Larimer County Cameron Peak Fire
Post-Fire Flood Recovery

Final Report

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Colorado Water Conservation Board
Colorado Watershed Restoration Program (CWRP) Grant
Attn: Chris Sturm

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LARIMER COUNTY
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EXECUTIVE SUMMARY

Even as efforts were being made to contain and control the Cameron Peak Fire, federal, state, and local entities were working together to assess post-wildfire risks and mitigation needs; particularly those related to flooding and debris flow from the burned watersheds. At the local level, Larimer County and the cities of Fort Collins and Greeley were focused on protection of public infrastructure. For the cities, a major focus was on watershed stabilization to help protect municipal water supplies. Larimer County was principally focused on protection of the public roadways and protection measures for residences and structures most directly at risk from flooding since most of the affected properties were in unincorporated Larimer County.

To help in these efforts, the National Resources Conservation Service (NRCS) through the Emergency Watershed Protection (EWP) program, provided technical and financial support to address flooding and erosion mitigation needs. The Colorado Water Conservation Board (CWCB) also provided monetary support to expand a rain and stream gage network to help enhance flood warnings capabilities and funded hydrologic and hydraulic assessments to characterize flooding risks in areas within and downstream of the burned area (under a separate grant agreement). Using this information, the County tasked engineering consultants with detailed analysis and design of mitigation measures that included improving road crossings to increase the flow capacity and/or withstand overtopping flows.

Work was carried out in partnership with the US Forest Service on various mainline county roads including LCR 63E (Pingree Park Road), LCR 69 (Manhattan Road), and CR 44H (Buckhorn Road). During 2022, significant and repeated flooding occurred in the Upper Buckhorn Creek along LCR 44H, where work to repair road damage from the 2013 flood event was underway.

Larimer County worked closely with at-risk property owners to develop and implement localized protection and conveyance measures using flood barrier bags and Muscle Wall. These measures on private property were put in place for willing landowners, mainly in The Retreat subdivision along Miller Fork and in the Crown Point subdivision located near Rustic in the Poudre Canyon.

Significant flood events occurred in Miller Fork and Black Creek, impacting homes and public roads in The Retreat Subdivision, located just east of Glen Haven. The County also made considerable efforts to improve and stabilize public roadway crossings along Streamside Drive and Black Creek Drive. These roadways have been subjected to repeated, damaging flood events transporting high sediment and debris loads.

This document details the steps and measures taken to address post Cameron Peak wildfire flood recovery and mitigation needs in unincorporated Larimer County.

Section 1.0 – Introduction provides pertinent background information immediately after the Cameron Peak Fire disaster. Also included in this section is a general timeline of events from the start of the fire (2020) through project closeout (June 2023).

Section 2.0 – Planning and Development provides high-level information about the data that were used to inform the recovery process.

Section 3.0 – Implementation provides detailed narratives at each of the project areas and provides a discussion about private property protection and debris removal efforts.

Section 4.0 – Environmental Mitigation discusses, given the exigent nature of the recovery work, what steps were taken to identify and mitigate for environmental impacts.

Section 5.0 – Conclusion summarizes the mitigative features which were implemented across the burn scar, lessons learned, schedule, final quantities, and costs. The contribution from the CWCB grant is outlined in the conclusion section.

Section 6.0 – References provides a list of references used in development of this report.

SECTION 1.0 - INTRODUCTION

1.1 Background

The Cameron Peak Fire was reported on Thursday, August 13, 2020, near Cameron Pass off State Highway (SH) 14 in Larimer County, Colorado. The fire burned an area of 208,913 acres over several months in Larimer County, affecting both private and public lands until being fully contained on December 2, 2020. Weather and fuel conditions influenced fire growth, behavior, and effects of the Cameron Peak Fire. Extreme temperatures, low humidity, rough terrain, and gusty winds reaching over seventy (70) miles per hour were just some of the elements that were contributing factors influencing fire development.

Photo 1: Typical Photo of a Severely Burned Area (Cameron Peak Fire, 2020)

Photo 2: Typical Severely Burned Area – After Full Containment (Cameron Peak Fire, early 2021)

Within its burn perimeter, the Cameron Peak Fire reduced or eliminated above ground vegetation cover and altered soil structure, resulting in varying degrees of post-fire hydrophobicity. These direct changes to vegetation, structure, composition, and density lead to reduced precipitation interception, decreased soil infiltration capacity, and elevated runoff compared to pre-fire conditions. The Soil Burn Severity (SBS), soil erosion, hydrology and debris flow modelling results obtained and used in the risk analysis indicated that post-fire there would be an increase in watershed response. This means:

- Increased erosion and sedimentation
- Areas that flood or had debris flows pre-fire will have larger magnitude events
- Areas that occasionally flood or had debris flows pre-fire will see more frequent events
- Areas that previously did not have streamflow or debris flow may now flood or have debris flows
- Private and public infrastructure are at an increased risk of damage to post-fire flood events
- Additional impacts to aquatic and terrestrial habitats are likely to occur

Larimer County, utilizing the United States Forest Service (USFS) Burned Area Emergency Response (BAER) Report (Appendix A), the Cameron Peak Fire Risk Assessment, *Stantec Consulting Services Inc. for Synergy*

Disaster Recovery, March 15, 2021 (Appendix B), the Colorado Water Conservation Board (CWCB) hydrological and hydraulic analyses (prepared by Enginuity Engineering Solutions, April 2021), as well as several field reconnaissance trips, identified several primary locations where damage had already occurred to public infrastructure and identified over 150 private properties where the potential for moderate- to severe- post-fire flooding had or could occur.

Larimer County's Board of County Commissioners, in consultation with the Office of Emergency Management and the Engineering Department, determined that County funding would be set aside for the implementation of repairs and resiliency projects, erosion and sedimentation prevention projects, and structure protection. Larimer County also worked to obtain funding through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Emergency Watershed Program (EWP) and the Colorado Water Conservation Board (CWCB) Colorado Watershed Restoration Program (CWRP).

Larimer County also collaborated with the United States Department of Agriculture United States Forest Service (USFS), Big Thompson Watershed Coalition (BTWC), Coalition for the Poudre River Watershed (CPRW), City of Greeley, local homeowners' and road associations, regional and local volunteer fire departments, and other active stakeholders. The goal was to communicate to ensure there were not any gaps in the work as part of the recovery process and engagement with these entities is still ongoing as some of these agencies have recovery work and long-range planning still forthcoming.

1.2 Timeline

The following is the timeline of events – both during the fire and post-fire recovery efforts, planning, design, and implementation milestones.

- Cameron Peak Fire: Aug. 13, 2020 to Dec. 2, 2020
- Larimer County Disaster Declaration: August 16, 2020
- State of CO Disaster Declaration: August 18, 2020
- FEMA Major Disaster Declaration: January 15, 2021
- BCC Approve Funding for Recovery: October 12, 2020
- NRCS EWP Original Execution Date: December 2, 2020
- Damage and Risk Assessments: December 2020 to March 2021
- Preliminary Priority Area Identification: March 2021 to July 2021
- Black Hollow Disaster: July 20, 2021
- Damage Assessments and Debris Removal (Black Hollow): July to August 2021
- Preconstruction Meeting for Infrastructure Projects: November 2021
- CWCB CWRP Grant Execution Date: December 2021
    - Amendment for The Retreat January 2022
- Development of 80% Project Plans: July 2021 to Spring 2022
- Identification of Private Property Eligible for Str. Protection: February 2022
    - 143 Parcels (Burn Scar)
    - 17 Parcels (The Retreat)
- July 2022 Flooding: July 15, 24, 27, 2022
- Additional Areas Added to Scope: August 2022

    - The Retreat Reconstruction
    - Crown Point Drive
    - CR 44H Culvert Crossings and Debris Removal
- Construction Completion: June 2023

1.3 Initial Disaster Recovery Efforts

In response to this Cameron Peak Wildfire and anticipated post-fire flooding, the Larimer County Office of Emergency Management (LCOEM) took a proactive approach to facilitate a comprehensive and efficient post-wildfire recovery. Understanding the importance of collaborative efforts and access to affected areas, LCOEM launched an extensive community outreach campaign. One of the components of this campaign was encouraging community members to sign a Right of Entry form. This form granted access to multiple agencies and facilitated various mitigation efforts and projects on private properties in or around the Cameron Peak burn scar. The goal of the Right of Entry campaign was to streamline the coordination between agencies, empowering them to carry out critical tasks such as hazard tree and other debris removal, risk and vulnerability assessments, infrastructure repair, and fire/flood migration without unnecessary delays. The success of this effort was a testament to the unity and resilience of the community, as a large number of residents in and around the burn scar willingly participated in signing the form, allowing for swift and effective recovery initiatives. Additionally, LCOEM recognized the need for transparent communication with the affected communities. To achieve this, we launched a monthly Community Recovery Newsletter, which provided comprehensive updates on the progress of recovery initiatives, upcoming projects, and available resources. This allowed community members to be made aware of current and future projects as well as current and future resources.

1.4 2021 Black Hollow Disaster

On July 20, 2021, a rainfall event moved over the Poudre Canyon, and was observed by the National Weather Service Denver/Boulder at approximately 1600 hrs. A Flash Flood Advisory was issued at 1629 hrs followed by a Flash Flood Warning at 1653 hrs and another at 1724 hrs. Heavy rainfall occurred in the Poudre Canyon. Rainfall totals over the Upper Poudre Basin were approximately one- to two- (1 to 2) inches per sixty (60) minutes. Mandatory evacuations were issued in the area on July 20, 2021. The Black Hollow drainage had a massive debris flow that came down onto SH 14, causing the destruction of multiple structures and the death of four people. A damage assessment team completed an initial assessment on July 21, 2021, confirming six residential structures destroyed, one damaged, and one detached garage destroyed.

Photo 3: Black Hollow Disaster Debris Field – looking North towards SH 14 (July 20, 2021)

Search and rescue and debris removal efforts started immediately following the disaster since people were still reported missing. Larimer County mobilized debris removal contractors from the wildfire area to the debris flow to assist in rescue and recovery efforts for several days. The operation then shifted to clearing the Poudre River of debris due to the additional flash flood threats that occurred in the vicinity of the drainage. The Colorado Geological Survey team and representatives from other disaster recovery agencies toured the area surrounding Black Hollow and issued a report on July 27, 2021.

