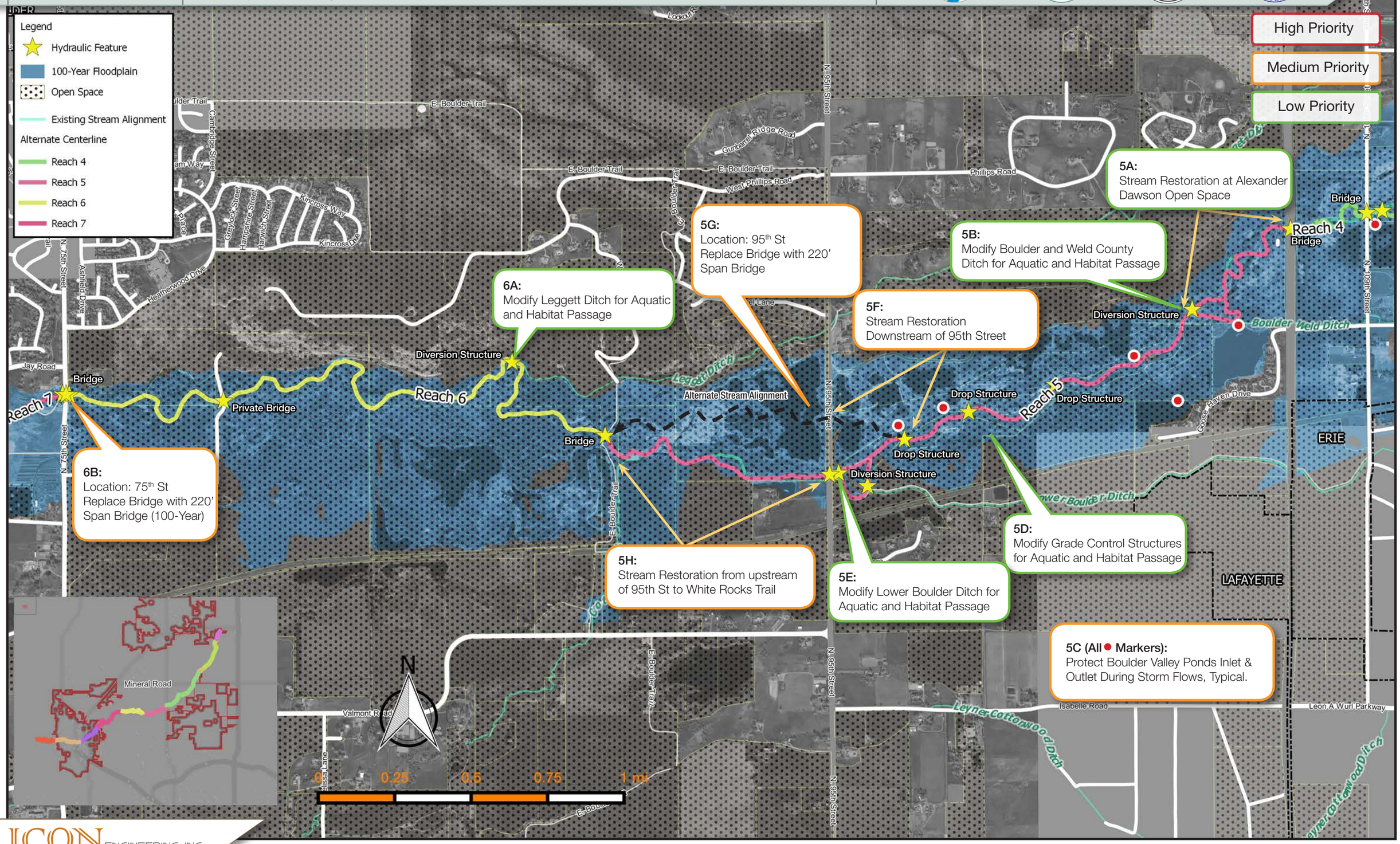

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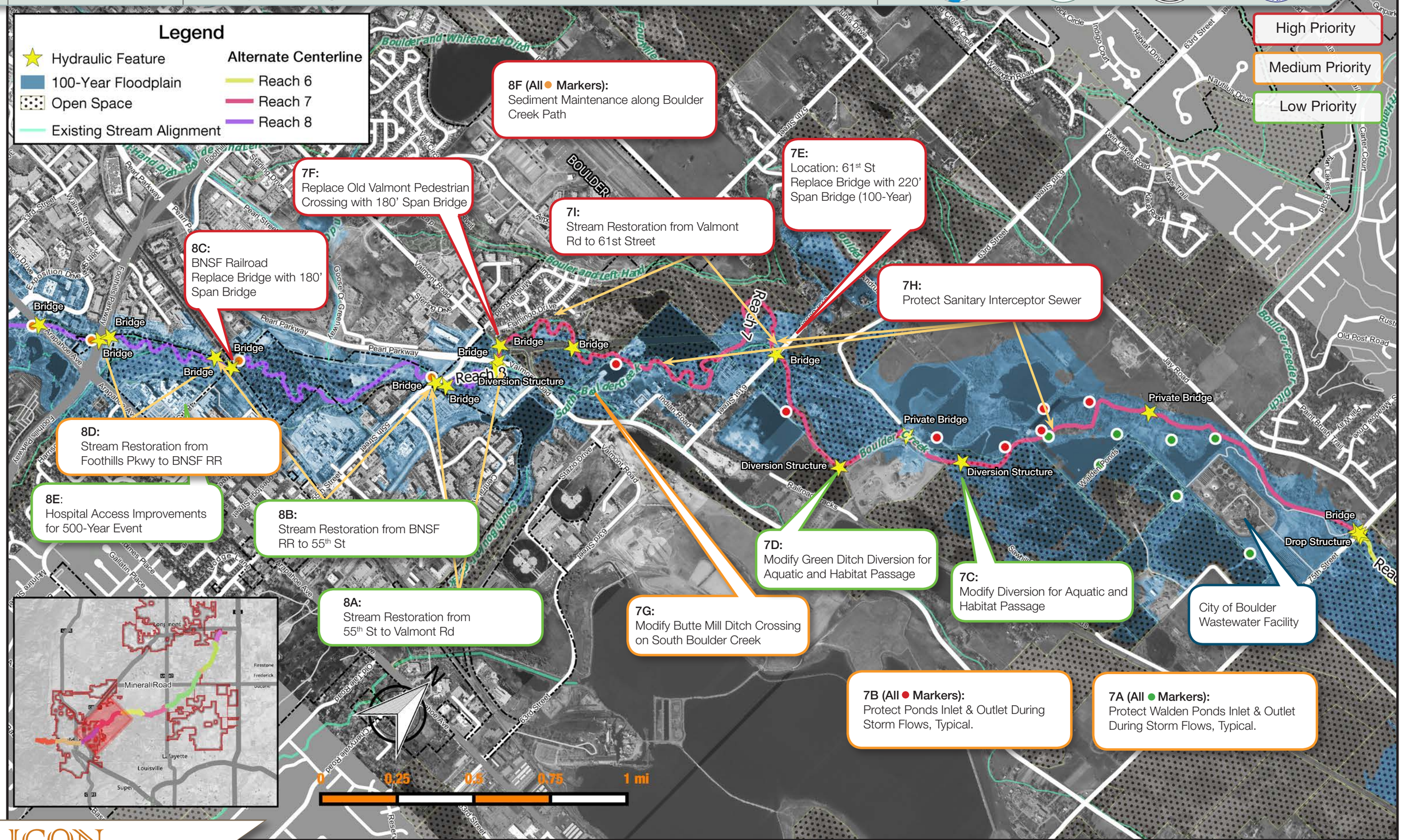
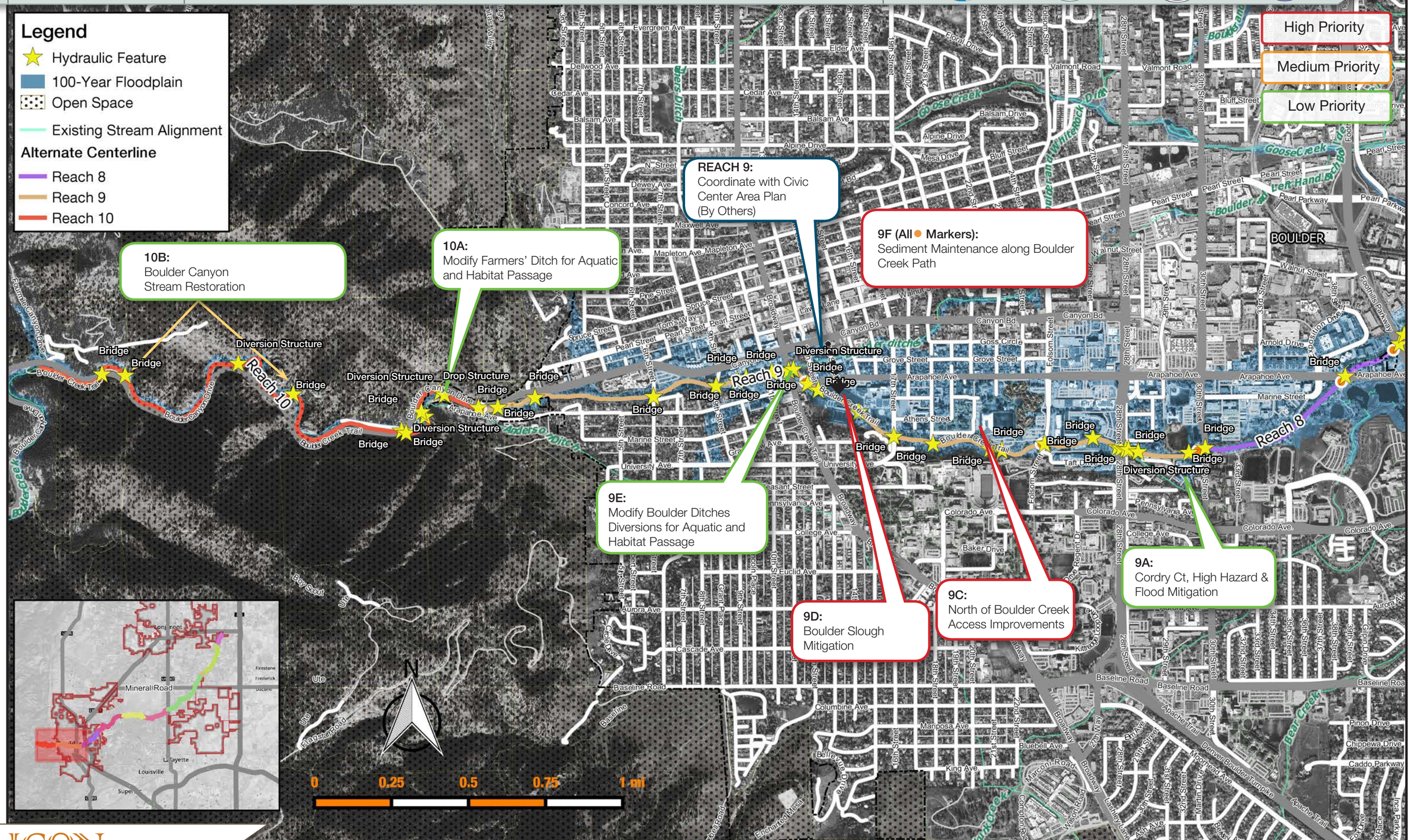
Figure 11-5

