BEAR CANYON CREEK

FLOOD MITIGATION PLAN

October 17, 2016

Project Sponsors

CITY OF BOULDER

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

CONTENTS

TABLES AND FIGURES

APPENDICES

EXECUTIVE SUMMARY

PURPOSE AND OBJECTIVE

The purpose of this study is to analyze the existing conditions within the Bear Canyon Creek floodplain, develop drainageway planning concepts to mitigate flood damages and prepare recommended flood mitigation improvements including prioritization and costs. This plan will also be beneficial in completing grant applications and securing funding for future projects.

STUDY AREA & PROJECT NEED

The study area and current 100-year floodplain for Bear Canyon Creek, shown on the figure at right, extends just west of city limits downstream to Foothills Parkway.

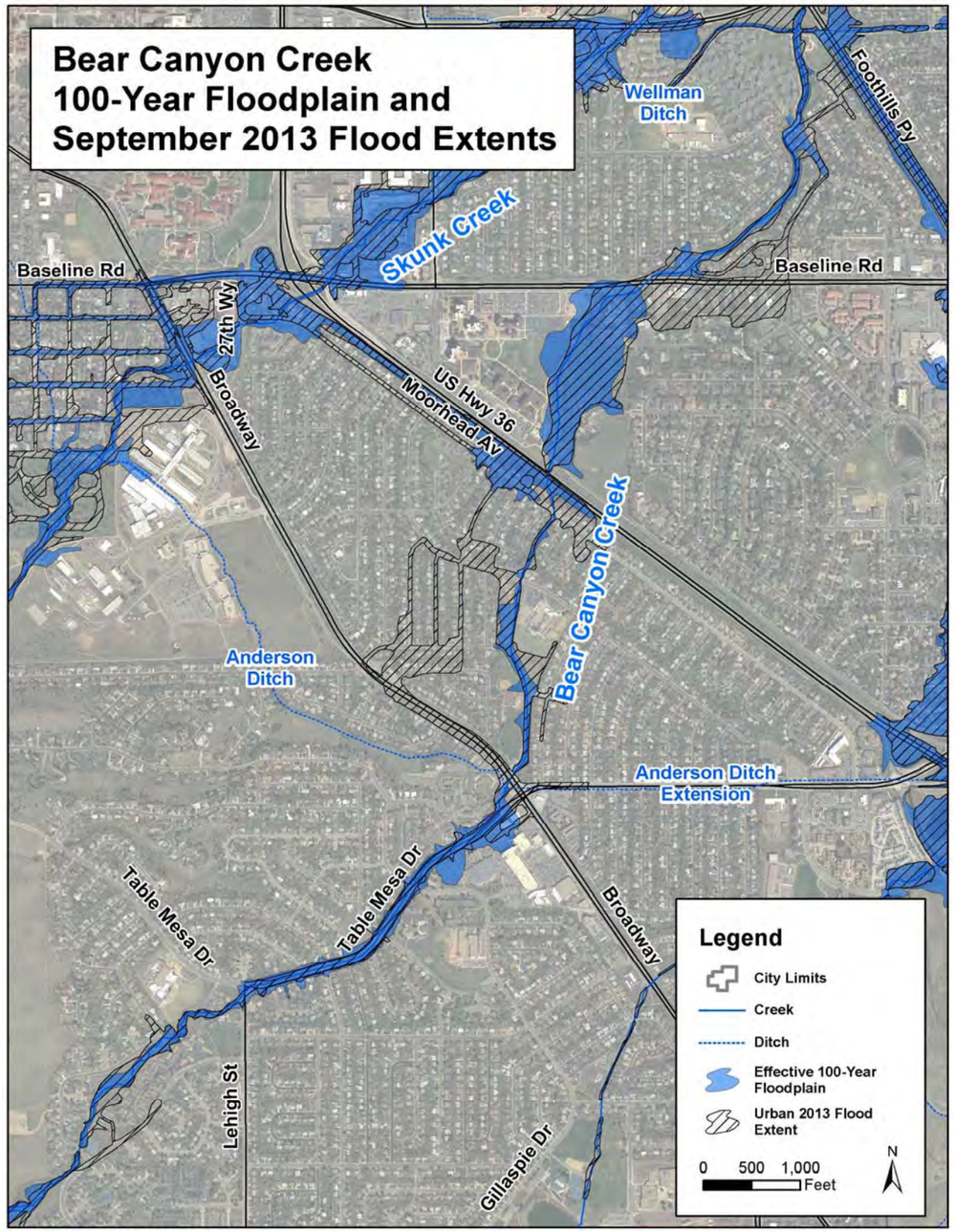
The September 2013 flood brought to light some key issues which contributed to property damage and safety concerns. In general, problems stemmed from areas of hydraulic limitation, in which the creek experienced limited conveyance capabilities, debris blockage or lack of effective flow return zones. Following the 2013 flood, the community expressed a strong desire for flood mitigation improvements along Bear Canyon Creek. Amec Foster Wheeler was selected as the engineering consultant team to help develop flood mitigation alternatives and this mitigation plan.

ALTERNATIVES ANALYSIS

Amec Foster Wheeler analyzed Bear Canyon Creek with several modeling techniques and mitigation opportunities were identified. Improvements were analyzed based on a bookend approach: maintenance measures, such as sediment and debris removal, were evaluated and compared to capital improvements, which included increasing culvert capacities to accommodate the 100-year storm. The final recommended improvements are a combination of maintenance and capital improvements that create the greatest reduction in flood risk.

Amec Foster Wheeler performed a Benefit Cost Analysis (BCA) and calculated a Benefit Cost Ratio (BCR) of 0.02 for the final recommended improvements. It is not uncommon for flood improvement projects to have a BCR of less than 1.0 because the BCR is calculated using financial factors of losses avoided and costs to construct. The higher costs of capital improvements compared to the relatively lower costs to reconstruct residential structures generally yields a lower BCR. FEMA's BCA tool does not completely quantify other social and environmental benefits such as emergency access during a storm event, safer routes to schools, public desire for project completion, reduced flood insurance premiums, water quality, tree canopy, improved habitat and vegetation. However, these other benefits should be taken into account when prioritizing and budgeting flood mitigation projects throughout the city.

Figure 1: Study Area & 100-year Floodplain



RECOMMENDED IMPROVEMENTS

Amec Foster Wheeler and city staff created final recommended improvements that include sediment and debris removal, channel grading and widening, stormwater reconfiguration and increased culvert capacity. The recommended improvements are described in the table below and illustrated on the figure at right:

Table 1: Summary of Recommended Improvements

Recommendation	Cost
Culvert Improvements: Increase culvert capacity at multiple locations along drainageway.	$7,200,000
Channel Improvements: Increase channel capacity to convey the 100-year storm and accommodate new culverts and bridges.	$3,800,000
Channel Maintenance: Remove sediment and debris, clear and grade culvert inlet/outlet	Incorporate into city maintenance plan
Reconfigure Stormwater Outfall: Re-align stormwater outfalls at three locations along drainageway	TBD
Total:	$11,000,000

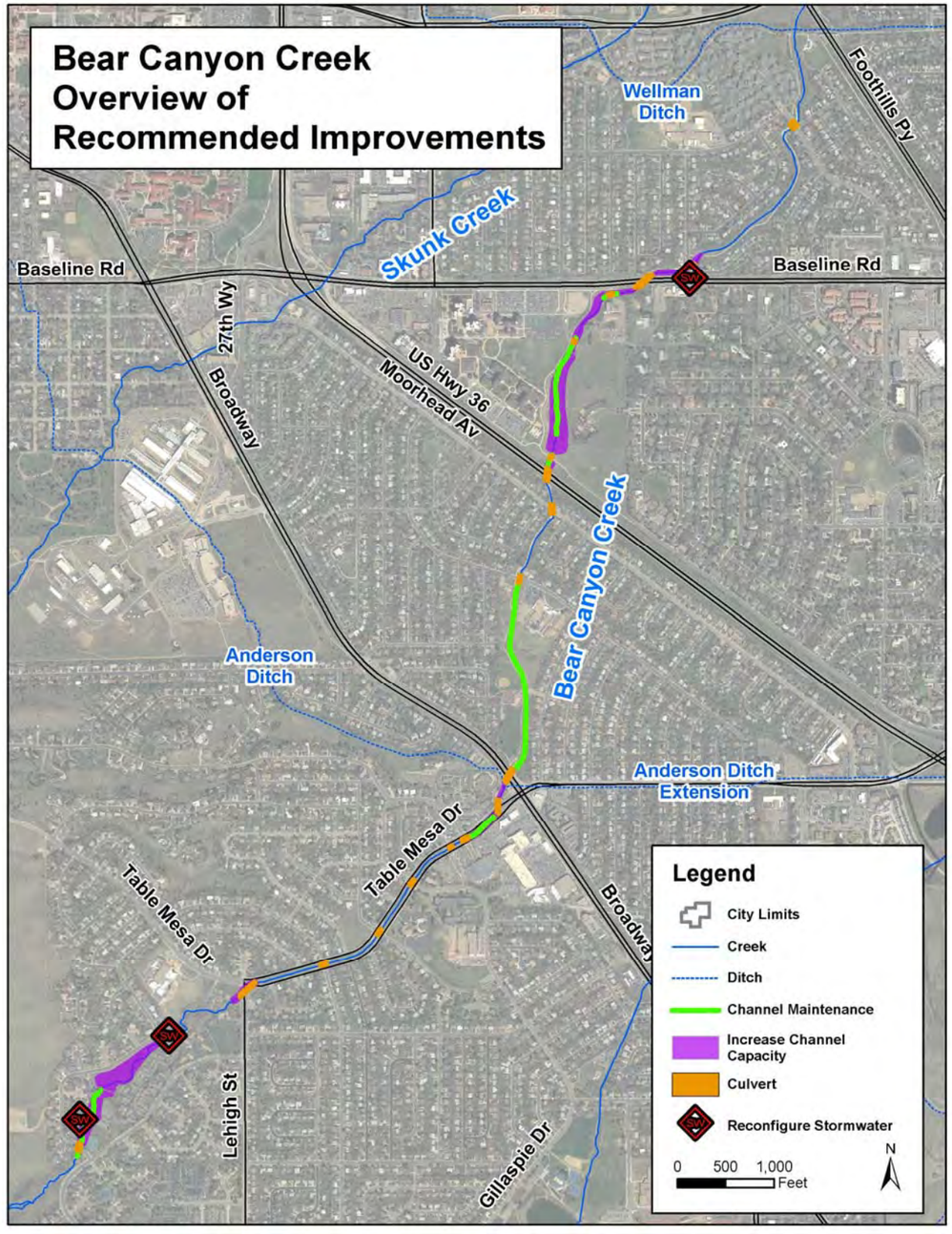
NEXT STEPS & PHASING

Some recommended improvements will undergo public process during the design phase which can include; a Community and Environmental Assessment Process (CEAP), input and recommendation from the Water Resources Advisory Board (WRAB), input and recommendation from other advisory boards such as Planning Board, and City Council. Once design is fully approved, funding for construction can be pursued. There may be opportunity for collaborative funding efforts with transportation projects, the University of Colorado or the Federal Emergency Management Agency (FEMA).

Other recommended improvements can be completed as major maintenance activities, removing rather than replacing infrastructure. These projects include the removal of the Ithaca Drive steel culvert or sediment clearing in the Wildwood Road culvert. The maintenance and vegetation removal schedules for Bear Canyon Creek can also be updated to clear sediment and debris, remove weeds, mow grass and cut trees that threaten to fall into the channel and block flow with greater frequency. The city is currently working on an asset management system to better plan and execute maintenance activities in all the drainageways including Bear Canyon Creek.

It is important to note that the improvements downstream of Baseline Road have priority for design and construction. Gilpin Drive is the main pinch point for the entire downstream section. Without increasing capacity at this culvert, any upstream improvements will cause negative downstream impacts, particularly near Mohawk Drive.

Figure 2: Summary of Recommended Improvements Map



SECTION 1: INTRODUCTION

STUDY AREA DESCRIPTION

Bear Canyon Creek originates in City of Boulder Open Space. From the city limits at Bear Creek Trail to its confluence with Boulder Creek, Bear Canyon Creek is approximately 6.3 miles in length and ranges in elevation from approximately 6170 feet to 5235 feet USGS. The watershed associated with this creek is approximately 5.3 square miles.

West of city limits, the upper part of the watershed is covered with a variety of rock outcroppings and thick soils on bedrock. These sandy composition soils contribute to sediment deposition downstream. Within city limits, the creek generally flows to the northeast through developed neighborhoods, crossing both public and private land. Historically, the area surrounding Bear Canyon Creek within city limits was used for farming and agriculture. These areas have experienced natural springs and shallow groundwater. During the late 1950's and early 1960's, the area was developed for residential use. This urban environment lends itself to increased runoff and higher flow velocities. Although much of Bear Canyon Creek has undergone mitigation improvements to pass 100-year storm events. The development surrounding the drainageway contributes to higher cost for improvements and a lower Benefit Cost Ratio. Please see **Appendix A** for more details on soils, land use, and notable landmarks for the Bear Canyon Creek watershed.

PREVIOUS STUDIES, PLANS & REPORTS

- 1970: Wright-McLaughlin Engineers prepared a Major Drainageway Planning document for South Boulder. This document recommended channel reconstruction primarily from Broadway to Wellman Canal, most of which has been constructed
- 1985: A Master Plan document for Boulder Creek Tributaries was prepared and outlined culvert and stream capacity improvement locations that are included in and expanded upon in this mitigation plan.
- 1985: A Flood Insurance Study (FIS) was conducted that produced detailed hydrologic and hydraulic information for the City of Boulder and its vicinity.
- 1987: Greenhorne & O'Mara, Inc. developed a final Hydrologic Analysis Report that developed a Flood Hazard Area Delineation (FHAD), or the effective 100-year floodplain for Bear Canyon Creek.
- 2004: a functional evaluation of individual wetlands was completed for the City of Boulder. According to the evaluation, the wetlands upstream of Lehigh Street are characterized as relatively high quality riparian corridor. Downstream of Lehigh Street to the confluence with Boulder Creek, the wetlands are described as having lower functional value. Wetland evaluation summaries are included in **Appendix B**.

The Boulder Valley Comprehensive Plan, the Comprehensive Flood and Stormwater Utility Master Plan, the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual and the Greenways Master Plan all contain policies related to floodplain preservation, development, and mitigation and guide flood mitigation master planning. Relevant excerpts can be found in **Appendix C**.

PREVIOUSLY COMPLETED PROJECTS

Several improvements have been constructed on Bear Canyon Creek including:

- 1991: Construction of an underpass at Baseline Road with trail connections to the CU main campus.
- 1992: Trail reconstruction between the Wellman Canal and Mohawk Drive.
- 1993: Trail extension between Mohawk Drive and Gilpin Drive, including riparian habitat widening and restoration, wetland creation, landscaping, the construction of an underpass at Arapahoe Avenue, and a low water crossing downstream of Mohawk Drive.
- 1995: Construction of an underpass beneath Mohawk Drive.
- 1996: Construction of flood capacity improvements, trail connections and underpasses beneath Martin Drive and Moorhead Avenue. In cooperation with the UDFCD, additional flood improvements were completed and a pedestrian and bicycle underpass was added at Gilpin Drive.
- 1998: Modification of Martin Park to provide 100-year flood containment, removing approximately 200 properties from the 100-year floodplain. A pedestrian/bicycle underpass and associated flood improvements were completed at South Broadway.
- 2000: Construction of a path connection 36th Street to the Bear Creek path.
- 2003: Completion of improvements to the levee along Bear Canyon Creek on Harrison Drive and capacity improvements along Foothills Parkway in conjunction with the development of the new hospital site at Foothills and Arapahoe.
- 2004-2006: Plantings on west bank in Martin Park.
- 2007: Construction of a new bicycle/pedestrian underpass and flood mitigation improvements at Foothills Parkway and Arapahoe Avenue.
- 2009: City Council accepted a Letter of Map Revision (LOMR) for Bear Canyon Creek from Foothills Parkway to Boulder Creek. The LOMR was prepared to reflect new mapping, an underpass at Arapahoe Avenue, and improvements to the Harrison Avenue Levee.

FLOOD HISTORY

Bear Canyon Creek, like much of Boulder, is highly susceptible to flash flooding because of its location at the base of the foothills. Significant flooding has occurred over the decades but most recently in September of 2013. During the September 2013 event, the National Oceanic and Atmospheric Association and the National Weather Service reported that precipitation totals in many parts of the Boulder Creek watershed had annual exceedance probabilities of a 1,000-year rainfall event. Wright Water Engineers prepared a "*Rainfall-Runoff Analysis for the September 2013 Flood in the City of Boulder, Colorado*", which was publicly released in September of 2014. According to this study, "the rocky soils and shallow bedrock in the

upper sub-watersheds limit infiltration, and intense periods of rainfall later in the event, when soils were saturated, produced significant runoff and debris flows."

The significant amount of rocks, sediment and debris blocking the culverts along Bear Canyon Creek the extent of flooding in September 2013 was beyond what would be normally mapped for a 25 to 50-year "clear water" flood. To determine runoff during the September 2013 event, Wright Water analyzed the city's inundation mapping which indicated that runoff during the event was generally contained with the 100-year floodplain boundary, with peak flows approaching 50-year levels at Broadway and Table Mesa Drive and further downstream, near Baseline Road, on the order of 25-year levels. The notable exception was Broadway north of Table Mesa Drive, where flows split to the north, flooding some areas in the Martin Park neighborhood that were not mapped in the 100-year floodplain.

It is significant that the Table Mesa Drive channel, which was known to be undersized for major flood events, fared well despite overtopped banks and high flow velocities down Table Mesa Drive. "During the 2013 flood, the Bear Canyon Creek channel and boulder drop structures held up well… several drop structures were damaged and bank erosion exposed a natural gas line; however, Table Mesa Drive remained passable throughout all but the most intense parts of the multi-day flood event" (*A September to Remember*).

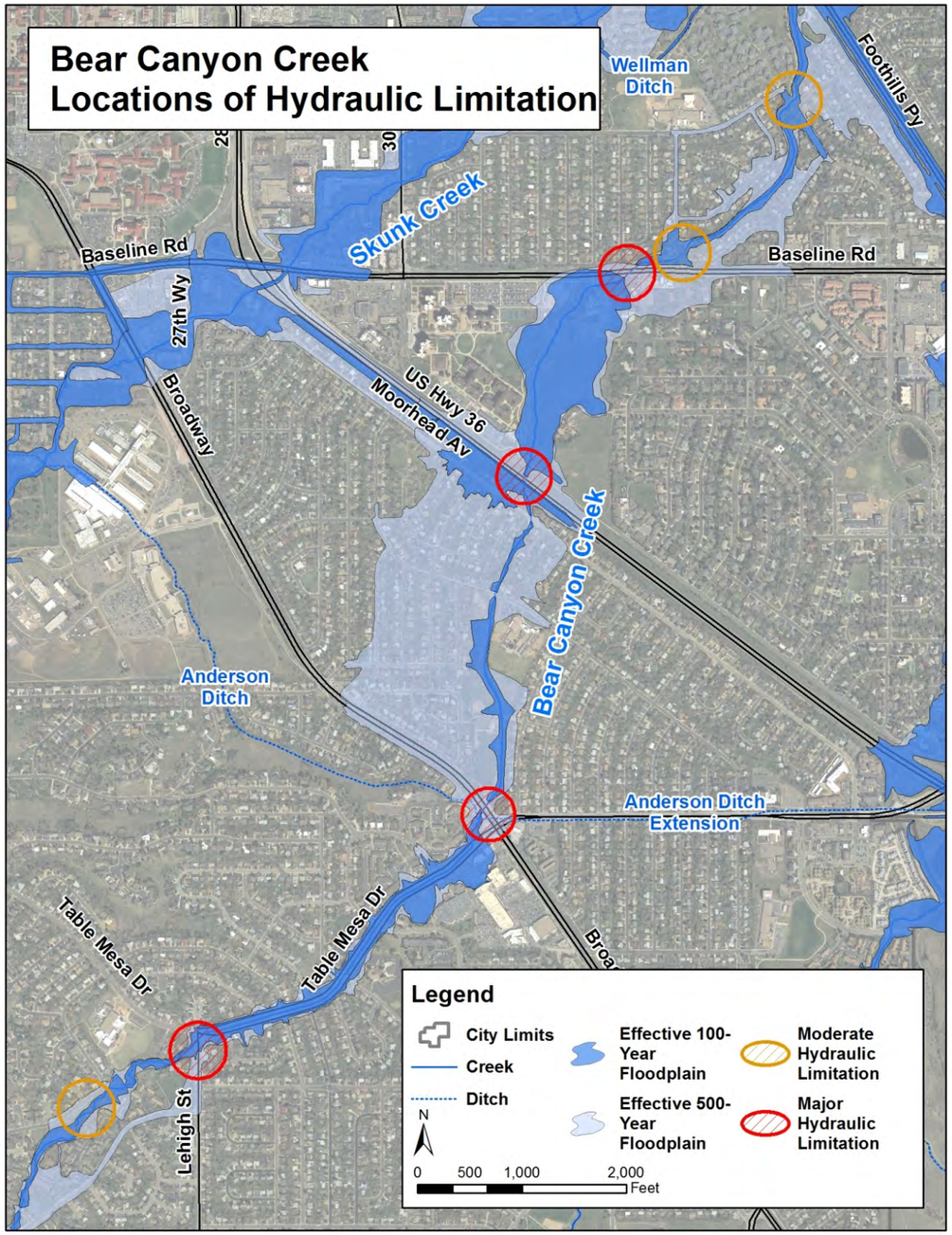
Along the creek, many culverts became partially or mostly clogged with rocks, sediment, and debris which forced the floodwaters to leave the stream banks and flow down the streets. The storm sewer system and sanitary sewer systems were also overwhelmed due to the flood waters and elevated groundwater. The 2013 flood highlighted key pinch points that hydraulically limited the flow capacity of the drainageway. These pinch points are illustrated in the figure on the following page and are the main focus of this mitigation plan's alternative analysis.