> The Black Hollow drainage and adjacent side slopes still contain a significant amount of sediment and boulders. It is a question of when not if additional debris flows or mud floods will occur. Even smaller mud floods pose safety risks to the remaining homes. In addition, the sediment currently in the Black Hollow drainage could also present a hazard to the homes immediately upstream of the alluvial fan, Highway 14, and homes and crossings downstream, should it enter into the Cache La Poudre River corridor. (*Black Hollow Debris Flow Preliminary Report, Colorado Geological Survey, July 27, 2021)*

Other areas within the burn scar saw moderate impacts during the 2021 monsoonal season and as the County was still in the process of evaluating the initial risk assessment to the cluster areas, the sense of urgency to begin installation of resiliency and mitigative measures was a top priority.

SECTION 2.0 – PLANNING AND DEVELOPMENT

The initial Cameron Peak Fire Risk Assessment was completed March 15, 2021 (Appendix B). The purpose of the report was to identify potential areas of elevated hazard quickly and efficiently with the focus of exigent threats to life, property, and the environment within the burn perimeter. This analysis was performed with the best available data at the time and a more detailed hydrological analysis was recommended to further assess threats for long-term planning. As a result of the initial threat assessment report, Larimer County requested further assistance from the state to provide more detailed hydrologic (predicted runoff flowrates from storm events) and hydraulic (predicted flow velocities, depths, etc.) analyses of the entire burn area and potential downstream effects. The state tasked its contractor, Enginuity Engineering Solutions (Enginuity), to provide these analyses which were completed at the end of April 2021.

The conclusions drawn from the Enginuity hydrology report were used along with the GIS-generated list of parcels and County-owned assets to determine the basis for several field reconnaissance missions. These field trips enabled the County to ground-truth areas where the risk for elevated water and debris flows were likely to occur. Additionally, the following conclusions were drawn from the Enginuity hydrologic analysis:

- Some landowners were at greater risk of rising flood waters from rivers and creeks; however, there were also locations where residents were at greater risk of localized debris floods from upslope areas (as identified in the CPF Risk Assessment), especially in steeper terrain.
- The certainty of the Enginuity model were not 100- percent accurate; however, calibrated hydrologic models would be needed to assess and refine the relative changes in runoff response between pre- and post-fire conditions under a variety of rainfall conditions.
- Assets located well outside of the burn perimeter may be at an elevated risk of potential flood hazards, particularly dislodged debris fields.
- Many homes already at risk within the 100-year regulatory floodplain along the Poudre and Big Thompson Rivers, were also at an elevated level of risk (increased depths and velocities) because of the fire.

Figure 1 shows the CPF burn scar and heat risk map, denoting “cluster” areas of higher risk. Figure 2 shows the neighborhoods at risk and Figure 3 shows the County-Owned Road Risk Map.

2.1 Hydrologic and Hydraulic Assumptions

The Enginuity Hydrologic and Hydraulic (H&H) preliminary evaluation showed the ratio of pre-fire to post-fire flow rates for the annual, 10-year, and 100-year rainfall events. It was expected at that time that a final calibration would be needed to show flow rates at all the Larimer County culvert/bridge locations; however, these were not totally finalized as part of that scope. Flooding extents were determined in the Enginuity model via a 2D rainfall/runoff model rather than coupling the HEC-HMS hydrology to the HEC-RAS model. The result was a more efficient process given the size of the burn scar and topographic data. Structures were given a low, medium, or high risk associated with them on a relative basis. Estimated depths and velocities for the 2- and 10-year post-fire events in a GIS layer called “Structures Values-at-Risk [VAR]” ranked layer.

The NRCS Emergency Watershed Protection (EWP) Program, under the Colorado Fire Recovery Projects, Project Engineering Guidance (April 2021) required projects to be designed in accordance with the NRCS

Conservation Practice Standards (CPS) available in Section IV of the NRCS Field Office Technical Guide (FOTG) and is based on using the ordinary standard of care and sound engineering judgement. Additional refined H&H analyses were required at each of the project areas. Larimer County utilized Anderson Consulting Engineers (ACE) (along with AVI, PC [AVI]) and Ayres Associates, Inc. (Ayres) to provide refined analyses and design reports. At most locations, a 25-year post-fire rainfall event was the minimum design event for resiliency improvements (e.g. culvert and riprap sizing). Where a 25-year event was not possible/practicable to design to, the engineer of record provided justification to the NRCS as to why a lesser event was selected for design/implementation.

Ayres provided the refined hydrologic and hydraulic analyses for The Retreat neighborhood, applying guidance from the USDA NRCS Technical Note 4, Part 630 of the National Engineering Handbook and data from the Colorado US and US Geological Survey for Soils. Due to geometric site constraints and resources, designing and implementing resiliency features designed to minimum 25-year post-fire flood flow was not a viable option, therefore the 5-year event was selected. Culverts were assessed using Federal Highway Administration (FHWA)'s HY-Culvert Analysis program. Existing conditions were modeled using elevations acquired from LIDAR data and field measurements.

The overall approach to mitigation and protection in The Retreat was to contain flows in the stream's corridor upstream and adjacent to infrastructure and allow spreading and dissipation of flow to encourage deposition and storage in selected areas downstream of infrastructure. Additional information can be found in the design report for The Retreat in Appendix C.

2.2 Identification of Project Areas

Project areas were extracted from the findings of the Risk Assessment and through several field reconnaissance missions. Details from the Risk Assessment can be found in Section 3.0 – Implementation. Photos, pre-construction, during construction, and post-construction can be found in Appendix D.

2.3 Engineer's Certification

The NRCS Certification of Conservation Practice Completion Form is included as Appendix E.

SECTION 3.0 - IMPLEMENTATION

3.1 Introduction

Table 1 shows the results from the Risk Assessment report; the "neighborhood pods" that were identified as High Risk are as follows:

Table 1: Neighborhood Pod Relative Risk Summary (based on Burn Severity, Potential Debris Flows, and FEMA Flood Zones, Risk Assessment, March 2021)

High Risk Neighborhood Pods
Big Bear
Crystal Mountain
Goodell Corner
Home Moraine
Monument Gulch
Poudre City
Upper Buckhorn
Storm Mountain

Based on the metrics of mapped soil burn severity, number of potential debris flow intersections, and proportion of County Road segment within a FEMA Flood Zone, the Risk Assessment report also identified the following road segments as having a moderate- to high-risk from post-fire flooding and debris flows:

Table 2: County Road Relative Risk Summary (Risk Assessment, March 2021)

High Risk CR Segments	Moderate Risk CR Segments
12964789 - CR 44H	12964549 - BUCKHORN ROAD
12964793 - BUCKHORN ROAD	12964791 - BUCKHORN ROAD
12965098 - PINGREE PARK ROAD	12964792 - BUCKHORN ROAD
12965171 - MANHATTAN ROAD	12965170 - PINGREE HILL
12965241 - LARAMIE RIVER ROAD	---

Risks to road/public infrastructure and structures within Rustic, Poudre City, Glen Echo, and Goodell Corner (i.e. neighborhoods surrounding SH 14 and Larimer County Road [LCR] 69) were associated with Sevenmile Creek flooding and debris flows stemming from moderate- and high- soil burn areas within multiple steep and narrow canyons with relatively large watersheds. Monument Gulch, Pingree Park Road, and Lazy D Ranch (i.e. neighborhoods surrounding LCR 63E to LCR 44H) were associated with Fish Creek, Pennock Creek, Little Beaver Creek, and the South Fork of the Cache la Poudre River. Upper Buckhorn included areas associated with Buckhorn Creek and debris flows stemming from moderate- and high- soil burn areas. Additionally, there were several single-point access to structures in this area and many of the access roads lie within canyons with elevated risk. LCR 44H (Buckhorn Road) was also severely damaged during the 2013 flooding and was only recently repaired/reconstructed in its entirety as part of a United States Department of Homeland Security Federal Emergency Management Agency (FEMA) flood-recovery

program. The Retreat and Storm Mountain area included flooding risks associated with Black Creek, Miller Fork, and the North Fork of the Big Thompson River. Single point access to structures was also very common in this area with The Retreat neighborhood being a large focus of repeated damage during the post-fire recovery phase.

The Risk Assessment results, combined with the field trips resulted in ground-truthing and refining the moderate- to high-risk project areas and is generally defined as either infrastructure, private property protection or debris removal in scope. The following sections break out the different project areas and provide in-depth information about the analyses, designs, and execution of construction. Figure 4 shows the general locations of the project areas (The Retreat is not shown for clarity on Figure 4 but is discussed separately in Section 3.9).

Finally, environmental impacts and mitigation for the entirety of the burn scar is discussed in Section 4.0.

3.2 Scope of Work

The following areas were identified during the 2021 initial assessment:

- Pingree Park Road (LCR 63E)
    - Bennett Creek (063E-8.00-44H)
    - Little Beaver Creek (LR63E-4.7-44)
    - Unnamed Tributary to the South Fork (SF) of the Cache la Poudre River (063E-3.87-44H)
- Sevenmile Creek Road (LCR 69)
    - Swamp Creek (069-3.41-68C)
    - Sevenmile Creek Upper Culvert (069-0.43-S14)
    - Sevenmile Creek Lower Culvert (069-0.25-S14)
- Laramie River Road (LCR 103)
    - Two and One Half Creek (103-4.56-S14)*

  *After additional field trips, it was determined that the impacts at 103-4.56-S14 were minimal, the streambed and area surrounding the culvert were well-established with vegetation, and that the culvert itself was in good condition. This project area was removed from the initial scope.
- The Retreat Neighborhood
    - Infrastructure
    - Structure Protection**
    - Debris Removal

  **Private property protection (both at The Retreat and elsewhere) is discussed in detail in Sections 3.9.6 and 3.14

Additional project areas were identified after the 2021 and 2022 flash flood events:

- Pingree Park Road (LCR 63E)
    - Pingree Park Road Cross-Culverts (a total of 5)
    - Lazy D Ranch Road
- Crown Point Drive (Rustic, CO off SH 14)

- Buckhorn Road (LCR 44H)
    - Channel embankment reconstruction and revetment
    - Revetment at post-fire installed culvert inlets/outlets
    - Debris Removal (after 2022 flash flood events)
    - Sheep Creek Culvert (after 2022 flash flood events)
    - Wildsong Road Culvert (after 2022 flash flood events)
    - Deerpath Street Culvert (after 2022 flash flood events)
- Debris Removal – Pingree Park Road, LCR 44H, and The Retreat
- Private Property Protection (additional sites not previously identified)

Appendix C contains copies of all the infrastructure design memos and as-built construction plans, organized by project area. Sections below provide further details of the work at each site with representative pre- and post-construction photos.