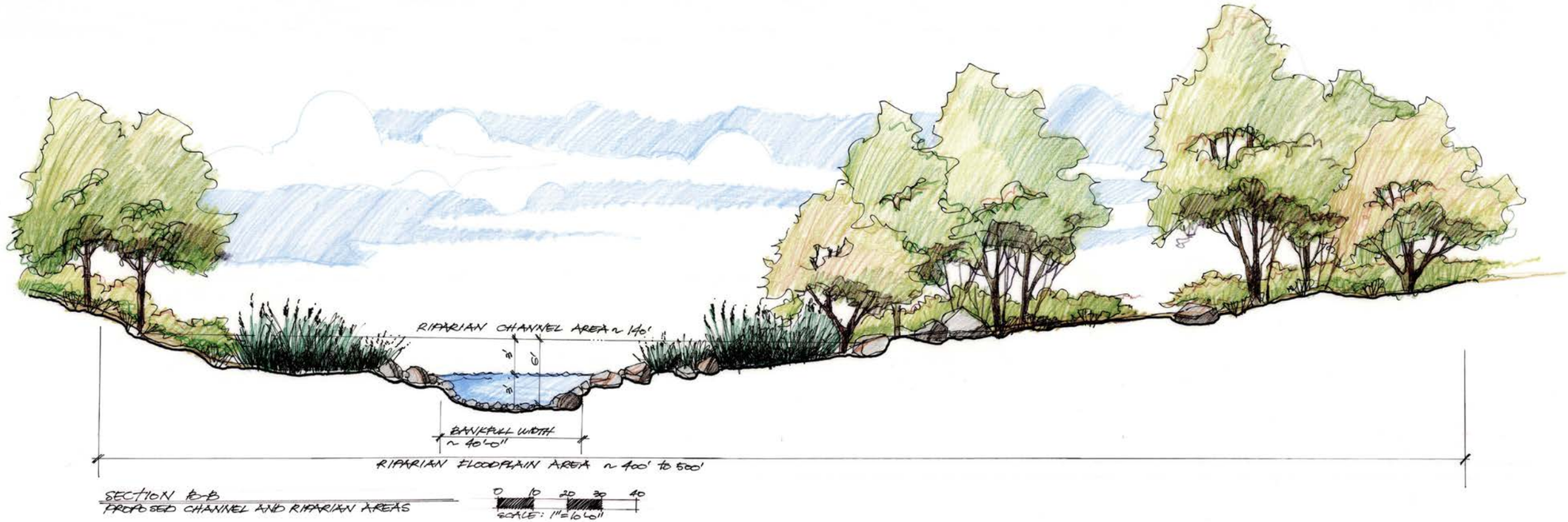
Boulder Creek Restoration Master Plan

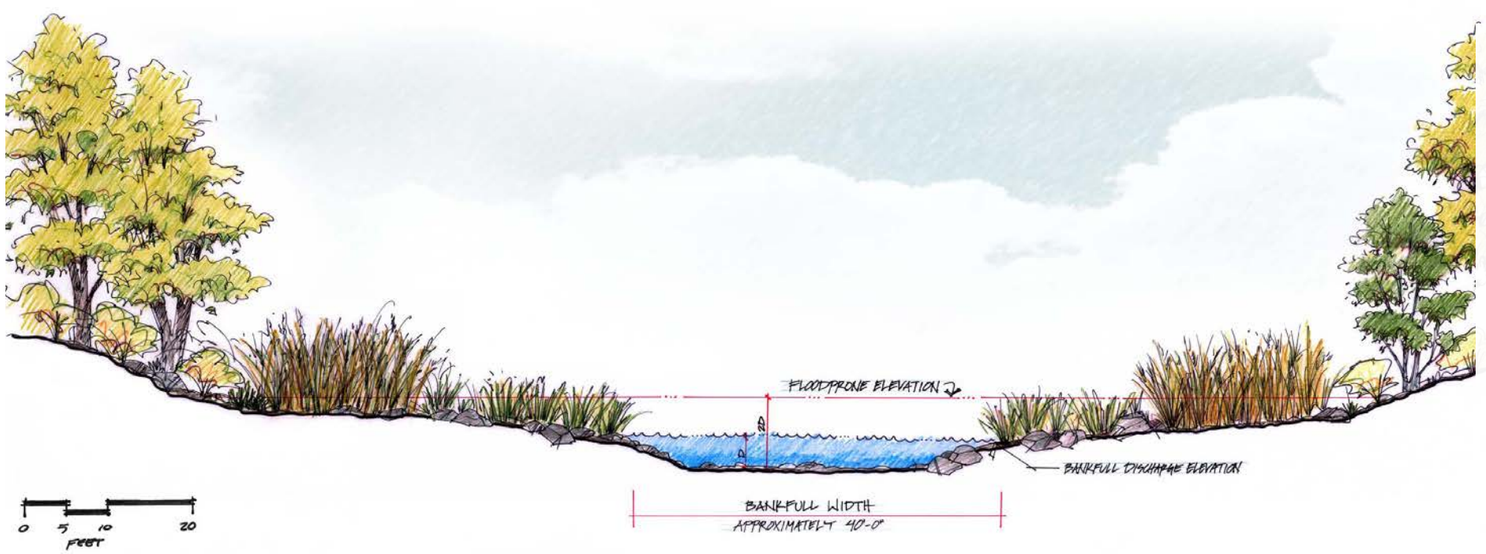
Conceptual Design

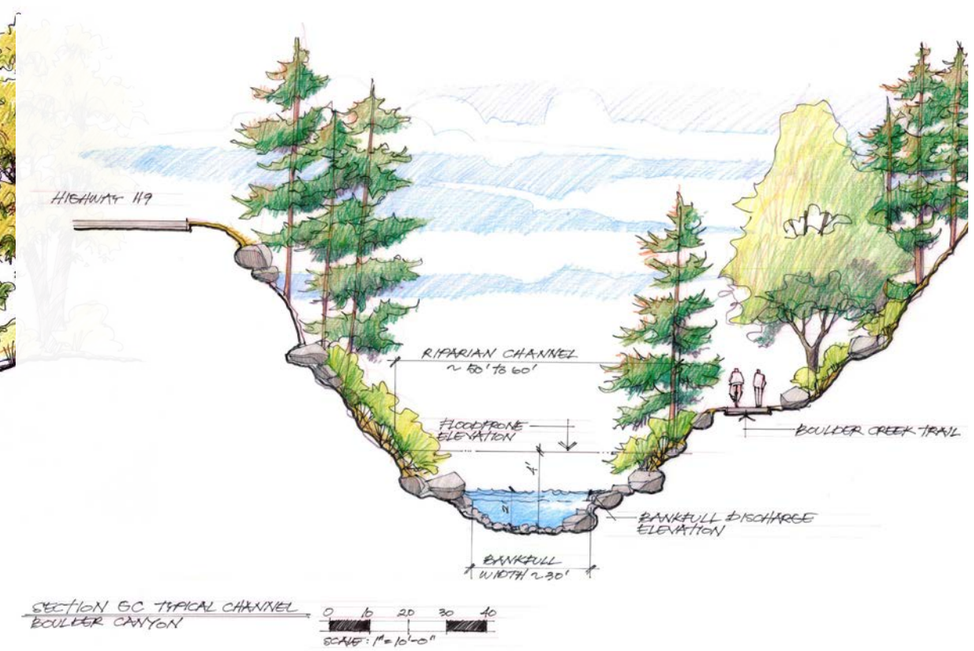


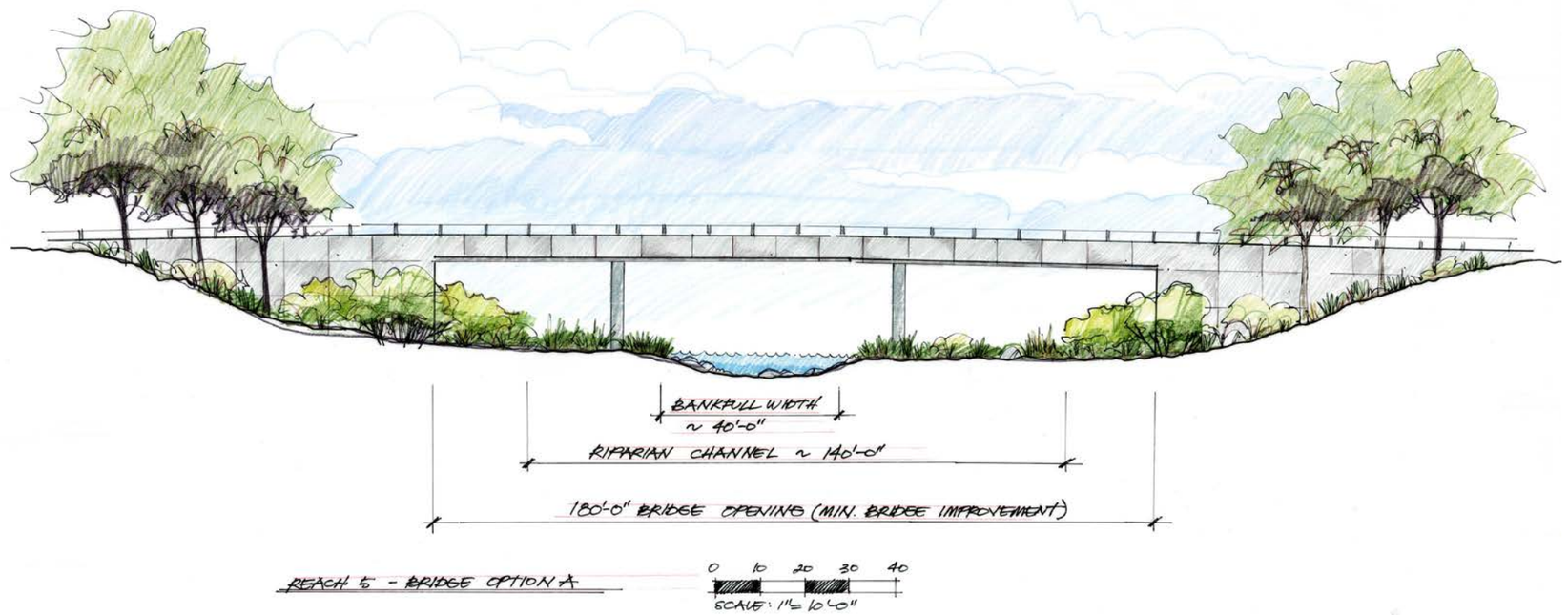
ICON ENGINEERING, INC.