After the September 2013 flood, the city commissioned a study to analyze the source of and amount of damage caused by the flood. The results are a compilation of data obtained via an online survey and also of claims submitted to FEMA for reimbursement. In the Bear Canyon Creek watershed, it is estimated that the total amount of damages exceeded just over $18,000,000. The primary sources of damage in the floodplain was a result of major drainageway flooding, flooding from local drainage, and sanitary sewer backups. It is estimated that approximately $1.5M in damage was caused in the 100-year floodplain, $3.5M in damage was caused in the 500-year floodplain, and the remainder was outside of the designated floodplains. (*Summary Report of Private Property and Resident Flood Impact Survey and Analysis, September 2013 Flood Disaster*)

ADDITIONAL DATA COLLECTION

Elevation data for the study area was taken from 2013 Light Detection and Ranging (LiDAR) data that was sponsored by FEMA and collected after the September 2013 flood event. In addition, survey collected as part of previous hydraulic studies or as-built construction drawings was also incorporated in the analysis.

Figure 3: Pinch Point Locations



In the fall of 2015, Amec Foster Wheeler completed an environmental and habitat assessment of Bear Canyon Creek (**Appendix D**). The assessment indicates that certain non-native species negatively contribute to the system function within city limits. Specifically, what is commonly known as crack willow: a tree that easily breaks off twigs and branches with an audible crack. These broken twigs and branches readily take root in waterways, causing increased vegetation and debris in the drainageway. In addition, some of the stream banks are incised with exposed roots and are not conducive to plant growth without additional bank stabilization.

PUBLIC INVOLVEMENT

One open house was held in 2014 and two open houses were held in 2015 to present potential alternatives and to solicit feedback from the public. Information items providing status updates of the Bear Canyon Creek Flood Mitigation Plan were submitted to the Water Resources Advisory Board (WRAB) in April and November of 2015. Comments received at the open house and the WRAB meeting were assimilated and the mitigation plan was further refined based on these comments, where feasible and practical.

Recommended improvements were developed by Amec Foster Wheeler based on the feedback from public meetings, project stakeholders, staff input and preliminary discussions with the WRAB. The recommended improvements work to minimize identified flooding issues along Bear Canyon Creek and includes improvements able to accommodate a 100-year storm event.

A fourth open house was held on June 20, 2016 to present the recommended improvements to the public. That same evening, a presentation was given to the WRAB. Feedback from the WRAB and the public at these meetings was used for final refinement of the recommended improvements.

SECTION 2: CREATION OF THE BEST AVAILABLE INFORMATION MODEL

A complete hydraulic model for the entire reach of Bear Canyon Creek (from city limits to its confluence with Boulder Creek) did not exist at the beginning of this study. Smaller hydraulic models had been developed for segments of Bear Canyon Creek, but did not seamlessly connect as one cohesive model. In order to fully analyze flows and potential improvements in the area of Bear Canyon Creek, a hydraulic model of the entire drainageway was needed.

The city and the UDFCD transferred all available modeling data to Amec Foster Wheeler who developed a "Best Avalable Information" existing conditions model. While refining the Best Available Information model and comparing it to actual inundation areas from 2013, Amec Foster Wheeler and city staff noted the need for further refinement in areas where spill flows occur.

During a major storm event, overtopping of Bear Canyon Creek is present at several major crossings along this creek, creating spill flows that become hydraulically disconnected from the main channel, flow overland through streets and neighborhoods and then rejoin the floodplain downstream. It was determined that the city's current two-dimensional model (FLO-2D) approach to define major flow paths and spill flows should be used. Traditionally, regulatory models are developed in HEC-RAS, which is a one dimensional model that analyzes flow only in the longitudinal direction and represents the terrain in a sequence of cross sections. In two dimensional models, such as FLO-2D, flows are allowed to move in both the longitudinal and lateral directions. FLO-2D is ideal for identifying flow paths that split away from the main channel.

UPDATING HYDROLOGIC DATA

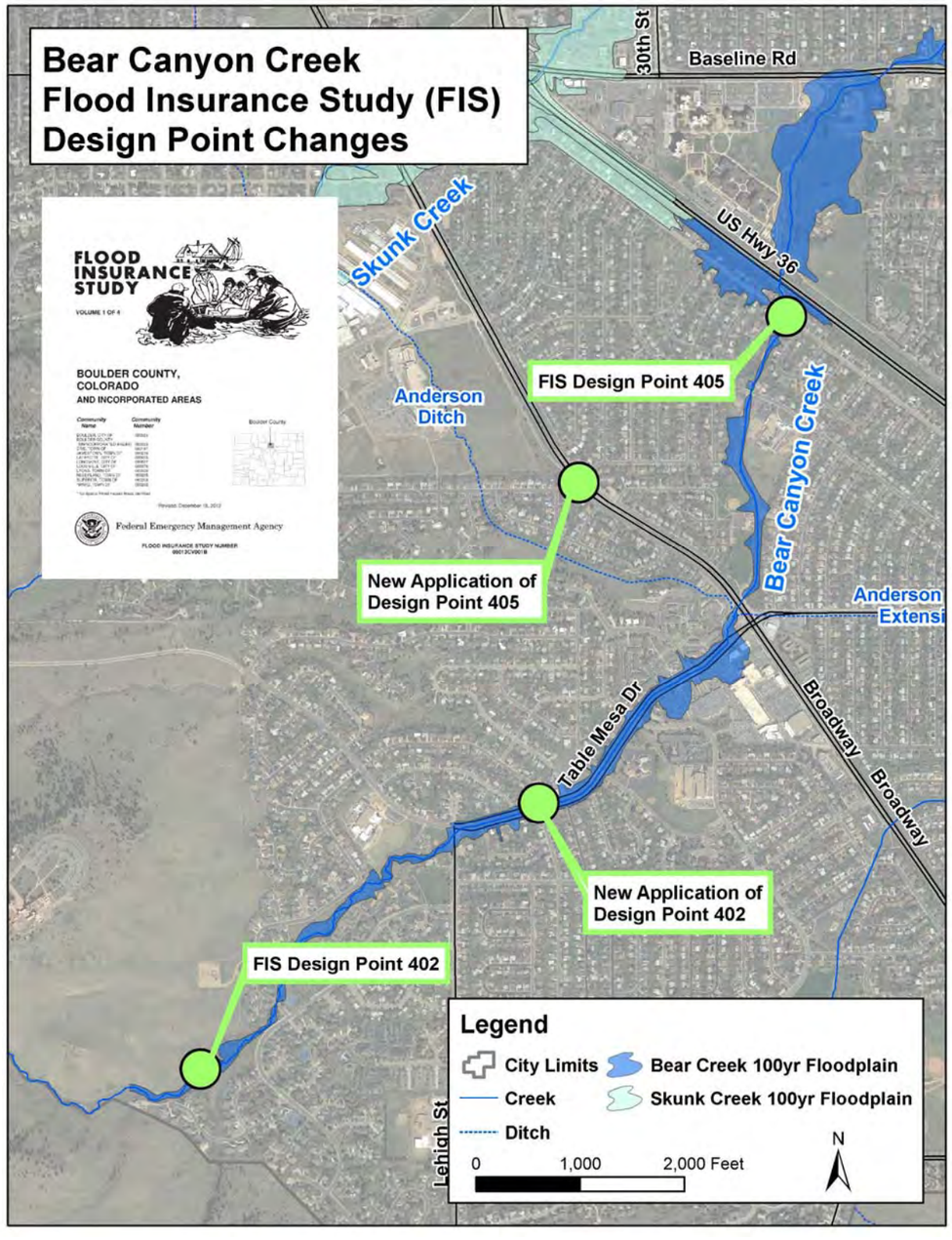
The FLO-2D output did not reflect spill flow paths observed during the September 2013 flood. Adjustments were made to two hydrological design points (shown in the figure at right):

- Design Point 402: peak discharge for this design point (1,600cfs) was originally applied at the upstream limit of the FIS, which yielded highly conservative flows upstream of Lehigh Street. In the Best Available Information model, the original design point application points and values were assigned. Design Point 401 was applied at the upstream limits and was assigned the correct flow of Design Point 402 was applied at Table Mesa Drive and Ithaca Drive, and was assigned the correct flow of 1,600cfs. Design Point 402 was applied at Table Mesa Drive and Ithaca Drive, and was assigned the correct flow of 1,600cfs.

- Design Point 405: peak discharge for this design point (540cfs) was applied near Moorhead Avenue along Bear Canyon Creek and represents of a 240-acre sub-basin near Baseline Road and Dartmouth Avenue. In the Best Available Information model, Design Point 405 was applied at the outlet of its sub-basin.

Staff also questioned whether flows from Skunk Creek, located north and west from Bear Canyon Creek, had any effect on Bear Canyon Creek flows. The effective 100-year flood mapping for these two drainageways shows a branch of Skunk Creek that extends into Bear Canyon Creek along US 36 and

Figure 4:Flood Insurance Study Design Point Changes



Moorhead Avenue. The topography in this area, however, creates a high point between the two creeks, indicating that this connection arm is not caused by overflow of either drainageway. The flooding experienced in this area is most likely due to surface runoff from Design Point 405 (mentioned above), located near Dartmouth Avenue.

UPDATING HYDRAULIC DATA

The 1987 FHAD, which established the original limits of flooding for Bear Canyon Creek, utilized a range of blockage values but did not give any explanation for them. The Lehigh Street and Broadway culverts were set at seventy-five percent, while the crossings along Table Mesa Drive were set at fifty percent, for example. Existing culvert blockages were determined by culvert size and location, but also through several field reconnaissance trips to assess existing culvert conditions.

Fifteen of the creek crossings carry traffic, and all were considered to be culverts from a hydraulic perspective. The four pedestrian bridges were considered to be clear spans with minor constrictions caused by their abutments, and were assumed to have no blockage for the purposes of hydraulic modeling. The two low flow crossings, a 60-inch steel pipe installed at Ithaca Drive between Lehigh Street and Wildwood Road and a pair of 18-inch culverts which cross Bear Canyon Creek on the CU Campus north of US 36, were assumed to be completely blocked during a significant event. Also, city staff directed Amec Foster Wheeler to use a minimum blockage of 15% in other culverts throughout the drainageway where feasible.

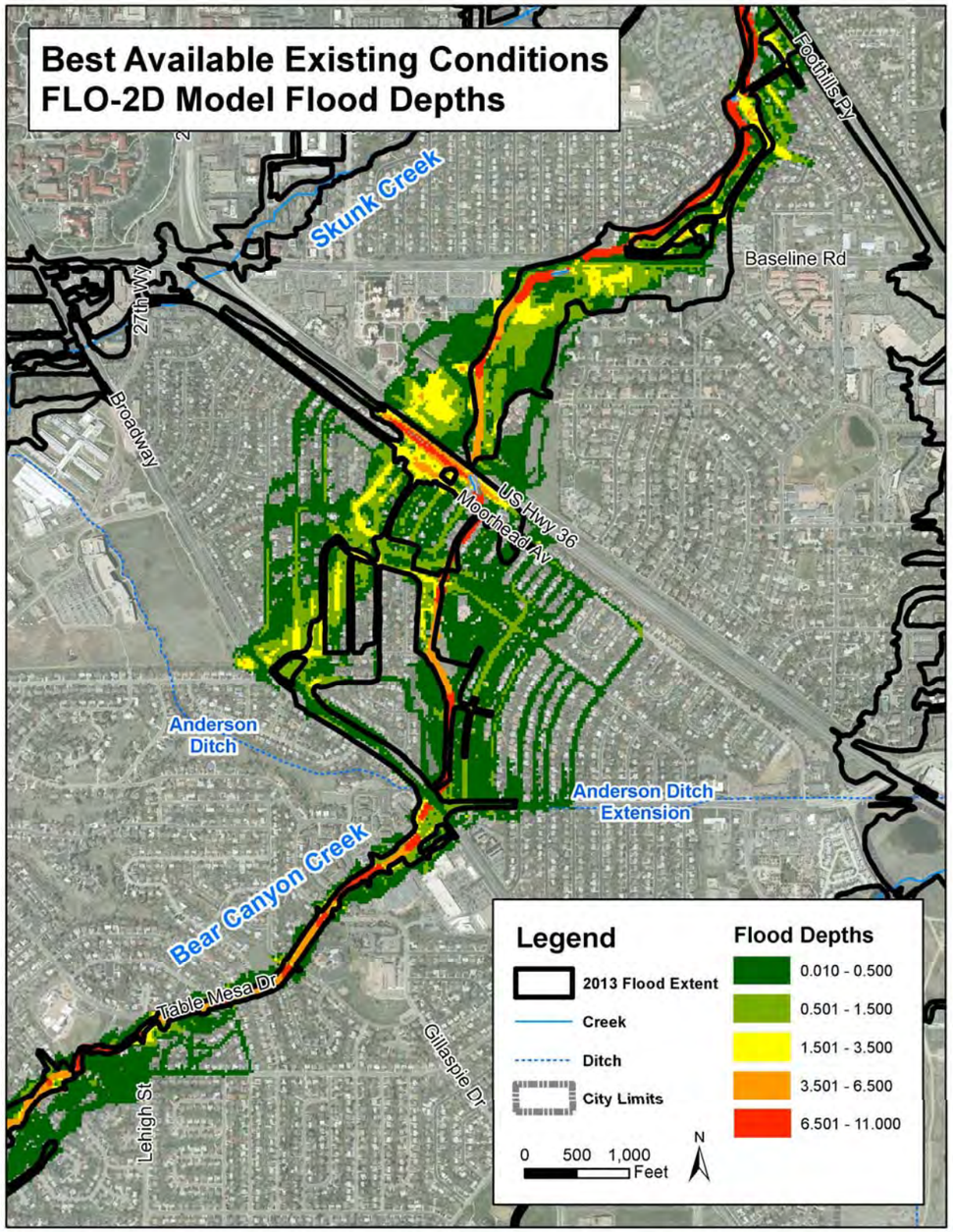
The blockages for the crossings were updated in the Best Available Information model to reflect the conditions identified in the field and was used as the baseline hydraulic condition for this analysis. The assumed existing blockage values compared to the original FHAD blockage values can be found in **Appendix E**. Manning's n-values were adjusted based on the surrounding land use and are listed in the table below:

Table 2: Manning's n-values

Land use Description	Manning's n Value
Residential	0.20
Forested	0.10
Forested, Dense Brush	0.09
Forested, Sparse	0.08
Landscaping, Light Brush	0.06
Scattered Brush	0.04
Pasture, no brush, short grass, open space	0.03
Streets	0.013

In general, the FLO-2D model confirmed regulatory model flood extents while identifying spill flows similar to what was observed during the September 2013 storm event. The FLO-2D model also confirmed the areas to focus efforts for the mitigation plan.

Figure 5: FLO-2D Model Output Compared to 2013 Flood Extents



SECTION 3: ALTERNATIVE ANALYSIS

City staff and Amec Foster Wheeler analyzed alternatives based on a bookend approach, evaluating the least costly mitigation (maintenance) and the costliest (increase culvert capacity at major intersections to accommodate the 100-year storm). The recommended improvements are a combination of the maintenance and capital improvement alternatives and include sediment and debris removal, channel grading and increased culvert capacity.

MAINTENANCE ALTERNATIVE

A maintenance alternative was created and input into the FLO-2D model for analysis. Maintenance activities included sediment and debris removal within the culverts and their surrounding channel area as well as vegetative thinning of invasive species to eliminate potential debris generation. The maintenance alternative assumed an initial overhaul of the channel and culverts with recurring annual maintenance at higher blockage locations (such as Lehigh Street) and recurring maintenance based on need in other locations. The city performs an annual inspection of all drainageway infrastructure which collects required culvert maintenance activities and the city's future asset management software will help coordinate activities with city maintenance teams. The maintenance alternative did not include any structural improvements to the channel such as grading or widening, and did not include any upsized culverts.

FLO-2D model output for the maintenance alternative followed the same general flow path as the existing regulatory model run, but resulted in more shallow flooding. A map of the FLO-2D output can be found in **Appendix F** as well as a summary table, prepared by Amec Foster Wheeler, displaying the existing and maintenance condition culvert blockages.

The maintenance alternative does not convey the 100-year storm throughout the channel and key pinch point areas remain. Although maintenance will be a part of the recommended alternative, maintenance alone is not enough to mitigate flood risk. This alternative removes 12 structures from flood risk with the most benefit corresponding to the reach 3B, between Baseline Road and Foothills Parkway as described in the graph on the following page.

The maintenance alternative highlighted culverts where upsizing is necessary to mitigate risk. To understand the impacts of increasing culvert capacities, a capital improvements alternative, which included new culverts to pass the 100-year storm event, was created and analyzed.

CAPITAL IMPROVEMENT ALTERNATIVE

A capital improvement alternative, which increased culvert and channel capacity to pass the 100-year storm event, was created and analyzed. The capital improvement alternative included the previously established maintenance alternative.

Each major culvert was isolated for evaluation to determine which improvement areas would provide the most significant positive impact to the remainder of the stream. When all culvert improvements were analyzed together, the total structures removed from risk (22) totaled higher than the maintenance run (12). However, the capital improvement alternative also added 10 structures to the 100-year floodplain in Reach 3B, north of Baseline Road.

Originally, Reach 3B was not a part of this mitigation plan. Upon running the 100-year improvement alternative, however, it was discovered that the culvert at Gilpin Drive was a major pinch point and negatively impacted structures downstream. These 10 structures would be added to the flood risk because opening up and expanding culverts upstream allows for higher flows to traverse down the channel. Without corresponding channel improvements and sediment/debris maintenance, or increased capacity at the Gilpin Drive culvert, the flows collect and pool at the low topography located near Pitkin Drive. This model run prompted staff to include Gilpin Drive in the recommended alternative.

The final analysis indicated Baseline Road and Gilpin Drive culverts as the primary hydraulic limitation points for Bear Canyon Creek north of US 36. Improvements at these two culverts and surrounding channel area need to be combined with improvements in Reach 3A (between US 36 and Baseline Road) in order to provide a 100-year flood mitigation benefit for the entire drainageway.

A map of FLO-2D model output for this alternative can be found in **Appendix F.**

SECTION 4: RECOMMENDED IMPROVEMENTS

DEVELOPMENT

Both the maintenance and capital improvement alternatives concluded that neither maintaining nor upsizing culverts alone is enough to mitigate risk. A combination of these two alternatives was needed. The recommended improvements are a combination of channel grading, debris and sediment removal and increasing culvert capacities. The recommended improvements are based on responding to and rectifying the issues highlighted during the 2013 flood and considers benefits to property, life safety, and cost effectiveness. Most of the recommendations are located on city owned property or right of way, with the exception of the University of Colorado (in Reach 3A). The table at right describes the recommendations and associated costs. A map of these improvements can be found in **Appendix G**.

RESULTING FLOODPLAIN & BENEFITS

The recommended alternative improvements were input into FLO-2D and the resulting floodplain depths were analyzed. A figure of the FLO-2D model output results can be found in **Appendix G**. The Best Available Information Model highlights areas of flood risk not previously identified in the current 100-year floodplain. Where the current 100-year floodplain identifies approximately 35 structures within its bounds, the Best Available Information Model identifies 477 primary structures of which 194 would potentially sustain damage (the majority of which are located in the area between Broadway and Moorhead Avenue). The recommended improvements would reduce the number of primary structures in the Best Available Information Model from 477 to 288 and would reduce the number of potentially damaged primary structures from 194 to 154.

Amec Foster Wheeler performed a Benefit Cost Analysis (BCA) utilizing FEMA's BCA tool. The Best Available Information model output was used for existing conditions and the recommended alternative model output was used for future conditions. The recommended alternative was determined by utilizing a loss analysis spreadsheet, originally developed by FEMA Region VIII and modified by Amec Foster Wheeler to summarize flood impacts associated with multiple structures for input into the BCA tool. The screening level loss analysis allowed for the determination of the alternatives that resulted in the greatest losses avoided. The BCA tool was then utilized to calculate the final benefit cost ratio or BCR.

FEMA's BCA tool compares the difference in the damages from the existing and future conditions (post project) floodplains and compares the costs associated with the improvements needed to lessen impacts to structures. The BCA tool also annualizes the damages from the 50, 100 and 500-year events and incorporates maintenance costs over the useful life of the project, which assumed the FEMA default value of fifty years. This process yields a final BCR. Many flood mitigation projects do not always receive a high BCR, particularly if there is minimal risk to the 50-year or more frequent events, which is generally the case along the Bear Canyon Creek corridor. Structure damage under existing conditions along Bear Canyon Creek is generally associated with shallow flooding, and due to the highly urbanized nature of the drainageway, it was not possible to completely eliminate all residual flood risk, even with the recommended

Table 3: Recommended Improvements by Reach

Reach	Location	Recommendation	Estimated Cost
Reach 1	Wildwood Road	Remove sediment in culvert, including gravel bars and vegetation blocking inlet and outlet	**work completed by UDFCD*
	Wildwood Road	Grade channel and widen floodplain from Wildwood Road to Ithaca Drive	$467,000
	Ithaca Drive	Remove steel culvert and grade channel in conjunction with stormwater improvement project at Ithaca Drive	$47,000
Reach 2A	Lehigh Street	Increase culvert size to 7.5ft x 28ft concrete box	$1,454,000
	Table Mesa Drive	Remove sediment in culverts at Ithaca Drive, Yale Road, Gillaspie Drive and Stanford Avenue including gravel bars and vegetation blocking inlet and outlet	$25,000 (each)
	Stanford Avenue	Increase channel capacity from Stanford Avenue to Harvard Lane	$307,000
	Harvard Lane	Increase culvert size to (2) 7.5ft x 10ft concrete boxes	$711,000
Reach 2B	Broadway	Modify inlet conditions to increase capacity	$67,500
	Broadway	Sediment and debris removal from Broadway to Martin Drive	$1,057,000
	Martin Drive	Continue good maintenance	-
Reach 3A	Moorhead Avenue	Continue good maintenance	-
	US 36	Increase culvert size to (2) 8.5ft x 14ft concrete boxes and reconfigure pedestrian separator wall in underpass and grade multi-use path and channel downstream to improve the inlet and outlet condition	$950,000
	US 36 to CDOT right of way	Increase channel capacity and reconfigure multi-use path	$30,600
	University of Colorado	Increase channel capacity in conjunction with CU Master Plan	$1,584,000
	Upstream of Church	Increase channel capacity	$56,000
	Saint Andrew Church	Replace culverts with 40ft driveway bridge	$493,000
	Downstream of Church	Increase channel capacity	$52,000
Reach 3B	Baseline Road	Increase culvert size to (2) 7.5ft x 28ft concrete box	$2,730,000
	Gilpin Drive	Increase channel capacity near Gilpin Drive	$102,000
	Gilpin Drive	Increase culvert size to (2) 8ft x 20ft concrete boxes	$785,000
	Mohawk Drive	Continue good maintenance	-
		TOTAL	**$11,000,00**

improvements. The higher costs of flood mitigation improvements in an urbanized environment also contributes to the lower BCR.