3.3 Bennett Creek (063E-8.00-44H)

A field visit of the site was conducted, and it was observed that the existing culvert was in good condition with plenty of established vegetation at both the upstream and downstream faces. Two areas of the road embankment had already experienced significant erosion and were identified as priorities for installation of protective measures. Figure 5 shows the approximate location of the Bennett Creek project area.

Photo 4: Pre-Construction – Stream erosion and large erosion hole (2021)

With this information in hand, a refined hydrologic and hydraulics (H&H) analysis was conducted and the proposed water surface elevation (WSEL), average channel depths and velocities were determined along

the Bennett Creek at the culvert. Anderson Consulting Engineers (ACE) was provided the Enguinuity HEC-HMS hydrologic model. ACE was able to confirm that the values published on the interactive map did apply to the Bennett Creek crossing. The pre- and post-fire discharges are shown in Table 3.

Table 3: Discharge Values for 063E-8.00-44H

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	34	86
10-year	145	642
100-year	864	2176

ACE then developed an Existing Condition HEC-RAS model utilizing field survey information, the 2013 DEM produced by FEMA, Manning's *n* values determined by ACE, and Enguinity's hydrology. The Existing Condition model was used to analyze the 2-, 10-, and 100-year flood events. Results of the Existing Condition Hydraulic Modeling can be found in Appendix C for each project area. Erosion countermeasure design was calculated in the FHWA Hydraulic Toolbox (version 4.4). The most severe hydraulics were associated with the 100-year event and resulted in sizing and recommending that Class 18 rock riprap be installed with a thickness of 3-ft along identified road embankment areas. Two primary areas were identified which had significant bank erosion received riprap to stabilize the bank slopes and roadway prism.

Photo 5: Post-Construction: Seeding and planting to stabilize erosion hole (2022)

3.4 Little Beaver Creek (LR63E-4.7-44H)

A field visit of the site was conducted, and it was observed that the north overbank consisted of gentle slopes and established vegetation. Any proposed overtopping of post-fire flood flow would be directed to the north of the structure. The banks and channel downstream of the bridge had gentle slopes and were covered with vegetation. Larimer County had previously observed some undermining at the south abutment. The existing bridge itself is a timber structure, 22-ft wide and approximately 7-ft tall. Figure 6 shows the location of the Little Beaver Creek project area.

Photo 6: Pre-Construction - Existing Bridge (2021)

No hydrologic values were published on Enginuity's interactive map for the Little Beaver Creek crossing. Enginuity provided ACE with their HEC-HMS hydrologic model. The runoff values of sub-basin B112 were utilized at the Little Beaver Creek crossing. The pre- and post-fire discharges are shown below:

Table 4: Discharge Values for LR63E-4.7-44H

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	16	205
10-year	77	532
100-year	630	1,959

Utilizing Larimer County's field survey information, the 2020 DEM produced by USGS, Manning's n values determined by ACE, and Enginuity's hydrology, an Existing Condition HEC-RAS model was developed for the project reach. The Existing Condition model was used to analyze the 2-, 10-, and 100-year flood events. Results of the Existing Condition Hydraulic Modeling can be found in Appendix C for each project area.

To reduce overtopping flows, a 4-ft wide berm between the upstream guardrail and hillside on the south side of the bridge was proposed. ACE modified the Existing Condition hydraulic model to create a Proposed Condition model which was used to evaluate the impact of the berm on the 2-, 10-, and 100-year flood events. Results of the Proposed Condition Model indicated that the 100-year event would still overtop the berm; however, the berm was expected to reduce overtopping of the south roadway for smaller flow events.

Erosion countermeasure design was calculated in the FHWA Hydraulic Toolbox (version 4.4). The most severe hydraulics were associated with the 100-year event and resulted in sizing and recommending that Class 12 rock riprap be installed with a thickness of 2-ft along identified road embankment areas. Riprap was installed on the stream side of the proposed berm and down the bank to the edge of the existing rocks. The upstream northern bank was also armored with riprap from the top of bank down to the edge of the active channel. The downstream face of the bridge has gentle slopes and is well vegetated and Larimer County opted to minimize channel grading in order to keep the heavily-vegetated willow bushes intact.

Photo 7: Post-Construction - Installation of the Earthen Berm (2022)

3.5 Unnamed Tributary to the SF of the Cache la Poudre River (063E-3.87-44H)

A field visit of the site was conducted and it was observed that the existing corrugated metal pipe (CMP) arch culvert was deformed and in fair shape. The outlet of the pipe was perched above the invert and a plunge pool had formed. Figure 7 shows the location of the Unnamed Tribute culvert project area.

With this information in hand, a refined hydrologic and hydraulics analysis was conducted and the proposed water surface elevation (WSEL), average channel depths and velocities were determined along the Unnamed Tributary to the South Fork of the Cache la Poudre River at the culvert. To reduce overtopping flows and provide additional bank protection, the existing 50" x 30" elliptical CMP was replaced with an 84" CMP. The new 84" CMP was modeled to include a rock drop structure using 36" diameter boulders to help regrade the channel directly upstream of the proposed culvert. Additional 24" boulders (grouted) were proposed on the upstream and downstream openings of the culvert.

Photo 8: Pre-Construction - Undersized Culvert Inlet (2021)

Larimer County provided ACE with detailed survey of the Unnamed Tributary Creek site. Beyond the detailed survey, ACE utilized the post-flood DEM developed by FEMA in 2013. All elevations were referenced to the NAVD 88 vertical datum.

Enginuity provided ACE with their HEC-HMS hydrologic model. The project was located at the downstream portion of subbasin B110, identified in the Enginuity HEC-HMS model. The pre- and post-fire discharges are shown in Table 5.

Table 5: Discharge Values for 063E-3.87-44H

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	11	57
10-year	46	204
100-year	445	998

The Unnamed crossing discharged into the South Fork of the Cache la Poudre (South Fork). The South Fork was modeled using a 10-year flow of 1338 cfs taken as identified in the Enginuity hydrology study.

ACE then developed an Existing Condition HEC-RAS model utilizing field survey information, the 2013 DEM produced by FEMA, Manning's *n* values determined by ACE, and Enguinity's hydrology. The Existing Condition model was used to analyze the 2-, 10-, and 100-year flood events. Results of the Existing Condition Hydraulic Modeling can be found in Appendix C for each project area.

The new 84" CMP was modeled with an upstream invert of 7927-ft and a downstream invert of 7925-ft. ACE proposed the construction of one 18" rock drop structure using 36" diameter boulders to help regrade the channel directly upstream of the proposed culvert to an elevation of 7927-ft. The HEC-RAS model indicated that a hydraulic jump was likely to occur at the proposed culvert for multiple flow events. ACE recommended placing grouted 24" boulders directly upstream and downstream of the culvert. Riprap with a D50 of 12" and a thickness of 2-ft was placed alongside the road adjacent to the grouted boulders on the downstream end of the culvert to minimize erosion from overtopping flows.

Photo 9: Unnamed Tributary looking Upstream at the grouted boulders (2022)

3.6 Swamp Creek (069-3.41-68C)

A field visit of the site was conducted and it was observed that the downstream face of the culvert (identified as a 40" CMP by surveyors) was damaged but deemed serviceable. The areas immediately upstream and downstream of the existing culvert were identified as locations where erosion protection measures could be installed to provide protection to the road embankment. Figure 8 shows the location of the Swamp Creek culvert project area.

Photo 10: Pre-Construction - Existing Swamp Creek Culvert Conditions (2021)

With this information in hand, a refined hydrologic and hydraulics analysis was conducted and the proposed water surface elevation (WSEL), average channel depths and velocities were determined along Swamp Creek at the culvert. Riprap on both the upstream and downstream sides of the culvert was proposed.

No values were published on Enginuity's interactive map for the Swamp Creek crossing. Enginuity provided ACE with their HEC-HMS hydrologic model. The Swamp Creek crossing was located within a larger subbasin, titled B168, identified in the Enginuity HEC-HMS model. ACE utilized the post-flood DEM, developed by FEMA in October 2013, to delineate the portion of subbasin B168 that drained to the Swamp Creek Crossing. ACE found that 1.9 square miles of the total 7.8 square miles in B168 drained to the crossing. The area weighted average discharge values for the Swamp Creek crossing are shown in Table 6 below.

Table 6: Discharge Values for 069-3.41-68C

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	8	52
10-year	32	124
100-year	179	419

Utilizing Larimer County's field survey information, Manning's n values determined by ACE, and Enginuity's hydrology, an Exiting Condition HEC-RAS model was developed for the project reach. The Existing Condition model was used to analyze the 2-, 10-, and 100-year flood events. Results of the Existing Condition Hydraulic Modeling can be found in Appendix C for each project area.

The Hydraulic Toolbox rock riprap sizing methodology indicated that riprap with a d50 of 9 inches, would be stable. ACE recommended that Class 12 rock riprap be installed with a thickness of 2 feet along the identified road embankment areas.

Photo 11: Post-Construction (2023)

3.7 Sevenmile Creek Upper (069-0.43-S14)

A field visit of the site was conducted, and it was observed that the project reach upstream of the existing culvert was found to be in good condition. The existing culvert is a 60" corrugated metal pipe (CMP) at a skewed angle to the stream upstream and downstream of the crossing. The northern portion of the

downstream road embankment showed some signs of prior erosion from the tributary channel coming from the north. Figure 8 shows the location of the Sevenmile Creek project.

With this information in hand, a refined hydrologic and hydraulics analysis was conducted and the proposed water surface elevation (WSEL), average channel depths and velocities were determined along Sevenmile Creek at the culvert. The existing culvert had limited capacity and was in fair condition. Larimer County, in consultation with the United States Forest Service (USFS) installed a plate arch culvert and the USFS provided input into a better inlet alignment (as reflected in the final construction plans). Additionally, 24" riprap was placed upstream and downstream of the culvert inverts.