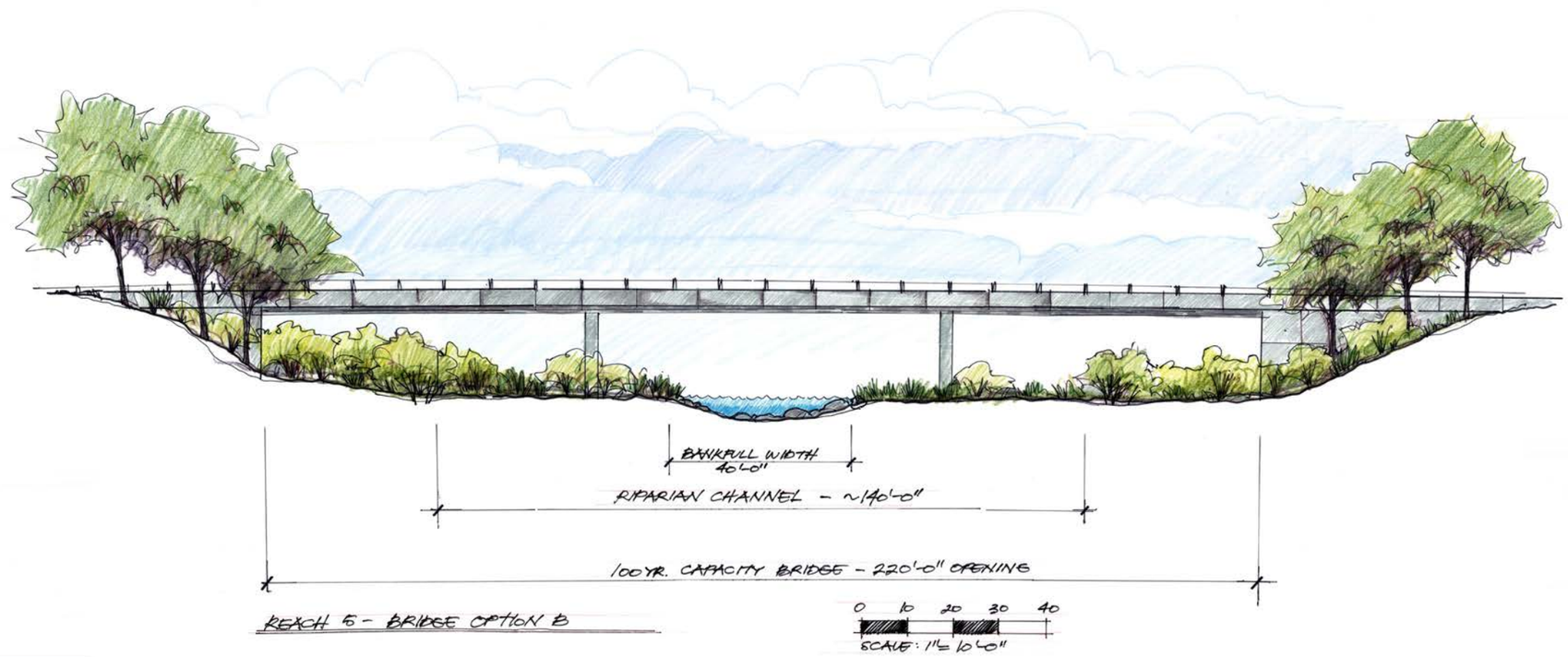

Legend
Hydraulic Feature
100-Year Floodplain
Open Space
Existing Stream Alignment
Alternate Centerline
Reach 8
Reach 9
Reach 10
High Priority
Medium Priority
Low Priority
10B:
Boulder Canyon
Stream Restoration
10A:
Modify Farmers' Ditch for Aquatic
and Habitat Passage
REACH 9:
Coordinate with Civic
Center Area Plan
(By Others)
9F (All Markers):
Sediment Maintenance along Boulder
Creek Path
9E:
Modify Boulder Ditches
Diversions for Aquatic and
Habitat Passage
9D:
Boulder Slough
Mitigation
9C:
North of Boulder Creek
Access Improvements
9A:
Cordry Ct, High Hazard &
Flood Mitigation
Reach 10
Reach 9
Reach 8
Bridge
Diversion Structure
Drop Structure
BOULDER
N
0
0.25
0.5
0.75
1 mi

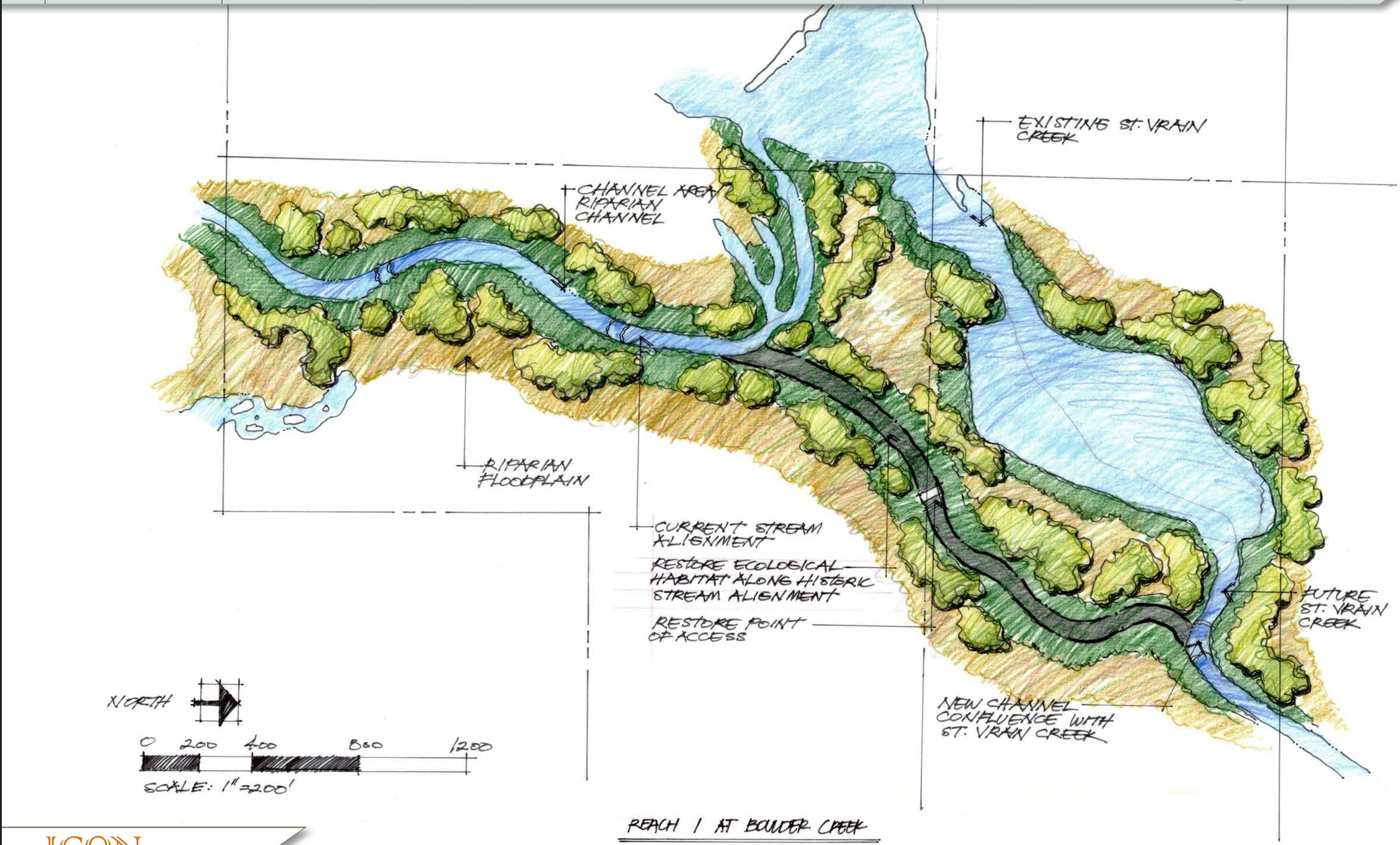

RIPARIAN CHANNEL AREA ~ 140'
8'
6'
3'
BANKFULL WIDTH
~ 40'-0"
RIPARIAN FLOODPLAIN AREA ~ 400' to 500'
SECTION B-B
PROPOSED CHANNEL AND RIPARIAN AREAS
0 10 20 30 40
SCALE: 1"=10'-0"


FLOODPRONE ELEVATION
BANKFULL DISCHARGE ELEVATION
BANKFULL WIDTH
APPROXIMATELY 40'-0"
0 5 10 20
FEET

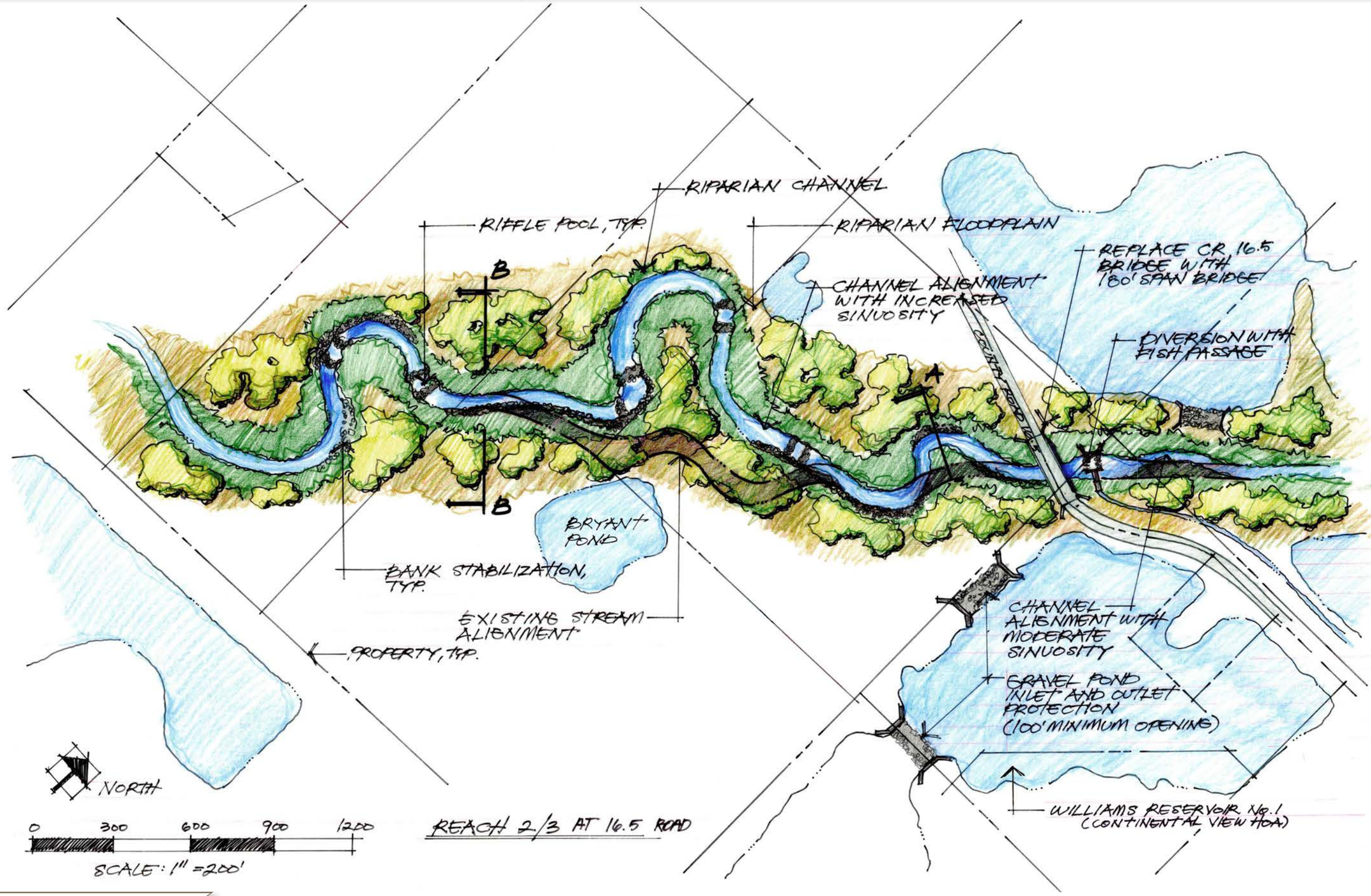

HIGHWAY 119
RIPARIAN CHANNEL
~ 50' TO 60'
FLOODPRONE
ELEVATION
BOULDER CREEK TRAIL
BANKFULL DISCHARGE
ELEVATION
BANKFULL
WIDTH ~ 30'
SECTION C-C TYPICAL CHANNEL
BOULDER CANYON
0 10 20 30 40
SCALE: 1"=10'-0"