The final BCR for the recommended improvements is 0.02. Reducing losses to residential structures was the primary benefit analyzed; factoring in benefits to city infrastructure, roadways, emergency vehicle access, and life safety could result in a much improved BCR and is a noted limitation of this analysis. While these benefits are not accounted for in the BCA, it should be noted that the recommended alternative provides additional benefits, such as:

- Safer emergency access on Table Mesa Drive and Broadway during a major storm event, including safer emergency access to Bear Canyon Creek Elementary,
- Partnership and coordination with CU that allows for greater flood control measures on CU property,
- Safer multi-use underpass configurations, and
- Safer access on Baseline Road for emergency vehicles during a major storm event.

Amec Foster Wheeler's flood loss estimation calculations can be found in **Appendix H**.

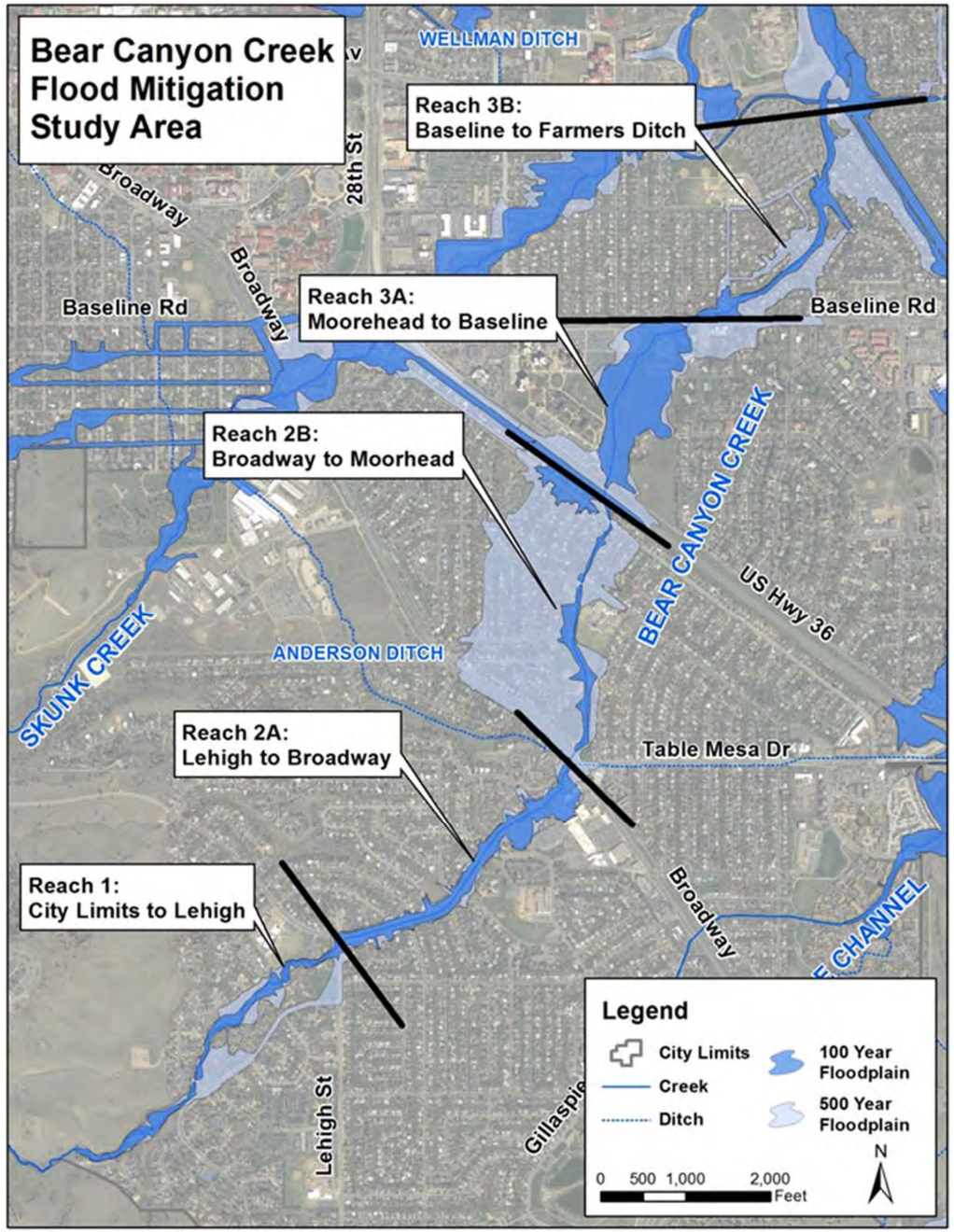
RECOMMENDED IMPROVEMENTS BY STUDY REACH

The drainageway was divided into five reaches described below and illustrated on the figure at right.

- Reach 1: City Limits to Lehigh Street
- Reach 2A: Lehigh Street to Broadway
- Reach 2B: Broadway to Moorhead Avenue
- Reach 3A: Moorhead Avenue to Baseline Road
- Reach 3B: Baseline Road to Wellman Ditch

Recommended improvements for each reach are detailed in the following pages. A map of all recommended improvements is located in **Appendix G.**

Figure 6: Study Reaches



REACH 1: UPSTREAM CITY LIMITS TO UPSTREAM OF LEHIGH STREET

There are two culverts in Reach 1 located at Wildwood Road and Ithaca Drive.

Culvert R1-1: Concrete Box Culvert at Wildwood Road

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 7' x 12'	12	Box	100	74%
Maintenance	(2) 7' x 12'	12	Box	100	100%

During the September 2013 flood, the Wildwood Road culvert became almost entirely blocked by sediment. The flood waters pooled upstream of the culvert until they overtopped Wildwood Road. Maintenance of this culvert, including removal of sediment in the culvert, gravel bars and vegetation blocking the inlet and outlet was performed by UDFCD in 2016. Similar maintenance should be repeated every 2 to 5 years. The city owns a 20-foot access easement on the upstream side of the culvert that allows maintenance vehicles access.

Culvert R1-2: Steel Pipe Crossing at Ithaca Drive

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	5' Diameter	5	Steel Pipe	16	0%
Remove	Remove steel culvert and grade channel in conjunction with stormwater improvement project at Ithaca Drive			100	100%

The existing steel pipe was originally used as a farmer's crossing over the creek. Today, it acts as a social trail for the community. In major storm events, the steel pipe completely clogs with debris and creates high erosion impacts downstream. After the 2013, flood the steel pipe was cleaned and repaired, but the next heavy rain event in the summer of 2014 eroded the repair. The city owns the property where the culvert is located and there are no access issues. A stormwater reconfiguration project is planned for Ithaca Drive and the outfall located upstream of the steel culvert. The steel culvert removal would be more cost effective and cause less disruption to stream and neighborhood activities if completed in conjunction with the Ithaca Drive stormwater project.

Culvert R1-2: Ithaca Drive Steel Pipe

Reach 1: Channel Improvements & Stormdrain Reconfiguration

Location	Improvement	Length (ft)	% of 100-year Storm
Wildwood Road Culvert	Grade channel and widen floodplain downstream of culvert	760	100%
Bear Condominiums	Reconfigure stormdrain	n/a	n/a
Ithaca Drive	Reconfigure stormdrain	n/a	n/a

The channel downstream of Wildwood Road is shallow with dense vegetation and trees. Widening the floodplain bench, deepening the low flow channel area, and removing nuisance trees and sediment deposits from the floodplain will greatly increase the channel's capacity. Stabilizing channel banks, specifically on the south side of the creek, will work to protect property owners in that area.

A storm drain at the US National Center for Atmospheric Research (NCAR) property outfalls into the creek opposite of Bear Condominiums, downstream of Wildwood Road, and deposits sediment directly into the channel. The re-alignment of this storm drain, by pointing the outfall parallel to creek flows instead of perpendicular, should be considered during the design phase of these channel improvements.

The channel in this area is on city owned property and there are no access issues.

REACH 2A: LEHIGH STREET CULVERT TO UPSTREAM OF BROADWAY

Bear Canyon Creek exits Lehigh Street culvert into the center median of Table Mesa Drive where it passes through numerous culverts until it re-joins the multi-use path and crosses under Broadway. Table Mesa Drive to Lehigh Street is a primary access route for Bear Canyon Creek Elementary School and Mesa Elementary School. Construction of improvements should occur during the summer months so as not to disrupt students' school commute.

Culvert R2-1: Concrete Box Culvert at Lehigh Street

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 4' x 8'	16	Box	191	9%
Replace	(1) 7.5' x 28'	28	Box	191	100%

The 4-foot high openings for the Lehigh Street culvert are easily blocked with debris and difficult for maintenance crews to enter. During the September 2013 flood, the Lehigh Street culvert became entirely blocked by sediment and the flood waters overtopped Lehigh Street and Table Mesa Drive. The city owns an access easement upstream of the culvert and right of way downstream for construction and maintenance access.

Culvert R2-2 to R2-5: Box Culverts on Table Mesa Drive

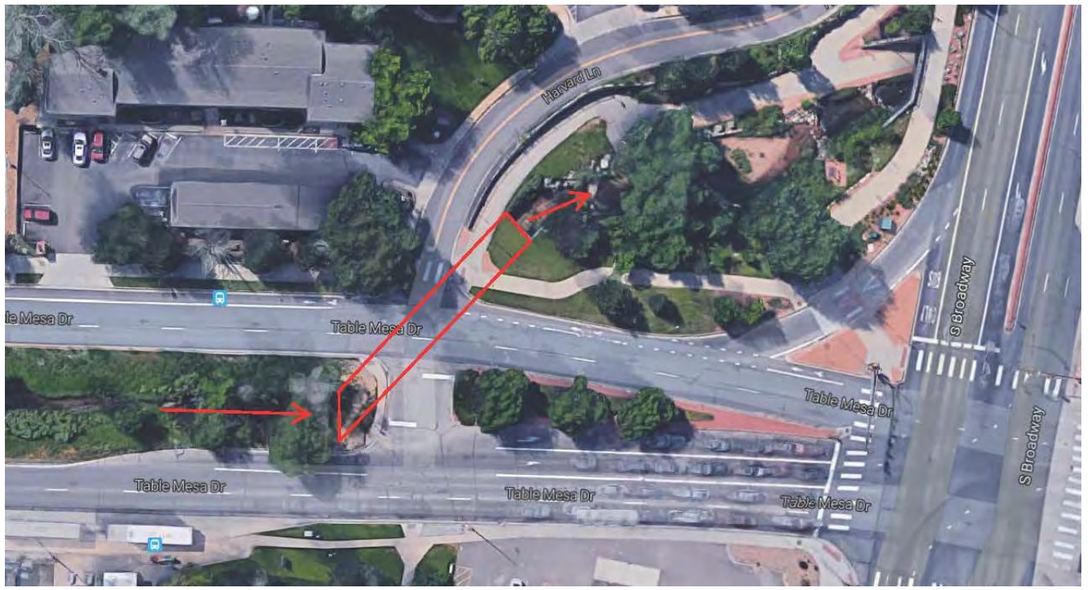
Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 4' x 8'	16	Box	60	20%
Maintenance	(2) 4' x 8'	16	Box	60	30%

From Lehigh Street, Bear Canyon Creek flows north and east along the center of Table Mesa Drive where it passes through four culverts at Ithaca Drive, Yale Road, Gillaspie Drive and Stanford Avenue. These culverts act as roadway crossings over the drainageway and are sized for approximately a 10-year storm event. However, the roadway itself is designed to carry 100-year storm events and conveyed flood waters during the September 2013 flood event. The culverts are located in the median of Table Mesa Drive. There are no access issues.

Culvert R2-6: Box Culvert at Harvard Lane

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 4.5' x 8'	16	Box	116	15%
Replace	(2) 7.5' x 10'	20	Box	116	100%

The existing culvert at Harvard Lane needs to be replaced with a larger capacity culvert in order to pass a 100-year storm event. During the design phase of this culvert, it is highly recommended to review the inlet and outlet conditions for reconfiguration. The current angle from Table Mesa Drive to the Broadway underpass could be less acute and create a smoother transition with less overtopping at Harvard Lane. The upstream portion of this culvert is on city right of way and the downstream portion is located on city property. There are no access issues.



Harvard Lane Existing Culvert Configuration

Reach 2A: Channel Improvements

Location	Improvement	Length (ft)	% of 100-year Storm
Stanford Avenue to Harvard Lane	Grade channel and widen floodplain to create better inlet conditions at Harvard Lane culvert.	822	100%

REACH 2B: BROADWAY TO UPSTREAM OF MOORHEAD AVENUE

From Harvard Lane, Bear Canyon Creek passes under Broadway alongside a multi-use path and extends north through Martin Acres Neighborhood and Martin Park.

Culvert R2-7: Concrete Underpass at Broadway

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	7.5' x 23'	23	Box	83	58%
Reconfigure	Reconfigure inlet	23	Box	83	100%

Culvert R2-7: Broadway Underpass

In order to pass 100-year storm events at Broadway, an additional foot of rise is required in the culvert. This additional rise can be acquired by modifying the existing wingwalls and should be analyzed in greater detail at the time of design. The culvert in located on city owned property and there are no access issues.

Culvert R2-8: Box Culvert at Martin Drive

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	7.5' x 24' multi-use underpass 6.5' x 7.5' channel	31.5	Box	62	81%
No Improvement					

Culvert R2-8: Martin Drive

The underpass at Martin Drive was constructed in 1996 and has held up well in previous large-scale storm events such as September 2013. No capacity increases are recommended for this culvert. However, the roadway at Martin Drive directly above the underpass should be noted as having a low topographic point at approximately Martin Drive and 35th Street. Surface nuisance drainage flows away from the creek and the street could be re-graded to direct flows back towards the creek and off of street surfaces.

Reach 2B: Channel Improvements

Location	Improvement	Length (ft)	% of 100-year Storm
Broadway to Dartmouth Avenue	Remove sediment and debris, channel mowing, boulder edging and channel modification	1942	100%

REACH 3A: MOORHEAD AVENUE TO UPSTREAM OF BASELINE ROAD

From Moorhead Avenue, Bear Canyon Creek passes under US 36 and extends north through University of Colorado property towards Baseline Road.

Culvert R3-1: Concrete Underpass at Moorhead Avenue

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	7.5' x 24'	24	Box	120	61%
No Improvement					

The underpass at Moorhead Avenue has performed well during previous storm events. The Best Available Information model indicates that if downstream improvements are in place, any upstream improvements will not create additional damage at Moorhead Avenue or downstream. The culvert is located on city owned property and there are no access issues. No improvements are recommended at this time.

Culvert R3-2: Concrete Underpass at US 36

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 7' x 14'	28	Box	112	22%
Increase capacity and remove pedestrian separator wall	(2) 8.5' x 14'	28	Box	112	100%

At the US 36 culvert, the pedestrian underpass and drainageway are separated upstream and downstream by a rock separator wall (shown in photo below). The separator wall prevents flows from the multi-use path from entering the channel, creates ponding on the path and effectively cuts capacity of this culvert in half. In addition to increasing culvert capacity, removing the pedestrian separator wall and grading the inlet and outlet conditions for the creek and path would allow greater flows to pass through this culvert unencumbered. Pedestrian and creek separation and safety will be addressed during the design phase. It is anticipated that the multi-use path will carry some flow during smaller events such as a 2-year storm. The culvert in located on city right of way and there are no access issues.

Culvert R3-2: Underpass at US 36

Culvert R3-3: Steel Pipe Culverts at Saint Andrew Church Driveway

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 43" x 68"	12.5	Elliptical	40	0%
Replace	Driveway Bridge	40	Bridge	40	100%

Culvert R3-3: Saint Andrew Church Driveway

The driveway culverts at Saint Andrew Presbyterian Church are undersized and become completely blocked during flood events. During the September 2013 flood event, waters passed over the driveway, peeling away asphalt and blocking main access to the church from Baseline Road. Removing these culverts and replacing with a driveway bridge will alleviate the hydraulic limitation and allow larger storm event flow to pass more easily through this area. The culvert in located on private property and an easement agreement will be needed.

Reach 3A: Channel Improvements

Location	Improvement	Length (ft)	% of 100-year Storm
US 36 to CDOT Right of Way	Increase channel capacity and re-grade multi-use path	142	100%
CU Property	Increase channel capacity in conjunction with CU Master Plan	2004	100%
Church Property (upstream of driveway)	Mowing, grading, edging with boulders and channel widening	56	100%
Church Property (downstream of driveway)	Mowing, grading, edging with boulders and channel widening	94	100%

REACH 3B: BASELINE ROAD TO UPSTREAM OF FOOTHILLS PARKWAY

Bear Canyon Creek crosses under Baseline Road and then through culverts at Gilpin Drive and Mohawk Drive. The drainageway then passes over Wellman Ditch, past Foothills Parkway and confluences with Boulder Creek near the intersection of Arapahoe Avenue and Foothills Parkway.

Culvert R3-4: Concrete Underpass at Baseline Road

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	(2) 7' x 12'	25	Box	186	27%
Replace	(2) 7.5' x 28'	56	Box	186	100%

Culvert R3-4: Underpass at Baseline Road

The underpass and culvert at Baseline Road are at an acute angle that can be uncomfortable for multi-use path users and do not pass 100-year storm flows. This culvert should have increased capacity and a wider angle in the path that can provide improved line of sight for users. The culvert in located on city right of way and there are no access issues.

Culvert R3-5: Concrete Underpass at Gilpin Drive

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	7' x 20'	20	Box	51	43%
Replace	(2) 8' x 20'	40	Box	51	100%

The culvert at Gilpin Drive is a major pinch point for the entire Bear Canyon Creek drainageway. Increasing capacity at this location will allow for improvements upstream to take place without increasing damage downstream. Gilpin Drive is also a heavily used secondary access for High Peaks Elementary School and construction should occur during the summer months to prevent disruption of students' school commute.

Culvert R3-6: Concrete Underpass at Mohawk Drive

Improvement	Size	Width (ft)	Shape	Length (ft)	% of 100-year Storm
Existing	7' x 20'	20	Box	72	41%
No Improvements					

The underpass at Mohawk Drive has performed well in previous large-scale storm events such as September 2013. The Best Available Information model indicates that upstream improvements will not create additional risk at this location. No capacity increases are recommended for this culvert.

Reach 3B: Channel Improvements & Stormdrain Reconfiguration

Location	Improvement	Length (ft)	% of 100-year Storm
Near Gilpin Drive	Channel grading and widening including multi-use path reconfiguration	613	100%
Gilpin Drive Culvert	Reconfigure stormdrain on upstream end in conjunction with box culvert replacement	n/a	100%

The channel at Gilpin Drive needs to be extensively graded and widened to accommodate the proposed Gilpin Drive underpass. In addition, there is a stormdrain outfall on the upstream headwall of the culvert. Should design and construction ensue, this stormdrain should be moved to the downstream end of the culvert and reconfigured to point more in parallel with the creek flows. The culvert in located on city owned property and there are no access issues.

SECTION 5: PHASING & NEXT STEPS

PROJECT PHASING

The Gilpin Drive and Baseline Road box culverts are the key pinch points in the drainageway. Without upsizing these culverts, improvements upstream of Baseline Road will create negative impacts downstream of Gilpin Drive. Recommended phasing for improvements is described in the table at right. Generally, improvements go from downstream to upstream in accordance with engineering best practices. However, there are some recommended improvements that can be constructed out of sequence with no negative downstream impacts. These projects include; sediment removal at the Wildwood Culvert, removal of the Ithaca Drive steel culvert and sediment and debris removal throughout the drainageway.

VEGETATION MANAGEMENT & MAINTENANCE PLAN

Proper vegetation management in riparian, wetland, and stream areas can provide many benefits to ecosystems including wildlife habitat, bank stabilization, water filtration and can assist with preventing or reducing the impacts of flooding. Mitigation design needs to contain vegetation seeding and planting plans that are comprised of native plants that provide habitat for wildlife, debris transport, treatment and removal of non-native species and monitoring of vegetation following implementation to ensure condition is not compromised over time. The city is currently implementing new asset management software that will provide greater accuracy in determining maintenance needs and improved efficiency when scheduling for regular maintenance activities.

FUTURE FUNDING

The city's flood management program is comprised of Boulder Creek and fourteen major drainageways, where over $160M of flood mitigation improvements have been identified city wide. Based on current funding levels, it is anticipated that it will require more than 80 years to complete these projects. In the Stormwater and Flood Management Utility, the majority of the project funding is prioritized by life safety (high hazard) and critical facility (vulnerable population) hazard mitigation issues but other factors apply, such as:

- Flood emergency response capability
- Property damage mitigation
- Collaboration with other Greenways Program Objectives
- Potential for operation and maintenance cost savings
- Accommodating new growth and development
- Opportunities to leverage outside funding

The current six-year Capital Improvements Program (CIP) includes approximately $500,000 for improvements along Bear Canyon Creek. The city will seek all opportunities for collaborative funding efforts including; adjacent transportation projects, the University of Colorado or the Federal Emergency Management Agency (FEMA).