Photo 12: Pre-Construction - Inlet of the existing 069-0.43-S14 culvert (2021)

Enginuity provided ACE with their HEC-HMS hydrologic model. ACE was able to confirm that the values published on the interactive map did apply to the Sevenmile Upper crossing. The pre- and post-fire discharges are shown in the table below.

Table 7: Discharge Values for 069-0.43-S14

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	40	288
10-year	140	617
100-year	1,039	2,191

Utilizing Larimer County's field survey information, the 2020 DEM produced by USGS, Manning's n values determined by ACE, and Enginuity's hydrology, an Existing Condition HEC-RAS model was developed for the project reach. This Existing Condition model was used to analyze the 2-, 10-, and 100-year flood events. The existing culvert had a capacity of approximately 117 cfs and was undersized for post-fire flows.

Initially, a 66" CMP was selected to replace the existing 60" pipe; however, in consultation with the USFS, Larimer County selected a 137" x 87" pipe arch culvert with a 2-ft buried invert to better meet AOP criteria (the land surrounding the culvert was USFS property).

Riprap sizing for the road embankment was calculated in FHWA Hydraulic Toolbox (version 4.4) using the results from the Existing Condition HEC-RAS model. The most severe hydraulics are associated with the 100-year event, and accordingly, modeling results for the 100-year discharge were evaluated through the area of concern upstream of the culvert crossing. The Hydraulic Toolbox rock riprap sizing methodology indicated that riprap with a D50 of 23 inches, would be stable. ACE recommends that Class 24 rock riprap be installed with a thickness of 4 feet along the identified road embankment areas.

Photo 13: Post-Construction - View looking downstream (2023)

3.8 Sevenmile Creek Lower (069-0.25-S14)

A field visit of the site was conducted, and it was observed that a berm in the channel upstream of the culvert was deflecting water towards the road embankment where erosion was already occurring. The existing culvert was a 68” x 51” horizontal elliptical corrugated metal pipe (CMP). Figure 8 shows the location of the Sevenmile Creek project.

Photo 14: Pre-Construction - Looking South towards the line of cabins; the existing culvert had frequent overtopping events (2021)

With this information in hand, a refined hydrologic and hydraulics analysis (both 1D and 2D HEC-RAS models) was conducted and the proposed water surface elevation (WSEL), average channel depths and velocities were determined along Sevenmile Creek at the culvert.

The published values for the Sevenmile Lower crossing were significantly larger than the values published for the 069-0.43-S14 (Sevenmile Upper) crossing. This was not consistent with the physical features and location of the lower crossing. Enginuity provided ACE with their HEC-HMS hydrologic model. ACE was able to confirm that the values published on the interactive map for the 069-0.43-S14 (Sevenmile Upper) crossing was appropriate to apply the Sevenmile Lower crossing as there was no significant contribution areas between the two crossings. The pre- and post-fire discharges are shown in the table below.

Table 8: Discharge Values for 069-0.25-S14

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
2-year	40	288
10-year	140	617
100-year	1,039	2,191

Utilizing Larimer County's field survey information, the 2020 DEM produced by USGS, Manning's n values determined by ACE, and Enginuity's hydrology, a 1-dimensional (1D) and a 2-dimensional (2D) Existing Condition HEC-RAS model was developed for the project reach. The 2D model extended from the Sevenmile Creek confluence with the Cache la Poudre River at the downstream end to just upstream of the Sevenmile Lower crossing at the upstream end. The 1D model covers only the immediate area near the Sevenmile Lower crossing. Results from the 1D Existing Condition Model can found in the design memo in Appendix C.

Riprap sizing for the road embankment was calculated in FHWA Hydraulic Toolbox (version 4.4) using the results from both the 1D and 2D Existing Condition HEC-RAS models. The most severe hydraulics were associated with the 100-year event, and accordingly, modeling results for the 100-year discharge were evaluated through the project reach. The 2D model results indicated that 100-year event depths could exceed 18-ft and velocities could exceed 20 fps.

The Hydraulic Toolbox rock riprap sizing methodology indicated that riprap with a D50 of 112 inches, would be stable. This size of riprap does not exist, nor would it have been feasible to install. As the existing channel is approximately 5 feet deep ACE recommended that 4-foot diameter boulders be stacked along the road embankment with Class 24 rock riprap be installed with a thickness of 4 feet through the channel and on the opposite bank.

The existing berm upstream of the structure was removed and the creek was straightened at the inlet of the culvert. River complexity was still one of the core objectives at this location; the USFS provided field support to ensure any bends, checks, and drop structures already present within the channel were kept intact. Additionally, 24" riprap was placed along the side slopes to stabilize and protect the channel.

Finally, structure protection was proposed at three of the four cabins downstream of the culvert. To mobilize in the equipment necessary to install either concrete block walls or flood barrier bags, two property culvert accesses were removed and replaced (construction access) to accommodate the larger equipment necessary to set the structure protection.

Photo 15: Post-Construction - Looking downstream at the culvert inlet and construction of a low-water crossing to help facilitate flows back into Sevenmile Creek past the downstream end of the structure (2023)

3.9 The Retreat Subdivision

3.9.1 Project Background

The Retreat is a community located in Larimer County, Colorado along County Road 43 (LCR 43) approximately 2 miles East of Glen Haven (Figure 9). It is located along the confluence of Miller Fork and Black Creek whose contributing watershed was severely burned by the 2020 Cameron Peak Fire. Most of the upper watershed was classified as high intensity burn.

In July of 2021, The Retreat subdivision saw multiple flood events in both the Black Creek and Miller Fork drainages. The flooding caused severe damage to Streamside Drive and Black Creek Drive, as well as damage to private accesses, property, and homes. In July of 2022 the area saw more flood events causing severe damage to repaired areas that were constructed in 2021. Photo 16 and Photo 17 show resulting damage from 2021 and 2022 events, respectively. Additional photos are included in Appendix C.


Photo 16 (Left): Upper Streamside Drive Culvert (The metal pipe clogged with debris which resulted in severe erosion), 2021. Photo 17 (Right): Upper Streamside Drive – July 2022 Flooding: An 84" reinforced concrete pipe (RCP) was installed after the 2021 flood; however, the culvert was overtopped during multiple storm events in 2022. The D50 24" riprap (ungrouted) was replaced with D50 12" matrix (partially-grouted) riprap in 2022 to improve resiliency.

After the 2021 and 2022 flood events, representatives from Larimer County, Ayres Associates (Ayres), and Connell Resources (Connell) visited The Retreat, to begin planning short-term and long-term recovery efforts. The project was broken into three phases based on priority and material availability. Phase I included repairs to Black Creek Drive, Phase II included Streamside Drive repairs, and Phase III included structure protection. Each phase required repairs after the four storm events in July 2022. In addition to the three phases of the project, debris removal was included as well as subsequent re-vegetation of the affected areas.

The primary goal of the project was to mitigate the risk to life, property, and public infrastructure within The Retreat Subdivision as well as downstream of the project. Secondly, the project sought to mitigate water quality impacts that result from increased sediment loads from fire-affected basins. This section presents a summary of the design and construction performed for The Retreat

3.9.2 Team Members

Larimer County acted as the project manager and utilized contracts with Ayres for engineering guidance, Connell Resources for construction, and DRC as the debris removal contractor. Immediately after a pre-construction meeting and walk-through was held, Connell mobilized and began repairing damage and establishing construction access. Concurrent to this work Ayres began design work and provided plans that were implemented by Connell.

3.9.3 Hydrology

The hydrologic analysis for Black Creek applies guidance from USDA Technical Note No. 4, Part 630 of the National Engineering Handbook, and data from the Colorado and US Geological Survey for soils, land use, and elevation terrain.

This analysis evaluated the 2-, 5-,10-, and 25-year design storms due to both the high probability of occurrence and the sensitivity of peak flows and timing to burned conditions. Table 9 shows the peak flows for the pre-burn and post-burn hydrology. The design team originally selected the 5-year post-burn flow as the basis for design approach and structure sizing. Most locations were not practical to design to full 25-year storm event protection with the resources and space available at the site. However, where feasible, the 25-year event was used for mitigation design.

Table 9: Peak Flow Hydrology for Black Creek showing pre and post fire affected hydrology results

Point Description	Calculated Peak Discharge (cfs)							
	2yr Pre	2yr Post	5yr Pre	5yr Post	10yr Pre	10yr Post	25yr Pre	25yr Post
Miller Fork US	244	1101	553	1832	988	2701	1895	4262
Miller Fork DS	346	1476	765	2469	1343	3624	2509	5663
Black Creek US	143	574	303	921	521	1316	958	2003
Black Creek Lower	165	605	351	982	601	1413	1102	2165

The modeling results show approximately three-times the discharges for any given storm event when compared to the same non-burned watershed. The increase in runoff and lack of vegetation upstream of The Retreat resulted in multiple large debris flows that caused damage to public infrastructure and private property.

3.9.4 Mitigation Design and Summary

The design focused on protecting people and property without degrading stream health by leveraging stream processes to assist in water quality outcomes when practical. This design strategy balances the risk to valuable structures at risk (VARs) with the desire to improve water quality outcomes. Ayres performed hydrology and hydraulic calculations for use in designing NRCS approved mitigation structures. Mitigation techniques and designs are primarily based on guidance and examples from the NRCS (Practice Selection Guide & Post-Fire Engineering Guidance).

Recovery efforts included: establishing construction and resident access, upgrading, and replacing crossings to meet the 5-year post-fire floods, revetment on Streamside Drive, and protecting structures within the 25-year post-fire flood limits. The calculations and summaries of proposed mitigation and protection practices are described below. A full list of implemented features and quantities are provided in Table 10.