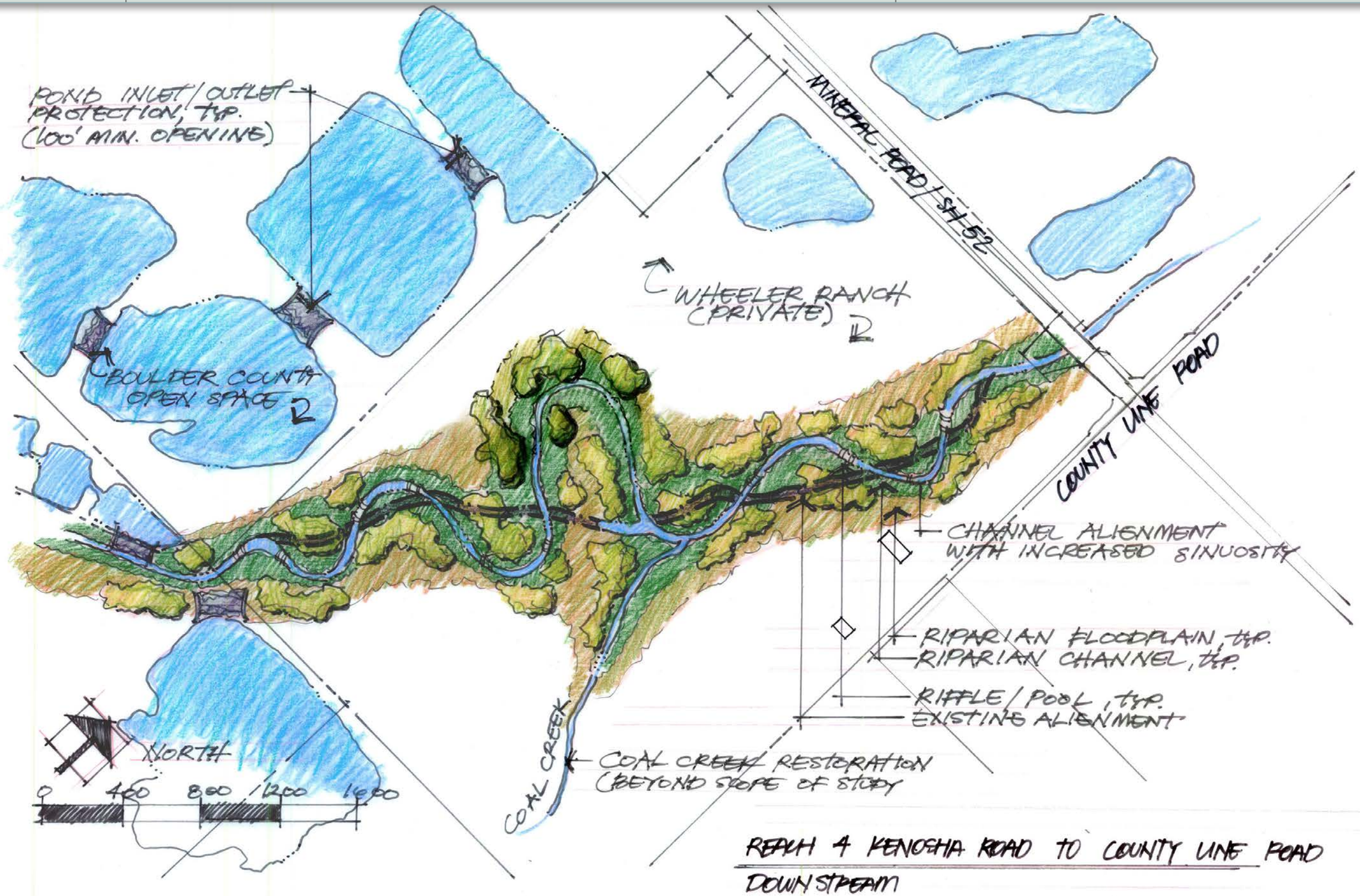

BANKFULL WIDTH
~ 40'-0"
RIPARIAN CHANNEL ~ 140'-0"
180'-0" BRIDGE OPENING (MIN. BRIDGE IMPROVEMENT)
REACH 5 - BRIDGE OPTION A
0 10 20 30 40
SCALE: 1"= 10'-0"

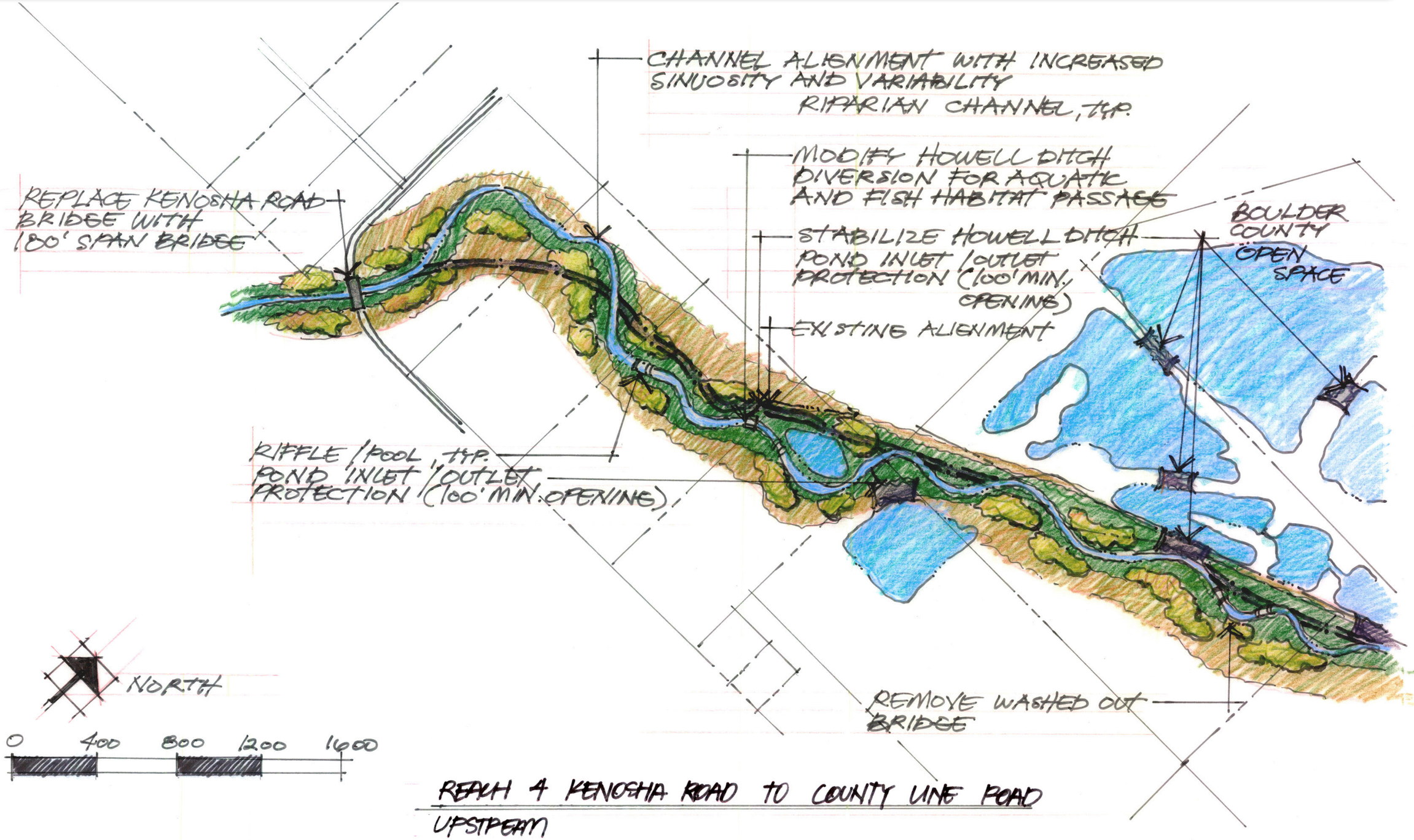

BANKFULL WIDTH
40'-0"
RIPARIAN CHANNEL - ~140'-0"
100 YR. CAPACITY BRIDGE - 220'-0" OPENING
REACH 5 - BRIDGE OPTION B
0 10 20 30 40
SCALE: 1"= 10'-0"