Table 4: Recommended Improvements Phasing Plan

Phase	Location	Recommendation	Phase Cost
1	Gilpin Drive	Increase channel capacity near Gilpin Drive	$3,617,000
	Gilpin Drive	Increase culvert size to (2) 8ft x 20ft concrete boxes	
	Baseline Road	Increase culvert size to (2) 7.5ft x 28ft concrete box	
2	Downstream of Church	Increase channel capacity	$601,000
	Saint Andrew Church	Replace culverts with 40ft driveway bridge	
	Upstream of Church	Increase channel capacity	
3	University of Colorado	Increase channel capacity in conjunction with CU Master Plan	$1,584,000
4	US 36 to CDOT right of way	Increase channel capacity and reconfigure multi-use path	$980,600
	US 36	Increase culvert size to (2) 8.5ft x 14ft concrete boxes and reconfigure pedestrian separator wall in underpass and grade multi-use path and channel downstream to improve the inlet and outlet condition	
5	Broadway	Sediment and debris removal from Broadway to Martin Drive	$2,142,500
	Broadway	Modify inlet conditions to increase capacity	
	Harvard Lane	Increase culvert size to (2) 7.5ft x 10ft concrete boxes	
	Stanford Avenue	Increase channel capacity from Stanford Avenue to Harvard Lane	
6	Table Mesa Drive	Remove sediment in culverts at Ithaca Drive, Yale Road, Gillaspie Drive and Stanford Avenue including gravel bars and vegetation blocking inlet and outlet	$1,554,000
	Lehigh Street	Increase culvert size to 7.5ft x 28ft concrete box	
none	Wildwood Road	Grade channel and widen floodplain from Wildwood Road to Ithaca Drive	$514,000
	Ithaca Drive	Remove steel culvert and grade channel in conjunction with stormwater improvement project at Ithaca Drive	
none	Wildwood Road	Remove sediment in culvert, including gravel bars and vegetation blocking inlet and outlet	n/a
	Martin Drive	Continue good maintenance	
	Moorhead Avenue	Continue good maintenance	
	Mohawk Drive	Continue good maintenance	
		TOTAL	$11,000,000

MITIGATION PLANNING & CLIMATE CHANGE

"The mean global surface temperature has risen by about 0.7- 1.5º F during the last century. This increased temperature contributes to rising sea levels, increased summer drought in some areas, more intense precipitation and weather events, habitat disruption that could lead to species extinction, and other possible serious effects.

For Colorado, climate change will likely mean diminished snow pack, increased drought, more insect outbreaks in forests, an earlier and longer wildfire season, reduced habitat for native species, and less economic growth, according to studies on the impacts of climate change on the Rocky Mountain region."

-City of Boulder Climate Action Plan

Traditional floodplain models utilize historic flood events for hydrologic input. Because of climate change, variations in temperature and precipitation are anticipated, although the impact of these changes on flooding and flood risk in the front range are unknown. Climate change and future flood risk should be taken into account during design of mitigation measures outlined in this document.

SECTION 6: REFERENCES & ACKNOWLEDGEMENTS

REFERENCES

A September to Remember; Urban Drainage and Flood Control District, 2014.

Boulder Valley Comprehensive Plan; 2010; https://www-static.bouldercolorado.gov/docs/boulder-valley-comprehensive-plan-2010-1-201410091122.pdf

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ACKNOWLEDGEMENTS

This report was completed with the support and input from various individuals at the City of Boulder, the UDFCD and Amec Foster Wheeler. The key participants in the development of this memorandum are shown in the following table:

Project Team	Affiliation	Role
Ward Bauscher	City of Boulder	Project Manager
Annie Noble	City of Boulder	Flood and Greenways Engineering Coordinator
Christin Shepherd	City of Boulder	Civil Engineer I
Ryan Martin	City of Boulder	GIS Analyst
Shea Thomas	UDFCD	Project Manager
Joel McGuire	Amec Foster Wheeler	Senior Water Resource Engineer
Jeff Brislawn	Amec Foster Wheeler	Lead Associate
Melissa Greulich	Amec Foster Wheeler	Biologist and GIS Analyst
Sara Johnson	Amec Foster Wheeler	Staff Engineer

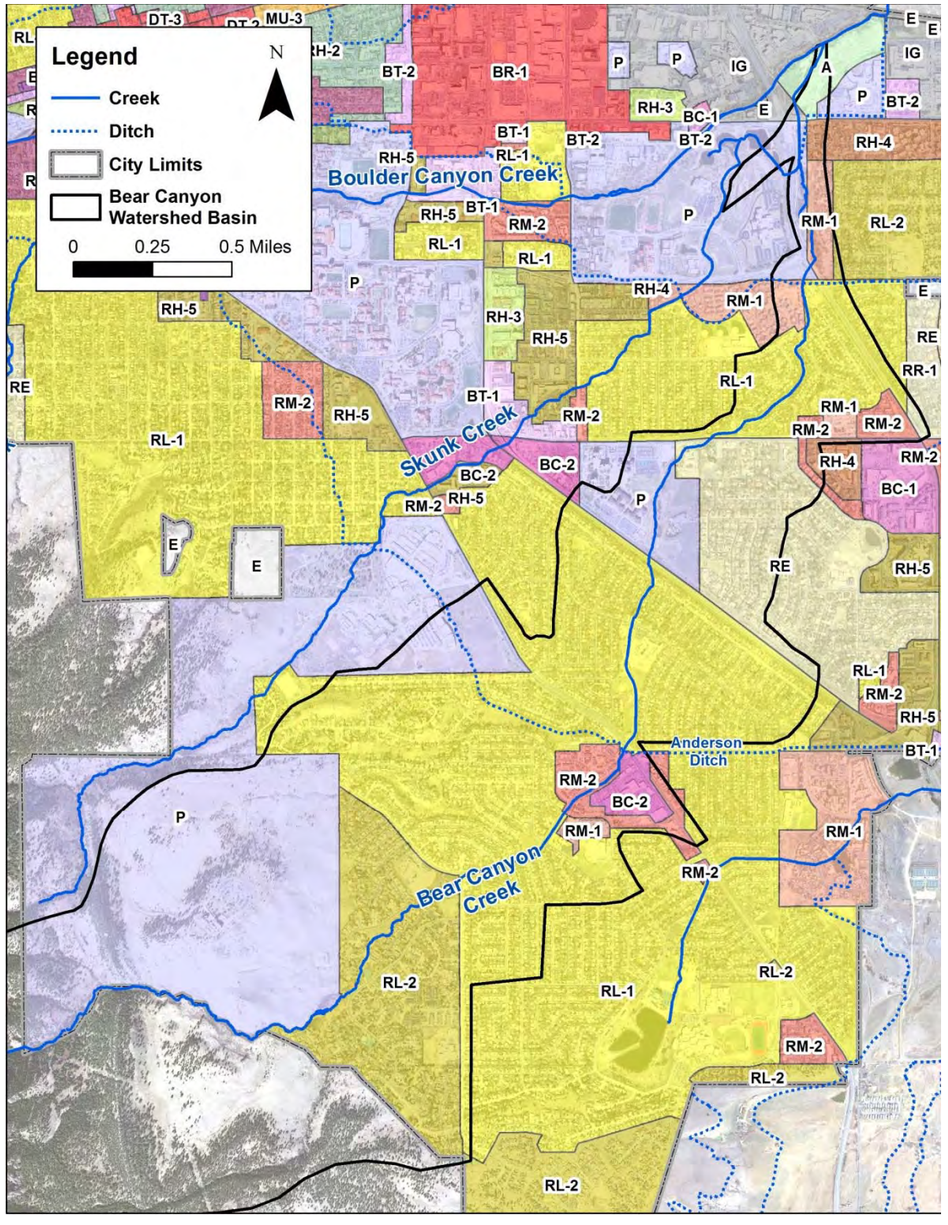
APPENDIX A: BEAR CANYON CREEK WATERSHED INFORMATION

Land Use

Upstream of the city limits, most of the land within the Bear Canyon Creek watershed is preserved as city Open Space. Within the city limits, the majority of the property is comprised of low density, residential zoning districts (RE, RL-1 and RL-2). Density intensifies at major intersections, such as Table Mesa and Broadway as well as Foothills Parkway and Baseline Road where property is zoned Mixed and High Residential (RM-1, RM-2, and RH-4) as well as commercial (BC-1 and BC-2). The land areas zoned Public (P) contain the National Institute of Standards and Technology (NIST), the University of Colorado, and Boulder Community Hospital. There is a small segment of Agricultural land (A) where Bear Canyon Creek converges with Boulder Creek.

The southeast corner of Table Mesa Drive and Broadway is currently developed as commercial property only but is zoned as commercial property with a mixed use buffer. Should future development occur in this area, it would provide an opportunity to increase flow capacity in Bear Canyon Creek along Table Mesa Drive as well as the culvert below Broadway.

The Bear Canyon Creek watershed is fully developed within city limits and future land use will be similar to existing conditions. Limited in-fill and development opportunities are available and areas within the floodplain are subject to city flood regulations which includes a ban on construction in the high hazard zone.



Soils

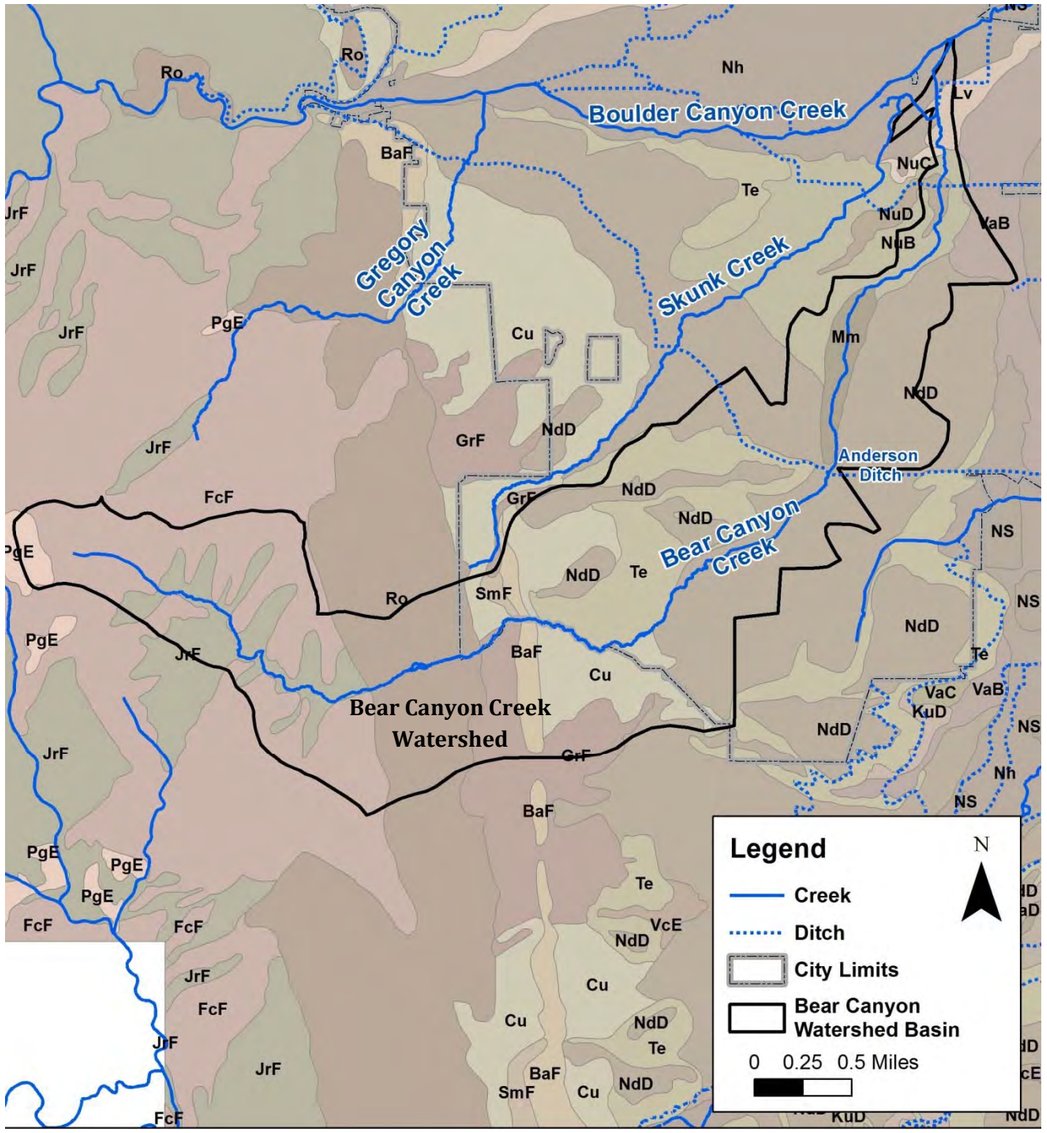
According to the Soil Survey of Boulder County Area, Colorado (United States Department of Agriculture Soil Conservation Service in cooperation with Colorado Agriculture Experiment Station (1975)), the land within the Bear Canyon Creek watershed is comprised of the following soil classifications: Baller Stony Sandy Loam (BaF), Colluvial Land (Cu), Fern Cliff-Allens Park-Rock Outcrop Complex (FcF), Godvale Rock Outcrop Complex (Gfr), Juget-Rock outcrop complex (Jrf), McClave Clay Loam (Mm), Nederland Series (NdD), Niwot Series (Nh), Nunn Clay Loam (NuB), Rock Outcrop (Ro), Terrace Escarpments (Te), and Valmont Clay Loam (VaB).

The upper portion of the watershed is predominantly Fern Cliff-Allens Park-Rock Outcrop Complex (FcF) and Juget-Rock outcrop complex (Jrf). These soils consist of stony sandy loam, gravely sandy loam and rock outcrops on mountain side slopes. The runoff potential is medium to rapid and the erosion potential is high.

The central part of the watershed contains Rock Outcrop (Ro) and Godvale Rock Outcrop Complex (Gfr). Steep rock outcrops with exposed bedrock dominate. Pockets of gravely, loamy sand allow roots to penetrate to depths of 40 to 60 inches or more. These areas provide ideal habitat for wildlife. A band of Baller Stony Sandy Loam (BaF) exists along the city limits in the middle watershed. These soils are shallow and well drained with rapid permeability, high erosion hazard and rapid runoff potential

Further down in the watershed, as Bear Canyon Creek enters the City of Boulder, Nederland Series (NdD) is the predominant soil type with pockets of Colluvial Land (Cu), McClave Clay Loam (Mm), and Terrace Escarpments (Te). The Nederland series (NdN) is made up of deep, well-drained soils that formed on old high terraces and alluvial fans. The soils developed on loamy alluvium that contains many cobblestones and other stones. These soils have moderate permeability and roots can penetrate to a depth of 60 inches or more. These areas have many stones and cobblestones on the surface. Runoff is slow to medium on this soil and the hazard is slight. Cu soils vary widely in depth, texture, color, and stoniness due to the runoff from adjacent slopes that these lands receive. Most areas of Colluvial land have stones and cobbles on the surface. The erosion hazard associated with Cu soils is high. McClave Clay Loam soils are made up of deep, somewhat poorly drained soils with moderate permeability. Runoff is slow and erosion hazard is slight. Te soils have many cobbles and stones on the surface. Runoff is rapid and the erosion hazard is high.

Nunn Series (NuB, NuC, and NuD) soils are located at the confluence with Boulder Creek. The Nunn series is made up of deep, well drained soils that have slow and moderately slow permeability. Roots can penetrate to a depth of 60 inches or more. Runoff ranges from medium to rapid on these soils and the erosion hazard is moderate to high.



Notable Landmarks & History

Notable Landmarks within the watershed include the Frederick W. Kohler Homestead, the William Martin Farmhouse, Green Mountain Cemetery, the NIST Facility, Martin Acres Neighborhood, Boulder Fire Station #3, the NCAR Building, the George Reynolds Branch Library, and Fairview High School.

Frederick W. Kohler Homestead

Built in 1862, Frederick W. Kohler and family homestead was an 800-acre farm along Baseline Road in Boulder. Kohler became a large stockholder in the Boulder National Bank and served two terms as Boulder County Commissioner. Kohler Reservoir was named after him and was originally used as a watering hole for his cattle.

William Martin Farmhouse

Built in 1875, William Martin built a farmhouse on an old campsite used in the 1860's by prospectors on their way to the mines.

Green Mountain Cemetery

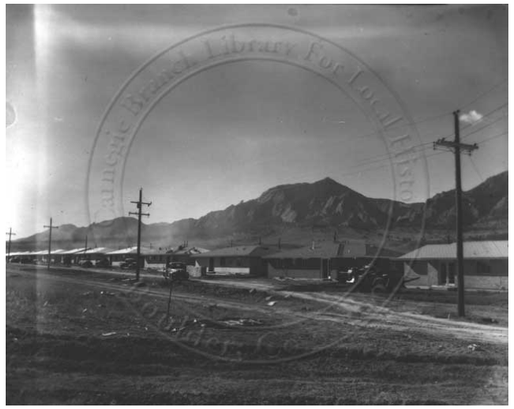
In 1904, the first burial at Green Mountain Cemetery took place. Graves from Columbia Cemetery, which was seen as a less desirable place for burial, were exhumed and brought to the new cemetery.

Post WWII Development

From the 1950's-1960's, South Boulder saw the addition of 2,500 residential houses immediately following the end of World War II.

National Institute of Standards &Technology Facility

In 1954, President Eisenhower dedicated the National Institute of Standards and Technology (NIST) facility.

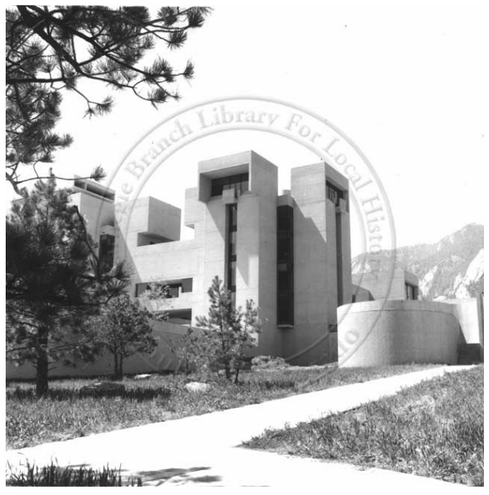


MARTIN ACRES NEIGHBORHOOD
In 1955, George and Everett Williams developed the Martin Acres neighborhood, named after William Martin, who used to operate a ranch in the area.

GEORGE REYNOLDS BRANCH LIBRARY
In 1969, the George Reynolds Branch Library, named after the CU literature professor, is the city's first branch library.

BOULDER FIRE STATION #3
In 1964, architects Thomas Nixon and Lincoln Jones designed Boulder Fire Station #3 in the Usonian style.

FAIRVIEW HIGH SCHOOL
In 1971, modernist architect Hobart Wagener designed Fairview High School, Boulder's second high school.



NCAR BUILDING
In 1966, Walter Orr Roberts worked with I.M. Pei to design the NCAR building. A ballot measure was passed to allow its construction on Table Mesa.

APPENDIX B: WETLAND EVALUATIONS

Wetland Evaluation

Wetland #: 40606 **Former #:** 12 **T_R_S:** TINR70WS32

Investigator: A. Carpenter, C. Browne **Date of Visit:** 6/8/2004 **Obs. Method:** Onsite

General Location: North of Baseline Road and east of 28th street surrounded by busy, paved roads

Description: Small pond in median parcel surrounded by roads.

Wetland Origin: Urban/ industrial **Primary Water Source:** Urban / industrial runoff

Hydroperiod: Permanently flooded **Max WaterDepth (ft):** 5

Major plant communities present	**% of wetland area**
peach-leafed willow/mixed graminoid	

% Vegetated: 5
% Bare ground: 0
% Water: 95

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater substrate Recharge	2	b	Depth to groundwater is mapped at 5-10 ft below ground surface so potential recharge area, however, unknown and may limit.
Groundwater Discharge	2	a	Unlikely, but could be local seepage iintersecting pond bottom during high water table periods.
Flood Storage / expected Floodflow Alteration	2	b	Small pond, that does not appear to receive stormwater drainage. (no obvious outlet observed but given volume of inflow)
Shoreline Anchor. / Stabilization	2	b	
Sediment Trapping / Retention	3	b	
Nutrient Retention (long-term)	3	b	
Nutrient Retention (short-term)	2	b	
Food Chain Support (export)	2	b	
Food Chain Support (within basin)	2	b	
Fish Habitat / Aquatic Diversity	1	b	
Wildlife Habitat	2	c	
Active Recreation	1	c	
Passive Rec / Heritage Value	1	c	

Comments: Inlet pipe (flowing at 0.5 cfs), no obvious outlet but one must exist to accomidate inflows, two pairs of red-wing blackbirds

Wetland Evaluation

Wetland #: 40701 **Former #:** 13 **T_R_S:** T1SR70WS7

Investigator: A. Carpenter, C. Browne, J. **Date of Visit:** 6/4/2004 **Obs. Method:** Onsite and viewed from property

General Location: In ravine east of Table Mesa Drive, in back yards of residences

Description: Unnamed drainage north of Bear Canyon Creek (and south of Skunk Creek) which flows through a narrow steep channel located between two hills formed by Pierre shale bedrock formations. The creek channel enters a storm drain pipe near Hartford Drive and is directed beneath a residential area and discharges into Bear Canyon Creek at Table Mesa Drive. Some of the wetland area is supported by seepage from the adjacent hillside.

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Intermittendly flooded **Max WaterDepth (ft):** 2

Major plant communities present	**% of wetland area**
crack willow-green ash / mixed herbaceous	54
Baltic rush - clustered field sedge	30
Baltic rush - wooly sedge	15
open water	1

% Vegetated: 94
% Bare ground: 5
% Water: 1

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater Recharge	2	b	Geohydrologic map shows potential for groundwater recharge or discharge depending on water levels.
Groundwater Discharge	2	b	Groundwater discharge likely to occur along interface between bedrock and alluvial deposits, but thin unconsolidated layer and discontinuous nature of groundwater minimizes opportunity.
Flood Storage / Floodflow Alteration	3	b	
Shoreline Anchor. / Stabilization	3	b	Trees and shrubs along corridor help to stabilize slopes.
Sediment Trapping / Retention	2	b	
Nutrient Retention (long-term)	2	b	
Nutrient Retention (short-term)	2	b	
Food Chain Support (export)	2	b	Limited high flows for export.
Food Chain Support (within basin)	3	b	
Fish Habitat / Aquatic Diversity	1	c	
Wildlife Habitat	3	b	deer encountered in stream
Active Recreation	1	c	
Passive Rec / quiet Heritage Value	3	b	Steep slopes on either side limit development and preserve element of natural setting. Provides private, greenscape for adjoining properties.