Table 10: Implemented Mitigation and Protection at The Retreat

Practice Code	CPS Name	Item	Qty	Unit	Notes
		Number of Private Residences Protected	12	EA	
362	Flood Barrier Bags, 4-ft High	Total Length of Flood Barrier Bags Installed	1774	LF	
		Total Length of Muscle Wall Installed	156	LF	
560	Access Road	Grading road surfaces		HR	
570	Road Overtopping Protection	Road Overtopping Structures Installed	488	CY	o Constructed with D50 = 24" Ø riprap in 2021 o Reconstructed with D50 = 12" Ø matrix riprap in 2022/2023
		Reinforced Concrete Culverts Installed	2	EA	Total Length = 96'
		Concrete Box Culvert Installed	2	EA	Total Length (4-FT x 8-FT) = 42'
		Corrugated Metal Pipe Installed	1	EA	Total Length = 61'
362	Concrete Waste Block Wall	Concrete Block Wall Installed	45	LF	
584	Rock Outlet Protection	Rock riprap apron outlets to reduce flow erosion	508	CY	
570	Trash Rack	Culvert Trash Racks Installed	2	EA	
560	Dips/Water-Bars	Water Bars Installed	4	EA	
578	Armored Drainage Crossings	Armored Drainage Crossings	7	EA	o Constructed with D50 = 24" Ø riprap in 2021 o Reconstructed with D50 = 12" Ø matrix riprap in 2022/2023
		Road Reconstruction/Construction Access	0.5	MI	(Black Creek Drive)
342/484	Hydroseeding & Hydromulching	Hydroseeding	5	AC	All disturbed areas
		Number of Properties Participating in Debris Removal	24	EA	33 Properties were contacted
500	Debris Removal		8959	CY	
326	Clearing and Grubbing	Clearing and Grubbing (as part of the Infrastructure Work)	2.2	AC	
570	Contour Straw Wattles	Erosion Logs	408	LF	

3.9.5 Overtopping Protection

Overtopping protection was added at three locations along the EWP funded sections of Miller Fork and Black Creek. All overtopping protection was added along Streamside Drive, two crossings of Miller Fork and at the crossing of Black Creek. The most downstream crossing of Miller Fork did not implement full overtopping protection due to the heavy timber present on the downstream side of the crossing.

Rock sizing larger than 24" was calculated, which led to the use of partially-grouted riprap also known as matrix riprap. Though there are not precise hydraulic limit tests set for guidance, matrix riprap has survived field applications where velocities exceeded 20 feet per second. Laboratory testing of matrix riprap at Braunschweig University, Germany demonstrated the ability to remain stable and undamaged in high velocity flow of 26 feet per second (HEC-23 Vol. 2). Summaries of calculations obtained from HY-8 can be found below (Table 11). All elements of the overtopping protection were sized based off the 5-year post flood event.

Table 11: Overtopping Protection Summary of Flows at Each Crossing

Miller Fork Upstream Culvert Summary Table									
	Event	2yr Pre	2yr Post	5yr Pre	5yr Post	10yr Pre	10yr Post	25yr Pre	25yr Post
	Peak Runoff (cfs)	244	1101	553	1832	988	2701	1895	4262
Existing 72" CMP Projecting	Passing Flow (cfs)	244	385	350	411	380	432	412	459
	Roadway Flow (cfs)	0	716	203	1421	608	2269	1482	3802
Proposed 84" RCP Headwall	Passing Flow (cfs)	244	631	552	689	620	740	693	812
	Roadway Flow (cfs)	0	470	1	1142	368	1961	1201	3450

Miller Fork Downstream Culvert Summary Table									
	Event	2yr Pre	2yr Post	5yr Pre	5yr Post	10yr Pre	10yr Post	25yr Pre	25yr Post
	Peak Runoff (cfs)	346	1475	765	2469	1343	3624	2509	5663
Existing Double Stacked CMPs	Passing Flow (cfs)	123	148	135	160	146	170	161	185
	Roadway Flow (cfs)	223	1326	630	2308	1197	3453	2348	5481
Proposed 84" RCP Headwall	Passing Flow (cfs)	346	484	442	521	478	552	522	592
	Roadway Flow (cfs)	0	990	323	1947	866	3072	1986	5070

Black Creek Downstream Culvert Summary Table (635 Streamside Drive)									
	Event	2yr Pre	2yr Post	5yr Pre	5yr Post	10yr Pre	10yr Post	25yr Pre	25yr Post
	Peak Runoff (cfs)	143	303	521	574	921	958	1316	2003
Existing 42" CMP	Passing Flow (cfs)	59	78	69	88	78	97	91	108
	Roadway Flow (cfs)	106	527	282	894	523	1316	1011	2057
PR-NA	Passing Flow (cfs)	na	na	na	na	na	na	na	na
	Roadway Flow (cfs)	na	na	na	na	na	na	na	na

D50 12" riprap was added around the inlets and over the roadway for additional embankment and roadway protection during an overtopping event. D50 12” riprap is sufficient to protect against the lower hydraulic forces seen on the upstream side of the culverts and from flow over the roadway.

During the 2021 construction efforts, due to time constraints, constructability and material availability, the decision was made to substitute matrix riprap along the downstream side of the upstream crossing of Miller Fork with D50 24” riprap. The flood events that occurred in July 2022 caused that D50 24” riprap to fail. The team then worked to come up with a solution to implement and construct the matrix riprap to be the permanent solution for flood overtopping resilience. The resulting crossing can be seen below in Photo 18.

Photo 18: Upper Streamside Culvert – This photo shows the grouting operation for the overtopping protection

3.9.6 Property Flood Protection

The property flood protection measures, either flood barrier bags or Muscle Wall, were designed using results from the 2-Dimensional model created by Ayres using Aquaveo's SMS-SRH2D software. Muscle Wall was proposed where the protection was located in a FEMA mapped floodplain; flood barrier bags were used everywhere else. The 2D model was created using 2014 LiDAR along with some supplemental survey data. Using the model, inundation maps and depth contours were plotted along with velocity vectors for the 25-year post fire event. With this data plotted, the heights and extents of the protection measures were strategically oriented to protect structures from the primary hydraulic forces and debris that are associated with these type of flooding events. Preliminary plans were developed and sent to property owners and onsite meetings were held to layout flood barrier bags and Muscle Wall in a manner that was amenable to all parties.

Most bags were added in 2021 and following the July 2022 flooding, there were several requests for additional protection, these requests are outlined below in Table 12. Included in the table are additions to existing measures, addition of new measures, and repairs. The 2D model had to be extended slightly to include the request at 10097 LCR 43 and at 56 Streamside Drive. The updated flood protection plan is included in the as-builts in Appendix C.

Table 12: Property Protection Summary

Property Protection Summary Revision 1				
Address	**Flood Protection Length (Feet)**			
	6-ft FBB	**4-ft FBB**	**2-ft FBB**	**Muscle Wall**
100 Fisherman's Ln		40		
1145 Streamside Dr		102		
1035 Streamside Dr		135	80	
931 Streamside Dr	95	195		
773 Streamside Dr		207	20	
719 Streamside Dr		144		
677 Streamside Dr		90		
635 Streamside Dr			60	
521 Streamside Dr		75	76	
134 Streamside Dr	60			
110 Streamside Dr			95	30
56 Streamside Dr				126
Confluence Bags		300		
TOTAL	**155**	**988**	**331**	**156**

The mitigation measures were instrumental in the protection of lives and property. The bags were installed in 2021, prior to major flooding seen in 2022. Photo 19 shows post July 21, 2022, event at 719 Streamside Drive. High water can be seen by the mud on the sides and tops of the bags, there were also several debris indentations seen along the bags. After the 2022 event, more property owners requested bags and there were some minor adjustments made to existing layouts.

Photo 19: Post-flood event at 719 Streamside - Flood barrier bags surround the home and were fully activated by the flood

3.9.7 Rock Ford Stream Crossings

On the lower portion of the Black Creek site, one (1) rock ford stream crossing was constructed over Black Creek crossing at Corner Court. It provided capacity and additional strength to the road crossing during flooding events. The original design implemented specified a riprap thickness equal to two times the D50 18". A tie in of 2H:1V upstream and 4H:1V downstream to tie in. A layer of crushed aggregate was then placed on top of the rock to choke it and make it a more drivable surface. No road base was placed on top of the crushed aggregate in the main channel section due to the amount of water that was expected through the crossing. The culvert that was previously there was removed due to the amount of sediment coming down the system and the limited capacity the culvert had. Cross-sectional area and rock sizing were calculated using FHWA's Hydraulic Toolbox 5.0.

Constructability of the feature led to a steeper tie-in downstream than the design anticipated. The original design of D50 18" riprap was replaced with D50 12" matrix riprap. Stream ford crossings and matrix riprap details are included in the as-built plan sets provided in Appendix C.

3.9.8 Water Bars

Two water bars were installed along the road for Black Creek in 2021 in an effort to keep flow in the channel. In late-2022, two more water bars were added to the road along Streamside Drive upstream of the confluence of Black Creek to prevent further property damage. All locations were strategically placed to line up with flood barrier bags to combine mitigation efforts. The water bars were designed to provide protection from the 25-yr post flood event using the 2D model calculated depth values. The locations of the two additional water bars are shown in Figure 10. The effectiveness of the water bars and keeping the water in channel and off the road is shown in Photo 20 below during a high flow event on August 19, 2022. The updated plans for these locations are included with the plan revisions included in Appendix C.

Photo 20: Effectiveness of Water Bar Demonstrated During High Flow Event

3.9.9 Debris Removal

Areas of debris that had potential to negatively impact downstream infrastructure and water quality were identified based on field visits with Ayres, Larimer County, and private property owners. Larimer County reached out to 33 properties for debris removal, and removal was performed on 17 properties. The debris removal efforts comprised of two components: removing deposited sediments and woody materials and regrading overbanks and limiting vertical and unstable banks. Debris was removed to provide maximum floodplain conveyance and storage for future events. Sediment, woody materials, and small trees were removed to accomplish this goal. The material was also removed so that it could not be transported during future events. There were also several locations with vertical and unstable banks where the incision was mitigated to allow for better floodplain conveyance and to limit further degradation of banks. All these efforts were completed to help debris and floodplain conveyance and storage for future events. The total estimated quantity of debris removal within The Retreat was nearly 9,000 CY.

3.10 Pingree Park Road Culverts

Several areas along LCR 63E were added to the project areas in 2022. Private property owners in the vicinity of Lazy D Ranch, approximately 0.2-miles North of the intersection of LCR 63E and LCR 44H, contacted Larimer County about active roadway bank erosion and headcutting at several drainages which drain into Pennock Creek and the South Fork of the Cache la Poudre River. Several field visits were conducted along LCR 63E and it was determined that there were two drainages in particular, which fed into existing 18" CMP cross-culverts, would benefit from a series of rock check dams and regrading to minimize incising of the hillslope. A rock chute was also proposed at one of the culvert inlets. Erosion protection was also proposed at the other three culvert locations. Figure 11 shows the approximate locations of the five culverts. Additional details can be found in the as-built plans in Appendix C.