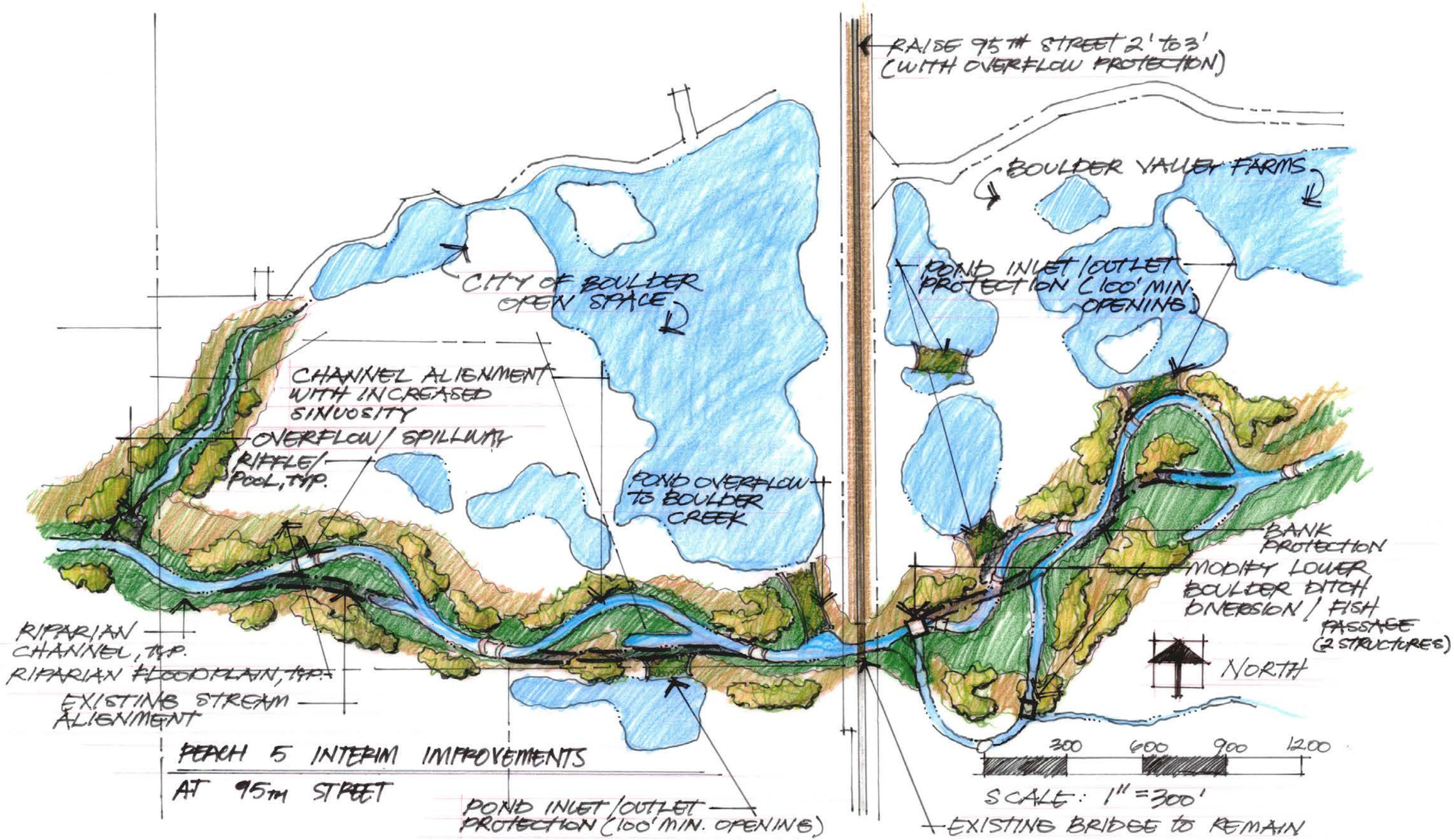


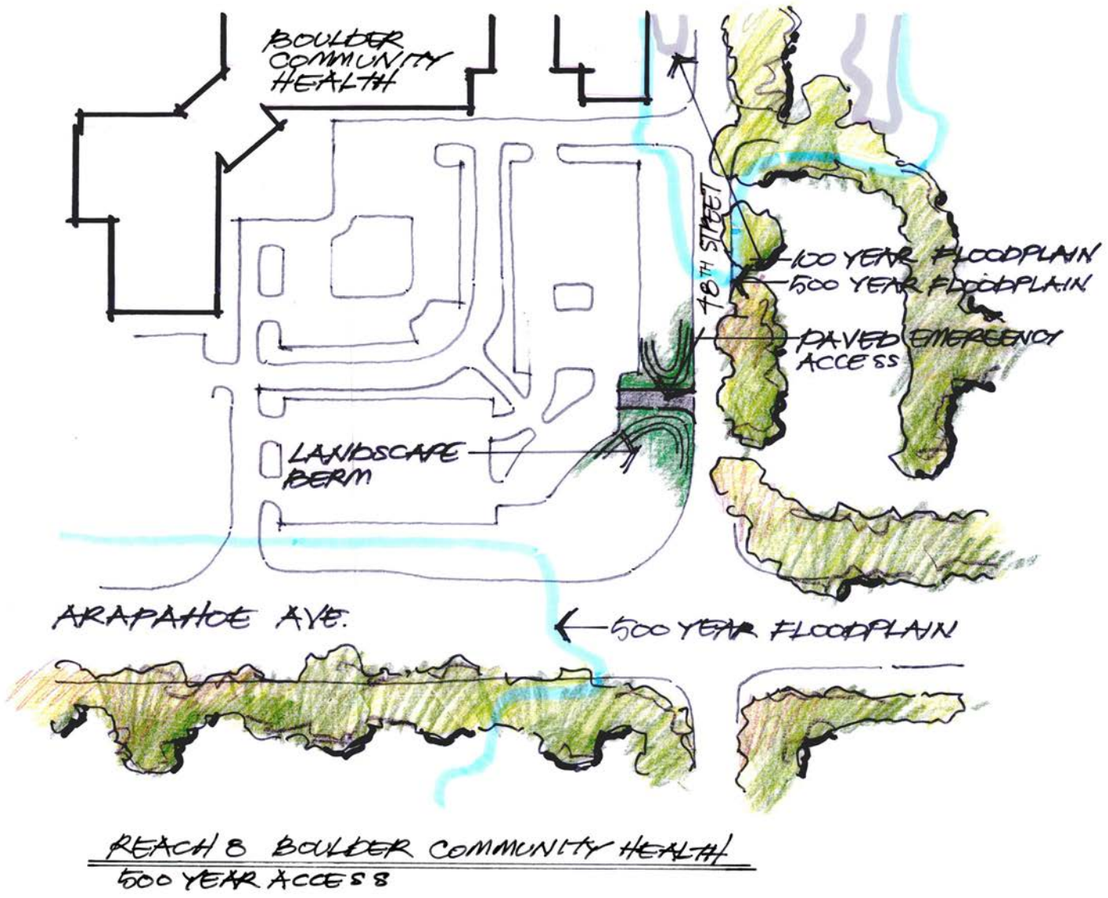
REACH 1 AT BOULDER CREEK


RIPARIAN CHANNEL
RIFFLE POOL, TYP.
RIPARIAN FLOODPLAIN
REPLACE CR 16.5 BRIDGE WITH 180' SPAN BRIDGE
CHANNEL ALIGNMENT WITH INCREASED SINUOSITY
DIVERSION WITH FISH PASSAGE
COUNTY ROAD 16.5
B
A
BRYANT POND
BANK STABILIZATION, TYP.
EXISTING STREAM ALIGNMENT
PROPERTY, TYP.
CHANNEL ALIGNMENT WITH MODERATE SINUOSITY
GRAVEL POND INLET AND OUTLET PROTECTION (100' MINIMUM OPENING)
WILLIAMS RESERVOIR NO. 1 (CONTINENTAL VIEW HOA)
NORTH
0 300 600 900 1200
SCALE: 1" = 200'
REACH 2/3 AT 16.5 ROAD

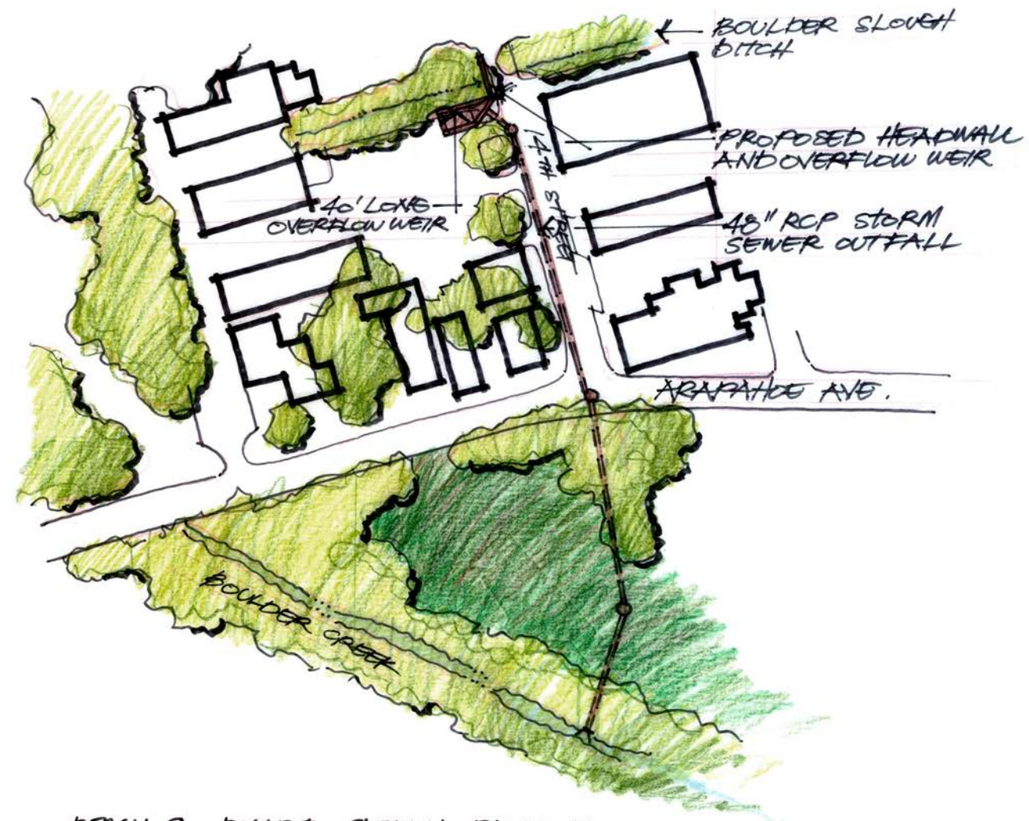

POND INLET/OUTLET PROTECTION, TYP. (100' MIN. OPENING)
KENOSHA ROAD / SH 52
WHEELER RANCH (PRIVATE)
BOULDER COUNTY OPEN SPACE
COUNTY LINE ROAD
CHANNEL ALIGNMENT WITH INCREASED SINUOSITY
RIPARIAN FLOODPLAIN, TYP.
RIPARIAN CHANNEL, TYP.
RIFFLE / POOL, TYP.
EXISTING ALIGNMENT
COAL CREEK
COAL CREEK RESTORATION (BEYOND SCOPE OF STUDY)
NORTH
0 400 800 1200 1600
REACH 4 KENOSHA ROAD TO COUNTY LINE ROAD
DOWNSTREAM


CHANNEL ALIGNMENT WITH INCREASED SINUOSITY AND VARIABILITY
RIPARIAN CHANNEL, TYP.
MODIFY HOWELL DITCH DIVERSION FOR AQUATIC AND FISH HABITAT PASSAGE
STABILIZE HOWELL DITCH POND INLET/OUTLET PROTECTION (100' MIN. OPENING)
EXISTING ALIGNMENT
REPLACE KENOSHA ROAD BRIDGE WITH 180' SPAN BRIDGE
BOULDER COUNTY OPEN SPACE
RIFFLE/POOL, TYP.
POND INLET/OUTLET PROTECTION (100' MIN. OPENING)
REMOVE WASHED OUT BRIDGE
NORTH
0
400
800
1200
1600
REACH 4 KENOSHA ROAD TO COUNTY LINE ROAD
UPSTREAM