Comments: Wetland very narrow, vegetation very weedy

Wetland Evaluation

Wetland #: 40702 **Former #:** 5 (in part) **T_R_S:** T1SR70WS7

Investigator: A. Carpenter, C. Browne **Date of Visit:** 7/7/2004 **Obs. Method:** Onsite

General Location: Bear Canyon Creek from City boundary east to Lehigh Street

Description: This wetland consists of a relatively high quality riparian corridor flowing through residrntial areas and open space in the southwestern edge of the city. The creek flows along the southeastern edge of a Pierre Shale bedrock feature (on top of which is the National Center for Atmospheric Research). There is no signficant shallow groundwater in this area ("thin, discontinuous and transient"). Functional values include shoreline stability, wildlife habitat, food chain support, and passive recreation.

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Seasonally flooded **Max WaterDepth (ft):** 2

Major plant communities present	% of wetland area
narrowleaf cottonwood / chokecherry	45
narrowleaf cottonwood / hawthorn	45
plains cottonwood / choke cherry	10

% Vegetated: 10
% Bare ground: 50
% Water: 40

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater Recharge	2	b	There is no signficant shallow aquifer in this area and the underlying rocks limit infiltration, although some minor infiltration may occur,
Groundwater Discharge	2	b	Geohydrologic map shows potential for groundwater discharge particularly upgradient along the contact with the Pierre shale formation but absence of a significant shallow aquifer limits the opportunity.
Flood Storage / Floodflow Alteration	2	b	Somewhat slowed water flows and minor amounts of storage (e.g., just west of Lehigh) but generally expect flood waters to be transported through with little alteration.
Shoreline Anchor. / Stabilization	4	b	Abudnant shrubs and moderate tree cover with rocky slopes effectively stabilize slopes in most of this section.
Sediment Trapping / Retention	2	b	
Nutrient Retention (long-term)	2	b	Some long-term retention in woody species.
Nutrient Retention (short-term)	3	b	In herbaceous plants and short residence time sediment deposits.
Food Chain Support (export)	4	b	Trees and shrubs provide leaf litter and flushing flows provide opportunity for export.
Food Chain Support (within basin)	4	b	High shrub productivity
Fish Habitat / Aquatic Diversity	2	b	No fish habitat but aquatic insects observed.
Wildlife Habitat	4	b	Deer fawn & warbler nest observed. Large size buffer zone and open space access provide good connection and diversity. Lots of food choke cherry, wild plum, hawthorn, in well developed shrub layer.
Active Recreation	2	a	Hikers and kids may use.
Passive Rec / Heritage Value	4	c	Trail access through open space and natural setting increase this functional value.

Comments: Dense shrubby vegetation along stream; very nice riparian wetland; plant communities present elsewhere in study area

Wetland Evaluation

Wetland #: 40703 **Former #:** 5 (in part) **T_R_S:** T1SR70WS8

Investigator: A. Carpenter, C. Browne **Date of Visit:** 7/6/2004 **Obs. Method:** Onsite

General Location: Bear Canyon Creek down stream from Lehigh Street to Broadway

Description: This section of creek flows through the median strip on Table Mesa Drive to at newly constructed wetland in 100- foot segment just west of Broadway. The channel has been straightened and contains many grade control structures.

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Seasonally flooded **Max WaterDepth (ft):**

Major plant communities present	% of wetland area
reed canary grass	85
coyote willow / reed canarygrass	10
open water	5

% Vegetated: 94
% Bare ground: 1
% Water: 5

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater Recharge	2	b	see below
Groundwater Discharge	2	b	Geohydrologic map shows potential for groundwater discharge or recharge depending on water levels and location. But, thin discontinuous nature of shallow groundwater limits effectiveness of this function.
Flood Storage / Floodflow Alteration	2	b	Some small pools with relatively low storage and flood plain is restricted by edge of median strip in Table Mesa Drive.
Shoreline Anchor. / Stabilization	2	b	No signficant woody veg. Engineered structures provide most of stabilization. Bank was observed to be undercut in places.
Sediment Trapping / Retention	3	b	Moderate deposits of sand from roadside runoff in vicinity of bridges and behind dams, and in settling pools. But, most expected to flow through with significant settling occurring at the new wetland just west of Broadway.
Nutrient Retention (long-term)	2	b	Some long-term storage in coyote willows and sediments but uncertain as to extent that deposits are temporary.
Nutrient Retention (short-term)	3	b	Assumes mostly short residence sediments
Food Chain Support (export)	2	b	Low to moderate overhanging limbs to supply leaf litter. (Cooper evaluation referred to larger stream segment)
Food Chain Support (within basin)	2	b	see above
Fish Habitat / Aquatic Diversity	1	b	
Wildlife Habitat	2	c	
Active Recreation	1	c	
Passive Rec / Heritage Value	2	b	

Comments: Channel completely straightened; low diversity wetland with lots of reed canarygrass

Wetland Evaluation

Wetland #: 40704 **Former #:** 5 (in part) **T_R_S:** T1SR70WS5

Investigator: A. Carpenter, C. Browne **Date of Visit:** 7/7/2004 **Obs. Method:** Onsite and viewed from property

General Location: Bear Canyon Creek from Broadway downstream (north) to US Highway 36

Description: This section of channel has been stgraightened and is lined with boulders on one (and sometimes both sides) for most of the length; nearly all of channel bottom is filled with cobbles; some sectrions of channel are concrete lined on sides and bottom; At Broadway, headgate to Anderson Ditch indicates diversions that reduce flows in this section of Bear Canyon Creek (but did not evaluate extent of flow alterations).

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Seasonally flooded **Max WaterDepth (ft):** 1.5

Major plant communities present	% of wetland area
urban forest / mixed herbaceous	60
plains cottonwood / coyote willow	30
open water	10

% Vegetated: 5
% Bare ground: 20
% Water: 75

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no **Confidence in rating: c = high, b = medium, a = low**

Groundwater Recharge	2	b	see below
Groundwater and Discharge	2	b	Geohydrologic map shows potential for groundwater discharge or recharge depending on water levels location. But, thin discontinuous nature of shallow groundwater limits effectiveness of this function.
Flood Storage / Floodflow Alteration	2	b	
Shoreline Anchor. / Stabilization	3	b	Water flows in this section are altered by upstream diversion into Anderson ditch so reduced opportunity. .
Sediment Trapping / Retention	2	b	Urban runoff provides source but flashing flows appear to transport out.
Nutrient Retention (long-term)	2	b	
Nutrient Retention (short-term)	2	b	
Food Chain Support (export)	3	b	Significant overhanging limbs to supply leaf litter.
Food Chain Support (within basin)	3	b	
Fish Habitat / Aquatic Diversity	1	b	
Wildlife Habitat	2	a	
Active Recreation	2	a	Kids observed playing in the stream.
Passive Rec / Heritage Value	2	b	Bear Creek greenway trail follows alongside much of the creek and creek flows through a city park

Comments: wetland defined by bankful channel; forested wetland along creek; not very weedy; channel armored downstream of Martin

Wetland Evaluation

Wetland #: 40705 **Former #:** 6 **T_R_S:** T1NR70WS33

Investigator: A. Carpenter, C. Browne **Date of Visit:** 7/2/2004 **Obs. Method:** Onsite

General Location: Bear Canyon Creek from 300 feet southwest of Baseline Road downstream (north) into Wellman Ditch and beyond as creek channel continues north and parallel to Foothills Parkway up to inlet from Skunk Creek (Note this wetland includes former Cooper #6 as well as a portion of #7)

Description: Bear Canyon Creek flows into Wellman Ditch just west of Foothills with some water passing through a control structure to continue flowing north. Channel south of ditch is straightened and entrenched, downcutting has isolated creek from floodplain in places. Northern section is broader floodplain, more than one channel, with mature trees.

Wetland Origin: Natural **Primary Water Source:** Urban / industrial runoff

Hydroperiod: Seasonally flooded **Max WaterDepth (ft):** 2

Major plant communities present	% of wetland area
crack willow / mixed herbaceous	75
reed canarygrass	2
open water	1
plains cottonwood - crack willow / mixed	22

% Vegetated: 9
% Bare ground: 1
% Water: 90

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no **Confidence in rating: c = high, b = medium, a = low**

Groundwater Recharge	2	b	
Groundwater Discharge	2	b	High water table (within 5 ft) so potential for discharge.
Flood Storage / Floodflow Alteration	4	b	Side channels with small islands throughout. Northern section includes broad floodplain.
Shoreline Anchor. / Stabilization	2	c	Signs of downcut channel and erosion occurring since Cooper evaluation. Most of shoreline consists of grassy banks with interspersed crack willows.
Sediment Trapping / Retention	3	b	Evidence of deposits in pockets, side channels and overflow areas.
Nutrient Retention (long-term)	3	b	Some long-term retention in sediments and mature trees. (Could have higher value in north end of wetland.)
Nutrient Retention (short-term)	3	b	Could be somewhat lower value in southern portion of wetland.
Food Chain Support (export)	4	b	Abundant mature willows in north section.
Food Chain Support (within basin)	3	b	Could be higher value in north section.
Fish Habitat / Aquatic Diversity	3	b	Lots of minnows and a 6" trout observed, also crayfish.
Wildlife Habitat	3	b	
Active Recreation	1	b	
Passive Rec / Heritage Value	4	b	Bike trail has improved access and passive recreation use since previous evalutiaon.

Comments: Narrow strip of forested wetland along Bear Canyon Creek; mostly crack willow.Functional values of wetland are higher in northern portion of this wetland where floodplain broadens. Inflow from Skunk creek is north boundary of this wetland.

Wetland Evaluation

Wetland #: 40706 **Former #:** 7 **T_R_S:** T1NR70WS33 &

Investigator: A. Carpenter, C. Browne **Date of Visit:** 8/14/2004 **Obs. Method:** Onsite

General Location: East of Foothills Parkway/ north and south of Arapahoe Ave

Description: Bear Canyon Creek includes section downstream of inflow from Skunk Creek. Creek flows through bottomlands as approaches Boulder Creek to the north and receives significant urban runoff from Arapahoe and Foothills Parkway. (Note that the small wetland north of Arapahoe which Cooper Id'd as No. 11 is also included in this wetland.)

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Seasonally flooded **Max WaterDepth (ft):** 2

Major plant communities present	% of wetland area
cattail marsh	10
coyote willow	35
reed canary grass- cattail	10
open water	45

% Vegetated: 55
% Bare ground: 0
% Water: 45

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater Recharge	2	b	May recharge during low water table periods, but not significant.
Groundwater Discharge	2	b	
Flood Storage / Floodflow Alteration	3	b	
Shoreline Anchor. / Stabilization	3	b	Cooper's higher value probably reflects difference in boundaries.
Sediment Trapping / Retention	4	b	
Nutrient Retention (long-term)	3	b	
Nutrient Retention (short-term)	3	b	
Food Chain Support (export)	3	b	
Food Chain Support (within basin)	3	b	Some aquatic vegetation, abundant willows.
Fish Habitat / Aquatic Diversity	3	b	Small minnows observed in channel.
Wildlife Habitat	3	b	Good for birds, fragmented by roads. Deer trails and beds.
Active Recreation	1	b	
Passive Rec / Heritage Value	2	b	Access ok but area is narrow and bounded by Parkway on the west.

Comments: Water source includes the re-routed end of Skunk Creek from outlet of wetlands north of CU research park.

Wetland Evaluation

Wetland #: 40801 **Former #:** 12 (in part) **T_R_S:** T1SR70WS8

Investigator: A. Carpenter, C. Browne, J. **Date of Visit:** 6/4/2004 **Obs. Method:** Onsite

General Location: Viele Lake, immediately south west of South Boulder Rec. Center

Description: Lake is probably located in natural depression that was enhanced for the park. Located at base of bedrock formation where it collects surface water runoff from hillside and local groundwater seepage along contact with rock interface. Water was turbid at time of visit; pond has sport fishing; used by anglers on shore.

Wetland Origin: Agriculture **Primary Water Source:** Ground water

Hydroperiod: Permanently flooded **Max WaterDepth (ft):** 3

Major plant communities present	% of wetland area
cattail	4
American three square	0.5
Baltic rush	0.5
open water	95

% Vegetated: 5
% Bare ground: 0
% Water: 95

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater Recharge	2	b	Some recharge may occur along the north downgradient side, but opportunity to infiltrate may be restricted by permeability of underlying rocks and thin unconsolidated layer.
Groundwater Discharge	3	b	Geohydrology maps indicate groundwater discharge likely from south and east sides along contact with Pierre shale bedrock feature. Relative inputs from subsurface inflows versus surface water runoff from surrounding hillsides is uncertain.
Flood Storage / Floodflow Alteration	3	b	Site visit probably coincided with high water levels hence no water line exposed. But, likely to have some moderate aboveground storage capacity.
Shoreline Anchor. / Stabilization	2	b	Mowed to edge in places. Limited opportunity other than wind.
Sediment Trapping / Retention	4	b	Erosion from steep hillside slopes provides source of sediments.
Nutrient Retention (long-term)	3	b	Accumulation of sediments and high input of nutrients from geese.
Nutrient Retention (short-term)	3	b	Some short-term sediments and herbaceous/ermergent retention.
Food Chain Support (export)	2	b	Overhanging vegetation provides some input but flushing flows and high levels to export are probably infrequent.
Food Chain Support (within basin)	3	a	
Fish Habitat / Aquatic Diversity	4	b	Fish observed and farily large lake.
Wildlife Habitat	3	b	Active urban park setting may limit amount of wildlife. Great blue heron observed along with waterfowl.
Active Recreation	5	b	Few lakes of this size and accessibility close to residences within Boulder. Provides value for boating and fishing uses.
Passive Rec / Heritage Value	5	b	Visitors to rec. center enjoy paths and view.

Comments: Most of Russian olives have been killed; lots of weeds surrounding the wetland

APPENDIX C: RELEVANT PLANNING DOCUMENT EXCERPTS

Boulder Valley Comprehensive Plan

The following applicable policies are included in the BVCP:

3.19 Preservation of Floodplains

Undeveloped floodplains will be preserved or restored where possible through public land acquisition of high hazard properties, private land dedication and multiple program coordination. Comprehensive planning and management of floodplain lands will promote the preservation of natural and beneficial functions of floodplains whenever possible.

3.20 Flood Management

The city and county will protect the public and property from the impacts of flooding in a timely and cost-effective manner while balancing community interests with public safety needs. The city and county will manage the potential for floods by implementing the following guiding principles: a) Preserve floodplains b) Be prepared for floods c) Help people protect themselves from flood hazards d) Prevent unwise uses and adverse impacts in the floodplain e) Seek to accommodate floods, not control them. The city seeks to manage flood recovery by protecting critical facilities in the 500-year floodplain and implementing multi hazard mitigation and flood response and recovery plans.

3.21 Non-Structural Approach

The city and county will seek to preserve the natural and beneficial functions of floodplains by emphasizing and balancing the use of non-structural measures with structural mitigation. Where drainageway improvements are proposed, a non-structural approach should be applied wherever possible to preserve the natural values of local waterways while balancing private property interests and associated cost to the city.

3.22 Protection of High Hazard Areas

The city will prevent redevelopment of significantly flood-damaged properties in high hazard areas. The city will prepare a plan for property acquisition and other forms of mitigation for flood-damaged and undeveloped land in high hazard flood areas. Undeveloped high hazard flood areas will be retained in their natural state whenever possible. Compatible uses of riparian corridors, such as natural ecosystems, wildlife habitat and wetlands will be encouraged wherever appropriate. Trails or other open recreational facilities may be feasible in certain areas.

3.23 Larger Flooding Events

The city recognizes that floods larger than the 100-year event will occur resulting in greater risks and flood damage that will affect even improvements constructed with standard flood protection measures. The city will seek to better understand the impact of larger flood events and consider necessary floodplain management strategies including the protection of critical facilities

Comprehensive Flood and Stormwater Utility Master Plan

The CFS contains the following guiding principles for flood management:

1. Preserve Floodplains (Preservation);
2. Be Prepared for Floods (Preparedness);
3. Help People Protect Themselves from Flood Hazards (Education);
4. Prevent Adverse Impacts and Unwise Uses in the Floodplain (Regulation);
5. Seek to Accommodate Floods, Not Control Them (Mitigation).

More detail about each of these guiding principles can be found in Chapter 3 of the CFS. The fifth principal, as listed above, is directly related to mitigation and, in the CFS, more completely states:

- Seek to accommodate floods, not control them through planned and monitored system maintenance, nonstructural flood proofing, opening non-containment corridors, overbank land shaping to train flood waters, and limited structural measures at constrained locations. Possible tools for implementation include:
  - Update mitigation master plans to emphasize nonstructural measures.
  - Re-evaluate mitigation priorities to eliminate bottlenecks, acquire land to avoid channel improvements, provide non-structural overbank grading, target limited flood protection improvements for high hazards, and research alternative mitigation approaches.
  - Assess any need for structural improvements with evaluation of multiple alternatives.
  - Focus on mitigating high hazard locations citywide and give priority to areas of the greatest risk.

Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual

The UDFCD Drainage Criteria Manual contains the following basic policies:

- The major drainageway system shall be capable of conveying water without flooding buildings and shall remain relatively stable during a 100-year flood.
- Public safety is fundamental to the major drainageway system.
- Public acceptance of the major drainageway system depends on a multitude of factors such as public perception of flood protection, channel aesthetics, right-of-way, open space preservation, and channel maintenance.
- Identify areas with potential for recreational use.
- Consider environmental impacts and benefits and examine the advantages and disadvantages.
- Open channels are more desirable than underground conduits in urban areas because they are closer in character to natural drainageways and offer multiple use benefits.
- Consider two-stage channels. In some cases, it may be desirable to balance the 100-year flow between a formal channel and the adjacent floodplain.

Greenways Master Plan

The Greenways Program in the City of Boulder was an outgrowth of the Boulder Creek Corridor Project. It was created on the basis of recognition that stream corridors are a vital link in the larger environmental system and

that each stream is a natural and cultural resource. The purpose of the Greenways Program is to extend the stewardship of the City of Boulder to the important riparian areas along the tributaries of Boulder Creek. The objects of the Greenways Program include:

- Protect and restore riparian, floodplain and wetland habitat;
- Enhance water quality;
- Mitigate storm drainage and floods;
- Provide alternative modes of transportation routes or trails for pedestrians and bicyclists;
- Provide recreation opportunities;
- Protect cultural resources.

Objectives and goals core to the Greenways Master Plan and related to the vegetation management portion of the project include:

- Protect and enhance areas with high habitat value
- Restore habitat for native species
- Protect areas for species of concern
- Protect and restore high quality wetlands
- Maintain and enhance stream channel stability
- Preserve and enhance stream corridor water quality function

APPENDIX D: ENVIRONMENTAL REPORT & HABITAT ASSESSMENT

RIPARIAN AREA FIELD ASSESSMENT
Bear Canyon Creek
Boulder, Colorado

1. INTRODUCTION

A survey for the Bear Canyon Creek Master Plan was conducted along Bear Canyon Creek (Creek) July 23, 2015. Ten pre-determined plots in Reaches 1 and 3 of the Creek corridor were visited (**Appendix A**). Data was collected on invasive and Colorado state-listed noxious weeds and flood hazards with relation to biological resources such as vegetation. Notes were also taken on incidental data such as habitat condition and presence, species present, and potential Waters of the US. However, this data was not specifically surveyed for and will likely require further surveying. This report summarizes findings of the surveys.

2. VEGETATION, NOXIOUS WEEDS AND INVASIVE SPECIES

Several invasive and noxious weed species were present in plot locations. All plots had at least two species of invasive or noxious weeds. A total of four Colorado State List C species, four Colorado State List B species, and eleven non-listed invasive species were found within the plots. In addition to these species, two additional state-listed noxious weeds were seen outside of plots and were noted. **Table 1** below lists all noxious weeds and invasive plants documented on site. Data forms that contain information about growth stage and density of populations documented can be found in **Appendix B** and photos of plots can be found in **Appendix C.**

TABLE 1. NOXIOUS WEEDS AND INVASIVE PLANTS DOCUMENTED DURING THE BEAR CANYON CREEK SURVEY

Scientific Name	Common Name	Colorado Noxious Weed List
Ambrosia artemisiifolia	Common ragweed	Not listed
Arctium minus	Common burdock	C
Bromus inermis	Smooth Brome	Not listed
*Bromus tectorum**	Downy Brome	C
Carduus nutans	Musk thistle	B
*Cichorium intybus**	Chicory	C
Cirsium arvense	Canada thistle	A
Clematis orientalis	Chinese clematis	B
Conium maculatum	Poison hemlock	C
Convolvulus arvensis	Field bindweed	C
Descurainia sophia	Flixweed	Not listed
Dipsacus fullonum	Common teasel	B
Glychyrrhiza lepidota	Wild licorice	Not listed
Lactuca serriola	Prickly lettuce	Not listed
Medicago sativa	Alfalfa	Not listed
Melilotus albus	White sweet clover	Not listed
Melilotus officinalis	Yellow sweet clover	Not listed
Rumex crispus	Curly dock	Not listed
Salix fragilis	Crack willow	Not listed
Toxicodendron radicans	Poison ivy	Not listed
Verbascum thapsus	Common mullein	C

*Indicates species was found along Bear Canyon Creek but not within a plot.

Noxious weed and invasive plant species on site hinder the ability of native plant species to establish and alter the overall ecology of the site. Several plot locations had very high densities of non-native plants and little native plant communities. Plot locations RA-R1-2 and RA-R1-4 both had nine to ten different non-native species present which dominated the landscape. Plot location RA-R3-3 only had two different non-native species present, but the two species dominated the site and therefore has a similar negative impact on the ecology of the location as the two previously mentioned plot locations.