Photo 21: Pre-Construction – Example of roadway embankment erosion at 063E-0.26-44H (2022)

Photo 22: Post-Construction – Example of rock checks and rock chute at culvert inlet (2022)

Enginuity provided ACE with their HEC-HMS hydrologic model. All five culvert crossings are located within a larger subbasin, titled B105, identified in the Enginuity HEC-HMS model. The 10-, 25-, and 50-year peak discharges from subbasin B105 are shown in Table 13. ACE utilized the post-flood DEM, developed by FEMA in October 2013, to delineate the portions of subbasin B105 that drain to each of the five crossings.

Table 13: Discharge Values for B105 Subbasin

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
10-year	183.2	377.8
25-year	414.2	735.6
50-year	644.7	1063.6

Utilizing the relative elevation data and Enginuity's post-fire hydrology, HY-8 culvert models were developed for the each of the crossings. Culverts 1, 2, and 3 were evaluated for existing capacity (18" CMP) and culverts 4 and 5 were evaluated for proposed capacity (24" CMP). All five culverts were designed to exceed the 50-year post-fire discharges. Larimer County criteria for cross-culverts requires culverts to pass the 25-year event without overtopping.

Riprap sizing for the armor upstream and downstream of the culverts was calculated in FHWA Hydraulic Toolbox (version 4.4). A minimum bank angle of 2H:1V was used in the riprap. Protected banks with

steeper than 2H:1V sections will need to be regraded to a 2H:1V. The most severe hydraulics were associated with the 50-year event. The riprap sizing calculations based on these hydraulic parameters assumed a factor of safety of 1.1. D50 12” riprap was recommended and installed at each of the culvert locations.

3.11 Lazy D Ranch Road

In late 2021, Larimer County was contacted by several landowners within the Lazy D Ranch area. A drainage just north of the Lazy D Ranch was showing signs of debris flow. The caretaker of the Lazy D Ranch shared video of runoff impacting multiple living structure and eroding the driveway. A preferred flow path had developed on the hillside that carried the majority of the runoff to the west towards a living structure. The rest of the runoff was unable to cross the road and ran to the east and was impacting another structure. Erosion wattles had already been placed on the hillside above the road, however they have already been overwhelmed and need maintenance. Evidence of erosion was visible along the road.

Enginuity provided ACE with their HEC-HMS hydrologic model. The drainage area above the Lazy D Ranch Road was located within a larger subbasin, titled B106, identified in the Enginuity HEC-HMS model. ACE utilized the post-flood DEM, developed by FEMA in October 2013, to delineate the portion of subbasin B106 that drains across Lazy D Ranch Road. Table 14 shows the averaged weighted discharge values for Lazy D Ranch Road.

Table 14: Discharge Values for Lazy D Ranch Road

Return Interval	Discharge (cfs)	
	Pre-Fire	Post-Fire
10-year	0.7	3.1
25-year	2.2	6.8
50-year	4.0	10.3
100-year	7.5	16.5

The results of the existing condition model, showing low discharge values, coupled with the alluvial fan-like nature of the hillside above the road, were not representative of the real-life conditions. Engineering judgement was exercised, and erosion control measures and grading changes were proposed to provide a more resilient long-term solution.

An earthen berm was installed at the mouth of drainage above Lazy D Ranch Road to force runoff to remain closer to the center of the hillside and away from the existing structure to the west. Below the berm, the roadway was lowered to concentrate flows across a concrete pan and into a rock chute. Additional details can be found in the as-built plans in Appendix C.

Photo 23: Pre-Construction – View of the Alluvial Fan at Lazy D Ranch Road

Photo 24: Post-Construction – View looking East of armored concrete low-water crossing (2022)

3.12 Crown Point Drive

Crown Point Drive is located in Rustic, CO, approximately 42 miles west of Fort Collins off SH 14. The neighborhood contacted Larimer County in 2022, asking for assistance with nuisance flows from Bears Gulch which spilled onto Crown Point Drive, fanned out onto several properties, and created erosion along the roadway and deposition in several low-lying areas. Figure 8 shows the location of the Crown Point Drive project.

Upon inspection of the Crown Point Drive and surrounding area, Larimer County along with Anderson Consulting Engineers (ACE) relied on engineering judgement and discussions with property owners to propose installation of a roadside ditch, low water crossings, site grading to facilitate drainage into the Poudre River, and erosion control measures.

To concentrate runoff into an existing preferred flow path, rock check structures were installed near the mouth of the gulch. These dams forced runoff to flow to stay within an engineered path rather than fanning out, uncontrolled. It was generally agreed to by the majority of the homeowners that flow paths should be created to direct the flows to the Poudre River. A roadside ditch was installed on the north side of Crown Point Drive and tied in to two different drainage ditches which were graded and armored to get flood flows to the Poudre River. The eastern diversion ditch was engineered with a D50 18” rock chute at the outlet end and several smaller rock checks. Low water crossings were needed at each driveway to direct flows. Additional details can be found in the as-built plans in Appendix C.

Photo 25: Pre-Construction - Looking West along Crown Point Drive (2023)

Photo 26: Post-Construction – Looking South at the rock check dams installed at Bears Gulch (2023)

3.13 Buckhorn Road (LCR 44H) – Buckhorn Creek

3.13.1 LCR 44H Revetment

In September 2013, flooding along the Northern Colorado Front Range damaged or destroyed much of Larimer County's road infrastructure along Buckhorn Creek. As Buckhorn Creek overtopped the shared channel bank/roadway embankment, LCR 44H was destroyed for long stretches west of the LCR 27 junction. During the preliminary design phase of flood recovery, numerous locations for revetment/ reinforcement of the road embankment were identified as critical to long-term stability. However, due to FEMA funding constraints, roadway embankment revetment was excluded as part of final design. In addition, the preliminary flood recovery design effort included numerous cross-culverts to serve feeder creeks and nuisance flows. Again, due to funding limitations, the system of cross-culverts identified during preliminary design was scaled back; as a result, the number and size of culverts was reduced.

In accordance with Larimer County criteria and FEMA requirements, the preliminary 2013 Flood recovery design focused on conditions associated with the 25-year (pre-fire) discharge. These 25-year discharges ranged from 820 cubic feet per second (cfs) above Twin Cabin Gulch to 2,410 cfs below Stove Prairie Creek.

For revetment protection, hydraulic modeling results generally identified 18" D50 rock riprap, 3 feet thick, with 1 foot of 12" minus rock riprap as filter material, for a total layer thickness of 4 feet, to provide stability for the specified hydraulic conditions.

Sizing for cross-culverts was also completed for the 25-year flood event, utilizing a discharge at each location determined by area-weighting. Cross-culverts for nuisance flows were identified to be field-fit by the contractor, using either 18" diameter CMPs every 250 feet or 24" diameter CMPs every 500 feet. Culverts ranging in size from 18" to 48" diameter was identified for minor drainages covering between 0.1 and 1.8 square miles. For drainage areas larger than 1.8 square miles, culvert installations larger than 48" diameter were designed based on contributing area.

The preliminary flood recovery design effort was documented and reported by Anderson Consulting Engineers (ACE) in November 2016 to the Larimer County Engineering Department in "Hydraulic Design and Floodplain Impacts Report, Buckhorn Creek/Larimer County Road 44H, Larimer County, Colorado."

A revised, scaled-back flood recovery design was used as the basis for construction efforts that occurred during 2019 and 2020. Large three-sided concrete box culverts sized for the 10-year (pre-fire) event were installed at LCR 44H crossings of Buckhorn Creek in the lower portion of the reach; cross culverts were installed at a limited number of problematic drainages to meet all funding restrictions. Erosion protection in the form of rock riprap was installed at each new culvert installation; no embankment protection was installed outside of the immediate vicinity of the new culverts.

Flood damage that occurred following the Cameron Peak Fire confirmed the need for revetment of the LCR 44H road embankment and for increased numbers and sizes of cross-culverts. Locations where new or more robust measures were needed correlated well with locations identified in the preliminary 2013 Flood recovery design. However, the 2013 Flood recovery design was not intended to protect the road from extreme post-fire hydrologic conditions; therefore, subsequent 2021 and 2022 post-fire flooding events informed where additional and/or increased measures were needed. Post-fire hydrology suggested a 25-year discharge of greater than 6,000 cfs above Twin Cabin Gulch, and 8,400 cfs below Stove Prairie Creek.

Photo 27: Typical Damage Sustained along LCR 44H (October 2020)

During 2020 and 2021, Larimer County constructed flood mitigation measures along LCR 44H using the original 2013 design as a starting basis. Three riprap gradations were utilized for the post-fire revetment. For most locations, 24" D50 rock riprap was used, installed to a depth of 4 feet. At locations where augmentation of existing protection was required on the upper portion of the embankment, 12" D50 riprap was installed to a depth of 2 feet. Finally, at some narrow locations in the canyon, 36" D50 riprap was stacked steeply to maintain the minimum width necessary for two vehicles to pass and maintain conveyance capacity of Buckhorn Creek. A variety of cross-culvert sizes were installed after the fire, in some cases up-sizing culverts that were installed prior to flooding; the new culvert sizes generally exceeded those identified in the 2013 design to better serve post-fire flooding conditions. Sizes ranged from 15" diameter CMPs for nuisance flow collectors, to much larger installations such as corrugated plate arch installed at the LCR 44H crossing of Sheep Creek.

Photo 28: Typical Riprap Installation (Completed in August 2021)

Additional details about the Sheep Creek, Wildsong, and Deerpath project areas can be found in subsequent sections.

Additional background information regarding the LCR 44H hydrologic and hydraulic analyses, revetment, riprap sizing, and culvert design for post-Cameron Peak Fire flooding can be found in Appendix C.

3.13.2 Sheep Creek

One of the locations that was damaged and continued to pose a risk to the LCR 44H was the culvert at Sheep Creek. This drainage had previously crossed under LCR 44H in a 60" diameter corrugated metal pipe culvert that had been installed after the 2013 flood. Figure 12 shows the location of the Sheep Creek project. Due to the burn scar in the watershed above, the water and debris overwhelmed this culvert and overtopped the road. This overtopping eroded the roadway enough to cut off access to properties west of the crossing. Replacement of the 60" culvert proved to be inadequate with overtopping events occurring several times after replacement. Based on available material and the roadway elevation and alignment and discussions with the USFS, the culvert was intended to remain in place, but additional

revetment would be placed upstream and downstream of the structure and through the roadway prism to minimize loss of material.