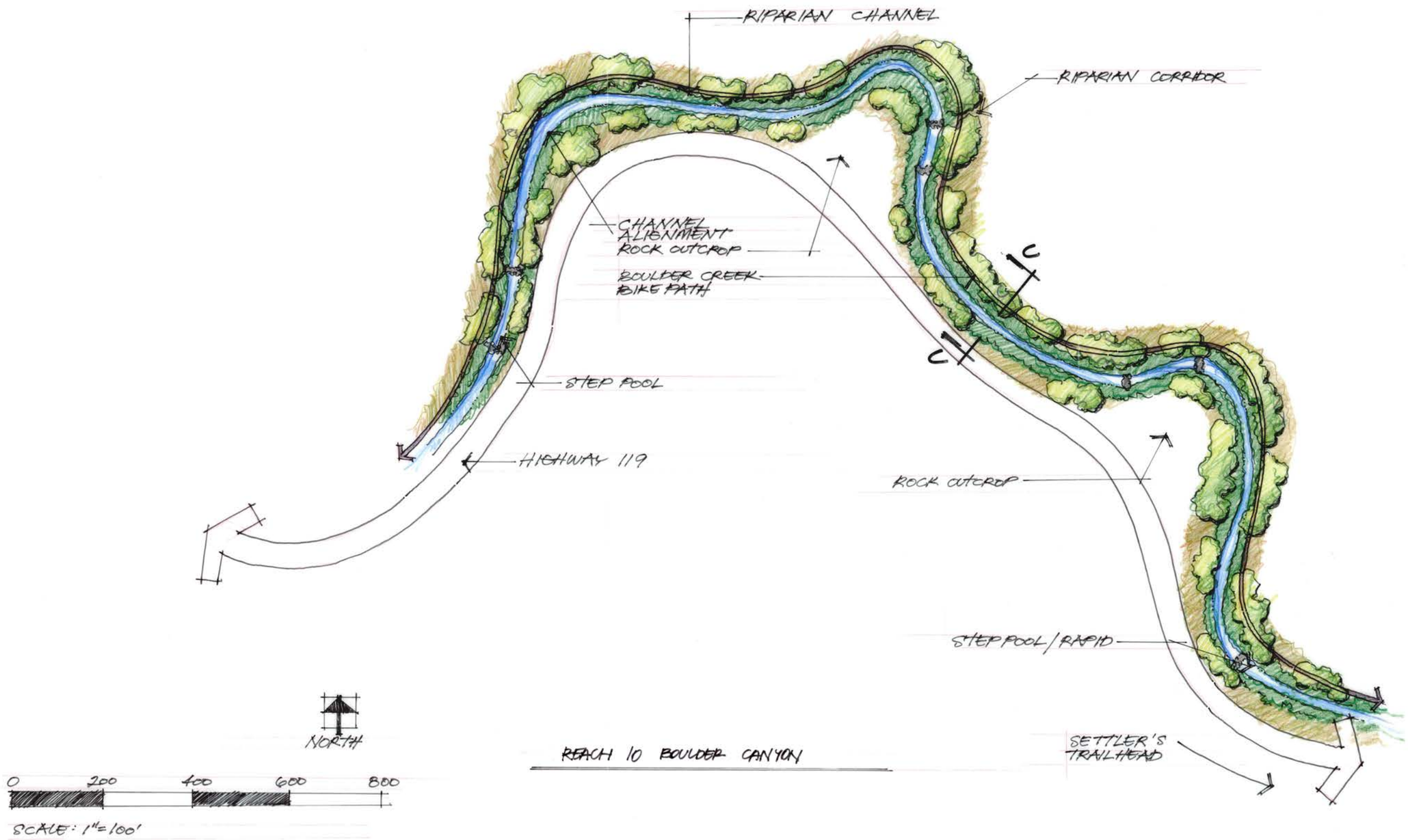

RAISE 95TH STREET 2' TO 3' (WITH OVERFLOW PROTECTION)
BOULDER VALLEY FARMS
POND INLET/OUTLET PROTECTION (100' MIN. OPENING)
CITY OF BOULDER OPEN SPACE
CHANNEL ALIGNMENT WITH INCREASED SINUOSITY
OVERFLOW/SPILLWAY
RIFFLE/POOL, TYP.
POND OVERFLOW TO BOULDER CREEK
BANK PROTECTION
MODIFY LOWER BOULDER DITCH DIVERSION/FISH PASSAGE (2 STRUCTURES)
NORTH
RIPARIAN CHANNEL, TYP.
RIPARIAN FLOODPLAIN, TYP.
EXISTING STREAM ALIGNMENT
REACH 5 INTERIM IMPROVEMENTS
AT 95TH STREET
POND INLET/OUTLET PROTECTION (100' MIN. OPENING)
0 300 600 900 1200
SCALE: 1" = 300'
EXISTING BRIDGE TO REMAIN

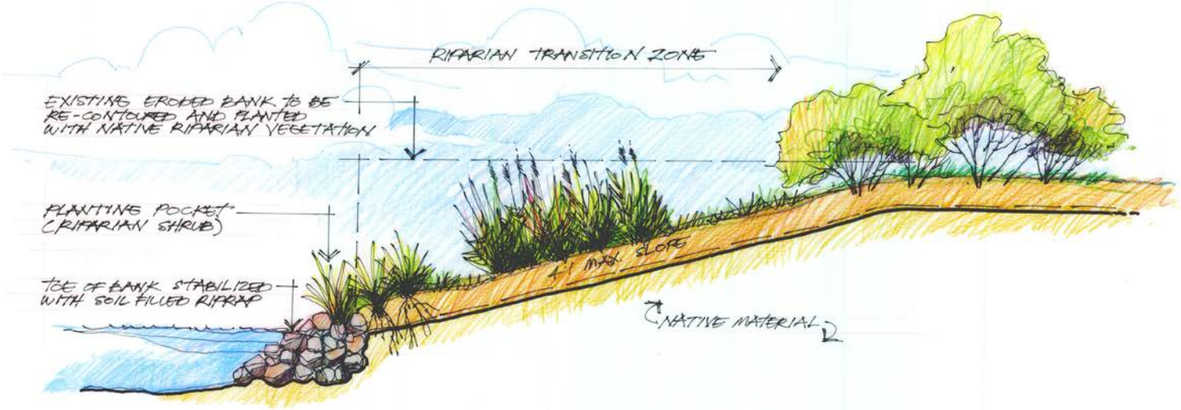


REACH 8 BOULDER COMMUNITY HEALTH
500 YEAR ACCESS

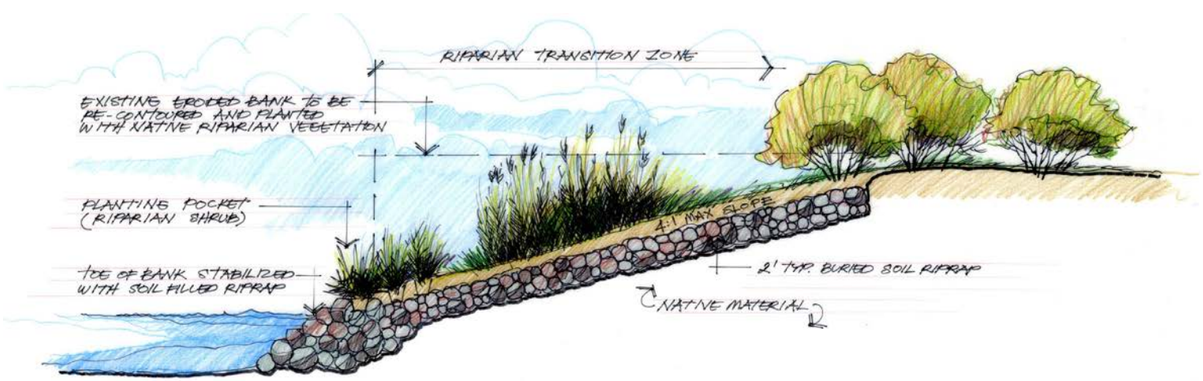


REACH 9 BOULDER SLOUGH DIVERSION

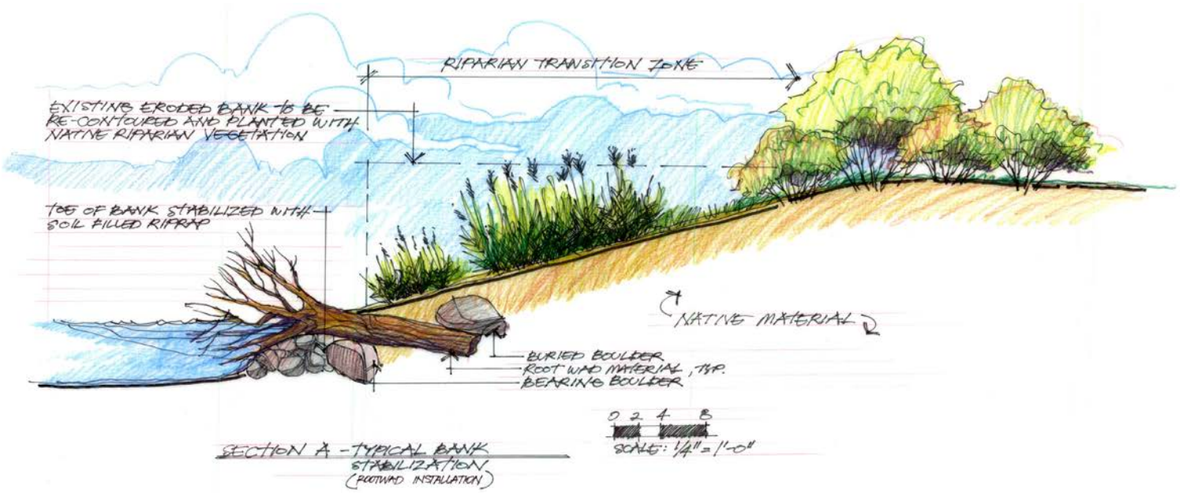

RIPARIAN CHANNEL
RIPARIAN CORRIDOR
CHANNEL ALIGNMENT
ROCK OUTCROP
BOULDER CREEK BIKE PATH
C
C
STEP POOL
HIGHWAY 119
ROCK OUTCROP
STEP POOL / RAPID
SETTLER'S TRAILHEAD
NORTH
0
200
400
600
800
SCALE: 1"=100'
REACH 10 BOULDER CANYON



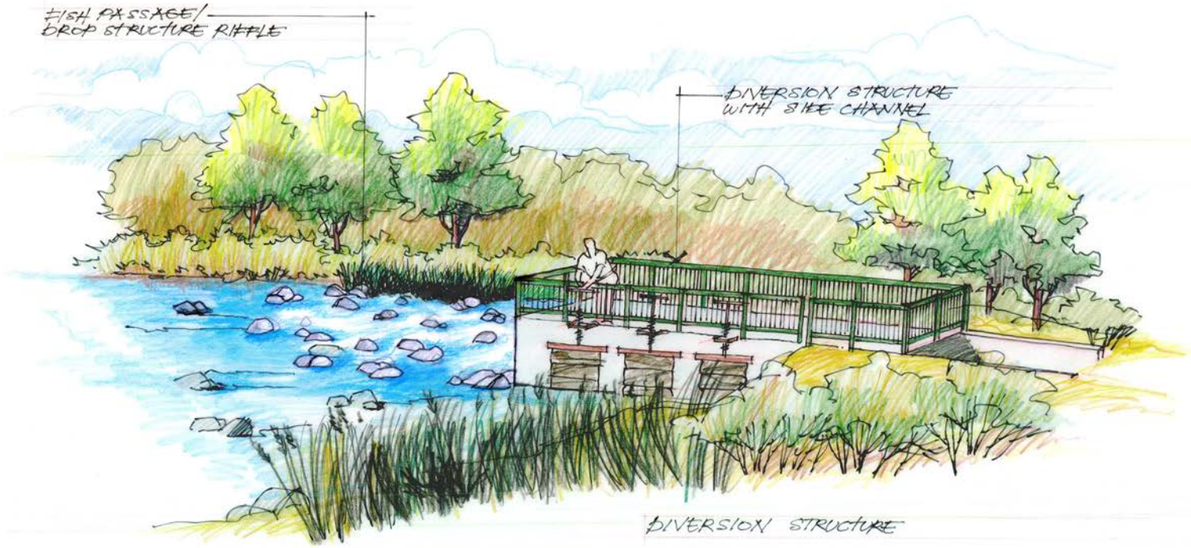
SECTION A - TYPICAL BANK STABILIZATION



SECTION A - TYPICAL BANK STABILIZATION (NO FAF INSTALLATION)



SECTION A - TYPICAL BANK STABILIZATION (ROOTWAD INSTALLATION)



12.0 PRIORITIZATION

In general, projects presented by this master plan are isolated in nature and can be implemented in any order without affecting adjacent projects upstream and downstream. Stream restoration and ecological enhancement will be most affected when Boulder Creek has been restored in a consistent manner across the entirety of the study length.

Since many of the alternatives in this study are not directly comparable, each recommended alternative has been grouped into a distinguishing category for prioritization. The four categories reflect: stream and Ecological Restoration, Bridge Replacement & Emergency Access; Public Safety; and Stream Maintenance. Within each category, projects were ranked in terms of a high, medium, or low priority. Top priority was given to project which serviced an immediate need; high level of stakeholder interest or collaboration; and presented higher levels of feasibility for implementation. Lower priority was assigned to locations posing less immediate threat to public safety, or integrated more long term planning goals.

12.1 Stream and Ecological Restoration

Prioritization of stream and ecological restoration projects are presented below. Examples of higher priority projects include restoration upstream and downstream of County Road 16.5 in Weld County, where erosion continues to threaten adjacent infrastructure and property. Similar prioritization was made within the City of Boulder Open Space, where stream restoration is also an integral component to implementing roadway improvements in the area. Lower priority was given to project more isolated by open space areas with less immediate threat to public safety, such as near the confluence with the Saint Vrain Creek, or Alexander Dawson Open Space. In general, modification to grade control and irrigation diversion structures were generally given lower priority, except in cases where the changes were also an integral part of the restoration activities.