Noxious weeds and invasive plant species contribute to poor hydrologic conditions along the Creek. Species such as crack willow have branches that easily break and large root systems, both of which may congest the creek corridor. This species also readily displaces other vegetation present and can establish large monotypic stands. Once limbs or twigs break from the parent tree or shrub, they are capable of establishing roots and then eventually can grow to become shrubs or large trees (Tamar Valley 2013). Crack willow is present along most of Reach 1 at low densities and is present in moderate to high densities along Reach 3. Reach 3 contains extremely large crack willow trees that likely have contributed large amounts of debris during flooding events.

Native willow species are also present along the stream corridor, and may contribute to flooding issues. In extreme flooding cases, species that typically may slow waterflow or stabilize banks may become uprooted or break, and contribute to blocking waterways (Hickey & Salas 1995). Similarly to crack willow, native willow species such as sandbar willow (Salix exigua), may have limbs that break and grow roots (NHT n.d.). Native willow species are essential to some Colorado riparian habitats and although native species may contribute to flooding issues, it does not mean removing all plants is necessary. The issue at hand is much more complex than simply removing all obstructing vegetation. The hydrologic system present needs considerable improvements in addition to vegetation management to ensure debris does not enter the waterway during flooding events.

It is important to note that geomorphologic change and flooding is heavily tied to the natural succession of riparian vegetation and is an essential process. Depending on the system, plant survival often will depend on the species that is inundated, the severity of flooding, and the size of the

plants impacted by flooding. Many native trees rely on flooding to open up the canopy and to deposit water and nutrients on land for new growth. Channel narrowing following a flood has been found as the most prominent influence on vegetation succession in eastern Colorado (Hickey & Salas 1995). Therefore, flooding can be a positive influence on a system if the system is naturally-functioning prior to the flooding.

3. HYDROLOGY

As mentioned in the Noxious Weed and Invasive Species section above, species such as crack willow and other non-native and native species may add to the altered hydrology of Bear Canyon Creek by contributing debris to the waterway and subsequently obstructing the Creek, causing overland flow and flooding. In addition to contributing debris, vegetation is not able to sustain itself on the banks of the creek because of bank erosion, incised channels, and a lack of gradual slopes. This likely has resulted in entire individual shrubs or trees being removed, which contributes more debris and also removes soil from stream banks which exacerbates erosion and sedimentation issues. In order to restore a more natural riparian corridor in these areas, the following measures are recommended:

- Restore historical stream meandering
- Regrade slopes to allow vegetation to transition from riparian to upland habitat
- Reconnect the floodplain where the channel is incised and constrained by development on both sides

Bank erosion, incised channels, and sedimentation of the creek were noted at many of the plots. Data forms in **Appendix B** provide more information about each plot location and specific issues seen and photos of hydrologic features can be found in **Appendix C.**

4. HABITAT QUALITY

Information regarding habitat quality and vegetation health were also documented, but not in as much detail. A summary of general findings include:

- Vegetation strata were well represented throughout the Reaches. Reach 1 had much denser vegetation and diversity than Reach 3. Reach 1 also generally had more non-native species present.
- Native plant habitat could be enhanced with restoration, but currently is lacking because of the density of and competition from non-native species.
- Bird habitat is present along the entire creek, and several species were seen and heard during the survey. Reach 3 has less diversity and more disturbance from mowing of nearby upland grasslands, which is likely to disrupt nesting in the area. Reach 1 and 3 are very narrow and species that require large swaths of contiguous habitat will not use these areas.

- Aquatic habitat quality was variable throughout Reach 1 and 3. Positive habitat quality characteristics documented were the presence of cover from fallen logs and overhanging vegetation, riffles from rocks in stream, and creek meandering. However, some areas completely lacked these positive characteristics. Additionally, some of these characteristics, such as the presence of vegetative and fallen log cover, compromise the flow of the stream. A balance between aquatic habitat availability and healthy stream geomorphology must be met.
- Preble's meadow jumping mouse habitat potentially occurs at some of the plot locations. With enhancement and/or restoration, additional areas could provide habitat for the species. However, the corridor is very narrow, and it is uncertain if the riparian-upland width habitat requirements for the species could be met with the land available for restoration.

More information about individual plots and habitat quality can be found in the data sheets in **Appendix B** and photos of habitat features can be found in **Appendix C.**

5. CONCLUSION

The survey conducted found twenty-one non-native plant species within plot sites along Bear Canyon Creek. Several species were dominant at sites, which limits the ability of native vegetation to establish. Additionally, some species are present that impede the ability of the waterway to flow easily and contribute debris to the corridor when disturbed. The presence of these species negatively impacts the overall ecology and hydrology of the system. Management of identified species is recommended in order to see improvements.

In addition to poor vegetation quality, the hydrologic system present is faulty and must be corrected to see improvements. The system in place does not allow for native or non-native plant species to remain established on banks due to erosion, a lack of a proper floodplain, and a lack of stream meandering. Restoring natural stream characteristics to Bear Canyon Creek must be considered the core of planned improvements.

If the hydrology and vegetation issues are improved, naturally, the wildlife community will become more diverse. Presence of native plant communities and hydrologic regimes will support native fauna. Currently, habitat exists for many wildlife species, but biodiversity levels and habitat quality are moderate to low.

If objectives regarding non-native species control, hydrologic restoration, and wildlife habitat enhancement are accomplished, many objectives and goals for habitat and water quality outlined in the 2011 Greenways Master Plan will simultaneously be met. Objectives and goals core to the Greenways Master Plan and related to the vegetation management portion of the project include:

- Protect and enhance areas with high habitat value

- Restore habitat for native species
- Protect areas for species of concern
- Maintain and enhance stream channel stability
- Preserve and enhance stream corridor water quality function

These goals can be found in the Greenways Master Plan on page 3-1 within Table 3-1 Objectives and Goals of the Greenways Program. These goals will be carried forward in the vegetation management plan for Bear Canyon Creek.

6. REFERENCES

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Tamar Valley. 2013. Crack Willow -. Available from http://www.weeds.asn.au/tasmanian-weeds/view-by-common-name/crack-willow/ (accessed March 4, 2015).

APPENDIX E: CULVERT BLOCKAGES

The table below lists the culvert blockages used in the 1987 FHAD and the culvert blockages used in the Best Available Information model.

Existing Conditions Culvert Blockages

Culvert ID	Location	FHAD Blockage	Existing Condition Blockage
R1-1	Wildwood Road	40%	55%
R1-2	Ithaca Drive	100%	100%
None	Pedestrian Bridge upstream of Lehigh Street	30%	0%
R2-1	Lehigh Street	75%	75%
R2-2	Ithaca Drive	50%	50%
R2-3	Yale Road	50%	50%
R2-4	Gillaspie Drive	50%	50%
None	Pedestrian Bridge at Stanford Avenue	0%	0%
R2-5	Stanford Avenue	50%	50%
R2-6	Harvard Lane	0%	60%
R2-7	Broadway Street	75%	30%
None	Pedestrian Bridge at Dartmouth Avenue	75%	0%
R2-8	Martin Drive	50%	50%
R3-1	Moorhead Avenue	20%	20%
R3-2	US 36	0%	65%
None	Pedestrian Bridge downstream of US 36	0%	0%
None	University of Colorado	-	100%
R3-3	Saint Andrew Church	30%	75%
R3-4	Baseline Road	50%	50%
R3-5	Gilpin Drive	10%	15%
R3-6	Mohawk Drive	0%	15%

APPENDIX F: ALTERNATIVE ANALYSIS DATA

Flood Mitigation Master Plan

Bear Canyon Creek

Mitigation Alternative Inventory

Updated: jsm **3/30/16** v2.2

Record Count: 59

Reach Index	
Reach	Location
1A	City Limits to Bear Canyon Park
1B	Bear Canyon Park to Lehigh
2A	Lehigh to Broadway
2B	Broadway to Moorhead
3A	Moorhead to Baseline
3B	Baseline to Mohawk

Mitigation Type Index		
Code	Mitigation Type	Count
CR	Crossing Improvement	24
EC	Erosion Control / Channel Stabilization	16
DM	Debris Management Area	4
FC	Floodplain Connection / Storage Area	5
SC	Spill Control	6
RM	Riparian Management	5

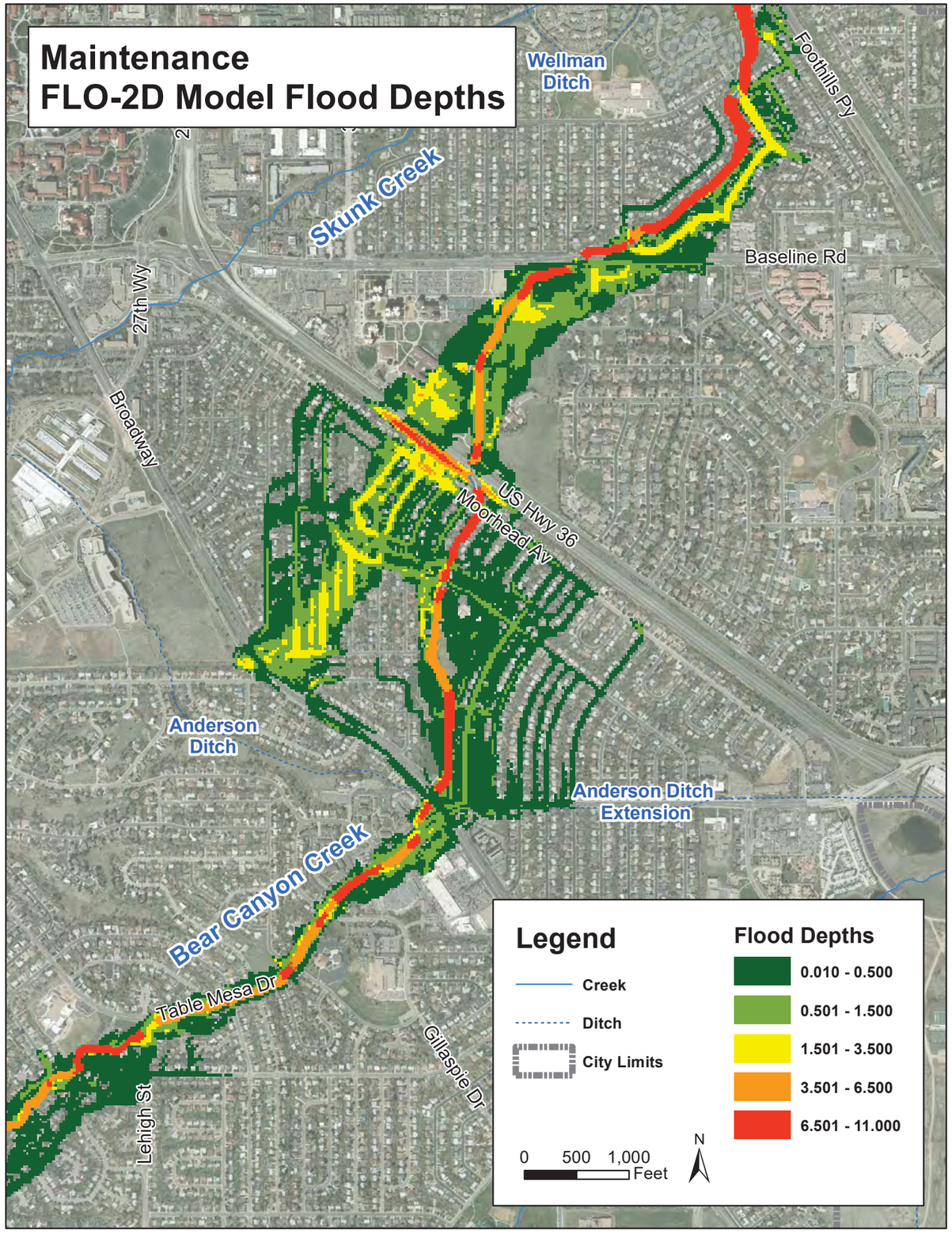
Conceptual Level of Effort Index		
Code	Effort	Count
MA	Maintenance	7
CM	Capital Maintenance	26
CI	Capital Improvement	16
NI	No Improvement	11

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Id	Site	Mit Code	Reach	No.	Con-ceptual Effort Code	Mitigation Type	Location	US River Station	DS River Station	Midpoint	Existing Conditions Description	100-Year Discharge (cfs)	FHAD Blockage	Reported FHAD Culvert/ Bridge Flow (cfs)	Theoretical Capacity (no blockage) (cfs)	Theoretical % of 100-Yr Capacity	15% (City) Capacity (cfs)	City % of 100-Yr Capacity	Existing Conditions Blockage	Existing Conditions Capacity (cfs)	Existing % of 100-Yr Capacity	Minimum Blockage (Good Maintenance)	Maint-enance Capacity (cfs)	Maint-enance % of 100-Yr Capacity	100-Yr Mitigation Concept	Level of Effort
4	**CR-R1-1.2**	CR	1	1.2	MA	Crossing	Wildwood Road Culvert	204+61	203+61	204+11	Debris blockage	1063	40%	1600	2002	188%			55%	792	74%	40%	1098	103%	Remove vegetation, gravel bars	Maintenance
10	**CR-R1-2.1**	CR	1	2.1	CM	Crossing	Boiler Culvert at Ithaca Drive (W)	188+16	188+00	188+08	1 cell culvert: 5'	1063	100%	-	-	-		-	100%	1063	100%	100%	-	-	Remove culvert	Capital Maintenance
11	**CR-R1-3.1**	CR	1	3.1	NI	Crossing	Pedestrian Bridge US of Lehigh	186+31	186+01	186+16	50'W Bridge, No Piers	1063	30%	-	-	-		-	0%	1193	112%	0%	1193	112%	No Improvement	No Improvement
13	**CR-R2-1.1**	CR	2	1.1	CI	Crossing	Lehigh Street Culvert	177+39	173+57	175+48	2 cell culvert: 4'R×8'S	1600	75%	352	623	39%	520	32%	75%	138	9%	30%	420	26%	Increase Capacity	Capital Improvement
17	**CR-R2-2.1**	CR	2	2.1	NI	Crossing	Ithaca Drive (E) Culvert	167+65	166+51	167+08	2 cell culvert: 4'R×8'S	1600	50%	427	647	40%	581	36%	50%	322	20%	20%	542	34%	No Improvement	No Improvement
21	**CR-R2-3.1**	CR	2	3.1	NI	Crossing	Yale Road Culvert	160+82	159+62	160+22	2 cell culvert: 4'R×8'S	1655	50%	415	681	41%	566	34%	50%	313	19%	20%	528	32%	No Improvement	No Improvement
23	**CR-R2-4.1**	CR	2	4.1	NI	Crossing	Gillaspie Drive Culvert	154+59	153+39	153+99	2 cell culvert: 4'R×8'S	1745	50%	401	452	26%	450	26%	50%	241	14%	20%	418	24%	No Improvement	No Improvement
25	**CR-R2-5.1**	CR	2	5.1	NI	Crossing	Stanford Avenue Pedestrian Bridge	148+64	148+46	148+55	40'W Bridge, No Piers	1835	0%	-	-	-		-	0%	-	-	0%	-	-	No Improvement	No Improvement
27	**CR-R2-6.1**	CR	2	6.1	CI	Crossing	Stanford Avenue Culvert	147+43	146+23	146+83	2 cell culvert: 4'R×8'S	1835	50%	378	541	29%	435	24%	50%	219	12%	20%	402	22%	Increase Capacity	Capital Improvement
28	**CR-R2-7.1**	CR	2	7.1	CI	Crossing	Harvard Lane Culvert	142+97	140+65	141+81	2 cell culvert: 4.5'R×8'S	1930	0%	258	669	35%	550	28%	60%	297	15%	20%	512	27%	Increase Capacity	Capital Improvement
31	**CR-R2-8.1**	CR	2	8.1	CI	Crossing	Broadway Street Culvert	139+32	137+66	138+49	Single cell culvert: 7.5'R×23'S	1930	75%	1930	1762	91%	1429	74%	30%	1119	58%	20%	1324	69%	Increase Capacity	Capital Improvement
41	**CR-R2-10.1**	CR	2	10.1	CI	Crossing	Dartmouth Pedestrian Bridge	128+88	128+78	128+83	Single cell culvert: 7.5'R×23'S	2100	75%	NA	1429	68%	1119	53%	0%	-	-	20%	-	-	Increase Capacity	Capital Improvement
32	**CR-R2-9.1**	CR	2	9.1	NI	Crossing	Martin Drive Culvert	117+10	116+48	116+79	Left Culvert: 7.5'R×24'S Right Culvert: 6.5'R×7.5'S	2210	50%	1398	1652	75%	1346	61%	50%	679	31%	20%	1243	56%	No Improvement	No Improvement
33	**CR-R3-1.1**	CR	3	1.1	NI	Crossing	Moorehead Avenue Culvert	109+21	108+01	108+61	Single cell culvert: 7.5'R×24'S	2210	20%	2210	1500	68%	1350	61%	20%	1350	61%	20%	1350	61%	No Improvement	No Improvement
36	**CR-R3-2.1**	CR	3	2.1	CI	Crossing	US-36 Culvert	106+36	104+12	105+24	2 cell culvert: 7'R×14'S	2925	0%	2925	2214	76%	1817	62%	65%	651	22%	50%	975	33%	Increase Capacity	Capital Improvement
39	**CR-R3-3.1**	CR	3	3.1	NI	Crossing	Bike Bridge DS of US-36	103+28	104+12	103+70	40'W Bridge, No Piers	2925	0%	-	-	-		-	0%	583	20%	0%	-	-	No Improvement	No Improvement
42	**CR-R3-4.1**	CR	3	4.1	CI	Crossing	CU Campus	90+45	90+55	90+50	2 cell culvert: 18" Dia	2925	-	-	-	-		-	100%	0	-	100%	-	-	Replace existing low flow crossing	Capital Improvement
44	**CR-R3-5.1**	CR	3	5.1	CI	Crossing	Church Driveway Culvert	84+46	83+66	84+06	2 elliptical cell culvert: 68"R×43"S	2925	30%	126	74	3%		-	75%	10	0%	50%	35	1%	Install bridge	Capital Improvement
45	**CR-R3-6.1**	CR	3	6.1	CI	Crossing	Baseline Road Culvert	80+98	79+22	80+10	2 cell culvert: 7'R×12'S	2925	50%	716	1774	61%	1451	50%	50%	798	27%	20%	1387	47%	Increase Capacity	Capital Improvement
46	**CR-R3-7.1**	CR	3	7.1	CI	Crossing	Gilpin Drive Culvert	74+81	74+58	74+70	Single cell culvert: 7'R×20'S	3065	10%	1407	1564	51%	1307	43%	15%	1307	43%	15%	1307	43%	Increase Capacity	Capital Improvement
47	**CR-R3-8.1**	CR	3	8.1	NI	Crossing	Mohawk Drive Culvert	54+70	53+26	53+98	Single cell culvert: 7.5'R×20'S	3065	0%	3065	1513	49%	1243	41%	15%	1243	41%	15%	1243	41%	No Improvement	No Improvement

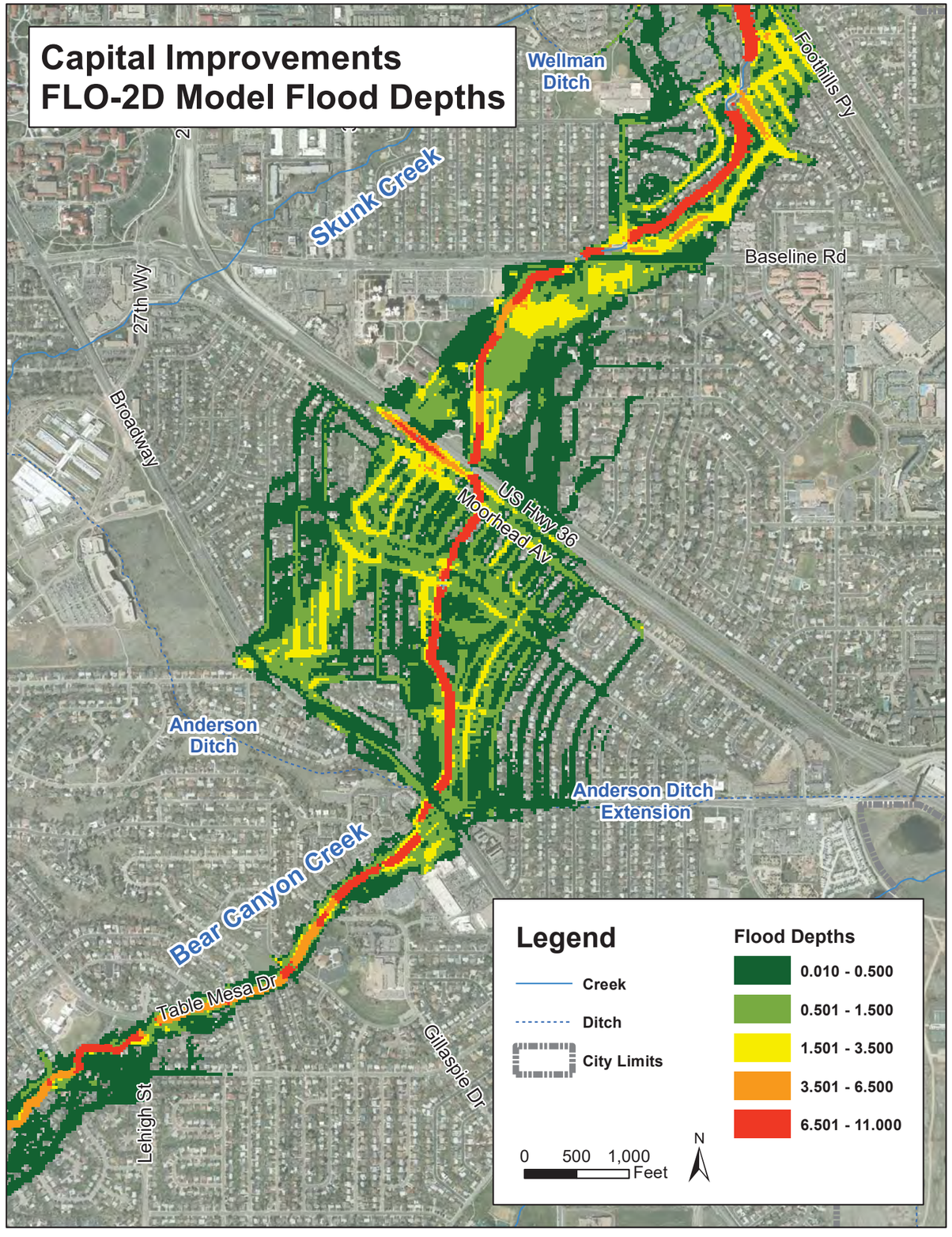
Col Explanation:

13 1987 FHAD discharge data
14 1987 FHAD reported structure blockage
15 1987 FHAD reported structure capacity
16 Theoretical capacity (no blockage) as calculated based on field measurements (HY-8v7.40)
17 Col 16 / Col 13 (%)
18 Capacity based on City requirement to assume 15% blockage
20 Blockage based on field observations (see "Blockage Memo", 2/2/16)
21 Capacity as determined with existing conditions blockage (HY-8v7.40)
22 Col 21/ Col 13 (%)
23 Blockage based on "Good Maintenance"; riparian management, routine debris control, regular structure inspection/maintenance
24 Capacity as determined with good maintenance blockage (HY-8v7.40)
25 Col 24/ Col 13 (%)
26 100-Yr Mitigation concept
27 Level of effort (Maintenance, Capitol Maintenance, Capital Improvement or No Improvement)

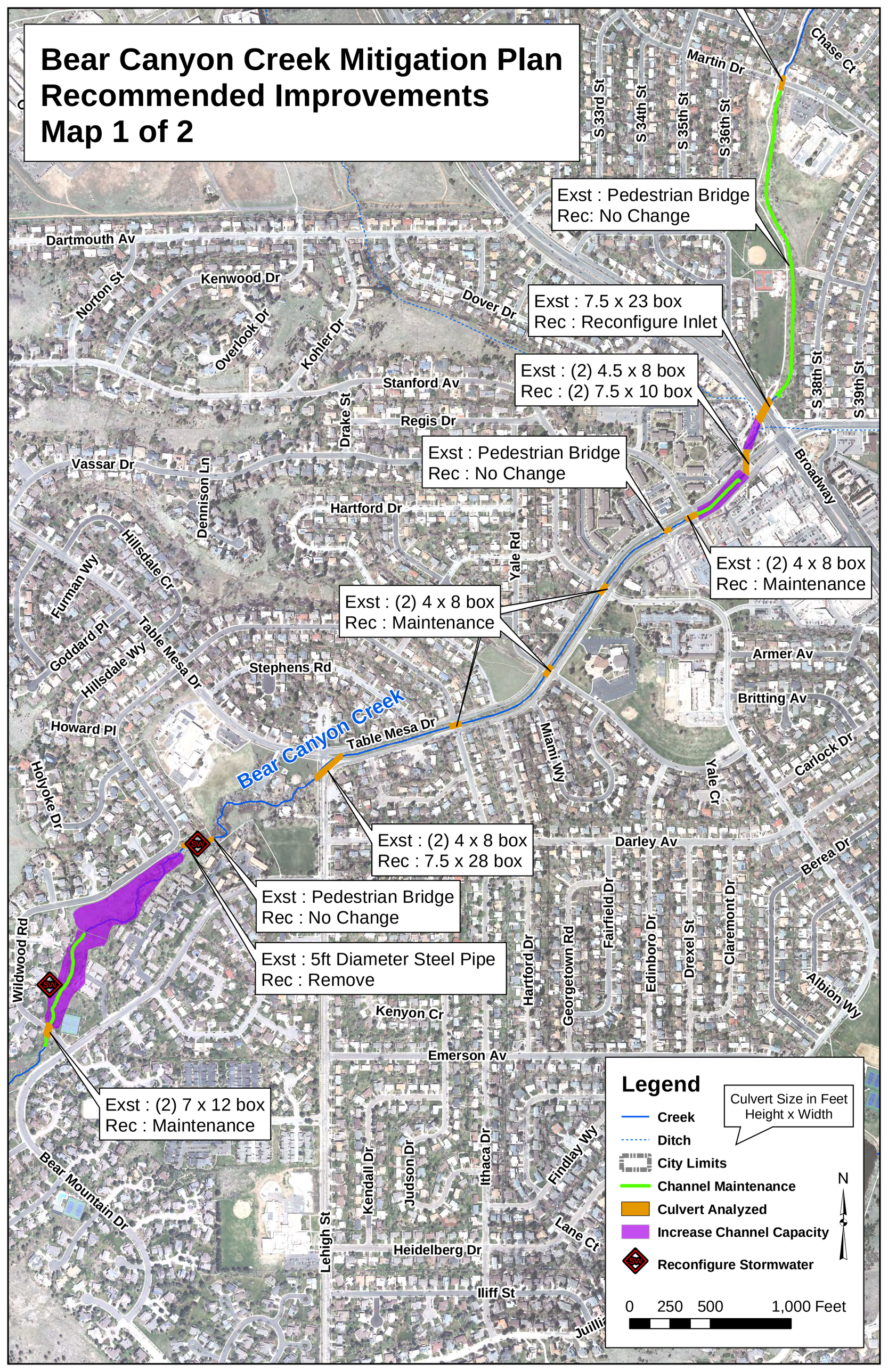
Maintenance
FLO-2D Model Flood Depths



Capital Improvements
FLO-2D Model Flood Depths



APPENDIX G: RECOMMENDED IMPROVEMENT MAPS


Bear Canyon Creek Mitigation Plan
Recommended Improvements
Map 1 of 2
Exst : Pedestrian Bridge
Rec: No Change
Exst : 7.5 x 23 box
Rec : Reconfigure Inlet
Exst : (2) 4.5 x 8 box
Rec : (2) 7.5 x 10 box
Exst : Pedestrian Bridge
Rec : No Change
Exst : (2) 4 x 8 box
Rec : Maintenance
Exst : (2) 4 x 8 box
Rec : Maintenance
Exst : (2) 4 x 8 box
Rec : 7.5 x 28 box
Exst : Pedestrian Bridge
Rec : No Change
Exst : 5ft Diameter Steel Pipe
Rec : Remove
Exst : (2) 7 x 12 box
Rec : Maintenance
Bear Canyon Creek
Dartmouth Av
Norton St
Kenwood Dr
Overlook Dr
Kohler Dr
Dover Dr
Stanford Av
Drake St
Regis Dr
Vassar Dr
Dennison Ln
Hartford Dr
Yale Rd
Broadway
Martin Dr
Chase Ct
S 33rd St
S 34th St
S 35th St
S 36th St
S 38th St
S 39th St
Armer Av
Britting Av
Carlock Dr
Yale Cr
Miami Wy
Darley Av
Berea Dr
Albion Wy
Claremont Dr
Drexel St
Edinboro Dr
Fairfield Dr
Georgetown Rd
Hartford Dr
Furman Wy
Hillsdale Cr
Goddard Pl
Hillsdale Wy
Table Mesa Dr
Stephens Rd
Howard Pl
Holyoke Dr
Wildwood Rd
Kenyon Cr
Emerson Av
Bear Mountain Dr
Lehigh St
Kendall Dr
Judson Dr
Ithaca Dr
Findlay Wy
Lane Ct
Heidelberg Dr
Iliff St
Legend
Culvert Size in Feet
Height x Width
Creek
Ditch
City Limits
Channel Maintenance
Culvert Analyzed
Increase Channel Capacity
Reconfigure Stormwater
N
0 250 500 1,000 Feet


Bear Canyon Creek Mitigation Plan
Recommended Improvements
Map 2 of 2
Shadow Creek Dr
Discovery Dr
Innovation Dr
Discovery Dr
Foothills Py
Harrison Av
Dallas Pl
Holly Pl
Pennsylvania Av
38th St
Colorado Av
E College Av
Skunk Creek
38th St
Wellman Ditch
(limits of study area)
Foothills Py
Kent St
Madison Av
Exst : 7.5 x 20 box
Rec : Maintenance
Morgan Dr
Adams Cr
E Euclid Av
35th St
36th St
Pitkin Dr
Orman Dr
Quinn St
Denton Av
37th St
Mohawk Dr
30th St
E Aurora Av
Bear Canyon Creek
34th St
38th St
39th St
Bixby Av
33rd St
Exst : 7 x 20 box
Rec : (2) 8 x 20 box
Evans Dr
Inca Pk
Talbot Dr
29th St
31st St
32nd St
Exst : (2) 7 x 12 box
Rec : (2) 7.5 x 28 box
Canyon Creek Rd
Gilpin Dr
Inca Py
Thomas Dr
SW
Baseline Rd
Laguna Pl
US Hwy 36
Exst : (2) 4 x 6 elliptical
Rec : 40ft Driveway Bridge
Comanche Dr
30th St
Exst : (2) 7 x 14 box
Rec : (2) 8.5 x 14 box
and Remove Pedestrian
Separator Wall
Exst : Pedestrian Bridge
Rec : Replace in conjunction
with CU Master Plan
Chippewa Dr
Caddo Py
Erie Dr
Fox Ct
Exst : 7.5 x 24 box
Rec : Maintenance
31st St
Fox Dr
Apache Ct
Ash Av
Exst : 7.5 x 24 box
and 6.5 x 7.5 box
Rec : Maintenance
Chase Ct
Davidson Pl
Moorhead Av
S 31st St
S 38th St
S 32nd St
S 33rd St
S 34th St
S 35th St
S 36th St
Martin Dr
Fuller Ct
Legend
Culvert Size in Feet
Height x Width
Creek
Ditch
City Limits
Channel Maintenance
Culvert Analyzed
Increase Channel Capacity
Reconfigure Stormwater
N
0 250 500 1,000 Feet

APPENDIX H: BENEFIT COST ANALYSIS

Flood Mitigation Master Plan Bear Canyon Creek

Phase 2: Existing Conditions 50, 100 & 500 year Flood Loss Estimation

Run Date: 8/24/2016

Return Period	Wet Centroid Count	Damaged Building Count	Building Damage	Contents Damage	Total Damages	Displacement Days
Reach 1; US Study Limit to Lehigh						
1 Total						
500-year Flood	122	3	$ 50,364	$ 9,413	$ 59,777	0 Days
100-Year Flood	63	2	$ 6,110	$ 2,268	$ 8,378	0 Days
50-Year Flood	41	2	$ 6,110	$ 2,268	$ 8,378	0 Days
Total	**226**	**7**	**$ 62,584**	**$ 13,949**	**$ 76,533**	**0 Days**
Reach 2A; Lehigh to Broadway						
2A Total						
500-year Flood	65	20	$ 326,597	$ 151,390	$ 477,988	0 Days
100-Year Flood	36	11	$ 36,085	$ 14,643	$ 50,728	0 Days
50-Year Flood	17	5	$ 14,672	$ 3,580	$ 18,253	0 Days
Total	**118**	**36**	**$ 377,354**	**$ 169,614**	**$ 546,968**	**0 Days**
Reach 2B; Broadway to Moorhead						
2B Total						
500-year Flood	414	206	$ 1,524,530	$ 547,750	$ 2,072,280	0 Days
100-Year Flood	282	151	$ 790,314	$ 307,864	$ 1,098,178	0 Days
50-Year Flood	224	121	$ 627,895	$ 248,536	$ 876,432	0 Days
Total	**920**	**478**	**$ 2,942,739**	**$ 1,104,151**	**$ 4,046,890**	**0 Days**
Reach 3A; Moorhead to Baseline						
3A Total						
500-year Flood	33	13	$ 341,716	$ 165,057	$ 506,773	0 Days
100-Year Flood	25	12	$ 296,538	$ 154,222	$ 450,759	0 Days
50-Year Flood	21	11	$ 272,208	$ 144,966	$ 417,174	0 Days
Total	**79**	**36**	**$ 910,462**	**$ 464,245**	**$ 1,374,707**	**0 Days**
Reach 3B; Baseline to Foothills Pkwy						
3B Total						
500-year Flood	90	22	$ 243,404	$ 76,347	$ 319,751	315 Days
100-Year Flood	71	18	$ 206,372	$ 65,937	$ 272,308	225 Days
50-Year Flood	68	17	$ 180,633	$ 58,322	$ 238,956	225 Days
Total	**229**	**57**	**$ 630,409**	**$ 200,606**	**$ 831,015**	**765 Days**
Total Damages for Study Area by Return Period						
Grand Total						
500-year Flood	724	264	$ 2,486,611	$ 949,958	$ 3,436,569	315 Days
100-Year Flood	477	194	$ 1,335,418	$ 544,934	$ 1,880,352	225 Days
50-Year Flood	371	156	$ 1,101,519	$ 457,673	$ 1,559,192	225 Days
Grand Total	**1572**	**614**	**$ 4,923,548**	**$ 1,952,565**	**$ 6,876,112**	**765 Days**

Flood Mitigation Master Plan Bear Canyon Creek

Phase 2: Recommended 50, 100 & 500 year Flood Loss Estimation

Run Date: 8/24/2016

Return Period	Wet Centroid Count	Damaged Building Count	Building Damage	Contents Damage	Total Damages	Displacement Days
Reach 1; US Study Limit to Lehigh						
1 Total						
500-year Flood	121	3	$ 50,364	$ 9,413	$ 59,777	0 Days
100-Year Flood	1	1	$ 1,385	$ -	$ 1,385	0 Days
50-Year Flood	1	1	$ 1,385	$ -	$ 1,385	0 Days
Total	**123**	**5**	**$ 53,134**	**$ 9,413**	**$ 62,547**	**0 Days**
Reach 2A; Lehigh to Broadway						
2A Total						
500-year Flood	57	17	$ 268,842	$ 131,993	$ 400,835	0 Days
100-Year Flood	23	10	$ 30,767	$ 12,091	$ 42,858	0 Days
50-Year Flood	12	4	$ 13,088	$ 3,580	$ 16,668	0 Days
Total	**92**	**31**	**$ 312,698**	**$ 147,664**	**$ 460,362**	**0 Days**
Reach 2B; Broadway to Moorhead						
2B Total						
500-year Flood	382	202	$ 1,467,246	$ 529,354	$ 1,996,600	0 Days
100-Year Flood	245	139	$ 738,842	$ 286,086	$ 1,024,929	0 Days
50-Year Flood	175	108	$ 575,660	$ 225,423	$ 801,084	0 Days
Total	**802**	**449**	**$ 2,781,749**	**$ 1,040,863**	**$ 3,822,612**	**0 Days**
Reach 3A; Moorhead to Baseline						
3A Total						
500-year Flood	28	4	$ 100,891	$ 84,858	$ 185,750	0 Days
100-Year Flood	10	0	$ -	$ -	$ -	0 Days
50-Year Flood	9	0	$ -	$ -	$ -	0 Days
Total	**47**	**4**	**$ 100,891**	**$ 84,858**	**$ 185,750**	**0 Days**
Reach 3B; Baseline to Foothills Pkwy						
3B Total						
500-year Flood	44	11	$ 182,101	$ 52,314	$ 234,415	315 Days
100-Year Flood	9	4	$ 131,464	$ 35,373	$ 166,838	225 Days
50-Year Flood	5	4	$ 109,773	$ 29,702	$ 139,475	225 Days
Total	**58**	**19**	**$ 423,339**	**$ 117,389**	**$ 540,728**	**765 Days**
Total Damages for Study Area by Return Period						
Grand Total						
500-year Flood	632	237	$ 2,069,445	$ 807,932	$ 2,877,377	315 Days
100-Year Flood	288	154	$ 902,459	$ 333,550	$ 1,236,009	225 Days
50-Year Flood	202	117	$ 699,906	$ 258,706	$ 958,612	225 Days
Grand Total	**1122**	**508**	**$ 3,671,810**	**$ 1,400,188**	**$ 5,071,998**	**765 Days**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R1-2.1
Boiler Culvert at Ithaca Drive

General Information

	Boiler Culvert at Ithaca Drive
Site Code:	CR-R1-2.1
UDFCD Costing Tab:	R1-Reach2.1
Model US Station:	18816
Model DS Station:	18800
Model Length:	16

Proposed Crossing Modification

Proposed CBC Design		
Span:	0	
Rise:	0	
Number of Barrels:	0	
Length:	0	LF/Barrel
Wingwalls?	No	

The existing culvert at Ithaca Drive is proposed to be removed but not replaced. The costing considers 2 channel improvements after the culvert removal:
1. 75 LF of 24" boulder edging
2. Grouted boulder drop structure (14 square yards of 18" boulders)

Proposed Culvert Removal and Excavation		
Remove existing 5-ft CMP		
Existing Structure Length:	16	LF
Existing Total Structure Width:	5	ft
Existing Structure Height:	5	ft
Existing Structure Volume:	400	ft^3
Proposed Structure Volume:	0	ft^3
Proposed Volume Removal = Proposed Excavation		
Proposed Excavation:	**15**	**CY**
Proposed Structure Removal:	**16**	**LF/Barrel**

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 11,380.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	LS	$5,000.00
Mobilization:	5%	$569.00
Traffic Control:	LS	$2,500.00
Utility Coordination:	LS	$10,000.00
Erosion Control:	5%	$569.00
Additional Costs Subtotal:		**$18,638.00**
Engineering:	15%	$4,503.00
Legal/Administrative:	5%	$1,501.00
Construction Mgmt:	10%	$3,002.00
Contingency:	25%	$7,505.00
Other Costs Subtotal:		$16,511.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:			LF	$1.00	$0.00
Inlet:			EA	$52.00	$0.00
Channel:	1	50	LF	$2.00	$100.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$100.00**

Total Capital Improvement Cost: **$ 46,529** Total Operation and Maintenance Costs Over 50 Years: **$ 2,148**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

EC-R1-1.1
Upper Bear Creek Park

General Information

	Upper Bear Creek Park
Site Code:	EC-R1-1.1
UDFCD Costing Tab:	R1-Reach1.1
Model US Station:	20512
Model DS Station:	19752
Model Length:	760

Proposed Channel Modification

Mowing:	1493	LF
Channel Modification Reach:	760	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	0	
Culverts:	50	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R1-1.1	0.223	3711	1493	0.056	0.167

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 215,291.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$21,529.00
Mobilization:	5%	$10,765.00
Traffic Control:	10%	$21,529.00
Utility Coordination:	10%	$21,529.00
Erosion Control:	5%	$10,765.00
Additional Costs Subtotal:		**$86,117.00**
Engineering:	15%	$45,211.00
Legal/Administrative:	5%	$15,070.00
Construction Mgmt:	10%	$30,141.00
Contingency:	25%	$75,352.00
Other Costs Subtotal:		$165,774.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	50	LF	$1.00	$50.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	760	LF	$2.00	$1,520.00
Mowing:	1	0.17	ACRES	$52.00	$9.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$1,579.00**

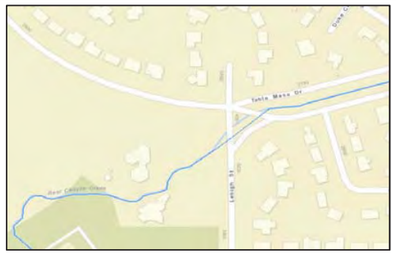
Total Capital Improvement Cost: **$ 467,182** Total Operation and Maintenance Costs Over 50 Years: **$ 33,920**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R2-1.1
Lehigh Street Culvert

General Information

	Lehigh Street Culvert
Site Code:	CR-R2-1.1
UDFCD Costing Tab:	R2A-Reach1.1
Model US Station:	17543
Model DS Station:	17352
Model Length:	191



Proposed Crossing Modification

Proposed CBC Design		
Span:	28	
Rise:	7.5	
Number of Barrels:	1	
Length:	191	LF/Barrel
Wingwalls?	Yes, at Inlet	

The proposed dimensions were not available from the CDOT M&S Standards, so the proposed culvert was input as two 14'S×8'R CBC Barrels for an initial estimate.

Proposed Culvert Removal and Excavation		
Remove two 8'S×4'R CBC's spaced 9 feet on center		
Existing Structure Length:	191	LF
Existing Total Structure Width:	17	ft
Existing Structure Height:	4	ft
Existing Structure Volume:	12988	ft^3
Proposed Structure Volume:	40110	ft^3
Proposed Volume Increase = Proposed Excavation		
Proposed Excavation:	**1005**	**CY**
Proposed Structure Removal:	**191**	**LF/Barrel**
Existing Pavement Removal:	**20**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**4.4**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 1,078.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$ 646,746.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$64,675.00
Mobilization:	5%	$32,337.00
Traffic Control:	10%	$64,675.00
Utility Coordination:	15%	$97,012.00
Erosion Control:	5%	$32,337.00
Additional Costs Subtotal:		**$291,036.00**
Engineering:	15%	$140,667.00
Legal/Administrative:	5%	$46,889.00
Construction Mgmt:	10%	$93,778.00
Contingency:	25%	$234,446.00
Other Costs Subtotal:		$515,780.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	191	LF	$1.00	$191.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$191.00**

Total Capital Improvement Cost: **$ 1,453,562**

Total Operation and Maintenance Costs Over 50 Years: **$ 4,103**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

EC-R2-6.1
Stanford Avenue to Harvard Lane

General Information

	Stanford Avenue to Harvard Lane
Site Code:	EC-R2-6.1
UDFCD Costing Tab:	R2A-Reach6.12
Model US Station:	14643
Model DS Station:	14306
Model Length:	337

Proposed Channel Modification

Mowing:	822	LF
Channel Modification Reach:	337	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	0	
Culverts:	0	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R2-6.1	0.213	3024	822	0.053	0.160

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 141,268.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$14,127.00
Mobilization:	5%	$7,063.00
Traffic Control:	10%	$14,127.00
Utility Coordination:	10%	$14,127.00
Erosion Control:	5%	$7,063.00
Additional Costs Subtotal:		**$56,507.00**
Engineering:	15%	$29,666.00
Legal/Administrative:	5%	$9,889.00
Construction Mgmt:	10%	$19,778.00
Contingency:	25%	$49,444.00
Other Costs Subtotal:		$108,777.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:		0	LF	$1.00	$0.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	337	LF	$2.00	$674.00
Mowing:	1	0.09	ACRES	$52.00	$5.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$679.00**

Total Capital Improvement Cost: **$ 306,552**

Total Operation and Maintenance Costs Over 50 Years: **$ 14,586**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R2-7.1
Harvard Lane Culvert

General Information

	Harvard Lane Culvert
Site Code:	CR-R2-7.1
UDFCD Costing Tab:	R2A-Reach7.1
Model US Station:	14161
Model DS Station:	14045
Model Length:	116

Proposed Crossing Modification

Proposed CBC Design

Span:	10	
Rise:	7.5	
Number of Barrels:	2	
Length:	116	LF/Barrel
Wingwalls?	Yes, at Inlet and Outlet	

The proposed dimensions were not available from the CDOT M&S Standards, so the proposed culvert was input as two 10'S×8'R CBC Barrels for an initial estimate.