The Sheep Creek crossing was reconstructed with a 16.3-ft by 5.9-ft aluminum box culvert with concrete headwalls at the culvert entrance and exit. The pre-project non-overtopping capacity of the crossing was 200 cfs; the post-project non-overtopping capacity is 650 cfs. The post-project crossing conveys the 25-year post fire discharge of 550 cfs without overtopping. Erosion countermeasures were designed for the 50-year event; the riprap sizing analysis yielded 18” D50 riprap, 36 inches deep for the LCR 44H road embankment and 24” D50 riprap, 48” deep for the Sheep Creek channel.

Photo 29: Typical Sheep Creek Damage (Looking North at Outlet end of Sheep Creek Culvert) 2022

Photo 30: Post-Construction - Sheep Creek Corrugated Plate Arch Structure – substantially complete (looking North) June 2023

3.13.3 Wildsong and Deerpath Structures

The Cameron Peak Fire and subsequent flooding damaged infrastructure along Larimer County watercourses and several areas in the Upper Buckhorn area (east end of LCR 44H) were identified in late-2022 after substantial impacts to private property and crossings. Figure 12 shows the location of the Wildsong and Deerpath culvert project areas. Both Wildsong Road and Deerpath Street serve as critical crossings for a handful of landowners; by 2022, the neighborhoods had tried to repair the existing multi-barrel culverts, but the structures kept getting washed away.

Though Wildsong Road and Deerpath Street are not maintained by Larimer County, flood events in Buckhorn Creek result in damage to LCR 44H because of the limited capacity of the existing culvert crossings and the proximity of LCR 44H to Buckhorn Creek. By upsizing the culverts, the project sought to increase resiliency and also to provide more reliable access to the neighborhoods while reducing the frequency with which LCR 44H was damaged by small to moderate flood events.

The pre-project crossing at Wildsong Road consisted of a 48” CMP that was heavily compromised and was reconstructed with a 23-ft by 6.1-ft aluminum box culvert. The non-overtopping capacity of this pre-project crossing was 40 cfs; the post-project non-overtopping capacity is 800 cfs. Though the post-project crossing does not convey the 25-year post fire discharge of 5,250 cfs without overtopping, the 800 cfs capacity is roughly 15 percent of the 25-year post-fire discharge and represents a substantial increase in the non-overtopping capacity of Wildsong Road. Erosion countermeasures were designed for the 50-year

event; the riprap sizing analysis yielded 18” D50 riprap, 48 inches deep. The layout of these erosion control measures considered the potential for substantial overtopping at the crossing.

The pre-project crossing at Deerpath consisted of four largely unprotected 60” CMPs and was reconstructed with a 31.4-ft by 7.3-ft aluminum box culvert. The non-overtopping capacity of the pre-project crossing was 750 cfs; the post-project non-overtopping capacity is 1,950 cfs. Though the post-project crossing does not convey the 25-year post fire discharge of 5,250 cfs without overtopping, the 1,950 cfs capacity is roughly 37 percent of the 25-year post-fire discharge. Erosion countermeasures were designed for the 50-year event; the riprap sizing analysis yielded 24” D50 riprap, 60 inches deep. The layout of these erosion control measures considered the potential for substantial overtopping at the crossing and the significant vertical component of overtopping flow.

Additional details can be found in the as-builts in Appendix C.

Photo 31: Pre-Construction - Wildsong Post-2022 Flooding

Photo 32: Post-Construction – looking North at new culvert crossing at Wildsong (2023)

Photo 33: Pre-Construction – Debris deposit on the upstream side of the Deerpath culvert (2022)

Photo 34: Post-Construction – Deerpath culvert looking South (2023)

3.14 Private Property Protection

Based on the Risk Assessment, over 150 landowners were contacted regarding installation of structure protection or other measures on their property. Flood barrier bags were the primary method of structure protection, with several properties utilizing earthen berms or riprap to provide protection. Details of structure protection utilized in The Retreat can be found in Section 3.9.6.

The standard NRCS detail for flood barrier bags (example detail from 06/04/2020 revisions) was utilized as the basis for implementation of the system at each property. In areas such as Lazy D Ranch Road/Pingree Park Road, several landowners opted for structure protection and preliminary layouts were drawn in CAD. Once Larimer County met or communicated with each landowner individually, a revised layout was issued for construction. In most cases, 4-ft tall flood barrier bags were utilized. A small number of parcels were with a mapped floodway or floodplain. In consultation with the Larimer County Floodplain Administrators, it was recommended that Muscle Wall be utilized in lieu of the flood barrier bags with the expectation that, after the duration of time which the property may be at the highest risk of debris and flood flows, the Muscle Wall will be removed by the landowner and be more temporary in nature than the barrier bags.

In total, between The Retreat and other project areas, approximately 1,984 LF of flood barrier bags were installed and approximately 156 LF of Muscle Wall was installed.

3.15 Debris Removal

In addition to the debris removal efforts within The Retreat in 2022 (removing over 8,900 CY of material from The Retreat Subdivision), the eastern portion of Buckhorn Creek on LCR 44H, before the intersection at LCR 27, saw heavy deposition downstream of Sheep Creek through the crossings at Deerpath and Wildsong. This vast deposition was the catalyst for replacing the Wildsong and Deerpath crossings because of its direct impacts to LCR 44H, reducing capacity within the channel, which then forced the flood water onto the roadway.

Larimer County utilized a debris removal contractor, DRC, to clean up the areas upstream of Wildsong. Approximately 8,600 CY of debris was removed from the area. Figure 12 shows the approximate limits of debris removal.

Photo 35: Typical deposition (looking upstream of Deerpath) on Buckhorn Creek (2022)

Photo 36: Post-Construction – Area upstream of Deerpath after debris removal (2022)

In other areas of the burn scar, there was more woody debris deposition; some of these areas were not caused by debris flows dislodging material directly. Rather, storm events knocked over large lodgepole pines and the concern Larimer County and the NRCS had, while conducting field visits, was the likelihood that these areas would trap additional smaller woody debris and cause flood flows to redirect onto roadways and private properties. The area surrounding Lazy D Ranch on LCR 63E was a prime example of the woody debris deposits.

Photo 37: (Left) Pre-Construction – Typical woody debris along the South Fork on LCR63E (2022)
Photo 38: (Right) Post-Construction – Typical river corridor clear of fallen trees on LCR 63E (2022)

SECTION 4.0 - ENVIRONMENTAL MITIGATION

The Natural Resources Conservation Service (NRCS) provided funding and technical assistance to Larimer County to implement the Emergency Watershed Protection (EWP) Program to protect life and property at risk from increased storm runoff following the Cameron Peak Fire. The NRCS determined that the EWP project may affect a federally threatened species, the Preble's meadow jumping mouse (*Zapus hudsonius preblii*) (PMJM) and its occupied and critical habitat. According to the emergency disaster response provisions of the Endangered Species Act Consultation Requirements, NRCS, and its EWP Sponsor Larimer County, incorporated Best Management Practices (BMPs) and Mitigation Requirements into its Cameron Peak EWP activities. Those activities, BMPs, and mitigation measures were reported to the U.S. Fish and Wildlife Service in an After-Action Report detailing the impacts to PMJM habitat and the criteria for mitigation of those impacts.

During the fall of 2021 and the spring, summer, and fall of 2022, Larimer County conducted several field reconnaissance trips along LCR 44H, LCR 63E, and LCR 69 to view the emergency watershed protection work sites and the initial habitat mitigation at replacement and new culvert sites. Additionally, Larimer County identified additional sites and expanded existing mitigation sites where PMJM habitat could be enhanced, established, and/or expanded. A primary goal of the field reconnaissance was to identify existing suitable habitat for the PMJM and enhance it and create connectivity between suitable habitat pockets and damaged or lost riparian habitat. Site-specific mitigation plans were prepared for each site identified during the field reconnaissance that had potential for the creation of PMJM habitat.

The three drainages included in the EWP Program include Buckhorn Creek on LCR 44H, Bennett Creek on LCR 63E, and Sevenmile Creek on LCR 69. Impacts to PMJM habitat were quantified and mitigated as described below. Impacts to PMJM habitat were determined using existing PMJM critical and occupied habitat mapping, on-site PMJM habitat assessments, and overlaying the proposed impact footprints of the proposed work. The construction completed at each drainage, the BMPs implemented, and how much PMJM habitat mitigation was needed at each drainage is described below.

- Buckhorn Creek on LCR 44H – Areas along LCR 44H at Buckhorn Creek were repaired as part of the EWP Program. Road locations washed out from overtopping by floodwaters were repaired using fill and regrading, and washed-out culverts were replaced, and in some cases upsized. In some areas between Buckhorn Creek and the road, riprap embankment protection was needed to prevent the road from continually washing out. All work completed was exigent and in response to flooding. The EWP Program work only occurred in the impacted riparian corridor and in disturbed areas including road and adjacent roadside pull-off areas. BMPs and Mitigation and Conservation Measures were implemented where possible and practical. Approximately 0.19 acres of PMJM habitat was permanently impacted by the implemented EWP Program work and mitigation occurred at a 2:1 ratio. The total PMJM habitat mitigation required for impacts on LCR 44H totaled 0.38 acres. Approximately 0.58 acres was available in this drainage for PMJM mitigation. A total of ten (10) sites were planted with riparian and/or upland shrubs, saplings, willow stakes and seeded with native grasses.