12.2 Bridge Replacement & Emergency Access

Prioritization for bridge replacements considered: the need to provide emergency access; age of structure (if known); existing bridge capacity; and current bridge size with respect to geomorphic recommendations. As shown by Table 12-2: Bridge Replacement & Emergency Access Prioritization Summary, most bridge replacements were classified as higher priorities for the watershed. The County Road 20.5 and 75th Street bridges were generally ranked as a medium priority based on existing capacity and size. The 95th Street bridge replacement was also ranked as a medium priority due to the newer age of the structure. However, interim improvements at 95th Street, as discussed previously, would be considered a high priority to reduce the frequency of overtopping.

12.3 Public Safety

Public safety oriented improvements are shown below. Prioritization considered the current overall threat to public safety; frequency of concern; and implementation. Higher priority was given to protection of the City of Boulder's sanitary interceptor line and Boulder Slough mitigation, where significant flooding occurred during 2013. High priority was also given to providing inflow and outflow protection for the Bryant Pond in addition to the Williams Reservoir No. 1, in Weld County, which has incurred damage since 2013. Medium priority was given to the remaining gravel pond locations. Low priority was applied to the Boulder Community Health Hospital Access and Cordry Court high hazard mitigation projects, where public safety issues would develop less frequently.

12.4 Maintenance

Maintenance oriented improvements are shown below. Prioritization considered the immediate impact to public and private facilities, trail access, and potential effects on the floodplain elevations.

Table 12-1: Stream Restoration Prioritization Summary

Reach	ID	Stream Restoration Prioritization	Jurisdiction	Priority
		HIGH PRIORITY PROJECTS		
2	G	Stream Restoration Downstream of CO Rd. 16.5	Weld County	High
3	A	Stream Restoration Upstream of CO Rd. 16.5	Weld County	High
4	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space	Boulder County	High
4	G	Stabilize Howell Ditch Diversion System, Modify Diversion for Aquatic and Habitat Passage	Boulder County	High
4	K	Stream Restoration Through Wheeler Ranch	Boulder County	High
7	I	Stream Restoration from Valmont Rd to 61st Street	City of Boulder	High
		MEDIUM PRIORITY PROJECTS		
4	D	Stabilize Bank at Bailey-Kenosha Pond Outlet	Boulder County	Medium
5	F	Stream Restoration Downstream of 95th Street	Boulder County	Medium
5	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail	City of Boulder*	Medium
8	D	Stream Restoration from Foothills Pkwy to BNSF RR	City of Boulder	Medium
		LOW PRIORITY PROJECTS		
1	A	Stream Maintenance and Ecological Enhancements City of Longmont Open Space	City of Longmont / Weld County	Low
2	B	Replace Existing Grade Control for Aquatic and Habitat Passage	Weld County	Low
2	C	Modify Rural Ditch for Aquatic and Habitat Passage	Town of Frederick / Weld County	Low
2	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage	Weld County	Low
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage	Weld County	Low
4	I	Replace Grade Control for Aquatic and Habitat Passage	Boulder County	Low
5	A	Stream Restoration at Alexander Dawson Open Space	Boulder County	Low
5	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage	Boulder County	Low
5	D	Modify Grade Control Structures for Aquatic and Habitat Passage	Boulder County	Low
5	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage	Boulder County	Low
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage	Boulder County	Low
7	C	Modify Diversion for Aquatic and Habitat Passage	Boulder County	Low
7	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage	Boulder County	Low
8	A	Stream Restoration from 55th St. to Valmont Drive	City of Boulder	Low
8	B	Stream Restoration from BNSF RR to 55th St.	City of Boulder	Low
9	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage	City of Boulder	Low
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage	Boulder County	Low
10	B	Boulder Canyon Stream Restoration	Boulder County	Low

* Although located in Boulder County this project is City of Boulder Open Space and Mountain Park managed land and has classified as City of Boulder jurisdiction

Table 12-2: Bridge Replacement & Emergency Access Prioritization Summary

Reach	ID	Bridge Replacement & Emergency Access Prioritization	Jurisdiction	Priority
		HIGH PRIORITY PROJECTS		
2	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	High
4	B	East County Line Road - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	High
4	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge	Boulder County	High
4	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel	Boulder County	High
7	E	61st Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	High
7	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge	Boulder County	High
8	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge	City of Boulder	High
9	C	North of Boulder Creek Access Improvements	City of Boulder	High
		MEDIUM PRIORITY PROJECTS		
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	Medium
5	G	95th St. - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	Medium
6	B	75th Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	Medium

Table 12-3: Public Safety Prioritization Summary

Reach	ID	Public Safety Prioritization	Jurisdiction	Priority
		HIGH PRIORITY PROJECTS		
3	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Weld County	High
7	H	Protect Sanitary Interceptor Sewer	Boulder County	High
9	D	Boulder Slough Mitigation	City of Boulder	High
		MEDIUM PRIORITY PROJECTS		
1	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County	Medium
2	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County	Medium
4	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County	Medium
5	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typical.	Boulder County	Medium
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County	Medium
7	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical	Boulder County	Medium
		LOW PRIORITY PROJECTS		
8	E	Hospital Access Improvements for 500-yr Event	City of Boulder	Low
9	A	Cordry Ct, High Hazard & Flood Mitigation	City of Boulder	Low

Table 12-4: Maintenance Prioritization Summary

Reach	ID	Maintenance Prioritization	Jurisdiction	Priority
		HIGH PRIORITY PROJECTS		
8	F	Sediment Maintenance along Boulder Creek Path	City of Boulder	High
9	F	Sediment Maintenance along Boulder Creek Path	City of Boulder	High
		MEDIUM PRIORITY PROJECTS		
7	G	Modify Butte Mill Ditch Crossing on South Boulder Creek	Boulder County	Medium
		LOW PRIORITY PROJECTS		
4	E	DS of Kenosha Rd. - Remove Washed Out Bridge	Boulder County	Low

12.5 Prioritization by Jurisdiction

Prioritization by jurisdiction is presented below. Overall prioritization in terms of high, medium, or low priorities have also been depicted on the master plan exhibits shown previously.

Table 12-5: Prioritization Summary by Jurisdiction

Reach	ID	Juristictional Prioritization	Jurisdiction	Priority
4	B	East County Line Road - 100-yr Option: Replace Bridge with 220 ft. Span Bridge	Boulder County	High
4	D	Stabilize Bank at Bailey-Kenosha Pond Outlet		High
4	F	Stream Restoration Through Doniphan, Wittemeyer Ponds, Bailey-Kenosha Ponds, and Open Space		High
4	G	Stabilize Howell Ditch Diversion System, Modify Diversion for Aquatic and Habitat Passage		High
4	H	Kenosha Rd. - Replace Bridge with 180 ft. Span Bridge		High
4	J	109th St. - Replace Bridge with 180 ft. Span Bridge; Restore Adjacent Channel		High
4	K	Stream Restoration Through Wheeler Ranch		High
5	C	Protect Boulder Valley Ponds Inlet & Outlet During Storm Flows, Typical.		High
5	F	Stream Restoration Downstream of 95th Street		High
5	G	95th St. - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		Medium
6	B	75th Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		Medium
7	A	Protect Walden Ponds Inlet & Outlet During Storm Flows, Typical		Medium
7	B	Protect Ponds Inlet & Outlet During Storm Flows, Typical		Medium
7	E	61st Street - 100-yr Option: Replace Bridge with 220 ft. Span Bridge		Medium
7	F	Replace Old Valmont Pedestrain Crossing with 180 ft. Span Bridge		Medium
7	G	Modify Butte Mill Ditch Crossing on South Boulder Creek		Medium
7	H	Protect Sanitary Interceptor Sewer		Medium
4	E	DS of Kenosha Rd. - Remove Washed Out Bridge		Low
4	I	Replace Grade Control for Aquatic and Habitat Passage		Low
5	A	Stream Restoration at Alexander Dawson Open Space		Low
5	B	Modify Boulder and Weld County Ditch for Aquatic and Habitat Passage		Low
5	D	Modify Grade Control Structures for Aquatic and Habitat Passage		Low
5	E	Modify Lower Boulder Ditch for Aquatic and Habitat Passage		Low
6	A	Modify Leggett Ditch for Aquatic and Habitat Passage		Low
7	C	Modify Diversion for Aquatic and Habitat Passage		Low
7	D	Modify Green Ditch Diversion for Aquatic and Habitat Passage		Low
10	A	Modify Farmers' Ditch for Aquatic and Habitat Passage		Low
10	B	Boulder Canyon Stream Restoration		Low
7	I	Stream Restoration from Valmont Rd to 61st Street	City of Boulder	High
8	C	BNSF Railroad - Replace Bridge with 180 ft. Span Bridge		High
8	F	Sediment Maintenance along Boulder Creek Path		High
9	C	North of Boulder Creek Access Improvements		High
9	D	Boulder Slough Mitigation		High
9	F	Sediment Maintenance along Boulder Creek Path		High
5	H	Stream Restoration from Upstream of 95th St. to White Rocks Trail		Medium
8	D	Stream Restoration from Foothills Pkwy to BNSF RR		Medium
8	A	Stream Restoration from 55th St. to Valmont Drive		Low
8	B	Stream Restoration from BNSF RR to 55th St.		Low
8	E	Hospital Access Improvements for 500-yr Event		Low
9	A	Cordry Ct, High Hazard & Flood Mitigation		Low
9	E	Modify Boulder Ditches Diversion for Aquatic and Habitat Passage		Low
1	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	City of Longmont / Weld County	Medium
1	A	Stream Maintenance and Ecological Enhancements City of Longmont Open Space		Low
4	C	Protect Gravel Ponds / Town of Erie Reuse Pond / Wittemeyer Ponds Inlet & Outlet During Strom Flows, Typical.	Town of Erie / Weld County / Boulder County	Medium
2	F	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical	Town of Frederick / Weld County	Medium
2	C	Modify Rural Ditch for Aquatic and Habitat Passage		Low
2	E	CO Rd. 16.5 - Replace Bridge with 180 ft. Span Bridge	Weld County	High
2	G	Stream Restoration Downstream of CO Rd. 16.5		High
3	A	Stream Restoration Upstream of CO Rd. 16.5		High
3	B	Protect Gravel Pond Inlet & Outlet During Storm Flows, Typical		High
2	A	CO Rd. 20.5 - Replace Bridge with 180 ft. Span Bridge		Medium
2	B	Replace Existing Grade Control for Aquatic and Habitat Passage		Low
2	D	Modify Idaho Creek Diversion for Aquatic and Habitat Passage		Low
4	A	Modify Godding A. and D. Plumb Ditch for Aquatic and Habitat Passage		Low