The proposed culvert is broken-backed; this was assumed to have minimal effect on costing and was not addressed for cost estimating purposes.

Proposed Culvert Removal and Excavation

Remove two 8'S×4.5'R CBC's spaced 9 feet on center

Existing Structure Length:	116	LF
Existing Total Structure Width:	17	ft
Existing Structure Height:	4	ft
Existing Structure Volume:	7888	ft^3
Proposed Structure Volume:	17400	ft^3

Proposed Volume Increase = Proposed Excavation

Proposed Excavation:	**352**	**CY**
Proposed Structure Removal:	**116**	**LF/Barrel**
Existing Pavement Removal:	**20**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**4.4**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 1,078.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$ 316,393.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$31,639.00
Mobilization:	5%	$15,820.00
Traffic Control:	10%	$31,639.00
Utility Coordination:	15%	$47,459.00
Erosion Control:	5%	$15,820.00
Additional Costs Subtotal:		**$142,377.00**
Engineering:	15%	$68,816.00
Legal/Administrative:	5%	$22,939.00
Construction Mgmt:	10%	$45,877.00
Contingency:	25%	$114,693.00
Other Costs Subtotal:		$252,325.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	232	LF	$1.00	$232.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$232.00**

Total Capital Improvement Cost: $ 711,095 **Total Operation and Maintenance Costs Over 50 Years: $ 4,984**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R2-8.1
Broadway Street Culvert

General Information

	Broadway Street Culvert
Site Code:	CR-R2-8.1
UDFCD Costing Tab:	R2B-Reach8.1
Model US Station:	13791
Model DS Station:	13708
Model Length:	83

Proposed Crossing Modification

Proposed CBC Design

Span:	23	
Rise:	8.6	
Number of Barrels:	1	
Length:	83	LF/Barrel
Wingwalls?	Yes, at Inlet and Outlet	

The proposed culvert design does not involve full structure removal/replacement, just a modification of the culvert rise. This work was assumed to cost between $50,000 and $100,000.

Proposed Culvert Removal and Excavation

Modify 23'S×7.5'R CBC

Existing Structure Length:	83	LF
Existing Total Structure Width:	23	ft
Existing Structure Height:	7.5	ft
Existing Structure Volume:	14317.5	ft^3
Proposed Structure Volume:	16417.4	ft^3

Proposed Volume Increase = Proposed Excavation

Proposed Excavation:	**78**	**CY**
Proposed Structure Removal:	**0**	**LF/Barrel**

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 30,000.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$3,000.00
Mobilization:	5%	$1,500.00
Traffic Control:	10%	$3,000.00
Utility Coordination:	15%	$4,500.00
Erosion Control:	5%	$1,500.00
Additional Costs Subtotal:		**$13,500.00**
Engineering:	15%	$6,525.00
Legal/Administrative:	5%	$2,175.00
Construction Mgmt:	10%	$4,350.00
Contingency:	25%	$10,875.00
Other Costs Subtotal:		$23,925.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	83	LF	$1.00	$83.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$83.00**

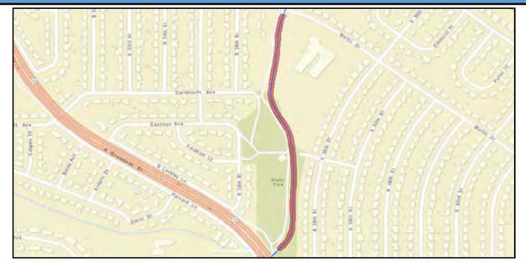
Total Capital Improvement Cost: $ 67,425 **Total Operation and Maintenance Costs Over 50 Years: $ 1,783**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

EC-R2-8.1
Broadway to Dartmouth

General Information

	Broadway to Dartmouth
Site Code:	EC-R2-8.1
UDFCD Costing Tab:	R2B-Reach8.12
Model US Station:	13688
Model DS Station:	11746
Model Length:	1942



Proposed Channel Modification

Mowing:	3967	LF
Channel Modification Reach:	1942	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	2	
Culverts:	0	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R2-8.1	0.535	6275	3967	0.134	0.401

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 470,223.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$47,022.00
Mobilization:	5%	$23,511.00
Traffic Control:	10%	$47,022.00
Utility Coordination:	15%	$70,533.00
Erosion Control:	5%	$23,511.00
Additional Costs Subtotal:		**$211,599.00**
Engineering:	15%	$102,273.00
Legal/Administrative:	5%	$34,091.00
Construction Mgmt:	10%	$68,182.00
Contingency:	25%	$170,456.00
Other Costs Subtotal:		$375,002.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:		0	LF	$1.00	$0.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	1942	LF	$2.00	$3,884.00
Mowing:	1	0.46	ACRES	$52.00	$24.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$3,908.00**

Total Capital Improvement Cost: **$ 1,056,824** Total Operation and Maintenance Costs Over 50 Years: **$ 83,952**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R3-2.1
US 36 Culvert

General Information

	US 36 Culvert
Site Code:	CR-R3-2.1
UDFCD Costing Tab:	R3A-Reach2.1
Model US Station:	10512
Model DS Station:	10400
Model Length:	112

Proposed Crossing Modification

Proposed CBC Design

Span:	14	
Rise:	8.5	
Number of Barrels:	2	
Length:	112	LF/Barrel
Wingwalls?	Yes, at Inlet and Outlet	

The proposed dimensions were not available from the CDOT M&S Standards, so the proposed culvert was input as two 14'S×9'R CBC Barrels for an initial estimate.

Proposed Culvert Removal and Excavation

Remove two 14'S×6'R CBC's spaced 15 feet on center

Existing Structure Length:	112	LF
Existing Total Structure Width:	29	ft
Existing Structure Height:	6	ft
Existing Structure Volume:	19488	ft^3
Proposed Structure Volume:	26656	ft^3

Proposed Volume Increase = Proposed Excavation

Proposed Excavation:	**290**	**CY**
Proposed Structure Removal:	**112**	**LF/Barrel**
Existing Pavement Removal:	**46**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**10.0**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 2,459.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$ 422,033.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$42,203.00
Mobilization:	5%	$21,102.00
Traffic Control:	10%	$42,203.00
Utility Coordination:	15%	$63,305.00
Erosion Control:	5%	$21,102.00
Additional Costs Subtotal:		**$189,915.00**
Engineering:	15%	$91,792.00
Legal/Administrative:	5%	$30,597.00
Construction Mgmt:	10%	$61,195.00
Contingency:	25%	$152,987.00
Other Costs Subtotal:		$336,571.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	224	LF	$1.00	$224.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$224.00**

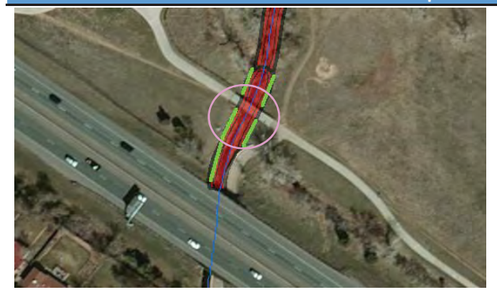
Total Capital Improvement Cost: **$ 948,519** Total Operation and Maintenance Costs Over 50 Years: **$ 4,812**

EC-R3-1.1
US 36 to CDOT Right-of-Way

General Information

	US 36 to CDOT Right-of-Way
Site Code:	EC-R3-1.1
UDFCD Costing Tab:	R3A-Reach1.1
Model US Station:	10435
Model DS Station:	10293
Model Length:	142

Proposed Channel Modification



Mowing:	221	LF
Channel Modification Reach:	142	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	1	
Culverts:	0	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R3-1.1	0.04	110	284	0.010	0.030

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 14,118.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$1,412.00
Mobilization:	5%	$706.00
Traffic Control:	10%	$1,412.00
Utility Coordination:	10%	$1,412.00
Erosion Control:	5%	$706.00
Additional Costs Subtotal:		**$5,648.00**
Engineering:	15%	$2,965.00
Legal/Administrative:	5%	$988.00
Construction Mgmt:	10%	$1,977.00
Contingency:	25%	$4,942.00
Other Costs Subtotal:		$10,872.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:		0	LF	$1.00	$0.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	142	LF	$2.00	$284.00
Mowing:	1	0.03	ACRES	$52.00	$2.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$286.00**

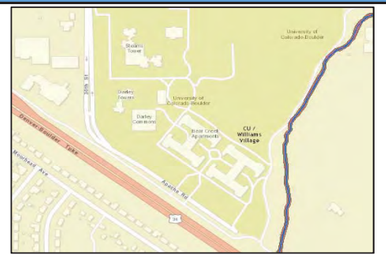
Total Capital Improvement Cost: **$ 30,638** Total Operation and Maintenance Costs Over 50 Years: **$ 6,144**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

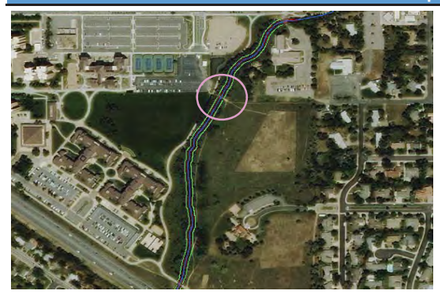
EC-R3-2.1
CU Campus between US 36 and Church Property

General Information

	CU Campus between US 36 and Church
Site Code:	EC-R3-2.1
UDFCD Costing Tab:	R3A-Reach2.12
Model US Station:	10440
Model DS Station:	8436
Model Length:	2004



Proposed Channel Modification



Mowing:	3675	LF
Channel Modification Reach:	2004	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	1	
Culverts:	0	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R3-2.1	0.536	16564	3675	0.134	0.402

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 704,673.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$70,467.00
Mobilization:	5%	$35,234.00
Traffic Control:	10%	$70,467.00
Utility Coordination:	15%	$105,701.00
Erosion Control:	5%	$35,234.00
Additional Costs Subtotal:		**$317,103.00**
Engineering:	15%	$153,266.00
Legal/Administrative:	5%	$51,089.00
Construction Mgmt:	10%	$102,178.00
Contingency:	25%	$255,444.00
Other Costs Subtotal:		$561,977.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:		0	LF	$1.00	$0.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	2004	LF	$2.00	$4,008.00
Mowing:	1	0.42	ACRES	$52.00	$22.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$4,030.00**

Total Capital Improvement Cost: **$ 1,583,753** Total Operation and Maintenance Costs Over 50 Years: **$ 86,573**

EC-R3-3.1
Church Property US of Driveway

General Information

	Church Property US of Driveway
Site Code:	EC-R3-3.1
UDFCD Costing Tab:	R3A-Reach3.1
Model US Station:	8484
Model DS Station:	8428
Model Length:	56

Proposed Channel Modification

Mowing:	105	LF
Channel Modification Reach:	56	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	0	
Culverts:	0	LF

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R3-3.1	0.018	677	100	0.005	0.014

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 24,871.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$2,487.00
Mobilization:	5%	$1,244.00
Traffic Control:	10%	$2,487.00
Utility Coordination:	15%	$3,731.00
Erosion Control:	5%	$1,244.00
Additional Costs Subtotal:		**$11,193.00**
Engineering:	15%	$5,410.00
Legal/Administrative:	5%	$1,803.00
Construction Mgmt:	10%	$3,606.00
Contingency:	25%	$9,016.00
Other Costs Subtotal:		$19,835.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:		0	LF	$1.00	$0.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	56	LF	$2.00	$112.00
Mowing:	1	0.01	ACRES	$52.00	$1.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$113.00**

Total Capital Improvement Cost: **$ 55,899** Total Operation and Maintenance Costs Over 50 Years: **$ 2,427**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R3-5.1
Church Driveway Culvert

General Information

	Church Driveway Culvert
Site Code:	CR-R3-5.1
UDFCD Costing Tab:	R3B-Reach5.1
Model US Station:	8428
Model DS Station:	8388
Model Length:	40

Proposed Crossing Modification

Proposed Bridge Design

The church driveway crossing will be expanded to span about 40 feet over Bear Canyon Creek. This alternative may be a bridge crossing, but the design is yet to be determined. For preliminary costing purposes, this crossing was modeled as two 20'S×8'R CBC's.

Proposed Culvert Removal and Excavation

Remove two 5.67'S×3.58'R elliptical culvert pipes

Existing Structure Length:	40	LF
Existing Total Structure Width:	12.5	ft
Existing Structure Height:	3.58	ft
Existing Structure Volume:	1790	ft^3
Proposed Structure Volume:	0	ft^3
Existing Structure Volume = Proposed Excavation		
Proposed Excavation:	**67**	**CY**
Proposed Structure Removal:	**80**	**LF**
Existing Pavement Removal:	**6**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**1.4**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 337.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$ 219,435.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$21,944.00
Mobilization:	5%	$10,972.00
Traffic Control:	10%	$21,944.00
Utility Coordination:	15%	$32,915.00
Erosion Control:	5%	$10,972.00
Additional Costs Subtotal:		**$98,747.00**
Engineering:	15%	$47,727.00
Legal/Administrative:	5%	$15,909.00
Construction Mgmt:	10%	$31,818.00
Contingency:	25%	$79,546.00
Other Costs Subtotal:		$175,000.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	80	LF	$1.00	$80.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$80.00**

Total Capital Improvement Cost: **$ 493,182** Total Operation and Maintenance Costs Over 50 Years: **$ 1,719**

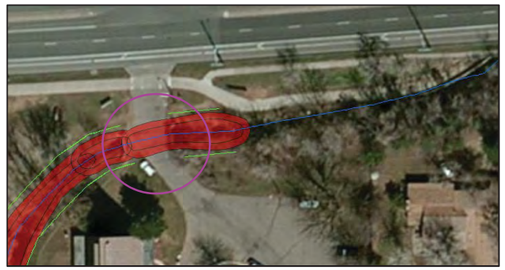
Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

EC-R3-3.2
Church Property DS of Driveway

General Information

	Church Property DS of Driveway
Site Code:	EC-R3-3.2
UDFCD Costing Tab:	R3B-Reach3.2
Model US Station:	8428
Model DS Station:	8334
Model Length:	94

Proposed Channel Modification



Mowing:	84	LF
Channel Modification Reach:	94	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	0	LF
Bridges:	0	
Culverts:	80	LF

(Double-Barrel)

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R3-3.2	0.031	658	84	0.008	0.023

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 23,235.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$2,324.00
Mobilization:	5%	$1,162.00
Traffic Control:	10%	$2,324.00
Utility Coordination:	15%	$3,485.00
Erosion Control:	5%	$1,162.00
Additional Costs Subtotal:		**$10,457.00**
Engineering:	15%	$5,054.00
Legal/Administrative:	5%	$1,685.00
Construction Mgmt:	10%	$3,369.00
Contingency:	25%	$8,423.00
Other Costs Subtotal:		$18,531.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	80	LF	$1.00	$80.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	94	LF	$2.00	$188.00
Mowing:	1	0.01	ACRES	$52.00	$1.00
Trails:		0	LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$269.00**

Total Capital Improvement Cost: **$ 52,223** Total Operation and Maintenance Costs Over 50 Years: **$ 5,779**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R3-6.1
Baseline Road Culvert

General Information

	Baseline Road Culvert
Site Code:	CR-R3-6.1
UDFCD Costing Tab:	R3B-Reach6.1
Model US Station:	8013
Model DS Station:	7827
Model Length:	186

Proposed Crossing Modification

Proposed CBC Design

Span:	28	
Rise:	7.5	
Number of Barrels:	2	
Length:	186	LF/Barrel
Wingwalls?	Yes, at Inlet and Outlet	

The proposed dimensions were not available from the CDOT M&S Standards, so the proposed culvert was input as four 14'S×8'R CBC Barrels for an initial estimate.

Proposed Culvert Removal and Excavation

Remove two 12'S×7'R CBC's spaced 15 feet on center

Existing Structure Length:	186	LF
Existing Total Structure Width:	25	ft
Existing Structure Height:	7	ft
Existing Structure Volume:	32550	ft^3
Proposed Structure Volume:	78120	ft^3

Proposed Volume Increase = Proposed Excavation

Proposed Excavation:	**1688**	**CY**
Proposed Structure Removal:	**186**	**LF/Barrel**
Existing Pavement Removal:	**47**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**10.2**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 2,510.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$1,214,259.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$121,426.00
Mobilization:	5%	$60,713.00
Traffic Control:	10%	$121,426.00
Utility Coordination:	15%	$182,139.00
Erosion Control:	5%	$60,713.00
Additional Costs Subtotal:		**$546,417.00**
Engineering:	15%	$264,101.00
Legal/Administrative:	5%	$88,034.00
Construction Mgmt:	10%	$176,068.00
Contingency:	25%	$440,169.00
Other Costs Subtotal:		$968,372.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	372	LF	$1.00	$372.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
Maintenance Costs Subtotal:					**$372.00**

Total Capital Improvement Cost: **$ 2,729,048** Total Operation and Maintenance Costs Over 50 Years: **$ 7,991**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

EC-R3-7.1
Near Gilpin

General Information

	Baseline Road to North of Gilpin
Site Code:	EC-R3-7.1
UDFCD Costing Tab:	R3B-Reach7.12
Model US Station:	7833
Model DS Station:	7220
Model Length:	613

Proposed Channel Modification

Mowing:	807	LF
Channel Modification Reach:	613	LF
10-ft-Wide Trail/Path:	0	LF
10-ft-Wide Sidewalk:	345	LF
Bridges:	1	
Culverts:	51	LF

NOTE: The Gilpin culvert may be removed. This analysis assumes the culvert is still in place during channel modifications.

Site Code	Area Disturbed (acres)	Excavation (CY)	Boulder Edging (LF)	Wetlands Plantings (acres)	Reclamation Seeding (acres)
EC-R3-7.1	0.298	330	520	0.075	0.224

Capital Improvement Cost Summary

Capital Improvement Subtotal: **$ 48,810.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$4,881.00
Mobilization:	5%	$2,441.00
Traffic Control:	10%	$4,881.00
Utility Coordination:	10%	$4,881.00
Erosion Control:	5%	$2,441.00
Additional Costs Subtotal:		**$19,525.00**
Engineering:	15%	$10,250.00
Legal/Administrative:	5%	$3,417.00
Construction Mgmt:	10%	$6,834.00
Contingency:	25%	$17,084.00
Other Costs Subtotal:		$37,585.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	51	LF	$1.00	$51.00
Inlet:		0	EA	$52.00	$0.00
Channel:	1	613	LF	$2.00	$1,226.00
Mowing:	1	0.09	ACRES	$52.00	$5.00
Trails:	1	345	LF	$5.00	$1,725.00
				Maintenance Costs Subtotal:	**$3,007.00**

Total Capital Improvement Cost: **$ 102,138.00**

Total Operation and Maintenance Costs Over 50 Years: **$ 64,597.00**

Bear Canyon Creek Flood Mitigation Master Plan
Preliminary Cost Estimate

CR-R3-7.1
Gilpin Drive Culvert

General Information

	Gilpin Drive Culvert
Site Code:	CR-R3-7.1
UDFCD Costing Tab:	R3B-Reach7.1
Model US Station:	7471
Model DS Station:	7420
Model Length:	51

Proposed Crossing Modification

Proposed CBC Design

Span:	20	
Rise:	8	
Number of Barrels:	2	
Length:	51	LF/Barrel
Wingwalls?	No	

Proposed Culvert Removal and Excavation

Remove 20'S×7'R CBC

Existing Structure Length:	51	LF
Existing Total Structure Width:	20	ft
Existing Structure Height:	7	ft
Existing Structure Volume:	7140	ft^3
Proposed Structure Volume:	16320	ft^3

Proposed Volume Removal = Proposed Excavation

Proposed Excavation:	**264**	**CY**
Proposed Structure Removal:	**51**	**LF/Barrel**
Existing Pavement Removal:	**39**	**SY**
Proposed Pavement Thickness:	**4**	**in**
Proposed Pavement Weight:	**8.5**	**tons**

Capital Improvement Cost Summary

Pavement Remove and Replace: $ 2,089.00 ($16.50/SY Removed, $170/ton Replaced)

Capital Improvement Subtotal: **$ 349,108.00**

Additional Capital Improvement Costs

	% of Subtotal	Cost (LS)
Dewatering:	10%	$34,911.00
Mobilization:	5%	$17,455.00
Traffic Control:	10%	$34,911.00
Utility Coordination:	15%	$52,366.00
Erosion Control:	5%	$17,455.00
Additional Costs Subtotal:		**$157,098.00**
Engineering:	15%	$75,931.00
Legal/Administrative:	5%	$25,310.00
Construction Mgmt:	10%	$50,621.00
Contingency:	25%	$126,552.00
Other Costs Subtotal:		$278,414.00

Maintenance Costs

	Frequency (per year)	Quantity	Units	Unit Cost	Cost
Culvert:	1	102	LF	$1.00	$102.00
Inlet:			EA	$52.00	$0.00
Channel:			LF	$2.00	$0.00
Mowing:			ACRES	$52.00	$0.00
Trails:			LF	$5.00	$0.00
				Maintenance Costs Subtotal:	**$102.00**

Total Capital Improvement Cost: **$ 784,620**

Total Operation and Maintenance Costs Over 50 Years: **$ 2,191**