Photo 39: Representative area along LCR 44H with plantings and BMPs in place

- Bennett Creek on LCR 63E – Along a small portion of Bennett Creek an eroding streambank and large scour hole were stabilized with riprap. The BMPs and Mitigation and Conservation Measures were implemented for the work in Bennett Creek. Approximately 380 square feet of PMJM habitat was impacted by this project. Temporary impacts occurred to 200 square feet of PMJM habitat requiring 300 square feet of mitigation (1.5:1 ratio) and permanent impacts occurred to 40 square feet of PMJM habitat requiring 80 square feet of mitigation (2:1). Approximately 719 square feet or 0.02 acres of PMJM mitigation acreage was available and used for mitigation at the scour hole fill site. One site was planted with upland shrubs and seeded with native grasses.
- Sevenmile Creek on LCR 69 - Culvert replacements were made at two sites on the lower portion of Sevenmile Creek on LCR 69. The BMPs and Mitigation and Conservation Measures implemented for the work in Sevenmile Creek. Approximately 0.05 acres of PMJM habitat was temporarily impacted by the culvert replacement work at these two sites. Approximately 0.075 acres of PMJM habitat mitigation was required for these impacts. Approximately 7,550 square feet or 0.17 acres of PMJM mitigation acreage was available and used for mitigation in this drainage. A total of 7 sites were planted with riparian and/or upland shrubs, saplings, willow stakes, and seeded with native grasses.

More PMJM habitat mitigation acreage was identified and used for mitigation than was required. Due to the dynamic nature of the drainages within the Cameron Peak Fire EWP burn scar and the propensity for additional flooding in years to come, additional mitigation sites were identified and planted to assure the

total PMJM habitat mitigation acreage is obtained by the end of the monitoring and reporting timeframe. Figures 13 to 16 show the project area with mitigation sites identified.

A copy of the final After-Action Biological Assessment for federally listed threatened species for the Cameron Peak Fire EWP Project is in Appendix F.

4.1 Permits

Environmental compliance for the projects included Section 404 permitting with the United States Army Corps of Engineers (COE) (NWO-2021-01897_20220119_NWP37; NWO-2021-01783_20211029_NWP37). Larimer County also received, via email confirmation, authorization under the same permits for work at additional sites within the impacted areas during summer 2022 (debris removal) and constructed in fall 2023 (culverts at Wildsong, Deerpath, Sheep Creek and The Retreat).

Several of the project areas were within the range of the Preble's Meadow Jumping Mouse (PMJM) Occupied or Designated Critical Habitat areas. Because the NRCS was the lead federal agency, they will consult with the United States Fish and Wildlife Service (USFWS) under Sec. 7 of the Endangered Species Act. Larimer County completed a Biological Assessment (BA) describing temporary and permanent impacts to PMJM habitats and the steps taken to mitigate those impacts. The NRCS will use the submitted BA in their consultation with the USFWS.

The only site requiring a CO State COR400000 permit certification for stormwater discharges associated with construction activities was The Retreat project area (COR414390). All other areas were <1 acre disturbance and >1/4 mile apart or already authorized under an existing permit certification (COR411010 Buckhorn Rd LCR 44H).

Floodplain Permitting was received from Larimer County Engineering for the culverts at Sheep Creek (23-FLD0050), Wildlsong (22-FLD0107) and Deer Path (22-FLD0116).

Appendix G contains copies of all the applicable permits.

SECTION 5.0 - CONCLUSIONS

The Cameron Peak Fire is the largest wildfire in Colorado's state history. The effects of the wildfire were far-reaching and can still be felt today. Efforts continue to assist in the stabilization of watersheds within the burn scar. Larimer County is in the third monsoon season, post-fire; some areas which were hard-hit in the first two seasons, have still been seeing cycles of sediment transport and deposition. However, the resiliency features which were installed as part of the Emergency Watershed Protection Program (EWPP) have held in place with minimal impacts. Photo 40 and Photo 41 show examples from The Retreat on August 3, 2023. Both crossings were installed as part of the initial flood repairs. Both crossings have remained intact, and the grouted (matrix) riprap have provided stability to any overtopping, particularly at the confluence of Black Creek and Miller Fork on Streamside Drive.

Other areas within the burn scar have begun to reestablish vegetative growth and will continue to be monitored in the coming years. Areas are LCR 44H (Buckhorn Road) may continue to see impacts to roadway embankments as Buckhorn Creek continues to find its new equilibrium.

In all, Larimer County installed over 15,000 tons of rock riprap through the burn scar to armor roadway and channel embankments, culvert end treatments, rock check dams, low water crossings, drop structures, and other installations. The amount of rock which was installed is the equivalent to over 1,100 side-dump trucks delivering rock to the project areas. Over 17,000 cubic yards (CY) of debris was removed from The Retreat Subdivision in Glen Haven and the Upper Buckhorn Creek area (near Wildsong and Deerpath crossings). Over 2,000 linear feet (LF) of flood barrier bags were utilized on private properties. Acres of seed and hydraulic mulch was used to provide stabilize to surfaces after projects were complete. Monitoring for reestablishment will be on-going.

Construction costs for all the EWPP projects was approximately $11,500,000 (final costs are still be tabulated). Larimer County's local match contribution and County-only costs (activities which were not EWP-eligible) totaled approximately $3,650,000. The Colorado Water Conservation Board (CWCB) Colorado Watershed Restoration Program (CWRP) provided approximately $538,000 in funds towards the work. Detailed documentation for the CWCB CWRP reimbursement process has already been submitted for review. Table X (page 53) provides a breakout for the eligible project areas, showing the CWCB awarded amount versus actual expenditures.

One of the biggest challenges of the recovery work was trying to strike a balance between implementing resiliency projects and recognizing that there were still areas which, before the Cameron Peak Fire, were considered a flood-prone risk area, and that there was still a high likelihood that even with the EWPP improvements, these areas would be susceptible to flooding and repeat damage. LCR 44H is an example of a corridor which was impacted by the 2013 flooding, in the final stages of repair from that disaster, and then was one of the hardest hit areas after the Cameron Peak Fire. Large swaths of roadway were impassable, and the river corridor was trying to find its equilibrium (and still is), cycling between heavy deposition in some segments and erosion and channel bank destabilization in others. Larimer County had to prioritize certain areas of LCR 44H to ensure that access could be restored rapidly in the case of another disaster. Culvert crossings, such as Sheep Creek, being on the east end of the roadway corridor, were considered "sacrificial" in that if overtopping of LCR 44H occurred at this crossing, it was an area which could accommodate an emergency on-site detour and could be repaired rapidly.

Areas such as The Retreat were challenging because of the natural topography and significant damage to the upland watershed. Larimer County worked closely with the local road association and, for those willing

to participate, the flood barrier bags had proven their effectiveness, particularly during the July 2022 flood events. Landowners provided direct feedback and, though some of the segments of bags had "failed," they had stopped debris and flood flows from furthering entering homes and outbuildings and gave landowners the ability to get through the monsoon season intact. Larimer County will be looking at protective measures like this in the future that could be rapidly deployed in the event of another disaster.

Long-term planning is essential to our operations at Larimer County; whom in the past 10 years has seen more natural disasters than perhaps in the half a century before it. The infrastructure improvements, made possible by the EWP program and in collaboration with the NRCS and CWCB agencies, ensures that we can respond rapidly to those in the mountain region and those living and working and traveling within our County. Our hope is that as the burn scar continues to heal, the impacts to life and property will be greatly diminished.

Photo 40: View of the Confluence of Black Creek and Miller Fork at the Box Culvert after the August 2023 Storm Event

Photo 41: View of Lower Streamside Drive after the August 2023 Storm Event

Table 14: CWCB Cost Breakdown

Project Area	Awarded					Actual Costs					Cost Share Delta
	NRCS/EWP Costs (80%)	Larimer County Cost Share (20%)	EWP Sub-Total (100%)	Larimer County Costs	CWCB Costs (20% EWP Cost Share)	NRCS/EWP Costs (80%)	Larimer County Cost Share (20%)	EWP Sub-Total (100%)	Larimer County Costs	CWCB Costs (20% EWP Cost Share)	
Little Beaver Creek (LR63E-4.7-44H)	$ 85,456.00	$ 21,364.00	$ 106,820.00		$ 21,364.00	$ 22,532.00	$ 5,633.00	$ 28,165.00		$ 5,633.00	$ 15,731.00
Unnamed Trib (063E-3.87-44H)	$ 412,552.00	$ 103,138.00	$ 515,690.00	$ 20,160.00	$ 123,298.00	$ 428,622.40	$ 107,155.60	$ 535,778.00	$ 20,160.00	$ 127,315.60	$ (4,017.60)
Bennett Creek (063E-8.00-44H)	$ 138,524.78	$ 34,631.19	$ 173,155.97		$ 34,631.19	$ 78,748.00	$ 19,687.00	$ 98,435.00		$ 19,687.00	$ 14,944.19
Sevenmile Creek (069-0.43-S14)	$ 154,088.64	$ 38,522.16	$ 192,610.80	$ 8,778.00	$ 47,300.16	$ 260,865.58	$ 65,216.40	$ 326,081.98		$ 65,216.40	$ (17,916.24)
Sevenmile Creek (069-0.25-S14)	$ 687,590.78	$ 171,897.70	$ 859,488.48		$ 171,897.70	$ 845,723.52	$ 211,430.88	$ 1,057,154.40		$ 211,430.88	$ (39,533.18)
Swamp Creek (069-3.41-68C)	$ 71,382.72	$ 17,845.68	$ 89,228.40		$ 17,845.68	$ 72,905.60	$ 18,226.40	$ 91,132.00		$ 18,226.40	$ (380.72)
Two and One Half Creek (103-4.56-S14)	$ 138,851.33	$ 34,712.83	$ 173,564.16		$ 34,712.83	$ -	$ -	$ -		$ -	$ 34,712.83
The Retreat	$ 347,852.21	$ 86,963.05	$ 434,815.26		$ 86,963.05	$ 806,524.58	$ 201,631.14	$ 1,008,155.72	$ 1,427,125.62	$ 90,503.34	$ (3,540.29)
	$ 2,036,298.46	**$ 509,074.61**	**$ 2,545,373.07**	**$ 28,938.00**	**$ 538,012.61**	**$ 2,515,921.68**	**$ 628,980.42**	**$ 3,144,902.10**	**$ 1,447,285.62**	**$ 538,012.62**	**$ (0.00)**

The awarded values for each project area were based on engineering estimates for each site. The scope and magnitude of the work changed, particularly after the 2022 flooding (more specifically, in The Retreat); therefore, there was a significant overrun for that project area. Larimer County is only seeking reimbursement for the portion of the work at The Retreat which brings the balance to the fully-awarded amount of $538,012.61. Two and One-Half Creek (103-3.41-S14) was removed from the scope of the work and the awarded amount was redistributed to other project areas where there were cost overruns.

SECTION 6.0 - REFERENCES

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