13.0 REFERENCES

1. CH2MHill, Report for Boulder Creek Hydrologic Analysis: Phase 2: Boulder Creek above St. Vrain Creek, Colorado Department of Transportation, 2015
2. Summary Report of Private Property and Resident Flood Impact Survey and Analysis, September 2013 Flood Disaster, City of Boulder Utilities Division, December 2014.
3. Sherry Oaks, Floods in Boulder County, Colorado, Boulder County, 1982
4. Greenway's Master Plan, City of Boulder, 2011
5. Phyllis Smith, History of Floods and Flood Control in Boulder, Colorado, City of Boulder, 1987.
6. Metcalf and Eddy, Report to the Boulder Creek Improvement Association upon The Improvement of Boulder Creek, pp. 23-24, 1912
7. Frederick Law Olmsted, Jr., "The Improvement of Boulder, Colorado," a report to the Boulder City Improvement Association, pp. 56, 1910
8. Wright Water Engineers, Inc., Rainfall-Runoff Analysis for the September 2013 Flood in the City of Boulder, Colorado, City of Boulder and Urban Drainage and Flood Control District, October 2014
9. Michael Baker International, St. Vrain Creek Watershed Master Plan, St. Vrain Creek Coalition, 2014.
10. Simons, Li & Associates, Inc., Major Drainageway Planning Study, Boulder Creek - South Boulder Creek Confluence Area, 1984.
11. Boulder County Parks and Open Space, Walden Ponds Habitat Management Plan, Boulder County, 2010.
12. Anderson & Company, Lower Boulder Creek and Coal Creek Open Space Master Plan, Boulder County, 1998
13. U.S. Army Corps of Engineers, Lower Boulder Creek Aquatic Ecosystem Restoration Project, Detailed Project Report and Environmental Assessment, Boulder County, 2011.
14. City of Boulder, The Plan for Boulder's Civic Area, City of Boulder, 2013
15. Anderson Consulting Engineers, Inc., Civic Center Master Plan Flooding Evaluation Memorandum, City of Boulder, 2012
16. Oz Architecture, North of Boulder Creek Master Site Development Plan, Concept Report, University of Colorado, Boulder, 2014
17. U.S. Army Corps of Engineers, Floodplain Information Report, FIR, 1969.
18. Muller Engineering Company, Lower Boulder Creek Flood Hazard Area Delineation, Boulder County, 1983.
19. Muller Engineering Company, Boulder Creek Flood Hazard Area Delineation, City of Boulder, 1983.
20. Federal Emergency Management Agency, Flood Insurance Study and Flood Insurance Rate Maps, Boulder County and Incorporated Areas, 2012
21. Anderson Consulting Engineers, Inc., Hydrology Verification Report for Boulder Creek, City of Boulder, 2009
22. Anderson Consulting Engineers, Inc., Boulder Creek Floodplain Mapping Study, City of Boulder, 2013
23. Gingery Associates, Inc., Floodplain Information Report – Upper Boulder Creek and Fourmile Creek, 1981
24. Colorado Department of Transportation, Final Hydraulics Report SH 52 at Boulder Creek, Boulder County, 2008
25. URS Company, Phase B Preliminary Design Master Plan, City of Boulder and Boulder County, 1979.
26. Boulder County Comprehensive Plan, 2nd Edition, Subsequent Updates, Boulder County 1996.
27. Boulder Valley Comprehensive Plan, City of Boulder, Boulder County, 2010.
28. LiDAR Acquisition for the Flooding in Central and Northern Colorado, Photo Science, USGS, October 2013
29. Anderson & Company Consulting Team. 1998. Lower Boulder Creek and Coal Creek Open Space Master Plan. Prepared by Anderson & Co. Ecoplanning, Queen of the River Fish Co., Inc., Don d'Amico, Plantae Consulting, Carron Meaney, Stephen R. Jones, Native Cultural Services, and Boyle Engineering for Boulder County Parks & Open Space. 62 pp. plus appendices.
30. Bellah, R. G., and L. C. Hulbert. 1974. Forest succession on the Republican River floodplain in Clay County, Kansas. Southwestern Naturalist 19(2):155-166.
31. CNHP 2008. Survey of Critical Biological Resources in Boulder County, Colorado 2007-2008. http://www.cnhp.colostate.edu/download/documents/2009/BoulderCoReportFINAL_6-26-2009.pdf
32. Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, Virginia. Available online at: http://www.natureserve.org/library/usEcologicalsystems.pdf.
33. Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service.
34. CPW. Colorado Parks and Wildlife. 2008. Recommended Buffer Zones and Seasonal Restrictions for Raptors. Available online at: http://wildlife.state.co.us/SiteCollectionDocuments/DOW/WildlifeSpecies/LivingWithWildlife/RaptorBufferGuidelines2008.pdf
35. _____. 2014. Colorado Listing of Endangered, Threatened and Wildlife Species of Special Concern.. Available at http://cpw.state.co.us/learn/Pages/SOC-ThreatenedEndangeredList.aspx
36. _____. 2015. Aquatic Data Request by ERC. Received via e-mail (AndrewTreble@state.co.us). January 26.
37. ELI. Environmental Law Institute. 2003. Conservation Thresholds for Land Use Planners. Washington DC.
38. _____. 2008. Planner's Guide to Wetland Buffers for Local Governments. March.
39. FGDC. Federal Geographic Data Committee. 2008. Vegetation Classification Standard, FGDC-STD-005, Version 2. Washington, DC., USA. Available online: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf.
40. FISRWG. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the US gov't). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. October.
41. Fischer, R. A. 2000. Width of riparian zones for birds. Ecosystem Management and Restoration Research Program Technical Notes Collection, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. www.wes.army.mil/el/emrrp.
42. J. Drake and S.B. Rolfsmeier. 1995. NatureServe Explorer. Association Detail Report: CEGL000659. Populus deltoides - (Salix amygdaloides) / Salix (exigua, interior) Woodland. Available online: http://www1.usgs.gov/csas/nvcs/nvcsGetUnitDetails?elementGlobalId=687120
43. Kittel, G., R. Rondeau, N. Lederer, and D. Randolph. 1994. A classification of the riparian vegetation of the White and Colorado River basins, Colorado. Final report submitted to Colorado Department of Natural Resources and the Environmental Protection Agency. Colorado Natural Heritage Program, Boulder. 166 pp.

44. Kittel, G., E. Van Wie, and M. Damm. 1997a. A classification of the riparian vegetation of the South Platte Basin (and part of Republican River Basin), Colorado. Submitted to Colorado Department of Natural Resources and the Environmental Protection Agency, Region VIII. Prepared by Colorado Natural Heritage Program, Colorado State University, Fort Collins.
45. Montgomery County Planning Commission. 2006. Guidebook for Riparian Corridor Conservation. Available online at: http://www.montcopa.org/DocumentCenter/View/4122
46. Simonin, Kevin A. 2001. Populus angustifolia. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2014, June 6].
47. UDFCD. Urban Drainage and Flood Control District. 2010. Preble's Meadow Jumping Mouse (PMJM), Ute Ladies Tresses Orchid (ULTO) and Colorado Butterfly Plant (CBP) Block Clearances for the Denver Metropolitan Area - Revised 2010. Available online at: http://www.udfcd.org/downloads/pdf/other/Threatened%20Species%20Map.pdf.
48. 2001. Urban Storm Drainage Criteria Manual – Volume 2, Chapter 12 Revegetation. June. Available online at: http://www.udfcd.org/downloads/pdf/critmanual/Volume%201%20PDFs/USDCM%20Vols%201%202%20Dec%202011%20.pdf.
49. Neid, S., J. Lemly, K. Decker and D. Culver. 2009. Final Report: Survey of Critical Biological Resources in Boulder County 2007-2008. Colorado Natural Heritage Program, Fort Collins, CO.
50. NDIS. Natural Diversity Information Source. 2013. Colorado Division of Wildlife, Species Reports & County Occurrence Maps. Available online at: http://ndis.nrel.colostate.edu/wildlife.asp.
51. Rood, S.B., Braatne, J.H., and Hughes, F.M.R. 2003. Ecophysiology of riparian cottonwoods: stream flow dependency, water relations and restoration. Tree Physiology (23): 1113–1124. Available online: http://treephys.oxfordjournals.org/content/23/16/1113.full.pdf
52. Stomberg, J., Tiller, R., Richter, B. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. Ecological Applications 6 (1): 113–131, doi:10.2307/2269558.
53. SWReGAP. 2001. US Geological Survey (USGS) Gap Analysis Program Download Land Cover Data. Southwest Region ESRI GRID File. Available online at: http://gapanalysis.usgs.gov/gaplandcover/data/download/
54. USFWS. US Fish & Wildlife Service. 1992. Interim Survey Requirements for Spiranthes diluvialis. Colorado State Office. November 23, 1992. Available online at: http://www.fws.gov/mountain-prairie/endspp/protocols/UteLadiesTress1992.pdf
55. ____.2004. Preble's Meadow Jumping Mouse Survey Guidelines. Revised April 2004. USFWS Ecological Services Colorado Field Office, Lakewood, CO.
56. ____.2010. Preble's Meadow Jumping Mouse Block Clearance Map for the Denver Metro Area. November 23. Available online at: http://www.fws.gov/mountain-prairie/species/mammals/preble/BLOCK_CLEARANCE/11-23-2010_USFWS_Prebles_Block_Clearance_Map_for_the_Denver_Metro_Area.pdf
57. ____.2010b. Final Environmental Assessment. Designation of Revised Critical Habitat for The Preble's Jumping Mouse in Colorado (Zapus hudsonius preblei). Available online at: http://www.fws.gov/mountain-prairie/species/mammals/preble/CRITICAL_HABITAT/12142010FinalEnvironmentalAssessment2010.pdf . Accessed April 2012.
58. ____.2014. Official Species List. List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project. Consultation Tracking Number 06E24000-2014-SLI-0736. June 19.
59. Williams, C.A. and Cooper D.J. 2005. Mechanisms of Riparian Cottonwood Decline along Regulated Rivers. Ecosystems (8): 1–14. Available online: https://www.clarku.edu/departments/geography/pdfs/Williams_Mechanisms%20of%20Riparian%20Cottonwood.pdf
60. Wright Water Engineers, Inc., Technical Review Guidelines for Gravel Mining and Water Storage Activities Within or Adjacent to 100-year Floodplains, UDFCD, 2013
61. Federal Emergency Management Agency, Benefit Cost Analysis (BCA) Tool, Version 5.0.0.0.
62. Anderson Consulting Engineers, Inc., Boulder Slough Floodplain Mapping Study, City of Boulder, September 2014
63. Anderson Consulting Engineers, Inc., MEMORANDUM – Civic Center Master Plan Flooding Evaluation, City of Boulder, February 2012
64. City of Boulder, Civic Center Master Plan Flood Hazard Issues, Draft – March 15, 2012
65. City of Boulder, The Plan for Boulder's Civic Area, Draft – September 2013
66. AECOM, The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100, Federal Insurance and Mitigation Administration, Federal Emergency Management Agency, June 2013
67. City of Boulder Open Space and Mountain Parks, Grassland Ecosystem Management Plan, 2009
68. Andrews 1984, Bed-Material Entrainment and Hydraulic Geometry of Gravel-Bed Rivers in Colorado, Geological Society of America, Volume 95, June 1984.
69. Earles, Mackenzie, Bennetts, Traylor, Planning for Variability & Uncertainty: Climate Change and the UDFCD Urban Drainage System, May 2015
70. Lukas, Barsugli, Doesken, Rangwala, Wolter, Climate Change in Colorado – A synthesis to Support Water Resources Management and Adaptation, Second Edition – August 2014
71. Borman, M., and L. Larson. 2002. Cottonwood: Establishment, Survival, and Stand Characteristics. EM 8800 Published March 2002.
72. Fischer, R. A. 2000. Width of riparian zones for birds. Ecosystem Management and Restoration Research Program Technical Notes Collection, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. www.wes.army.mil/el/emrrp.
73. Hines, C.A. 1999. Evaluating the Restoration Potential of Black Cottonwood (Populus trichocarpa) from Multiple Scales of Observation, Grande Ronde River Basin, Oregon, USA (M.S. Thesis, Oregon State University, Corvallis, Oregon).
74. Scott, M.L., G.T. Auble, and J.M. Friedman. 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana, USA. Ecological Applications 7:677–690.

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Photo 14: 95th Street flooding, photo courtesy of David Mallory, UDFCD